Development In Business Simulation & Experiential Exercises, Volume 18, 1991

INCREASING SIMULATION REALISM THROUGH THE MODELING OF STEP COSTS COST BEHAVIOR IN BUSINESS SIMULATIONS

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ABSTRACT

This paper addresses some of the theoretical problems involved in the modeling of fixed costs in business simulations. The theoretical nature of fixed costs as a special case of step costs is clarified. In addition, a mathematical technique is presented for the effective modeling of step costs within a computerized simulation model. Also, some of the consequences of significant amounts of step costs are illustrated.

INTRODUCTION

Creating a sense of realism in selected areas of decision-making activity is a goal of business simulation. Without an appearance of realism, the learning experience from a business simulation is not likely to be accepted. One aspect of business activity that appears easy to simulate is cost behavior. However, the author’s experience with developing business games has been that realistic cost behavior is much more difficult to achieve than is commonly believed. Furthermore, many simulations that appear to have realistic models of fixed cost behavior may need improvement.

Fixed costs, in fact, are a subset of a category of costs that may be labeled step costs. Step costs are lightly discussed in economic and management accounting textbooks and literature. Because of this inadequacy in literature, the author believes inadequate attention to step cost behavior has also carried over into business simulations.

The major problem in programming fixed costs is that these costs are not really “fixed.” They are fixed only in the short run relative to sales or production activity. Kaplan, an accounting theorist has recently called attention to this point (1987). In a simulation some fixed costs can change because they represent a decision made by a game player. For example, the amount of advertising may be increased or decreased at the whim of the decision-maker. However, once the decision is made, advertising will remain constant during the period regardless of the activity that is generated by the processing of decisions. The same would be true for other fixed costs such as the salaries of salesmen.

In most simulations there are some fixed costs that cannot be directly controlled by the decisions of game player. For example, salaries of top management, salaries of secretarial and clerical staff, salaries of engineers, etc. are often internal values. These costs are often referred to as administrative. These types of costs are parameters and are preprogrammed into the game model. However, it is highly unrealistic for these internally generated fixed costs to remain constant at all levels of activity. The problem expressed in the form of a question is: When should an increase in these internal fixed costs be triggered? Also, what mathematical equation if any, can be developed to easily compute the required increase in the total fixed cost?

COST BEHAVIOR IN BUSINESS SIMULATION

In this paper, the primary emphasis is on the modeling of fixed cost. Although major questions may be asked concerning the modeling of variable costs in simulations, this paper does not directly address those issues. The modeling of variable production costs has been partially addressed by Gold and Pray (1989) and Gold (1990)

Fixed costs by definition are constant and, therefore, supposedly unrelated to changes in activity. It would appear that in simulation modeling the correct approach would be co treat fixed costs as parameters whose value do not change throughout the play of the simulation. This view, for reasons which will be presented, is incorrect.

A commonly accepted definition is that fixed costs are those costs that do not increase or decrease with changes in activity. What this definition states is that changes in volume (sales or production) per se do not affect the amount of fixed cost expenditure. Changes in fixed costs occur for reasons other than volume changes.

Examples of fixed costs include machine rental, building rent or depreciation, supervisory cost, secretarial cost, and equipment. Fixed costs are often classified as discretionary and committed. An example of a discretionary fixed cost is advertising or a cost budgeted for the training of employees. Discretionary fixed costs lack the long term contractual nature of committed cost. A 10-year lease on a building would be another example of a committed fixed cost. In business simulations, discretionary fixed costs are usually generated by external decisions, that is, decisions explicitly made by the game player.

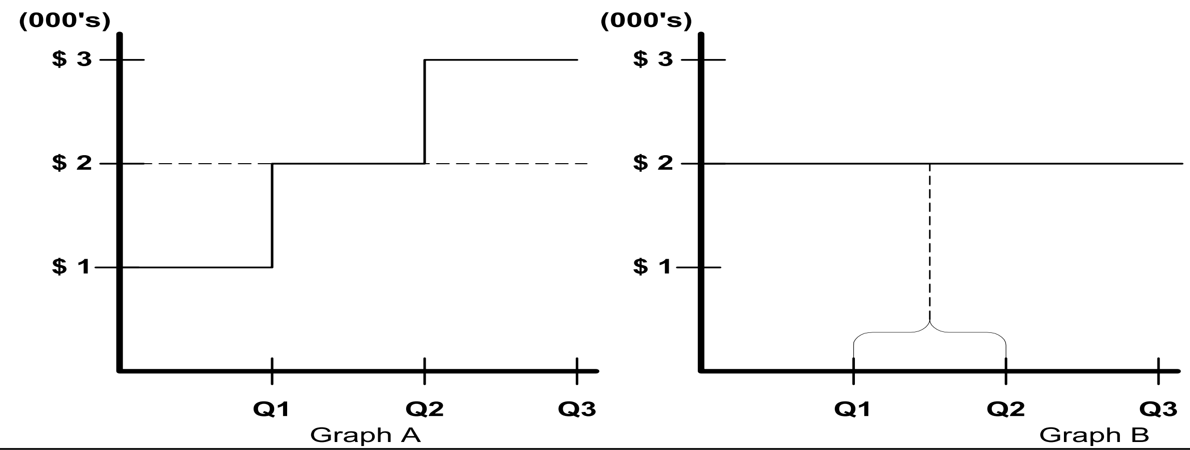
What definitions of fixed costs imply but do not directly state is that a fixed cost is “fixed” only for a single period; that is, per month, per quarter, or per year. It is important to understand that business simulations are never played for a single period but involve decision-making over multiple periods of time. Consequently, for any given fixed cost to remain constant over the entire range of possible sales or production activity is unrealistic.

An important question for simulation designers is: What is the proper view of fixed costs over multiple periods of time? The answer to this question requires an analysis and discussion of the relationship between fixed and step costs. A major premise of this paper is that all so-called fixed costs are actually a special case of step cost behavior.

RELATIONSHIP OF FIXED AND STEP COSTS

In order to understand the approach for modeling fixed costs that will be presented later in this

Figure 1 Relationship of Step costs to Fixed Costs



paper, it is first necessary to understand the relationship of fixed costs to step costs. The relationship is quite easy to illustrate. Fixed cost as illustrated in Figure lB is simply one step in the stair case of steps as shown in Figure lA. The graph of step cost behavior as shown in Figure 1A illustrates that at certain defined levels of activity, additional service units must be acquired in order to have the capacity required to attain the desired level of activity. In order for volume in the range of Q1 - Q2 to be attained, another service unit must be acquired. The acquisition of this service unit causes the total cost to increase to $2,000.

Theoretically, the preparation of a step cost graph as illustrated in Figure 1A can be prepared only after management has carefully evaluated resource requirements at different levels of production activity. It management decides that the most likely volume level is greater than Q2, then the required service units at that level create a fixed cost of $3,000 for the current period.

An understanding of the nature and cause of step costs is essential. The following is a brief outline of the salient factors.

1. Underlying the incurring of each type of fixed cost are identifiable service units. For example, factory supervisory cost is simply the total number of supervisors times average salary. Each supervisor is a separate service unit. Similarly, depreciation can be traced to separate identifiable machines or equipment units. Each machine is a service unit.

2. Each service unit provides production benefits over a measurable range of activity. That is, each unit has a maximum production potential or benefit. For example, a factory supervisor might have the capacity to supervise 10 workers. The ratio of maximum number of factory workers that one supervisor may manage or supervise may be called the capacity ratio or capacity range.

3. The attainment of a certain level of production or gales may sound a signal for the acquisition of another service unit. If this fixed cost resource is not acquired then the constraints imposed by current resources will prevent sales from rising to actual demand because of inadequate production. A simulation that allows substantial increases in production without increases in fixed costs is not realistic.

4. The event that triggers the actual purchase of an additional service unit should be a forecasted or planned activity and not the actual activity of the current period.

5. The decision to increase or decrease a step cost expenditure will be made at regular and well-defined intervals, e.g., monthly, quarterly or yearly. During the time between these decision points, the cost is committed and will not increase or decrease due to a difference in actual activity versus planned activity. That is, the commitment to a certain step or level of cost is inescapable during the current period of activity. Some step costs have the peculiar nature that they can be easily increased at regular increments in activity, but cannot be decreased when production or sales activity decreases. The game designer must explicitly take into account that some costs when incurred are committed for a number of periods.

6. In the design of simulations, step costs must be designated as either explicit decisions made by the game players or designated s internal to the game. For example, if the number of supervisors is a decision to be determined by the game player, then no equation is required to determine the total cost at different levels of activity. However, if the salaries of supervisors is internal to the game, that is, not a factor to be decided by the game player, then in order to achieve a step cost effect some means of achieving this effect must be programmed into the simulation.

7. The acquisition of a fixed cost service unit does not mean that all its service potential will be immediately used. Inherent in the nature of fixed cost service unit is the potential for idle or unused capacity.

8. The incurring of significant amounts of fixed cost resources or service units greatly increases risk of a business for

failure in the event of a decrease in demand.

In a simulation three types of costs require modeling: fixed, step and variable. The difference between a step cost and a variable cost may be summarized as follows: Variable costs are tied to individual units of actual output. Step costs are tied to a range of output based on planned production or planned sales. Step costs are determined at the decision interval between operating periods. Variable costs are incurred during the operating period at the same rate as actual production takes place. A fixed coat is determined at the start of the period.

AN EQUATION APPROACH FOR THE MODELING OF STEP COSTS

Theory

In order to develop a mathematical model for determining the amount of a specific fixed cost at different volume levels, the following values or parameters must be determined.

1. The cost of a single unit of the fixed cost resource (service unit).

2. The capacity ratio; that is, the ratio of the range of output to 1 service unit. If one supervisor can manage 10 workers, then output is 10 supervised workers.

3. A sales forecast and a production budget for the current period.

The objective here is to develop an general equation which will properly compute the required number of services units and the associated total cost at the proper volume intervals. The required resource units generated by these equations must be integer values. A fractional part of a supervisor or a fractional part of a machine can not be purchased.

In order to illustrate how to develop a simulation equation for determining the amount of a specific fixed cost, assume the following:

Capacity ratios:

Output per factory worker	220
Workers per supervisor	10
Planned sales/production	12,000
Salary of a supervisor	$3,000

Intuitively, an evaluation of the above data suggests that 55 factory workers are required: (12,000/220)

Therefore, mathematically, the equation for the number of workers is:

NW = SF/WOR
SF - Sales forecast
WOR - Worker output ratio

Since the capacity ratio is 10 workers to 1 supervisor, the required number of supervisors would be 6 (55/10); this is, NS NW/WSR where:

NS - number of supervisors
WSR - ratio of workers to 1 supervisor

The actual answer was 5.5. However, since one- half of a supervisor cannot be hired, then 6 supervisors must be hired. Since non-integer values cannot be allowed, an integer function must be used. Integer functions exists in computer languages such as BASIC or FORTRAN. Also, the integer function is found in electronic spreadsheet software such as Lotus 1-2-3.

The above analysis for supervisors can be stated mathematically as follows:

TSSC = INT((NW/WSR)+.999) x SAL

TSSC - Total supervisors salaries cost
INT - Function for computing integer values as defined in BASIC or electronic spreadsheet software such as Lotus 1 – 2 - 3.

WSR - Capacity ratio of workers to 1 supervisor
NW - Number of workers; the capacity range of 1 supervisor
SAL - Average salary of supervisors

In the equation, the term INT(NW/WSR) +.999 determines the number of necessary supervisors. This statement uses the Integer function. The Integer function rounds all fractional values down to the next lower integer. For example, 1.8 would be rounded to the value of 1. Therefore, the inclusion of the .999 parameter ensures that rounding up rather than down will take place.

The equation developed for computing total supervisory cost may be generalized for all types of step costs as follows:

TFC = INT((DF/CR) +.999) x CPRU
TFC = Total fixed cost
INT - Integer function
CR - Capacity range of
DF - Demand factor
CPRU - Cost per resource unit

This equation will automatically compute the service units required at each activity level and the total fixed cost.

Application and Illustration

This paper addresses only those fixed cost resources that the game designer has deemed internal. The first step is to define these resources. Examples of fixed costs that are often internal to a simulation are illustrated in Figure 2.

The above listed service units can be expressed mathematically in a manner similar to the equation established above for supervisors. In order to do this, let’s assume the following data and capacity ratios:

Capacity Ratios:

Output per worker	220
Required workers per mach.	5
Maximum workers per supervisor	10
Admn. details per admin. Personnel	1000
Staff per manager	1

Parameters:

Budgeted production		12,000
Cost per machine per pd	=	$10,000
Salary per supervisor	=	$ 3,000
Salary per administrator	=	$ 4,000
Salary per staff	=	$ 2,000

In a business an increase in activity, e.g., production creates the need for additional support activity. Output requires machines and machines require workers, Workers require supervision and supervisors require staff support. The common

Figure 2 Examples of Service units that Provide Capacity

SERVICE UNITS	DEMAND FACTORS(Output measures)	CAPACITY RATIO
Machines	Units of Product	Units of prod to 1 machine
Factory Supervisors	Supervised workers	No. workers to 1 supervisor
Administrative personnel	Admin. details	Admin. details to 1 mgr.
Staff (e.g. clerks,	Processed paper	Units of paper to 1 clerk

denominator in the above list of service units is output in the form of production or sales. The major factor in modeling step costs is to establish a ratio between each service unit and output. A capacity ratio may be stated directly in terms of specified output or indirectly to other factors which are related directly to output.

Based on the above assumed data, step cost functions for each of the above listed service units can be developed as follows:

Number of workers:
NW = (BP/OWR) = 12,000/220 = 55
Number of machines:
NM = (NW/WMR) = 55/5 = 11
TCM = 11 x 10,000 = 110,000
Number of supervisors:
NS = (NW/WSR) = (55/10) = 5.5 (= 6)
TCS = 6 x 3,000 = $18,000
Number of administrative personnel:
NAP = (BP/OAPR) = (12000/1000) = 12
TAPC = 12 x 4000 = $48,000
Number of Staff:
NST = (NS/SSR) = (6 / .5) = 12
TCST = 6 x 2,000 = $12,000

A general equation for all of these calculations may be simply expressed as follows:

A general equation for all of these calculations may be simply expressed as follows:

Number of fixed cost units = Demand factor/ capacity ratio
Total cost = No. fixed cost units x cost per unit

The capacity ratio is simply the maximum output that can be provided by one unit of the fixed cost resource. The demand factor can be a derived demand, that is, directly related to some measure of output. In all cases the ultimate determining factor for the demand factor is planned activity (production/sales). The number of supervisors is determined by the demand for workers, and the demand for workers is determined by the demand for the product. Consequently, the demand for supervisors can be also stated in terms of a capacity ratio based on units of sales or production units.

Example Using the Step Cost Equation

A simple simulation-using Lotus 1 - 2 - 3 was developed based on the above step cost equations. Results based on specified levels of demand are shown in Figure 3. The same results are shown graphically in Figure 4.

In this illustration in which five types of step costs are simulated, net income at each level of sales has been calculated. Both variable and step Costs have been computed at each assumed level of activity.

Some interesting results should be noted. As sales (units) increases net income appears, increases, and then disappears. These pockets of net income can be easily seen in Figure 4. At certain intervals the increased demand causes an increase in one or more step costs sufficient to eliminate any profit that was reported at a lower level of activity. Further increases in activity again results in profit. The profit may then disappear when another jump in step costs occurs.

This type of behavior is very common to many businesses. In this instance, the modeling of step costs created a more realistic cost behavior pattern. If significant amounts of step costs are built into simulations then students may have the opportunity to experience what many real world companies have learned: substantial growth in sales does not necessarily mean an increase in profit.

Evaluation

The above approach is a simplified approach to the modeling of step costs. It requires that capacity ratios for each service or resource unit be established. A basic assumption is that additional units acquired are homogeneous. Implementation of this approach is easy and involves a minimum of programming.

In many businesses, a substantial growth in activity allows for existing smaller units of equipment or machines to be replaced with larger, more expensive units that have a considerably larger capacity range. For example, a small computer can be replaced with a larger computer. The mathematical model just presented can be adapted to allow replacement of equipment to achieve an increase in the economy of scale. Of course, complexity of programming to achieve this effect would be increased somewhat by the need to compute gains or losses on the retirement of old equipment.

The general equation just presented for modeling step costs represents an effective means of increasing simulation realism by allowing fixed costs to assume their true nature as step costs over the entire range of activity that occurs in multiple periods of simulation play.

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Figure 3 Example of a Simulation with Step Costs

FIXED COST SIMULATION

Parameters:		Capacity ratios	
Price	50		
Var. selling rate	20	Output to 1 worker (OUR)	220
Material per unit	5	Workers to 1 supervisor (WSR)	20
Wage rate	10	Workers to 1 machine (WMR)	10
Hours per month	176	Supervisors to 1 staff (SSR)	0.5
Cast of 1 machine	240000	Sales (units) to 1 salesman (SLSMR)	1000
Supervisor salary	3000	Prod. (units) to 1 bldg. (PUBR)	50000
Staff worker salary	2000		
Salesman salary	2500		
Budgeted prod.	100000		
Useful life-mach.	120		
Sales	80000		
Rent-1 bldg.	500000		

EQUATIONS	Volume 10000	Volume 20000	Volume 30000	Volume 40000	Volume 50000	Volume 60000	Volume 70000	Volume 80000	Volume 90000
NW = INT(BP/OWR)	4(		13	182	228	273	319		410
TWC = (NW * (WR * HPWPM))	80960	160160	241120	320320	401280	480480	561440	64064(	721600
NS = INT(NW/WSR)	3	5	7	10	12	14	16	19	21
TSC (MS * 55)	9000	15000	21000	30000	36000	42000	48000	57000	63000
NM = INT(NW/WMR)	5	10	14	19	23	28	32	37	41
TMC = (NM * CPM)	1200000	2400000	3360000	4560000	5520000	6720000	7680000	8880000	9840000
DEPR = TMC/UL	10000	20000	28000	38000	46000	56000	64000	74000	82000
NST = INT(NS/SSR)	6	10	14	20	24		32	38	42
TSTC NST * SS	12000	20000	28000	40000	48000	560(	64000	76000	84000
NSM = INT(SL/SLSMR)	10								
TSMC = (NSM * SSM)	25000	500(	750(						
NBR INT(BP/PUBR)	1	1	1	1	1		2	2	2
TNBC = NBR * Rent	500000	500000	500000	500000	500000	1000000	1000000	1000000	1000000

Figure 3 (continued)

INCOME STATEMENT

Volume (units)	10000	20000	30000	40000	50000	60000	70000	80000	90000
Sales	500000	1000000	1500000	2000000	2500000	3000000	3500000	4000000	4500000
Expenses									
Variable:									
Mater ist	50000	100000	150000	200000	250000	300000	350000	400000	450000
Variable selling	200000	400000	600000	800000	1000000	1200000	1400000	1600000	1800000
Workers' wages	80960	160160	241120	320320	401280	480480	561440	640640	721600
Total	330960	660160	991120	1320320	1651280	1980480	2311440	2640640	2971600
Fixed									
Depreciation	10000	20000	28000	38000	46000	56000	64000	74000	82000
Supervisors' sal	9000	15000	21000	30000	36000	42000	48000	57000	63000
Staff sslaries	12000	20000	28000	40000	48000	56000	64000	76000	84000
Salesmen's sal	25000	50000	75000	100000	125000	150000	175000	200000	225000
Rent	500000	500000	500000	500000	500000	1000000	1000000	1000000	1000000
	556000	605000	652000	708000	755000	1304000	1351000	1407000	1454000
Total var. & fixed Net income	886960	1265160	1643120	2028320	2406280	3284480	3662440	4047640	4425600
	-386960	-265160	-143120	-28320	93720	-284480	-162440	-47640	74400

Figure 4 Graph of Simulation Results