Session xxxx

Time-Based Versus Quantity-Based Breakeven Analysis

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Introduction

Breakeven analysis has traditionally focused upon quantity-based breakeven analysis, which determines the production quantity at the specific breakeven point. This has worked for marketing, sales, and top-management for planning yearly goals, but it provides little assistance at the plant management level where the production quantity is not a variable, but it is a quantity specified by the customer. The production or manufacturing manager can control the time to produce the orders, but the manager cannot control the quantity as that is controlled by the customer. Time-based breakeven analysis is a relatively new concept¹⁻³ compared to the quantity-based breakeven analysis.

Two critical issues in breakeven analysis are the cost base used and the breakeven point used. Although the most frequently used breakeven point is the breakeven point at cost, three other breakeven points considered are the shutdown point, the breakeven at required return point, and the breakeven at required return after taxes. These points can be considered on either the quantity-based breakeven analysis or on the time-based breakeven analysis..

The selection of a cost base determines how a particular cost is considered with respect to being fixed, semi-variable or variable. If the cost base is quantity, then a cost item such as material cost would be considered as variable because when the production quantity increases, the total material costs would increase. If the cost base is time and the total production quantity is fixed, then the amount of materials used would be fixed and the material cost would be considered as a fixed cost.

Breakeven Points

The four breakeven points can be evaluated on either the quantity-based system or the time-based system. The four breakeven points are defined as:

1. <u>Shutdown Point(SD)</u> In the production quantity system, the shutdown point is the production quantity at which the revenues equal the sum of the variable and semi-

variable costs. In the production time system, the shutdown point is the production time at which the revenues equal the sum of the production cost components; that is, the fixed, variable, and semi-variable production costs. The shutdown point is sometimes designated as the point at which the "out-of-pocket" costs are recovered.

- 2. <u>Cost Point(C)</u> In the production quantity system, the cost point is the production quantity at which the revenues equal the sum of the variable, semi-variable, and fixed costs; that is the quantity at which the revenues equal the total costs. In the production time system, the cost point is the production time at which the revenues equal the sum of the production costs and the variable overhead costs; that is the time at which the revenues equal the total costs.
- 3. <u>Required Return Point(RR)</u> In the production quantity system, the required return point is the production quantity at which the revenues equal the sum of the total costs plus the required return. Similarly, in the production time system, the required return point is the production time at which the revenues equal the sum of the total costs plus the required return. In the production time-based system, the required return can be expressed as either a fixed amount or as a fixed rate per unit time.
- 4. <u>Required Return After Taxes Point(RRAT)</u> In the production quantity-based system, the required return after taxes point is the production quantity at which the revenues equal the sum of the total costs plus the required return plus the taxes on the required return. The required return after taxes in the production time-based system is the production at which the revenues equal the sum of the total costs plus the required return plus the taxes on the required return.

The breakeven points increase in quantity as one proceeds from the shutdown point to the required return after taxes point in the production quantity-based system. However, the breakeven points decrease in time as one proceeds from the shutdown point to the required return after taxes point in the time-based system. This indicates the importance of decreasing production time to increase profitability and, like the concept "just-in-time", focuses upon time rather than quantity.

Cost Bases

Costs are generally classified into the three major groups according to their variability as: fixed, variable, and semi-variable. How the costs are assigned to a group depends upon the cost base used. The two cost bases are the production quantity base and the production time base. Since production quantity has been the standard base, several costs will be considered first with respect to that base. Using the quantity base, fixed costs do not vary with respect to production quantity. Some examples of the fixed costs in the production quantity based system are property taxes, administrative salaries, research and development expenses and insurance. Variable costs vary linearly with production quantity and two examples of variable costs are direct labor and direct materials. The costs that do not fit into either of these two categories are classified as semi-variable costs and tend to have a fixed and a variable component. One example of semi-variable costs is maintenance costs. If one uses a time-based system, many of the cost components will be classified differently, especially in the fixed and variable groups. Most of the examples of fixed costs on the quantity base will be variable on the time base. The property taxes, administrative salaries, research and development expenses, and insurance expenses are overhead expenses and would be variable expenses on a time base. On the other hand, costs such as material costs that are variable on the quantity base are fixed on the time base as the customer fixes the quantity. Direct labor can be fixed or variable, depending upon the policies followed. For example, if direct labor is really fixed as management does not want to layoff employees and rehire, then it would be similar to administrative salaries and would be variable on a time-based system. However if the direct labor content does not vary at all per unit, then with a fixed quantity, the direct labor would be a fixed cost on the time-based system. The production costs. The production costs may have fixed, variable, and semi-variable components, but the overhead expenses are generally only variable in a time-based system.

Basic Illustrative Breakeven Example Problems

To illustrate the breakeven calculations and the graphical results, example problems are presented for both the quantity-based and time-based approaches to solving breakeven problems and interpreting the results. The production quantity-based method is illustrated first and then a different example is used to illustrate the time-based approach. The data for the production quantity example problem are presented in Table 1.

Table 1.	Data for Production	Quantity-Bas	ed Breakeven Anal	ysis Example Problem I
Item	\$/	/unit \$	Decim	al

	φ/umi	J.	Duill
Sales Revenue	20		
Costs			
Fixed Costs		2,400	
Variable Costs	3		
Semi-variable Costs	2	600	
Required Return		900	
Tax Rate(40%)			0.40

Calculations for Production Quantity-Based Breakeven Analysis

The calculations to obtain the four breakeven points are presented in a general form using the data from Table 1.

Let x = the units of production

a)	Shutdown P	oint
	Revenues	= Variable Costs + Semi-variable Costs
	20x	= 3x + 2x + 600
	15x	= 600
	Х	= 40 units

b)	Cost Point	
	Revenues	= Total Costs
	Revenues	= Variable Costs + Semi-variable Costs + Fixed Costs
	20x	= 3x + 2x + 600 + 2,400
	15x	= 3,000
	Х	= 200 units
c)	Required Re	eturn Point
	Revenues	= Total Costs + Required Return
	20x	=5x+3,000+900
	15x	= 3,900
	Х	= 260 units
d)	Required Re	eturn After Taxes Point
	Revenues	= Total Costs + Required Return + Taxes on Required Return**
	20x	= 5x + 3,000 + 900 + 900 + 900 * TR/(1-TR)
	20x	= 5x + 3,000 + 900/(1-TR)
	20x	= 5x + 3,000 + 900/(1-0.4)
	15x	= 4,500
	Х	= 300 units
2	**Taxes on Rec	uired Return to get the desired Required Return After Taxes

The results and actions for the various breakeven points are presented in Table 2. Figures 1 and 2 show the breakeven points versus Total Cost and Unit Cost. The Total Cost versus Production Quantity is the most common breakeven figure and the Unit Cost versus Production Quantity is often used to illustrate the effects of changing the selling price upon the various breakeven points.

Table 2. Results from the Production Quantity-Based Model for Example Problem I

Production Level(units)	Action/Implication
1. Shutdown Point or lower(<40 units)	Do nothing; reject order as out-of-pocket
	costs are not recovered.
2. Between Shutdown (40 units) and Cost	Will recover some fixed costs, but will be
(200 units) Breakeven Points	operating at a loss. Accept only if no
	other opportunities.
3. Between Cost(200 units) and Required Return	Will recover all costs, but will not obtain
(260 units) Breakeven Points	desired level of required return.
4. Between Required Return(260 units) and	Will recover all costs and attain desired
Required Return After Taxes(300 units) Points	level of return on a pre-tax basis, but not
	on an after tax basis.
5. Greater than Required Return After	Will recover all costs and exceed required
Taxes(>300 units) Point.	Return on an after tax basis.



Figure 1. Total Cost versus Production Quantity



Figure 2. Unit Cost versus Production Quantity

Calculations for Production Time-Based Breakeven Analysis

The calculations to obtain the four breakeven points using the production time base are presented in a general form using the data from Table 3.

Item		\$/hour	\$ Deci	imal
Sales	Revenue		26,000	
Produ	ction Costs			
	Fixed Costs		10,000	
	Variable Cos	its 8		
	Semi-variabl	e Costs 2	4,000	
Overl	nead Costs	20		
Requi	ired Return	18		
Tax F	Rate(40%)		0.40	
Let y	= production h	ours		
a)	Shutdown Po	oint		
,	Revenues	= Production Costs		
	26,000	= 10,000 + 8y + 2y -	- 4,000	
	10y	= 12,000		
	У	= 1,200 hours		
b)	Cost Point			
	Revenues	= Total Costs		
	Revenues	= Production Costs	+ Overhead Costs	
	26,000	= 14,000 + 10y	+ 20y	
	30y	= 12,000		
	У	= 400 hours		
c)	Required Ret	turn Point		
	Revenues	= Total Costs	+ Required Return	
	26,000	= 14,000 + 30y	+ 18y	
	48y	= 12,000		
	У	= 250 hours		
d)	Required Ret	urn After Taxes Point		
	Revenues	= Total Costs	+ Required Return	+ Taxes on Return**
	26,000	= 14,000 + 30y	+ 18y -	+ 18y * TR/(1-TR)
	26,000	= 14,000 + 30y	+ 18y/(1-TR)	
	60y	= 12,000		
**T	у	= 200 hours	10 104	A G T
** I az	xes on Require	a Keturn to get the desi	ea Kequired Keturn	Aner Taxes

The results and actions for the various breakeven points are presented in Table 4. Figures 3 and 4 show the breakeven points in hours versus Total Cost and Profitability. The Total Cost versus Production Time is similar to the Total Cost versus Production Quantity in Figure 1. The new plot is the Profitability Plot, which is the plot of Profits versus Production Time, which indicates the importance of time on the effects of profits and is presented in Figure 4. This plot can help in the justification of new equipment by indicating the importance of reducing production time upon profitability.



Figure 3. Total Cost Versus Production Time

Tab	ole 4	. R	esults	s from	the	Production	Time-	Ba	ised	M	odel	for	Example Problem II
_			_							_			

Production Level(hours)	Action/Implication
1. Shutdown Point or higher(>1,200 hours)	Do nothing; reject order as out-of-pocket costs are not recovered
2. Between Shutdown (1,200 hours) and Cost(400 hours) Breakeven Points	Will recover some fixed costs, but will be operating at a loss. Accept only if no other opportunities.
 Between Cost(400 hours) and Required Return(250 hours) Breakeven Points Between Required Return(250 hours) and the Required Return After Taxes (200 hours) Point 	Will recover all costs, but will not obtain desired level of required return. Will recover all costs and attain desired level of return on a pre-tax basis, but not on an after tax basis.
5. Less than the Required Return After Taxes(300 hours)	Will recover all costs and exceed required Return on an after tax basis.



Figure 4. Profitability Plot of Profits Versus Production Time

Metalcasting Example Problem

A metalcasting example will be used to illustrate both the production quantity-based approach and the time-based approach to determining the four breakeven points. The same data will be used to illustrate that both methods can be utilized, but the time-based system gives results that are more meaningful.

A new job is being considered in the foundry. The order is for 40,000 castings and the tentative price is \$ 3.00/casting. The pattern will be designed for 4 castings per mold and the pattern cost has been quoted at \$ 10,000. The molding line is the rate controlling step in the production process in this particular foundry and the production rate is 125 molds/hr. The estimated time for the production of the 40,000 castings would be determined by:

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(40,000 \text{ castings}) / (4 \text{ castings/mold x } 125 \text{ molds/hr}) = 80 \text{ hr}
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The costs and overheads are included in Table 5 and the corporate tax rate is estimated at 40 percent.

Cost Item or Revenue		\$/unit	\$/hr	\$	Decimal
Revenue		3.00*		(120,000)	
Production Costs					
Direct Costs					
Material Costs					
Hot Metal Cost	1.00				
Core Costs	0.35				
Filter Cost	0.10				
Sand Preparation Cost	0.05				
	1.50	1.50*		(60,000)	
Pattern Cost				10,000**	
Labor Costs					
Melting	0.10				
Molding & Coremaking	0.08				
Finishing	0.15				
	0.33	0.33*	(165)		
Indirect Costs					
Plant Overhead Rate			(110)	8,800*	
Overhead Costs					
General Administrative, Sales, a	nd				
Marketing Overhead Rate			(150)	12,000*	
Required Return and Taxes					
Total Required Return			(200)	16,000*	
Required Return After Taxes			(120)	9,600*	
Tax Rate (40%)				,	0.40**
Taxes for Required Return			(80)	6,400*	
Notes					
*values used for quantity-based m	odel				
**values used for both models					
() values used for time-based mod	lel				
Conversion Factors for Data:					
Production Rate: 500 units/hr or	0.002 ho	urs/units and	d thus 0.33\$/	unit x 500 uni	ts/hr = 165 hr
Production Time: 40,000 units/ 5	00 units/	hr = 80 hour	rs and thus 1	10\$/hr x 80 hi	r = \$ 8,800

Table 5. Cost Data for Time-Based and Quantity-Based Breakeven Metalcasting Example

Production Quantity-based Calculations

The calculations for the four breakeven points are made using "X" as the variable representing the number of units of production.

Shutdown Point

	Revenues 3X 3X 3X 1.17X X	= Production Costs = Material Costs + La = 1.50X + 0.3 = 1.83X + 18 = 18,800 = 16,068 units	abor Costs + Tooling C 33X + 10,000 8,800	Costs + Plant Overhead Costs + 8,800
Cost P	oint			
	Revenues	= Total Costs		
	Revenues	= Production Costs	+ Overhead Costs	
	3X	= 1.83X + 18,800	+ 12,000	
	3X 1.17V	= 1.83X + 30,800		
	1.1/A X	= 30,800 = 26.324 units		
	Α	20,524 units		
Requir	ed Return Poin	ıt		
	Revenues	= Total Costs	+ Required Return	
	3X	= 1.83X + 30,800	+ 9,600	
	3X	= 1.83X + 40,400		
	1.17X V	= 40,400 = 24,520 units		
	Λ	-34,330 units		
Requir	ed Return Afte	r Taxes		
-	Revenues	= Total Costs	+ Required Return	+ Taxes for Required Return
	3X	= 1.83X + 30,800	+ 9,600	+ 9,600 x (TR/(1-TR))
	3X	= 1.83X + 40,400		+ 6,400
	1.1/X V	= 46,800		
	Λ	-40,000 units		

The results and actions for the various breakeven points are presented in Table 6. The results can be graphically illustrated using total costs versus production quantity as illustrated in Figure 5. The various breakeven points are shown increasing in quantity from the shutdown point to the required return after taxes. Figure 6 is a plot of unit cost versus production quantity and illustrates the various breakeven points. Unit Cost versus Production Quantity is often used by marketing personnel to analyze the effect of selling price on the breakeven points.

Table 6. Results of the Production Quantity-Based Model for Metalcasting Example Problem

Production Level(units)	Action/Implication
1. Shutdown Point or lower(<16,068 units)	Do nothing; reject order as out-of-pocket
	costs are not recovered.
2. Between Shutdown (16,068 units) and	Will recover some fixed costs, but will be
Cost(26,324 units) Breakeven Points	operating at a loss. Accept only if no
	other opportunities.
3. Between Cost(26,324 units) and Required	Will recover all costs, but will not obtain
Return(34,530 units) Breakeven Points	desired level of required return.
4. Between Required Return(34,530 units) and	Will recover all costs and attain desired
Required Return After Taxes(40,000 units)	level of return on a pre-tax basis, but not
Point	on an after tax basis.
5. Greater than Required Return After	Will recover all costs and exceed required
Taxes (>40,000 units) Point.	Return on an after tax basis.



Figure 5. Total Cost and Revenues Versus Production Quantity



Figure 6. Unit Cost versus Production Quantity

Time-Based Calculations

The calculations for the four breakeven points will be made using "Y" as the variable representing the hours of production.

Shutdown Point

Revenues	= Production Costs		
Revenues	= Material Costs + Labor	Costs + Tooling Cost	s + Plant Overhead Costs
120,000	= 60,000 + 165Y	+10,000	+ 110Y
120,000	= 70,000 + 275Y		
275Y	= 50,000		
Y	= 181.8 hours		
Cost Point			
Revenues	= Total Costs		
Revenues	= Production Costs	+ Overhead Costs	
120,000	= 70,000 + 275Y	+ 150Y	
120,000	= 70,000 + 425Y		
425Y	= 50,000		
Y	= 117.6 hours		
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Required Return Point

Revenues	= Total Costs	+ Required Retu	ırn
120,000	= 70,000 + 425Y	+ 120Y	
120,000	= 70,000 + 545Y		
545Y	= 50,000		
Y	= 91.7 hours		
Required Return Afte	er Taxes		
Revenues	= Total Costs	+ Required Return	+ Taxes for Required Return
120,000	= 70,000 + 425Y	+ 120Y	$+ 120Y \times (TR/(1-TR))$
120,000	= 70,000 + 425Y	+ 120Y	+ $120Y \times (0.4/(1-0.4))$
120,000	= 70,000 + 425Y	+ 120Y	+ 80Y
625Y	= 50,000		
Y	= 80.0 hours		

Table 7. Results from the Production Time-Based Model for Metalcasting Example Problem

Production Level(hours)	Action/Implication
1. Shutdown Point or higher(>181.8 hours)	Do nothing; reject order as out-of-pocket
	costs are not recovered.
2. Between Shutdown (181.8 hours) and	Will recover some fixed costs, but will be
Cost(117.6 hours) Breakeven Points	operating at a loss. Accept only if no
	other opportunities.
3. Between Cost(117.6 hours) and Required	Will recover all costs, but will not obtain
Return(91.7 hours) Breakeven Points	desired level of required return.
4. Between Required Return(91.7 hours)	Will recover all costs and attain desired
and the Required Return After Taxes	level of return on a pre-tax basis, but not
(80 hours) Point	on an after tax basis.
5. Less than the Required Return After	Will recover all costs and exceed required
Taxes(< 80 hours)	Return on an after tax basis.

The results can be graphically illustrated using total costs versus production time as illustrated in Figure 7. The various breakeven points are shown decreasing in time from the shutdown point to the required return after taxes. Figure 8 is the profitability plot, which shows the profitability as a function of the production time and shows the various breakeven points. It illustrates the importance of reducing production time for increasing profitability. The plot can illustrate either a constant amount or a constant rate of required return on the breakeven points. A constant amount would appear as a horizontal line parallel to the zero profit line at the value of required return selected.



Figure 7. Total Cost and Revenues Versus Production Time



Figure 8. Profitability Plot for Time-Based System

Time-Based Applications

There are at least three areas where time-based breakeven analysis would be more useful than production quantity breakeven analysis. The three areas are production delays; bottleneck evaluation and costing; and economic justification for improvements.

Production delays occur for a variety of reasons, but little thought is given to the cost of the delay. One of the advantages of the time-based analysis is that the profitability plot directly indicates the effect of delays upon profitability. Time has been listed as one of the areas for focus in supply chain management. The high cost of delays indicate that one of the factors to consider in the evaluation of the performance of management is the number and amount of delays that occur. Other factors, such as scrap rates and employee satisfaction are important as they also can cause delays. Delays require that more overhead be applied to the products and this is easily observed on the profitability plot.

The advantage of the time-based breakeven analysis is that it can answer questions such as what is the effect of a 4 hour delay due to a machine breakdown. The effect is not obvious from the quantity breakeven analysis, but the time-based breakeven analysis indicates that 84 hours is between the required return and required return after taxes breakeven times; that is all costs are recovered and the required return will be exceeded before taxes but not after taxes. This can be evaluated by determining the profit(total required return) from:

Profit = Revenues - Costs Profit = \$120,000 - (\$70,000 + 425\$/hr x time (hr)) Profit = \$50,000 - 225\$/hr x 84hr Profit = \$14,300 Profit after taxes = (1-TR) x 14,300 = 0.6 x 14,300 = 8,580

The total required return or profit when there was no delay was \$ 16,000 and the profit when there was a four hour delay was \$ 14,300. The loss in the required return before taxes would be the difference between \$ 16,000 and \$ 14,300 which is \$ 1,700. The loss on the time base system could easily be evaluated at \$ 425 per hour, and for the 4 hour delay the loss would be \$1,700.

The loss in the quantity-based system can be obtained by using some of the conversion factors; the loss of 4 hours is equivalent to the production loss of 2,000 units. This loss would be the labor lost plus the plant overhead and the overhead costs for four hours; thus the loss would be:

2,000 units x 0.33/unit + 4hr x (110 + 150) = 660 + 1,040 = 1,700

The time-based approach is much easier and more straightforward.

Time-based breakeven analysis would also be useful in evaluating the cost of bottleneck delays and provide data for the economic justification of new equipment to improve productivity. The high cost of delays indicate that one of the factors which should be considered in the evaluation management's performance and this can be done using a time-based system. The

evaluation of bottlenecks and delays is critical in the "theory of constraints" and supply chain management, where the focus is upon time in these situations^{4,5}.

One of the major problems of companies is the determination of product costs as the overhead costs tend to be the second largest cost component after material costs. One component of the problem is in the allocation of the overhead to specific products. In many manufacturing processes, one area tends to be the bottleneck and this is where the major variable overhead should be applied on a time basis because all other operations are really support operations for the bottleneck. In metal casting operations, the bottleneck may be the molding line, in forging operations the bottleneck may be a particular press, in steel mill operations it may be a particular rolling mill, and etc. The application of a high overhead rate on the bottleneck operation puts the focus on solving the bottleneck problem. The time-based system tends to follow the "pull system" as expressed in the theory of constraints.

The reduction of time at a bottleneck operation can be used to justify new equipment and the profitability plot can be used to estimate the savings. The overhead rate can be increased to include the cost of the new equipment, but changing the slope of the overhead component can do this rather easily. The use of the production time approach tends to decrease the work-in-progress as the focus is upon time as WIP tends to increase the total production times.

If there is more than one production line, the overhead rates must be applied proportionately to each of the lines. More research needs to be performed in instances where more than one production line exists or where a wide variety of products are produced with more than one bottleneck area. Time, however, appears to be a better parameter than the traditional direct labor costs for applying overhead to products. The time-based approach should be able to be applied more rapidly than developing an activity based costing system.

Conclusions

Time-based breakeven analysis has been presented along with the traditional quantitybased breakeven analysis to illustrate the differences and similarities in the two approaches. The same four breakeven points are obtained by either approach, but the breakeven quantities increase whereas the time decreases as one goes from the shutdown point to the required return after taxes point. The classification of costs as to whether they are fixed, variable or semivariable depends upon whether a time-based or quantity-based system is used.

In the terms of forecasting long-range plans, the quantity-based approach is appropriate as the marketing and sales staff must estimate the revenues obtained and predict the sales quantities. However, at the plant level where the daily operations are concerned, the focus is upon time and time-based breakeven analysis is more appropriate at this level as time is the variable that can be somewhat controlled and whereas the quantity has been determined and is not variable. Time-based breakeven analysis is also more appropriate to the newer approaches to production management, such as the "theory of constraints", "just-in-time", and "lot-size-of-one" than the quantity-based breakeven analysis approach.

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