# The investment decision under uncertainty

by H. M. WELLS*, Pr. Eng., M.Sc. (Fellow)


## SYNOPSIS

The future outcome of a proposed investment is uncertain at the time the decision must be made to accept it or reject it. This uncertainty can be expressed in the form of a probability distribution. An attempt is made to rationalize the investment decision under these circumstances, especially when the range of possible outcomes extends into both the acceptable and unacceptable domains.

A rigorous definition of *risk* is proposed, and a criterion of risk aversion is developed that forms the boundary between acceptable risk and unacceptable risk (called the loss limitation line). It is shown that this decision criterion can also serve as a quantitative yardstick in the evaluation of various possibilities for 'tailoring' the proposal to make it more compatible with the particular financial circumstances of the company concerned.

## SAMEVATTING

Die toekomstige uitslag van 'n voorgestelde belegging is onseker wanneer daar besluit moet word of dit aanvaar of van die hand gewys moet word. Hierdie onsekerheid kan in die vorm van 'n waarskynlikheidsverdeling uitgedruk word. Daar word 'n poging aangewend om die beleggingsbesluit onder hierdie omstandighede te rasionaliseer, veral wanneer die strek van moontlike uitslae tot in sowel aanvaarbare as onaanvaarbare gebiede loop.

Daar word 'n streng definisie van *risiko* aan die hand gedoen en 'n maatstaf vir risikoafwending ontwikkel wat die grens tussen 'n aanvaarbare en 'n onaanvaarbare risiko (bekend as die verliesbeperkingslyn) vorm. Daar word getoon dat hierdie beslissingsmaatstaf ook as 'n kwantitatiewe maatstaf kan dien by die evaluering van verskillende moontlikhede om die voorstel aan te pas ten einde dit meer verenigbaar te maak met die besondere finansiële omstandighede van die betrokke maatskappy.


## INTRODUCTION

A mineral valuation is essentially an endeavour to predict the financial outcome of a potential mine. This prediction is uncertain because the future behaviour of the determinant parameters is uncertain. However, it is possible to quantify this uncertainty in terms of a probability distribution by means of the Monte Carlo simulation technique. The problem is how to determine the acceptability of such a probabilistic outcome, especially in the marginal situation where the range of possible outcomes may extend well into both the positive and the negative domains.

The problem is a very complex one. It involves not only the intrinsic uncertainties of the project under review, but also the composite uncertainties of the overall portfolio of investments in relation to the resources available to the business as a whole — and the willingness of the decision-maker to take risks.

Because of the complexity of the problem there is a tendency to by-pass it by assuming a state of 'quasi-certainty'. Thus it is common practice to incorporate a risk premium into the yield criterion used to demarcate the GO/NO GO decision boundary. Even after the time and effort expended in determining a probabilistic outcome, the tendency is to 'simplify' by reverting to a single composite criterion such as 'the expected value' or even 'the expected utility value' [1–4]. Such apparent simplification is retrogressive in that it obscures the true nature of the problem, and it negates much of the potentially valuable information that may be derived from a recognition of the intrinsic uncertainty of the situation.

Before an attempt is made to rationalize this problem, some considerations that will fundamentally affect the decision-making logic must be critically examined.

## FACTORS AFFECTING THE INVESTMENT DECISION

### Uncertainty and Risk

Porterfield[5] distinguishes between uncertainty and risk as follows:

> Risk refers to a situation wherein the possible future outcomes of a present decision are plural; however, the dimensions and probabilities of these outcomes are known in advance. Uncertainty refers to a situation wherein the possible future outcomes are also plural; however, their dimensions and/or the probabilities cannot be objectively specified in advance.

In terms of this concept, risk simply refers to a situation in which the uncertainties are probabilistically quantified. The magnitude of the risk is undefined. Other writers consider the spread of the distribution (standard deviation) as a measure of risk, especially in its standardized form (standard deviation divided by the mean of the distribution). However, these criteria are inadequate as a measure of risk because it is the possibility of making a loss that is of fundamental importance to the businessman. Consider the two outcome distributions in Fig. 1.

Although the two distributions are of similar shape, distribution B indicates that the uncertainty of the outcome is a matter of making more or less profit; distribution A on the other hand indicates a very real possibility of making either a profit or a loss. It is the consequences, should the outcome turn out to be a loss, that constitute the real business risk.

In the Oxford dictionary the word *risk* is defined, inter alia, as 'the chance or hazard of commercial loss'. In terms of this definition, risk is a function of two uncertain possibilities concerning the future outcome of a commercial decision, namely:

— the amount of the possible loss,
— the chance of this loss occurring.

On the assumption that the uncertain outcome of an investment opportunity is represented by a probability distribution, the risk is fully defined by the portion of the distribution that falls in the loss domain. To clarify this concept, consider the probabilistic outcome represented by the cumulative distribution in Fig. 2.

The risk is fully described by the heavy portion of the curve. If this curve is translated into numbers, it can be described in the form of a

*Department of Mining Engineering, University of the Witwatersrand.

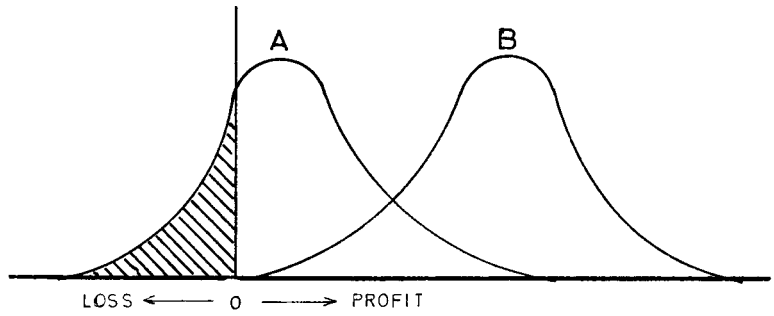


Fig. 1

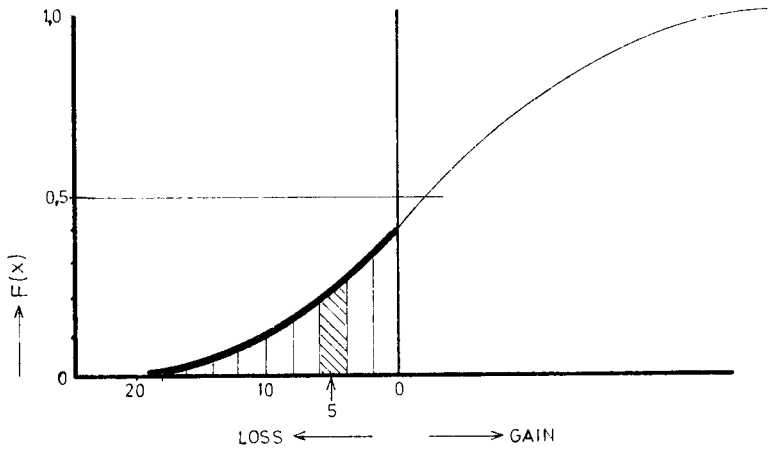


Fig. 2

schedule (Table I), either in terms of the chance that the loss will be equal to or more than any given amount, or in terms of the probability that the loss will fall into a specified category, which may be represented by its midpoint.

## The Concept of Risk Aversion

Under conditions of uncertainty, the investment decision becomes a matter of offsetting the attraction of possible gains against the aversion to possible losses. The decision-maker must weigh the risk involved in relation to his investment objectives, taking account of the financial resources of his company available to underwrite the possible loss if it should occur.

The concept of risk aversion can be illustrated by the representation of an investment opportunity as a simple gamble involving a *single* toss of a coin. The stake represents the purchase price, and the probabilistic outcome is

tails — loss of stake

heads — recovery of stake plus winnings (return).

Suppose the stake is initially set at R10, and the return offered is R11. The 50 per cent chance of a gain of R1 may not be sufficient incentive to overcome the player's aversion to the risk of a 50 per cent chance of losing R10. If the return offered is now increased step-wise, the stake being kept constant, there will come a stage when the favourable 'odds' will just motivate the player to accept the gamble. If the stake is now increased step-wise, the odds being kept constant, sooner or later he will reject the gamble, despite the favourable odds offered, because he is concerned at the magnitude of the possible loss in relation to his available financial resources. However, he may be tempted to take up the gamble again if the odds offered are increased still further. A very considerable increase in the favourable odds would be required to make a normally prudent man take the risk of losing an amount of money that would seriously jeopardize his life-style; a conservative player may reject the gamble altogether at a much lower stake regardless of the odds in his favour.

An individual's aversion to risk, as measured above by the favourable odds required to entice him to accept the gamble, will in general increase exponentially as the magnitude of the possible loss approaches the limit of his resources. However, each man's personal risk-aversion characteristic will be related to his own concept of what he believes he can afford to lose. It is not only a matter of his ability to finance the possible loss — it depends to a large extent on the individual's psychological makeup, which determines his willingness to assume risk; that is, his personal risk propensity.

## Measurement of Investment Risk

The principle of risk aversion applies to a company in the same way as it applies to an individual. In the limiting case, it is the

TABLE I

RISK SCHEDULE CORRESPONDING TO FIG. 2

| Cumulative limit ($x$) | $P$ (outcome $\leqslant x$) $F(x)$ | Category midpoint | Probability of occurrence |
|---|---|---|---|
| 0 | 0,40 | | |
| | | —1 | 0,09 |
| —2 | 0,31 | | |
| | | —3 | 0,06 |
| —4 | 0,25 | | |
| | | —5 | 0,05 |
| —6 | 0,20 | | |
| | | —7 | 0,05 |
| —8 | 0,15 | | |
| | | —9 | 0,05 |
| —10 | 0,10 | | |
| | | —11 | 0,04 |
| —12 | 0,06 | | |
| | | —13 | 0,03 |
| —14 | 0,03 | | |

*magnitude* of the possible loss in relation to company resources that is significant. However, an investment differs from a simple gamble as illustrated above, in that it does not take place in an instant of time; it is made up of a cash flow, in and out, over a period of time. Under these circumstances, a convenient measure of the magnitude of the outcome in monetary terms is given by the present value of the net cash flow over the life of the project; that is, by the net present value (NPV).

The interpretation of the meaning of the NPV is complicated by the fact that its value varies with the rate of discount used to calculate it. The problem lies in the determination of what is the minimum required return on investment capital. This subject has been extensively analysed in modern technical literature[1–4], and there still remains a substantial area of disagreement among the pundits. We shall return to this subject later, but for the moment let us assume that the rate of discount is the return on investment capital that will satisfy the minimum requirements of the decision-maker.

On the above assumption, a negative NPV would not represent an absolute loss; rather, it signifies an *implicit loss*, representing a shortfall below the desired (or required) minimum return on investment capital. Likewise, an NPV of zero represents a condition of satisfaction where the required minimum return on capital is exactly achieved; and an NVP greater than zero is a bonus condition where the required return on capital is exceeded.

## Company Risk Propensity

The penalty for accepting an investment having a negative NPV would become apparent in future years as a shortfall on the required cash contribution of the investment to company earnings. The significance of such a reduction in future cash flow depends on the consequences it may have in terms of the future cash availablility and cash commitments of the company.

Donaldson[6] examines the risk of corporate debt in relation to a probabilistic forecast of the future cash flow under assumed conditions of economic depression. He identifies two degrees of cash insufficiency, namely:

— Cash inadequacy — not enough cash at any one time to meet the expenditures that management may wish to preserve, such as dividend payments, retained earnings to finance expansion.

— Cash insolvency — not enough cash at any one time to meet immediate legal commitments, such as debt servicing, creditors, wages.

With regard to the subject of cash forecasting, Donaldson states[7]:

> An analysis of the risk of cash inadequacy, of which cash insolvency is the extreme case, can be highly complex, involving a variety of sophisticated mathematical and statistical techniques.

It is not the intention to explore the complications of cash forecasting here. Suffice it to say that the future cash flow of any company will be made up of a combination of some uncertain and some relatively certain flows of income and expenditure. Presumably, prudent management will plan to avoid excessive fluctuations in the year-by-year cash position, so that it will remain consistently above some minimum 'safe' level considered adequate to cater for possible adversity. The capacity of such a company to take on a new investment will depend on the risk management would be prepared to assume that the additional investment may create a shortfall on the minimum safe cash level at some time in the future.

Insofar as timing is concerned, it is necessary to discriminate between the short-term and the long-term situation. The confidence limits of the estimates of future probabilistic cash flows deteriorate very rapidly with time[6]. In a mining investment company, it is probably safe to say that a year-by-year cash forecast beyond the period of financing of a new mining venture, say up to five years, becomes very vague, although a forecast of composite average earnings covering a long period of time may be more realistic. It is reasonable to expect that firm arrangements will be made to finance the negative cash flow period of a proposed mining venture, with adequate provision to make a serious cash deficit unlikely in this time. No irrevocable commitment to the investment should be made unless this prerequisite is met; if this requirement is satisfied, then we can proceed to consider the return on the investment capital as represented by the positive cash flow period.

The funding of a new investment will inevitably create its own future demands on cash. Should the venture not meet expectations, it may not generate sufficient funds to meet these additional cash needs; in which case, it would make inroads on the existing cash resources of the company, and embarrass, inconvenience, or jeopardize the survival of the company according to the magnitude of the shortfall. The risk propensity of the company is the chance that the decision-maker will assume that any of these eventualities may occur.

The primary problem is to quantify the amounts of money representing the above range of consequences. This is not an easy problem; it is one requiring very thorough research into the financial structure, profit potential, and policy objectives of the company.

Although the following does not pretend to present a complete solution to this problem, it is necessary for the sake of pursuing the argument to synthesize a highly simplified theoretical approach to it.

Suppose that a company's investment policy is defined in terms of a minimum acceptable return on investment capital. Under conditions of certainty, an investment opportunity, to be acceptable, should offer at least this return; that is, if its NPV when discounted at the required rate is zero or more, it will satisfy the company's profit motive for investment.

If uncertainty were taken into account, the outcome of a valuation would be declared in terms of a probability distribution. In this case, the NPV may range on either side of zero. In a marginal situation, the chance of the outcome turning out to be equivalent to zero NPV or more will be the same as the chance of it being zero or less (median NPV=0).

If an investor accepts an investment having a median outcome of zero NPV, he would be taking a chance of 1 in 2 ($P$=0,5) that the outcome will be satisfactory. By definition, this also means that he will be taking the same chance [illegible] scenario, as in Table II.

Table II is derived by considering the consequences to the company as a whole of possible future cash shortfalls below the target level required by company policy. The investment under consideration could feasibly become the direct cause of such a shortfall if its eventual outcome turns out to be one of the unfortunate possibilities predicted by a negative NPV (negative tail of the valuation distribution). Therefore, it is necessary for purposes of comparison to convert the risk aversion schedule derived in terms of cash shortfall (Table II) into an equivalent risk aversion schedule in terms of negative NPV.

It must be remembered that a prerequisite condition to this analysis is that the negative cash flow period is considered independently in relation to the short-term year-by-year cash forecast of the company. Therefore, we are now concerned only with the long-term period thereafter; in view of the uncertainties of long-range forecasting, it is preferable to treat this period as if the cash flow were in the form of an annuity.

Let us examine the derivation of the NPV in relation to the two cash flow periods.

Let $N$=present value of the negative cash flow period

$P$=present value of the positive cash flow period.

[illegible] be achieved only if NPV=0, that is in this case if $P$ were to improve from $P_o$ to $(P_o+\Delta N)$.

$\therefore$ Deviation from requirement $= P$(actual) $- P$(required)
$= P_o - (P_o+\Delta N)$
$= -\Delta N.$

(ii) If $P<P_o$ and $N=N_o$
Let $P=P_o-\Delta P$
$\therefore$ NPV $= P-N$
$= (P_o-\Delta P) - N_o$
$= -\Delta P.$

The cash flow target would be achieved in this case if $P$ were to improve from $(P_o-\Delta P)$ to $P_o$.

$\therefore$ Deviation from requirement $= P$(actual) $- P$(required)
$= (P_o-\Delta P) - P_o$
$= -\Delta P.$

(iii) Under this condition, both $N$ and $P$ could change. The outcome will become a negative NPV provided the relative change is such that $N$ becomes greater than $P$. Following similar logic to the above, it can be shown that the magnitude of the negative NPV is equal to the present value of the resulting shortfall in required [illegible] Hence, the risk aversion schedule given in Table III is derived in terms of negative NPV from the values in Table II.

TABLE II

RISK AVERSION TO POSSIBLE CASH SHORTFALLS

| Cash shortfall (R million per annum) | Limiting chance $P$ (outcome ⩽ shortfall) |
|---|---|
| 0 | 1 chance in 2 ($P$ = 0,5) |
| −1 | 1 ,, ,, 3 ($P$ = 0,33) |
| −2 | 1 ,, ,, 5 ($P$ = 0,2) |
| −3 | 1 ,, ,, 10 ($P$ = 0,1) |
| −4 | 1 ,, ,, 20 ($P$ = 0,05) |

TABLE III

RISK AVERSION IN TERMS OF NEGATIVE NPV

| NPV | $P$ (outcome ⩽ NPV) |
|---|---|
| 0 | 0,50 |
| −3,6 | 0,33 |
| −7,2 | 0,20 |
| −10,8 | 0,10 |
| −14,4 | 0,05 |

The above schedule is represented by the curve LL in Fig. 3.

If we consider a negative NPV as an implicit loss, then LL is the loss limitation curve representing the risk aversion characteristic of the company. It provides a boundary line between acceptable risk (below the LL curve) and unacceptable risk (above the LL curve).

## Rate of Return on Investment Capital

Under conditions of quasi-certainty, the rate of return on investment capital comprising the GO/NO GO decision boundary can be considered as an amalgamation of four elements:

(i) the cost of capital,
(ii) a premium to motivate investment,
(iii) a premium to offset risk, and
(iv) a measure of the risk propensity of the decision-maker.

The last two elements are fully accounted for when uncertainty is

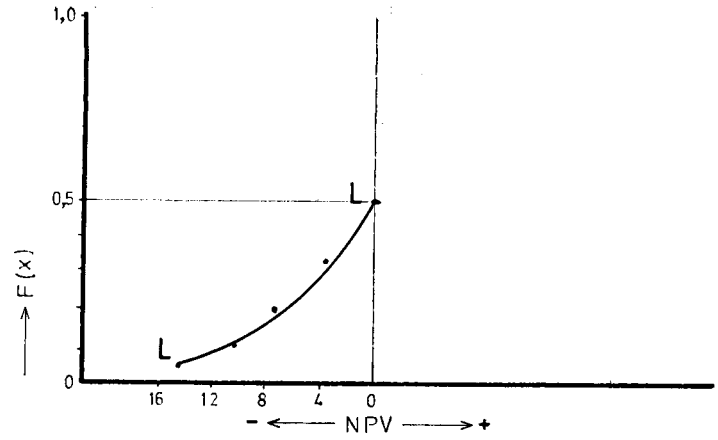


Fig. 3

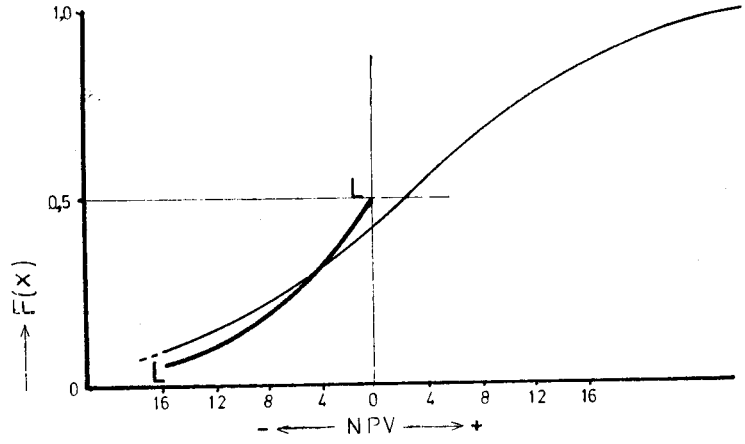


Fig. 4

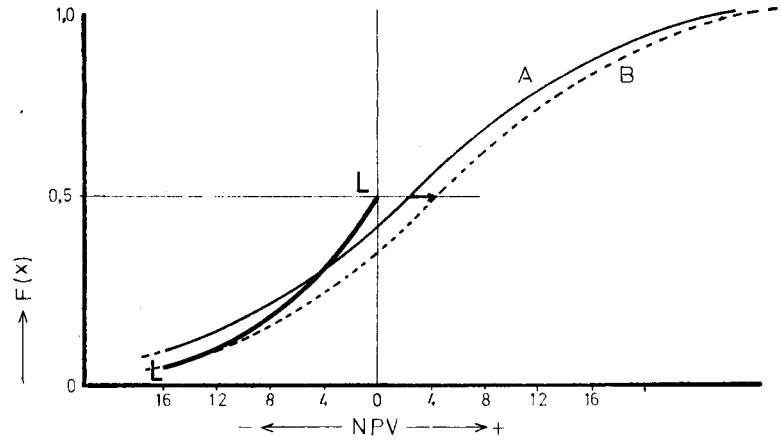


Fig. 5

taken into consideration. The risk is defined by the probabilistic outcome distribution; risk propensity, by the shape of the LL line. Therefore, we are left with the cost of capital plus the premium required to motivate investment.

Although methods have been propounded for objectively determining the cost of capital, the premium required to motivate investment is a purely subjective assessment. Together they represent the rate of return on investment capital that the decision-maker thinks would constitute a satisfactory long-term average business outcome. It is important to bear in mind that there is no question of risk involved in this assessment.

## THE INVESTMENT DECISION

It is proposed that an investment proposal should be subjected to two tests of acceptability: the short-term test covering the negative cash flow period, and the long-term test covering the positive cash flow period.

The short-term test is an assessment of the ability to finance the investment without over-straining the financial resources of the company over the period for which it is practicable to make a realistic year-by-year forecast of the cash flow within reasonable limits of confidence. If, under adverse circumstances, cash inadequacy appears likely within the period considered, then it would be unwise to assume the additional burden of a new investment, regardless of its ultimate attractiveness. Timing is of the essence in the above context. A suitable shift in the timing of a new investment may avoid the superimposition of commitments, thus dampening possible fluctuations in cash demand.

The long-term test is one of general risk limitation. In Fig. 4 we see the LL line superimposed on the cumulative distribution curve representing the outcome of a valuation (as produced by a computer using the Monte Carlo technique). The median outcome of this proposal is well above zero NPV, which, if considered in isolation, would give a positive accept signal. However, when risk is taken into account, the proposal would not be acceptable because the negative portion of the distribution crosses the LL line into the unacceptable risk area. For instance, the probability of a negative NPV of R16 million is approximately twice that of the acceptable limit; hence, the investment proposal in its present form carries too much risk of financially crippling the company.

While this investment proposal is not acceptable in its existing form, it does not mean that the project itself is intrinsically unacceptable. There are many ways and means of 'tailoring' the proposal to bring its risk characteristics more into line with the requirements and constraints of the company as repre-

sented by its LL line. Some of these possibilities are considered below.

### Re-negotiate Terms of Ownership

In Fig. 5, curve A is the cumulative distribution of an existing investment proposal. It is not acceptable in relation to the LL line.

This venture could be made acceptable if it were possible to shift the whole distribution horizontally to the position shown by curve B. The minimum amount of the required shift is indicated by the horizontal arrow in Fig. 5. In this instance it is approximately R2 million on the horizontal scale.

Such a quantitative objective could form the basis for re-opening negotiations on such determinants as the purchase price, lease or royalty payments, or other imposed demands made on the gross mining profit.

### Review Estimates

A refinement in the probabilistic estimates of the input parameters would tend to reduce the dispersion of the outcome distribution. However, it may not necessarily improve the situation, because the median of the new distribution could move towards the left or towards the right. In Fig. 6, B is the new distribution in which the median has in fact moved towards the left, but, owing to its smaller spread, it now does not transgress across the LL line.

### Optimize Technical Design

Suppose that curves A and B in Fig. 6 represent the relevant outcomes of two independent evaluations of the same ore-body, each based on different design parameters. For instance, A may be based on a high-production, short-life proposal (a large mine), whereas B may be for a small-production, long-life proposition (a small mine). Although A has a higher median and greater profit potential than B, it is unacceptable in relation to the LL Line. Plan B may be sub-optimum for a larger company with greater financial resources, but it is more suitable for the company concerned because its risk does not exceed the limits of company policy.

For an ore-body of finite dimensions, there is usually scope for such 'tailoring' of the technical design of a mining proposal, bearing in mind the financial constraints of the entrepreneur. Parameters that may be examined in this respect are

(a) the size of the mine in terms of tonnes per annum,
(b) the extraction grade, if selective mining is possible,
(c) the rate of build-up to full production, and
(d) the mining sequence in terms of physical location.

### Selection of Investments

Curves A and B in Fig. 6 may alternatively be considered as the outcome distributions of two different and competing investment proposals. Although A has the higher profit potential, B should be preferred on argument similar to that above.

A special problem arises in the situation where it is required to rank two or more acceptable investments. The choice lies between the attraction of the profit potential and the wish to minimize risk. No simple rule of thumb applies in this situation. The choice must be a subjective one, taking into account the current cash situation, the make-up of the current investment portfolio insofar as risk susceptibility is concerned, the company policy with regard to horizontal or vertical diversification, resource availability other than cash, and the personal preference of the decision-maker.

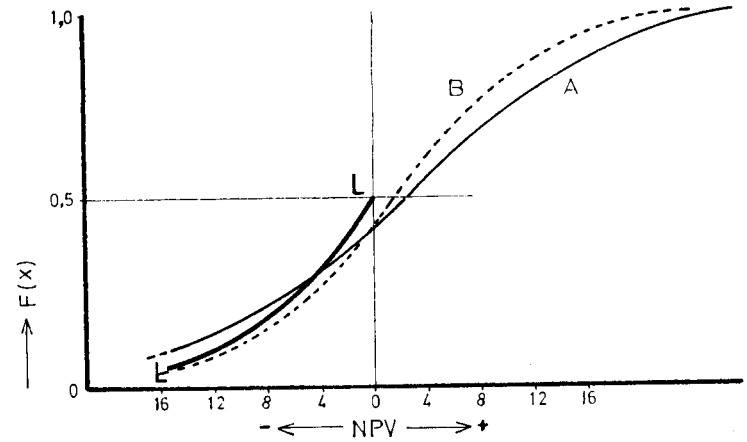


Fig. 6

### Optimize Financial Gearing

The financing of the negative cash flow period of an investment may be in the form of equity and/or loan funds. Under conditions of assumed certainty, the leverage effect of financial gearing on the 'yield on equity capital' is well known; it is levered upwards when the cost of loan capital is less than the average yield on total capital employed and *vice versa*. Under conditions of uncertainty, if the valuation outcome were to be declared in terms of a probability distribution of the yield on equity capital, it is clear that the portion of the distribution greater than the cost of loan funds would be stretched in the positive direction, while the lesser portion would be stretched in the negative direction; that is, the range of uncertainty would be increased.

What is the effect of gearing on the NPV outcome distribution? Consider first the case where the negative cash flow is financed entirely from equity funds. The NPV, being the difference between the present value of the positive cash flow and the present value of the negative cash flow, can be considered as a measure of the 'present worth' of the project over and above its prerequisite return on total capital invested. The intrinsic worth of the project will not change with gearing. However, equity capital does not draw interest, whereas loan capital does; hence, under conditions of financial gearing, the NPV will be reduced by an amount equal to the present value of the cash flow representing the after-tax interest payable and the repayment of loan capital.

Suppose that curve A in Fig. 5 is derived for an investment proposal financed by equity and loan funds. It is unacceptable in relation to the LL line. However, by reducing the loan to equity ratio, the curve will shift horizontally to the right. Curve B would represent the condition of optimum acceptable gearing.

### Spread Equity Holding

Suppose that curve A in Fig. 6 represents the outcome of an investment proposal in which the company will provide all the equity capital. Curve B would represent the outcome of the *company's interests* in a partnership arrangement in which the risk is shared between participating parties, each providing a portion of the equity and being identified with the same share of the total cash flow.

The sale of stock to the public can be considered in the same way as the above.

## CONCLUSION

An attempt has been made to thread a logical path through the maze of complexities associated with the problem of rationalizing the investment decision in an uncertain world. A methodology is proposed. It appears to make the most out of the procurable information derived from an investment analysis when considered in relation to the financial constraints imposed by the entrepreneur. Some of the potential benefits that may accrue from this approach are briefly reviewed below.

(1) The short-term financing test is directly referred to the immediate cash flow resources and commitments of the company. The capacity to finance the project safely is a primary prerequisite to acceptance.

(2) The LL line is individually tailored to express the long-term investment policy of the firm in relation to its own particular resources and its future cash commitments, as determined by the propensity of the decision-maker to assume risk.

(3) The LL line is probabilistically defined in terms of negative NPV so that it can be compared directly with the risk of the investment proposal, as defined also by the negative portion of the NPV distribution.

(4) The LL line does not limit the size of the investment — only the amount of acceptable risk (the magnitude and the probability of possible loss as represented by the negative NPV of the outcome distribution).

The valuation outcome of any investment proposal can be expressed as a probability distribution in terms of the return on investment capital (the yield), or in terms of the NPV. The spread of the distribution of the yield is a measure of the uncertainty of the outcome. The spread of the distribution of the NPV is a function of the size of the investment outlay and of the uncertainty (as expressed by the yield distribution).

Curve A in Fig. 7 could represent an uncertain small investment, or an extraordinarily certain large investment. Curve B would be a very large investment of normal uncertainty. It is seen that an investment of type A is acceptable provided its median NPV is equal to or greater than zero, whereas a very large investment of type B is limited by the lower end of the LL curve representing the maximum acceptable risk of a major loss that would jeopardize the survival of the firm. It is seen in Fig. 7 that the median of a type B investment must be well above zero NPV.

We conclude that a small investment merely needs to meet the marginal requirement of median NPV=0*, whereas a very large investment to be acceptable must either have a very small range of uncertainty, or it must offer a potentially high yield on investment capital (median NPV > 0). It is postulated that this logic conforms with intuitive judgement — its great advantage is, however, that it is quantified.

(5) It must be remembered that the discount rate used in the derivation of the NPV does not incorporate any provision for risk. The shortcomings of the concept of endeavouring to compensate for risk by merely adding a blanket 'risk premium' to the discount rate becomes clear when considered in the context of the above argument. Insofar as type A investments are concerned, an inflated discount rate could result in the rejection of potentially advantageous investment opportunities; for type B investments, an underestimate of the risk premium could indicate acceptance of a potentially dangerous investment commitment.

(6) The LL line not only provides a first accept/reject criterion; it also provides a quantitative yardstick in the evaluation of

*If the outcome distribution is negatively skew, the mean of the distribution should be equal to or greater than zero.

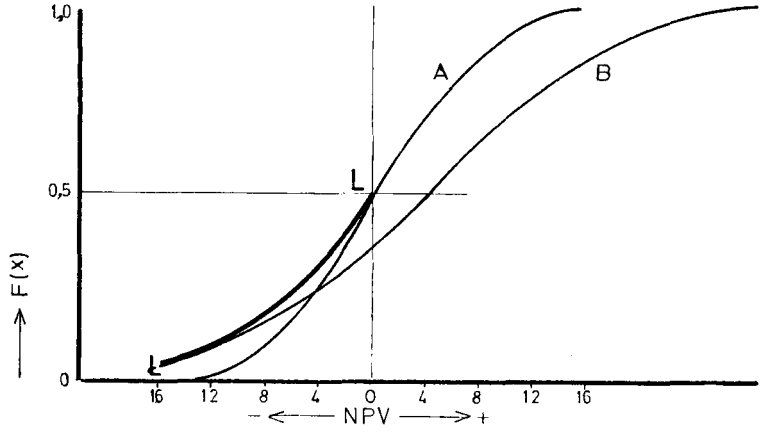


Fig. 7

alternative proposals for risk optimization.

(7) Normally, as a routine of financial management, cash forecasts and liquidity commitments are reviewed on an annual basis — that is an appropriate time to review the LL policy for the new year. However, any major new investment would materially change the pattern of future cash flows, necessitating a review of the ensuing LL policy. A change in the shape of the LL line immediately represents a change in investment policy, which is easily communicable to all interested parties within the firm.

Bearing in mind the potential benefit that may flow from the use of the LL line as the criterion in an investment decision, it is appropriate to take a critical look at the weaknesses of the method. Palpably, the fundamental queries must lie in the derivation of the LL line, and in the validity of the probabilistic outcome distribution of the valuation. In an uncertain world, there can be no absolute solution to the investment-decision problem — the objective, therefore, must be to make the best possible use of the procurable information at the time that the decision has to be made.

While some effort has been made to identify the underlying logic of the situation, it is clear that the application of this logic would present many difficulties in practice. Initially it is suggested that the LL line should be derived subjectively, bearing in mind past investments that have been either accepted or rejected. As experience is gained with subsequent investment proposals, the LL line may be either relaxed or tightened up until it is a reflection of the current investment policy of the decision-maker. Such a subjective approach does not preclude the need for fundamental research into the problem of objectively deriving a criterion that will enable investment decisions to be made consistently in the best interests of the company. It is hoped that this theoretical analysis of the subject may make some contribution in this direction.


## ACKNOWLEDGEMENT

Grateful acknowledgement is made to Professor R. P. Plewman, Head of the Department of Mining Engineering of the University of the Witwatersrand, for the encouragement given the author in his research and for permission to publish this paper. A special word of thanks is due to the students, academicians, and professional men who have listened patiently to the arguments and have contributed to the conclusions expressed in this paper. Finally, acknowledgement must be made to the authors quoted in the list of references; and apologies if, inadvertently, material has been used without specific reference.


## REFERENCES


1. VAN HORNE, J. C. *Financial management and policy.* Second edition, Prentice-Hall.
2. PORTERFIELD, J. T. S. *Investment decisions and capital costs.* Foundation of Finance Series, Prentice-Hall.
3. SOLOMON, E. *The theory of financial management.* Columbia University Press.
4. BIERMAN, H., and SMIDT, S. *The capital budgeting decision.* Collier-MacMillan.
5. PORTERFIELD, J. T. S. *op cit.*, pp. 107, 108.
6. DONALDSON, G. *Corporate debt capacity.* Harvard University Press.
7. DONALDSON, G. *Ibid.*, pp. 157, 158.


## FURTHER READING


DONALDSON, G. *Strategy for financial mobility.* Howard University Press.

HICKS, Sir J. *Critical essays in monetary theory.* Oxford University Press.


# Jet cutting

The Third International Symposium on Jet Cutting Technology is to be held in Chicago from 11th to 13th May, 1976. The topics to be discussed are as follows: Fluid Mechanics of Jets, Experimental Studies of Pulsed Jets, Jet Cutting Equipment, Mining Applications, Rock Cutting, Industrial Applications, Jet Cleaning, and Safety Aspects.

Enquiries should be directed to N. G. Coles, Organising Secretary, 3 ISJCT, BHRA Fluid Engineering, Cranfield, Bedford MK43 OAJ, England.

# Mineral processing

The 12th International Mineral Processing Congress is to be held in Sao Paulo, Brazil, from 29th August to 3rd September, 1977.

The following are the topics for discussion:

Applied Sciences and Basic Research in Mineral Processing
Process and Unit-operation Research and Development
Process and Installation Design
Plant Operation and Practice
Economics of Mineral Processing.

Further information is obtainable from Paulo Adib Anderdy — Secretario Executivo, Comissao Organizadora do 12° Congresso Internacional de Processamento de Minerais, Rua Gabriel dos Santos 419, CEP-01231, Sao Paulo, Brasil.