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COPING WITH FUTURE UNCERTAINTIES THROUGH PROBABILISTIC BUDGETING

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ABSTRACT

The management of risk poses a difficult and demanding challenge to traditional planning and budgeting techniques and to management attitudes towards and use of these techniques. Probabilistic budgets are potentially effective devices for meeting this kind of challenge.

THE CHALLENGE

Uncertainty is an increasingly serious challenge for managers. Rapid inflation, government regulations, societal and technical changes all increase the risks business faces in estimating and planning for the future. Decisions regarding new facilities, new products, new markets and new businesses are increasingly more difficult to make and current operating plans become more and more unreliable as they are swamped by unexpected competitive, consumer, regulatory and price changes.

Unfortunately, while planning has become more difficult, traditional planning, and particularly budgeting techniques have not evolved to help the manager better cope with the increasing complexities of his responsibilities.

The difficulty with traditional plans and budgets is that they tend to ignore uncertainty or at least significantly underestimate the potential degree of risk facing the organization. For the firm, the implication of this weakness is that because risks are under estimated, or ignored, no deliberate attempt is made to either understand these risks, or to prepare adequate contingency programs to cope with the risks identified.

PROBABILISTIC BUDGETING

A Definition

Probabilistic budgeting represents an extension of existing budgeting practices to incorporate in the budget specific estimates of uncertainties. This extension is made possible through the concepts of decision analysis and “Monte-Carlo" simulation.

A Practical Illustration

The feasibility and potential value of probabilistic budgeting has been demonstrated within a small transport company specializing in the movement of perishable produce to Canada from the United States. The firm, Floral Transport operates a fleet of modern high- way tractors and temperature-controlled trailers between the grower’s fields, the firms southern consolidation terminal, and its customers in Canada.

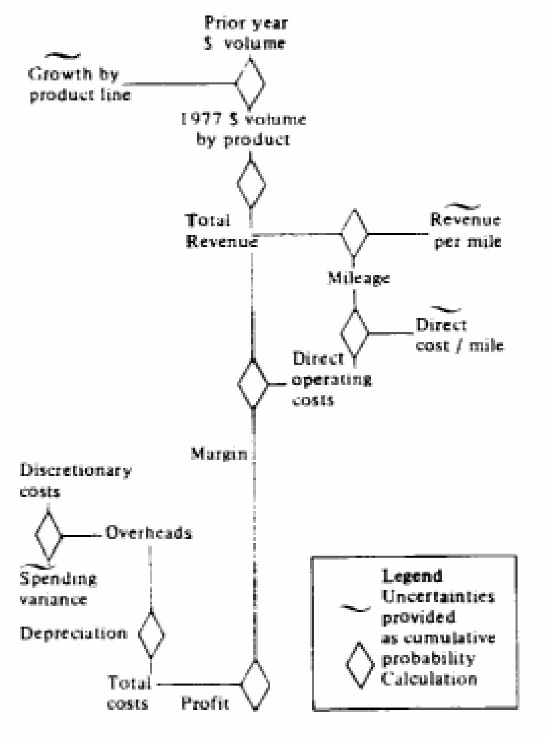
About a year ago, in the face of growing volume, the firm substantially expanded its fleet. As a result of this expansion, Floral sought a more reliable process for estimating future operating results. The president wanted to be prepared for any potential problems he might face in meeting the payment commitments on his new equipment. Addressing this concern required building a model of the firm, identifying the areas of uncertainty facing the firm, eliciting estimates of the ranges of these uncertainties and simulating the operations of the firm.

The Model

The Floral model provides an explicit statement of the problem and identifies the data which had to be gathered to address the problem. For the Floral model this structure was provided by the firm’s chart of accounts and its financial reports. This structure was chosen because management was familiar with the components of the financial system, because historical data was available for estimating some of the parameters of the model and because it allowed for comparison of the model and actual results. The Floral model, outlined in figure 1, is a relatively simple model. Sales are estimated by increasing the prior year’s sales (in dollars) for each product line by the expected growth in that product line. Since these growth rates are uncertain the resulting estimate of revenue is also uncertain.

FIGURE 1

Floral Transport Schematic



Total revenue is then used to estimate anticipated operating mileage and operating costs per mile are estimated for the miles to be operated. Revenue less operating costs represents Floral's trucking margin. Overhead and depreciation costs are deducted from the trucking margin to generate the estimated profit for the year.

Data Collection

The model revealed significant areas of uncertainty:
growth in volume, revenues, direct operating costs and overhead. The next step in the probabilistic process was to assemble the best available information about these uncertainties. To gather this information key management personnel were interviewed using a successive subdivision protocol [1]. This series of questions helped to lead the manager to reflect on changes in operating and external factors which might affect Floral's operations.

The presidents thinking on the cost of fuel per mile was typical of the responses: 'The records show that fuel is costing about 16c a mile, but I know we can expect a price increase of maybe as much as a nickel a gallon before the year is out. On the other hand, our new equipment is supposed to operate at 6 miles per gallon compared to the 4½ miles per gallon we're presently getting. Besides, by installing our own fuel supply tanks in the south we can reduce our highway purchases. Considering all these pieces, I'd expect, in spite of the price increase, we'd maintain our fuel cost about where it is. If we don't see the price jump and the boys really baby the new tractors we might see 11¢ or 12¢ per mile; on the other hand if the price goes up more than nickel and the drivers get lead feet' it could jump as high as 20¢."

The answers to the protocol questions were interpreted to represent descriptions of the potential variability of each of the components of the Floral model (table
1). The table, referring to the Cost of fuel, can be interpreted as follows.

There is a fifty per cent probability fuel will cost more than 16c and a fifty per cent chance it will cost less than 16¢. There is no chance it will be less than 11c or more than 20c. There is a 25 per cent chance it will be more than 17¢ and 75 per cent chance it will be more than l4½¢.

TABLE 1

Floral Transport
Cumulative Density Functions Describing Major Uncertainties in the Floral Transport Model

	Points on Cumulative Density Function					
	.00	.25	.50	.75	1.00	
Growth - product line 1	0.0	12.5	20.0	25.0	30.0	%
- product line 2	-10.0	-3.5	0.0	2.5	5.0	%
- product line 3	0.0	25.0	50.0	100.0	200.0	%
- product line 4	0.0	17.5	25.0	32.5	50.0	%
- product line 5	15.0	23.5	25.0	26.5	35.0	%
- product line 6	25.0	30.0	35.0	41.0	50.0	%
- product line 7	10.0	17.5	25.0	35.0	100.0	%
Margin - product line 1	40.0	43.0	45.0	50.0	60.0	%
- product line 2	0.0	12.0	15.0	17.0	20.0	%
- product line 3	10.0	20.0	22.5	25.0	40.0	%
Transport revenue per mile	.80	1.10	1.15	1.20	1.25	$
Direct costs per mile						
- manpower	.18	.21	.225	.24	.30	$
- maintenance	.05	.075	.09	.10	.125	$
- fuel	.115	.145	.16	.17	.20	$
- licences, permits, insurance	.04	.05	.055	.06	.07	$
- hired vehicles	.10	.17	.20	.23	.30	$
- redelivery	.40	.50	.55	.60	.75	$
- communications	.020	.022	.024	.028	.035	$

In the model a simplifying assumption was made about the firm's overhead costs. For example, it was determined that overhead costs were basically discretionary and could be regulated by management. Therefore, the budget level of overhead costs was provided to the model. The only uncertainty inherent in these costs was expected to be price changes. To represent this uncertainty, a spending variance distribution was built into the model so that overheads would be within ± 10% of budget two-thirds of the time and within ± 20% of budget ninety-five per cent of the time.

Simulation

After the data was collected, it was processed using a computer model written in SIMPAK, a special-purpose FORTRAN based language for simulation of complex problems. SIMPAK provides detailed cumulative density functions for each element of uncertainty and makes them available to the logic model provided by the analyst. The logic model describes relationships between the various uncertainties and the output generated by the model. SIMPAK retained results for up to 500 trials, generated financial summaries and provided statistical profiles describing the uncertainty inherent within each element of the income statement.

The simulation provides information not available from the more familiar single figure or point estimate budget. The results reported in Table 2 are based on the hypothetical operation of Floral's business over and over again, gaining the benefit of experience without the passage of real time. In some trials combinations of costs and revenues produce very unfavorable projections, while other combinations results in high efficiency and revenues. By recording and analyzing these results, we may ascertain the range of possible outcomes for each element of the budget as well as the likelihood or probability that various levels of revenue, expenses and profitability will be achieved.

TABLE 2

Floral Transport Fiscal 1977 Budget
(based on 500 trials)

	Expected Value	Cumulative Probabilities .00	.25	.50	.75	1.00
	(budget amounts in 000's)					
Mileage	880112	778	845	871	905	1098
Revenue Per Mile	$ 1.260	$1.098	$1.226	$1.27	$1.307	$1.375
Transport Revenue	$1109870	$1040	$1086	$1109	$1132	$1191
Manpower	$ 199139	161	189	197	207	253
Maintenance	77450	55	71	77	83	102
Fuel	139593	109	131	139	146	172
Licence & Insurance	48482	38	45	48	50	59
Hired Vehicles	201288	145	195	199	215	275
Redelivery	100079	71	90	99	109	145
Total Transport	$ 766031	666	734	761	794	925
Transport Margin	$ 343839	223	317	347	376	446
Sales Margin	28267	21	26	27	30	18
Total Margin	$ 372106	249	344	376	402	472
Utilities	$ [illegible]	[illegible]	7	7	8	8
Telephone	30156	24	28	29	31	38
Facilities	7982	7	7	7	8	8
Office Wages	90483	69	86	90	95	106
Office Expenses	16998	15	16	16	17	18
Running Supplies	4650	4	4	4	4	4
Warehouse Expense	6199	5	6	6	6	6
Property Taxes	900	0	0	0	0	1
Total Operating	$ 165365	144	160	165	170	183
Salaries	$ 29230	27	28	29	29	31
Professional Fees	10010	9	9	10	10	10
Interest	25527	24	25	25	25	27
Travel	9510	8	9	9	9	10
Advertising	2002	1	1	2	2	2
Total Admin	$ 76279	71	75	76	77	80
Depreciation	$ 55000	55	55	55	55	55
Total Expenses	$ 296644	273	291	296	301	314
Profit	$ 75462	-45	50	78	106	182
Cash Flow (profit plus depreciation)	$ 130462	10	105	133	161	237

The probabilistic budget reinforced the president's concern about the volatility of his operations. While the expected profit was $75,462, the simulation indicated operating results could vary from a loss of $45,000 to profits of $182,000 for the next year.

More significantly, the chance that operations would generate enough cash to meet the firm's $130,000 repayment commitment on the new equipment was only about 50 per cent.

The reliability of the Floral probabilistic budget was tested by the passage of the fiscal year. (table 3)

TABLE 3

FLORAL TRANSPORT
ACTUAL VS PROJECTION 1977

	PROJECTED RESULTS			ACTUAL RESULTS
	LOW	EXPECTED	HIGH	
Mileage	778	880	1,058	858
Revenue	1,040	1,110	1,191	1,D12
Manpower costs	161	199	253	195
Maintenance costs	55	77	102	66
Fuel costs	109	139	172	123
Licences and Insurance costs	38	48	59	61
Hired Vehicle costs	145	201	275	161
Redelivery costs	71	100	145	121
Total Trasnport costs	666	766	925	727
Transport Margin	223	344	446	285
Other Product Margin	21	28	38	26
Total Margin	249	372	472	311
Total Overheads	273	297	314	335
Profit (Loss)	(45)	75	182	(24)

Clearly, the typical single-point $75,000 profit estimate in Table 2 represents a budget that was simply wrong. Floral lost $24,000 in t977. On the other hand, the probabilistic budget did predict a loss of such magnitude was possible. In retrospect, while the Floral probabilistic budget could have been improved, because the model did not predict overhead costs with an acceptable degree of accuracy due to the simplifying assumption that overhead would be normally distributed with a standard deviation of 10%, the probabilistic budget did recognize the potential volatility in the firm's operations.

Its Potential

The potential of probabilistic budgeting is two fold. It provides an estimate of the degree of risk which the firm faces--an estimate which if anything understates that potential risk.[1] This estimate should alert and sensitize management to the risks they face, and hopefully will lead management to more carefully explore the riskiness of their activities and to more carefully consider the implications of these risks.

Secondly, the probabilistic budget provides information concerning the effect individual elements of the budget have on the overall riskiness of the firm. For example, the profit variability in table 2 can be attributed primarily to the variability of the transport expenses and transport revenues (table 4).

The important challenge for Floral's management is determining what operational or policy changes the firm might undertake to reduce this variability. Implicitly the challenge is to better control its operations--to both reduce costs and perhaps as importantly reduce the variability within the firm's costs and revenues.

Establishing tighter control implies an understanding of the uncertainties Floral faces -- their causes, and the extent to which they can be controlled.

[1] The Underestimate results from the difficulty the modeler faces in creating a sufficiently detailed model to encompass all possible uncertainties. It also can be attributed to the difficulty humans have in asses- sing the tails of probability distributions. [2]

The greatest variability in Floral's transport expenses is in the "hired vehicles' expense account (the largest element on the diagonal of table 5). The question facing the president is why is this expense so uncertain, and what can be done about it?

TABLE 4

VARIANCE INHERENT IN
THE FLORAL PROBABILISTIC BUDGET
(000's)

	Mean	Variance
Transport revenue	$1110	963540
expenses	766	2104330
Transport margin	344	1813514[2]
Sales margin	28	9284
Total margin	372	1822798
Operating	165	52853
Admin.	76	2924
Depreciation	55	
Total Expenses	296	55777
Profit	76	1878575

Floral rents equipment from other truckers, and from rental firms like Ryder when volume is greater than the firm's own capacity, or when breakdowns reduce the firm's capacity If management could foresee extra demand additional equipment could be added permanently to the fleet -- capital investment could reduce the

TABLE 5

FLORAL TRANSPORT
DIRECT COST VARIANCE/COVARIANCE MATRIX
ELEMENTS $(000's)[2]

	Manpower	Mainten-ance	Fuel	Licence	Hired Vehicles	Re-delivery
Manpower	220466	43275	63357	24631	97124	9241
Maintenance		82816	38672	10693	44013	7732
Fuel			130197	19129	89548	8241
Licence				13479	23729	4216
Hired Vehicles					507270	5405
Redelivery						172090
	Total Variance (sum of the diagonal)					1126318
	Covariance top above diagonal					489006
	below diagonal (not shown)					489006
	Total variance in transport expenses (table 4)					2104330

[2] While the mean of the transport margin equals the difference of the means of the transport revenue and transport expenses the variance of the transport margin is not equal to the difference of the variance of the transport revenue and the transport expenses because transport revenues and transport expenses are not independent. Instead the variance of the transport margin is equal to:

$$\sigma^2 x_1 + \sigma^2 x_2 - 2\sigma x_1 x_2,$$ where $\sigma x_1 x_2$ is the covariance of the transport revenue and transport expense terms [9], or,

$$963,540 + 2,104,330 - 2(627,178) = 1,813,514$$

necessity to utilize hired vehicles and could reduce the likelihood of major breakdowns. To date management has not had enough confidence in its ability to predict future volume to make this investment. Perhaps under probabilistic budgeting, where uncertainties can be explicitly examined, management may be more willing to undertake these investments.

The next major variation is attributable to the manpower account. Partially this variability is due to a multiplicity of pay plans and payment schedules utilized by Floral. A change in management policy to reduce the number of pay schemes could reduce this variability.

Fuel costs also vary. Management has already taken steps to reduce this variability and the total fuel cost. The installation of fuel supplies at its depots means Floral's trucks will no longer be as susceptible to the vagaries of the retail highway fuel market, and the new "fuel-economy" tractors should reduce actual fuel consumption.

The drivers behavior can significantly effect the fuel consumption of Floral's equipment over the long distances the company travels. By recording, monitoring and perhaps rewarding acceptable consumption, fuel cost variability may be reduced. The issue here is a greater demand for accurate information -- the firms information system may have to become more accurate and more detailed.

Summary

The information generated by the probabilistic budget, and the analysis of the results it projects raises serious questions about Floral's operations. If management responds appropriately to these questions the variability (riskiness) of the firm's operations can be reduced. This appears a totally appropriate goal for the company. Probabilistic budgeting appears to be a potentially powerful tool for this firm -- at least to the extent management can respond to the challenges it raises.

Implications of Probabilistic Budgeting for the Modeler

The variability which exists in the Floral simulation may be partially attributed to elicitation errors and to problems of interdependence between components of the model.

The effect of errors in the estimation of the probabilities upon which the simulation is developed may be small on the estimation of means, but it is large on the estimation of the standard deviation, or the range of outcomes reported. Only minor changes in the estimates provided the model change the degree of variability significantly. The picture of risk presented is highly susceptible to the accuracy with which we are able to develop management's initial assessments of uncertainty, [3].

While simple tests for internal consistency can be applied by the computer programs which manipulate the simulation model, such tests do not adequately deal with the problems of bias and instability in the manager's estimates. Until these serious behavioral questions can be answered, the feasibility of establishing accurate estimates of the manager's perceptions remains in doubt, and until better estimates can be obtained the reliability of the simulation also will be in doubt.

When developing the Floral simulation an important question concerned the model's assumptions about the relationships between the data introduced to the model and amongst the components of the model within the simulation. More precisely, what could be assumed about the interdependence of the data and the manner in which it was manipulated.

The issue of independence has important implications for the modeler. If independence cannot be assumed we face the practical problem of assessing joint probabilities, or of asking managers to describe the correlations between the elements of the model.

In Floral, while it was realized interdependencies could exist, all data gathered was elicited on an "independence' basis. In another model, where the inter- dependencies could not be ignored we asked management to think about the four quartiles of their estimates for sales volume and produce prices. We asked:

> If volume is in the upper quartile would you expect prices to be within the same quartile?

Based on responses to this question the simulation was constrained to generate correlations of .5, if management believed prices and volumes would reside in the same half of the distribution; correlation of .75 if management believed prices and volumes would reside in the same quartile, [4].

While exceptions to this rather crude approach which forced an "expected' dependence on the model, may be raised, historical estimates of intervariable relationships may provide a more reliable basis for coping with the interdependence problem. While sufficient empirical data may not exist to estimate intervariable relationships, conceptually there appears to be no reason why the modeler could not investigate the historic relationships between these variables, and if management believed historic patterns would continue in the future, to require his model to replicate these correlations in the future.

For the modeler, probabilistic budgeting raises significant technical questions. Before probabilistic budgeting can meet its potential as an aid to management these problems must be solved.

REFERENCES

[1] Lord, R. J ., "Probabilistic Budgeting", Cost and Management, Journal of the Society of Management Accountants of Canada, May - June 1978.

[2] Alpert, M. and Raiffa, H., A Progress Report on the Training of Probability Assessors, Harvard University, unpublished 1969.

[3] Lord, R.J., 'Improving Managements 1 Ability to Cope with Uncertainty Through Probabilistic Budgeting", Cost and Management, November-December, 1978.

[4] ibid