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FUND MANAGEMENT RISK CONTROL

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1. Introduction

Poor fund performance is the most significant risk for an investment management organisation. There are many further risks to the firm, such as operation and legal risks, but in this paper we concentrate on portfolio risk and in particular how it can be identified, monitored and controlled. The issues raised by this subject are not without controversy: there are some investment specialists who see no benefits from risk analysis for institutional funds and there are some fundamental problems associated with identifying and measuring the risk.

In other types of financial institutions, risk analysis techniques have developed rapidly. A substantial amount of research has taken place in the actuarial field on asset-liability management for pension funds and insurance companies. In the banking industry the development of sophisticated models to measure and manage risk has gathered pace in recent years partly as a consequence of customer demand for derivatives. The increasing power and reducing cost of computers has facilitated the introduction of risk analysis systems that previously would not have been cost-efficient. For fund management operations, however, risk control techniques have often not kept pace. Meaningful risk controls are not universally applied and their benefits often not fully recognised. However, fund advisors' demands are increasing. They are concerned not just with performance but how that performance has been obtained and in particular the risks taken.

In section 2 of the paper the importance of risk control to a fund management organisation is considered. The problems of defining risk in the context of management methods are discussed in section 3. Section 4 reviews the current approaches to risk assessment and we suggest how their robustness and accessibility to fund managers can be improved. In section 5 we outline a new epithet for risk that focuses on risk relative to a benchmark and demonstrate the application of this risk control technique to peer group risk. A description of an integrated risk management function is given in section 6. Section 7 illustrates the problems associated with defining a benchmark as an appropriate base asset distribution and then measuring portfolio risk against that benchmark.
We hope to show that risk control is an important part of the quality control process for fund management organisations. Superior risk control techniques which are appropriately applied should lead to a greater understanding of the characteristics of a portfolio and improved, more consistent performance.

We would like to thank B L Grayson and P M Booth for many useful comments during the preparation of this paper. Naturally we take full responsibility for any errors and omissions that remain.
2. Why Control Investment Risk?

To some it will appear self-evident that risk should be scientifically controlled. This is not a unanimous view. Others adopt a more dismissive attitude and believe that "if we look after the expected return the risk will look after itself" (Clarkson & Plymen, 1989). Unfortunately no professional fund management organisation guarantees outperformance of the market. If one did there would be no chance of poor relative performance for their investors. Indeed studies within the pension fund management business have shown that although some managers can achieve success for a period of years, consistent top quartile performance is almost impossible (WM, 1993). From a quantitative viewpoint even if a fund appears consistently to outperform, commentators assert that statistical proof of skill requires an analysis extending over at least fifteen years (Urwin, 1994). Changes in personnel and the investment process during the period are likely to make any conclusions wholly irrelevant. Even the most successful funds are unlikely to achieve their objectives from time to time. Investors are particularly concerned about underperformance and it follows that fund managers must focus on this feature as well; striving to control the probability of underperforming a predetermined benchmark and minimising its magnitude when it actually occurs.

If risk analysis has its uses, are there reasons why a fund management organisation may not wish to use it? One possible reason is that producing the analysis diverts resources away from the key task of selecting tomorrow's outperforming stocks, which in itself reduces the chances of underperformance. Also, risk analysis techniques are often complex and "black box" in structure, and output can be difficult to interpret and communicate to fund managers without statistical training. However recent developments of risk assessment methods have enhanced risk control techniques that are now more transparent in design and accessible to numerate fund managers. Furthermore with the increased power of computers and improvements to the presentation of risk analysis, control systems are now more effective and cost-efficient.

Critics argue that the output from a risk management system is unreliable and the dangers that can arise from misuse far outweigh the benefits derived from its production. Control systems which compensate for the inadequacies of the risk
methodology and limit the risk of misuse have now been designed. With any tool, however, there remains the possibility of misapplication by inexperienced or uneducated individuals.

It is suggested that risk is only a problem for funds holding a small number of securities and is not a relevant issue for professional investment managers maintaining reasonably well-diversified portfolios. A facet of risk that is germane to these institutional investors however (and discussed in this paper) is "league table risk" - the risk of a fund underperforming its designated peer group. The emphasis is on the relative rather than absolute risk positions of such funds. League table ranking is often a crucial factor when investors assess existing or prospective managers and is likely to be at the forefront of all fund management organisations' minds. There must therefore be value to be gained from analysing relative risk.

Perhaps the most controversial claim of risk analysis is that it improves performance; deviations from a benchmark are limited to a certain extent even when a formal risk analysis system is not in place. It may be possible though to obtain a higher expected return for the same risk (however defined) if a further understanding of the risk characteristics are known. Even though most risk analysis systems are far from exact, it is reasonable to assume that further understanding of risk creates the opportunity to move closer towards the optimal risk and return position. In this way the expected return from a portfolio may be increased by improved risk assessment.

While risk analysis has many benefits in theory, significant obstacles need to be overcome before its conclusions can be of practical use. A central problem is generating reliable estimates of risk statistics; precise calculation is unlikely to be possible. The derivation of dependable risk measures, their presentation in a user-friendly format and the subsequent effective control of the risk of underperformance are all major challenges for fund management organisations incorporating risk controls into their management process.
3. Fund Management Risk

"When I use a word, it means just what I choose it to mean - neither more or less."

*Humpty Dumpty in Through the Looking Glass by Lewis Carroll*

3.1 Risk Value Models

Defining a risk return framework which is both mathematically tractable and consistent with the way investors make investment choices in practice is fraught with difficulties. Such problems have been a major obstacle to the financial analysis of investor behaviour over the last few decades. There are several well known examples which demonstrate that expected return is not sufficient to rank the desirability of alternative portfolios and their utility does not necessarily specify investor preference (see appendix). A number of attempts have been made to develop risk value models that do not suffer the shortcomings of the established financial economic approaches. A range of potential risk value models have been suggested but these alternatives also have shortcomings (Sinha, 1994). Some researchers suggest that no single model can accurately predict risk and unique risk models ought to be specific to particular applications that have their own generally accepted notion of risk (eg. Sarin and Weber, 1993).

One of the main approaches to portfolio risk assessment has been Modern Portfolio Theory (MPT). MPT assumes the objective of all investors is to maximise their utility of wealth where utility is a function of expected return and variance. Historically, utility maximisation was derived via mean variance analysis in which portfolios were ranked according to their expected mean returns and volatility relative to a risk-free asset. A portfolio with the minimum variance for a given return is deemed an efficient portfolio. This definition of rational behaviour is referred to as the expected utility maxim but is rejected by many commentators. Not only is the principle of utility maximisation subject to exceptions (see appendix), but the meaning of risk, they argue, is unique to each investor and depends on their initial wealth and on-going liabilities. Therefore one investor's efficient (in MPT terms) portfolio may not be efficient in the
eyes of another investor. The multitude of alternative risk-free assets for the universe of investors combined with the existence of liability-led benchmarks invalidates this approach and also attempts to segregate the assessment of investment risk from an investor's liability structure (eg. Tobin, 1958).

The problems associated with defining a universal measure of risk and an "efficient fund" does not imply that risk assessment for individual portfolios is now redundant. If a suitable definition of risk can be found for a portfolio and appropriate approximations to the probability distributions of the asset returns defined, then a meaningful risk return assessment is possible.

3.2 Risk Measures

A number of methods to assess portfolio risk have been suggested. Some of these are used to produce ex-post risk-adjusted returns but can be modified to assess ex-ante risk-return attributes. Some measures are listed below:

1. **Jensen:** the expected return on a portfolio in excess of the risk-free rate divided by the portfolio beta (beta is defined in Section 3.3).

2. **Sharpe:** the expected return in excess of the risk-free rate divided by the standard deviation of return.

3. **Roy:** the probability of producing a return below a nominal (or benchmark) rate.

4. **Kataoka:** the portfolio return that can be achieved with a given level of confidence.

5. **Telser:** the expected portfolio return, but only for portfolios with a probability of achieving a benchmark return with a given level of confidence.
6. **Sortino:** the expected return in excess of the minimum acceptable return, divided by the downside risk (Sortino, 1991). Downside risk is the square root of the probability-weighted squared deviations of those returns falling below the benchmark rate.

Each of the above measures can be adapted when risk is measured relative to a benchmark rather than a risk-free rate. In effect the risk-free return is the benchmark return. The list highlights the wide range of different risk measures available based on different concepts of risk. The risk of performing below a benchmark appears to be the crucial risk for a fund manager and is most closely represented by the Sortino measure. This is discussed further in section 5.

### 3.3 Diversifiable and Non-Diversifiable Risk

In an assessment of risk it is common to separate diversifiable and non-diversifiable risk. It is suggested that diversifiable risk is less of a problem because it is reduced when combined with portfolios exhibiting other risks. Therefore it is the non-diversifiable risk that efforts should be made to control. This is examined below in the context of the usual derivations of non-diversifiable risk.

The basis of most attempts to identify non-diversifiable risk originate from the Capital Asset Pricing Model (CAPM) proposed by Sharpe in 1964. This has had a significant effect on the conceptual framework used to assess the risk characteristics of investment portfolios. In Sharpe's original paper, it was shown that in a mean variance framework, where risk is specified in terms of variance relative to a risk-free asset return and the market is in equilibrium, the expected return of all portfolios can be identified. The expected return from a portfolio is determined by its sensitivity to changes to an efficient portfolio, by applying the following formula:

\[
R_p = R_f + \beta_p * (R_m - R_f)
\]

Where \(R_p\) is the expected portfolio return, \(R_f\) the risk-free rate, \(R_m\) the return from an efficient portfolio and \(\beta_p\) is the covariance between the portfolio and an efficient portfolio divided by the variance of that efficient portfolio. CAPM rests on a number
of assumptions. We consider just two aspects of the model: the use of mean variance analysis by investors and the identification of an efficient portfolio which is used to calculate the beta coefficient.

The idea that there is an element of risk which cannot be removed simply by increasing the number of securities in a portfolio is not a controversial assertion. It follows directly from an analysis of portfolio variance. In the limiting case, for an equally weighted portfolio, the variance of a portfolio is the average of the covariances between the individual securities comprising the portfolio (Markowitz, 1987). The assertion that all investors are risk averse and they require additional return for accepting higher risk is similarly uncontroversial. This implies that securities which have volatility that cannot be diversified away are less attractive and require higher returns than securities with similar volatility that can be diversified. Again this can be accepted at least in theory and is close to the CAPM conclusions. Isolating non-diversifiable risk is a major obstacle in practice.

A key problem is the identification of an efficient (or fully diversified) portfolio. If markets are in equilibrium and investors act rationally they should all hold efficient portfolios. Also, if investors have the same definition of risk in terms of variance of return and risk-free rate then the combination of a number of efficient portfolios is an efficient portfolio (Black, 1972). The corollary is that the portfolio containing all assets held by all investors is also an efficient portfolio. This 'universe' includes both quoted and unquoted securities and investments. Investors have the opportunity to invest overseas and therefore foreign assets should also be included if investors are rational and follow solely mean variance guidelines. The computation of betas from all investible securities within this universe is impracticable.

CAPM further assumes all investors follow a mean variance framework for portfolio choice and have the same risk-free asset. In section 3.1 we discussed the suitability of a single measure of utility and the belief that the choice of risk-free asset is dependent on the investor's circumstances. Investors with a known fixed liability in, say, five years are likely to view a government stock of appropriate term (or duration)

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1Although this is not always true when investors' portfolios are subject to asset constraints (Markowitz, 1987).
as the risk-free asset. Conversely, a young final salary pension scheme is more likely to consider assets which produce returns more closely correlated to average earnings as the lower risk investments. It follows, therefore, that investors have different risk-free benchmarks (some of which may be theoretical constructs that match exactly their liabilities). A corollary from this is that risk preferences of the average investor change over time. For example the growth of final salary pension schemes and the wider appreciation of equities as suitable investments is likely to have changed the (average investor's) perception of riskiness of equities and hence lowered the risk premium. The risk premium might also be affected by the increasing ability of funds to invest overseas in a range of stock markets and diversify risk. Any estimation of the risk premium by reference to historic data that does not allow for such factors may therefore be invalid.

If the impact of the differences between reality and the assumptions of CAPM are not large then the relationship between the historic beta and return should follow the CAPM implications. The evidence, however, is inconclusive. While some tests have found a relationship between estimated beta and return others have found no connection (eg. Friend & Blume, 1970 and Fama & French, 1991).

To summarise, the beta calculation is likely to be impracticable, the assumptions underlying the risk theory are questionable and there is some evidence to suggest betas simply do not work as risk estimators. The concepts of non-diversifiable risk and an investor's requirement for additional return as reward for taking incremental non-diversifiable risk are not, however, invalidated by the above objections. The problem remains that if performance can be enhanced by adopting portfolios with additional non-diversifiable risk, how can that element of non-diversifiable risk be identified and what adjustment should be made to returns as a consequence?

A large number of variations on the theme of CAPM (see Elton & Gruber, 1987) and other models have emerged since Sharpe's work on the subject. One main development has been the arbitrage pricing model (Ross, 1976). This model does not assume mean variance efficiency, but that the market is driven by investors who believe that return is determined by exposure to a number of risk factors. While the concepts are useful and support the application of multi-factor models of risk, the
implications of the model are not inconsistent with the original CAPM (which says nothing about stock covariances) and leads us little closer to identifying an efficient portfolio and the risk premium associated with it.

3.4. Fund Objectives

Before identifying the appropriate risk measure for a portfolio it is necessary not only to consider different concepts of risk but also the objectives of the fund.

Objectives for investment funds can be set in a variety of ways. For many mutual funds they are specified in the trust deed and often more precisely in the associated marketing literature. A benchmark market index is normally quoted against which performance is continually compared. Explicit constraints take the form of legislative controls which prescribe minimum requirements for the various categories of trusts. In the case of unitised life and pensions products, again the objectives can be set out precisely or (for balanced funds) a more discretionary directive specified. Outperformance relative to the industry average is often a prerequisite for continuing sales of such funds. Business success can depend crucially on peer group ranking.

The assets supporting insurance and pension funds finance liabilities but often such funds' performance targets are linked to peer group returns. Historically in the UK, a large proportion of pension funds have followed the consensus investment strategy of the industry. Increasingly for segregated pension funds, it is debated whether this industry norm is appropriate for their specific liabilities. As a result of changing demographics, legislative pressures and the development of asset liability models, fund-specific investment objectives are becoming increasingly prevalent. These result in defined benchmarks which are more appropriate for a fund's liabilities than the consensus asset allocation.

The overall investment goal is to implement an asset strategy which minimises the possibility of not meeting contractual liabilities (where present) and meet the fund's stated objectives. When asset-liability analysis leads to the implementation of a fund-specific benchmark, the fund manager is still likely to deviate from the target investment strategy to try and enhance performance. This creates another form of
investment risk for the fund management company. If this is not rewarded, there is an increased probability that the organisation will lose business. Investor dissatisfaction leads to loss of business and it is this ultimate risk to a fund management business that needs to be controlled and minimised.

3.5 Fund Manager Operation

To help decide on a suitable approach to risk assessment it is first worthwhile to consider how a fund manager selects and maintains a portfolio of investments. For the vast majority of funds, performance is assessed relative to a prescribed benchmark. The fund manager, therefore, has a base or neutral portfolio position that closely resembles this benchmark. He then takes positions by selling and buying securities so that the net impact of the trades is an increase to the fund's expected relative return. In those cases where the fund manager attempts solely to choose stocks that are likely to produce superior performance, his portfolio stance can be restated in terms of a "benchmark-neutral" position combined with a number of under and overweight individual stock holdings.

Although significant and obvious anomalies are unlikely to remain in reasonably efficient stock markets, the positions taken by fund manager are selected in the belief that they offer relative value and over time will be recognised in the form of incremental performance. The distribution of portfolio returns from the fund manager's perspective is therefore positively skewed. Of course a manager does not have perfect foresight and the actual return achieved by a security or investment switch often falls short of the predicted return. The fund manager can protect himself, to some extent, from such adversity by taking a series of positions. If one stock proceeds to underperform due to unforeseeable circumstances, benefit will still hopefully accrue from the other positions. In essence the fund manager strives to limit the probability of underperforming his benchmark by diversifying the risk of unfavourable stock-specific events. It is usually preferable therefore for a fund manager to adopt a wide spread of positions rather than just a few positions with the highest expected return.

If a probability distribution for the expected return attached to each relative position can be determined, it is possible to identify a set of potential portfolios each with
varying expected returns and associated probabilities of under and outperformance. This allows the fund manager to attain the optimal trade-off between expected outperformance and risk of underperformance. In practice a move close to the optimal position might be all that can be hoped for.
4. Fund Management Risk Control

4.1 Risk Analysis Techniques

A wide range of approaches are employed to control risk within fund management organisations. A recent survey showed that 74% of UK houses apply quantitative tools to measure risk and of those, 90% adopt standard deviation as a measure of risk (Touche Ross, 1993).

The sub-sections below describe risk techniques currently used in practice. They are not mutually exclusive; there are considerable areas of overlap.

4.1.1 Mean Variance Analysis

To assess fund risk the main starting point using mean variance analysis is the production of a risk matrix. Risk is defined as the variability of fund performance, whether relative to a benchmark or in absolute terms. The dimension of the square matrix is equal to the number of factors which are deemed to influence performance and hence variability. The matrix itself quantifies the variability and relationship between each of these factors.

The number and type of risk factors selected is dependent on the purpose of the analysis. To review the risk of a multi-asset class fund, for example, asset allocation risk may be the only consideration and then the factors are the full list of investable asset classes. A similar method can be followed to evaluate asset allocation switches (see section 5). In other types of risk analysis the number of factors can be large. For an equity portfolio this can equal the number of stocks held and in such cases it is usual to reduce the number of risk factors.

The driving motivation for reducing the amount of risk factors was historically the need to reduce the size of the risk matrix at a time when computers could not efficiently cope with the production of covariances and mathematical manipulation on a large scale. It was also believed that shrinking the matrix by identifying the key drivers of risk produces more stable and therefore reliable risk matrices. This is
practised for equity portfolios, through the identification of those risk factors which are common to a number of stocks within the same market e.g. industry grouping is usually taken as a common risk factor. Principal components analyses that identify significant common discriminants of stock price performance (e.g. Feeney and Hester, 1967) have been used to do this. This had led to the emergence of multi-factor models (MFM) of stock price performance.

An MFM significantly reduces the dimensions of the risk matrix compared to Markowitz's original model. MFMs are designed on the premise that a finite number of identifiable factors influence stock performance over time. However, only quantifiable factors can be easily analysed and new factors are only recognised with significant delay. Although these discriminating factors are extensively researched for statistical significance their initial selection is subjective and their number limited. These shortcomings imply that MFMs tend to understate stock volatility and risk. Furthermore MFMs assume that the historical importance of the various factors is a reliable guide to their relevance in the future. This is a debateable assertion. In fact commercially available MFMs have changed their risk parameters over time.

Some MFMs restrict the common risk factors arbitrarily (e.g. to industry groupings) whilst others adjust the factors so that they are mutually independent (further reducing the task of mathematical manipulation). This distorts the interpretation of the factors, which are then not closely related to recognisable causes of relative share price performance. The use of independent risk factors also means that the breakdown of risk can become difficult to understand and scrutinise. For example, because the factors do not exactly correspond to familiar risk components it can be difficult to adjust them to allow for other market assumptions.

From a fund manager's perspective, however, there are benefits to be gained from using MFM's. These systems can quantify the amount of risk within a portfolio and reveal its principal components. They highlight stock and sector bets, indicate whether a portfolio is (for example) tilted towards high yielding stocks and estimate each risk factor's contribution to portfolio risk. Hence they can be useful to a fund manager who wishes to position his portfolio more accurately. For example a manager may wish to increase the yield on his portfolio but is concerned that high yielding stocks
are concentrated in particular sectors or are predominantly small capitalisation stocks. A multi-factor model can help him to adopt the high yield stance without increasing his existing bias to these sectors or small capitalisation stocks. Hence the fund obtains a bigger yield for a given level of portfolio risk.

These variants of mean variance analysis are commonly used by fund management organisations. However, the derivation of the risk matrix which underpins the whole process has come under close scrutiny. Suggestions for alternative construction methods and checks on its results have been put forward. Two approaches are described below.

4.1.2 Scenario Analysis

The use of scenario analysis to produce the required variances and covariances for a mean variance analysis can be traced back to 1975 (Hobman, 1975) and the technique was further developed by Markowitz and Perold (1981). The analysis usually involves the derivation of a limited number of scenarios, each with an expected probability of occurrence, that cover a range of possible investment conditions. The performance of all assets in a portfolio is estimated under each scenario and an optimal portfolio subsequently deduced.

The consideration of alternative investment outlooks to derive an appropriate portfolio stance is useful and commonplace but the production of a set of specific scenarios each with associated probabilities and expected asset returns has limited additional benefits in practice. The approach is susceptible to a number of inaccuracies. Firstly, the range of scenarios may not be as comprehensive as hoped for. It is the norm rather than the exception for unforeseen events to occur in the investment markets, thereby rendering the projections superficial. Secondly, the number of risk factors is likely to be severely restricted to make the analysis manageable, whereas in reality markets are driven by a wider range of influences. Finally, the estimated probabilities of the likelihood of each scenario combined with their expected outcomes are subject to substantial error.

Scenario analysis can be very time consuming and in retrospect has often been highly
inaccurate. Although some practitioners may suggest they have the prescience which allows the technique to be of value we doubt whether, except in very special circumstances, it is a practical aid to portfolio management. We have, however, found scenario analysis to be more useful to assess the merits of individual investment positions and switches.

4.1.3 Backtesting

Backtesting is a simple and transparent method of testing the validity of the results from a mean variance risk analysis. An advantage of this approach is the avoidance of model estimation error because no assumptions are required about the probability density functions of the asset returns. The simplicity often leads to a greater appreciation of the mean variance technique and its limitations. If computed over the same time period, the portfolio (relative) variability according to a risk matrix and that calculated by taking the standard deviation of the portfolio's actual (relative) returns are usually closely related.

The use of backtesting can quickly improve fund managers' appreciation of risk analysis. They soon understand that the results are not inherently accurate as a consequence of the sophistication of the mathematical technique, but depend on the particular events that occurred over the chosen period of analysis. This greater insight can lead to a fuller discussion of a risk analysis and a more appropriate application of its results. By combining backtesting over different periods and sensitivity analysis of the risk matrix, a more robust assessment of risk can be made.

4.1.4 Other Techniques

The main thrust to the development of risk control techniques has been provided by financial economists. There are a number of alternative techniques that are applied in practice either in preference or in addition to financial economics methods. These include:

(i) Upper and lower bound weightings for individual securities, sector and asset class exposures.
(ii) Load ratio and load difference constraints for the same hierarchy.

(iii) Similar constraints for other categories of securities such as growth, value and small capitalisation stocks. This type of risk control is intrinsic to style analysis.

There are some difficulties to overcome if appropriate limits for these constraints are to be established. Portfolio risk depends on the particular overweight and underweight positions taken and the limits should therefore be determined with reference to the correlations between those positions. Generally, if a plus or minus 2% load difference is deemed appropriate for a switch between two sectors then a higher load difference is likely to exercise sufficient constraint on a switch between stocks in the same sector. Also if the constraint on one factor is not fully utilised it is possible to relax the constraints on other positions to some degree. The amount by which this can be done and to which factors may not be straightforward to determine. Overall, the use of constraints in isolation tends to result in a less flexible approach to portfolio management which either constrains risk on average by more than is necessary or ineffectively controls the potential risk biases (or tilts) in a portfolio. However, load differences can be used as part of a control process that is primarily based on a risk model. They limit the impact of "model breakdown" and can provide some protection if the estimates of future covariance prove unreliable. For example the effect on portfolio risk of an unexpected adverse change in stock-specific risk is restricted by the limits on individual stock load-differences.

Many fund managers use load ratios to monitor risk within a fund as an alternative to load differences. For a given positive load difference the load ratio is higher for a smaller stock. The advantage of load ratios is that overweight positions in smaller stocks are restricted to a greater extent than for larger stocks. As the specific risk of smaller stocks is often relatively higher this is a useful attribute. An alternative (but more complicated method) is to vary the maximum load difference for each type of stock (not restricting the distinguishing attribute only to stock capitalisation) to reflect the perceived stock-specific risks of different securities.

The differences between employing these empirical controls and financial economics
techniques are similar to those between stratified sampling and optimisation techniques in the context of indexed management (see Rains et al, 1991). It is important to understand the limitations and advantages of both risk control methods and develop a risk control system which is understandable and meets its objectives subject to these identified drawbacks.

4.2. Problems with Conventional Mean Variance Analysis

The conventional mean variance approach takes a subset of past experience and projects it into the future. The simplifications to the risk matrix described in section 4.1, while subject to objections in their own right, retain the essential characteristics of mean variance analysis. There are, however, more fundamental objections to the approach as it is currently practised. These include the instability of the risk matrix, the non-normality of asset returns and the inappropriateness of variance as a risk measure. There are also objections to the optimisation of traditional actively managed portfolios using the conventional mean variance approach. These are considered below.

4.2.1 The Instability and Unsuitability of the Risk Matrix

The risk matrix does not stay constant with the passage of time and its relevance is often questionable. An example is the inappropriateness of historical currency correlations to help forecast risk prior to Britain's withdrawal from the ERM in September 1992. When European currencies were constrained within the ERM they had usually high correlations. The possibility of a breakdown in the ERM was not reflected in the correlation statistic but discounted in the different returns available on short term securities at that time. Unaltered data may therefore not reflect information currently known about the risk characteristics of individual securities. This shows that the use of the risk matrix can lead to an inaccurate and misleading view of the risks inherent in certain trades.

If the use of historical data is consciously rejected then subsequent application of mean variance analysis is dependent on a fund manager's ability to amend the covariance matrix. The adjustment is impracticable and adds an additional layer of subjectivity
to the analysis. In the case of a 100 stock portfolio, for example, this may involve up to 4,950 covariance revisions. We doubt whether any fund manager is an expert predictor of such statistics even if he has the time.

An illustration of the instability of the risk matrix and its implications for asset allocation risk analysis is given in section 5. This problem can be overcome to some extent by calculating the risk matrix over different historic time periods; showing the impact of different covariance assumptions and where appropriate considering particular adverse scenarios (or stress tests). A covariance matrix is more unreliable if the number of periods of relevant data is less than the number of securities analysed. This is because portfolios with zero variance can then be produced (Markowitz, 1987).

4.2.2 Non-Normality of Asset Returns

Although a normal distribution of security returns is consistent with the random walk theory associated with the efficient market hypothesis, it is widely recognised that over the medium to long term security return distributions have deviated from normality. Equity returns in particular have exhibited a degree of skewness that is inconsistent with the normal distribution. Even though the distributions are more akin to lognormality, the aggregate distribution of several random variables which are lognormally distributed is not (except in very special circumstances) lognormal. This further complicates portfolio risk assessment. In addition, over short periods security returns are better described by the more general Stable Paretian distributions than a normal distribution (JP Morgan, 1994). This similarly makes the portfolio risk calculation more complex. The return distributions of the more esoteric security types such as convertibles, warrants and options can be even more difficult to include within an overall risk assessment process.

Whilst the errors introduced by using solely the assumption of a normal distribution to quantify portfolio risk are not thought to be large, the spiralling efficiency of computers is likely to facilitate more accurate risk assessment using more realistic descriptions of the underlying probability distributions of asset returns.
4.2.3 Variance as a Risk Measure

Variance is a common risk measure within the field of financial economics but downside semi-variance is seen by many commentators as a preferable gauge of investment risk. Although the variability above the benchmark return may contain some useful information about the characteristics of a fund, its incorporation within a mean variance risk analysis has some unfortunate characteristics. Investments with greater upside variability usually have greater expected upside return and are preferred to those with lower upside variability. The variance measure penalises the former, however, and may decrease the perceived attractiveness of a stock unnecessarily. This problem is most acute for securities with skewed distributions (eg. options).

Apart from ease of mathematical manipulation there are other reasons why variance might be used. If markets are assumed to be broadly efficient, sharp upward price movements (that might affect a variance measure but not a downside semi-variance measure based on historic analysis) indicate the capacity for revisions to the outlook for a security. Consequently, dramatic improvements in a company's prospects may also suggest the potential for downward surprises and hence support the use of variance as a measure of risk. However, if a stock selection method that accurately picks undervalued shares is applied and leads to considerable outperformance this does not necessarily indicate an increased likelihood of underperformance but rather ex-ante undervaluation.

Downside portfolio risk for a conventional portfolio (when the manager anticipates an expected incremental return on his portfolio) can be estimated using mean variance analysis. An associated incremental performance for the fund over the period is estimated. The probability of performance beneath a benchmark is then derived by considering that part of the distribution of return that falls below the benchmark. In the past, downside risk assessments have been limited because they require Monte Carlo simulation techniques as well as quadratic optimisation and have been associated with high computing costs. Increased computing power has now improved its applicability and use (eg. Ferguson & Rom, 1994).

One corollary of allowing for expected outperformance in risk assessment from an
internal supervisory perspective is that, for consistency, adjustments to risk constraints should be made to reflect the increased risk of those fund managers expected to underperform. This is because in the same way that outperformance leads to lower downside risk, underperformance leads to higher downside risk. The statistics produced by performance measurement companies confirm that fund managers as a whole do not consistently outperform index benchmarks. This implies that roughly 50% of fund managers should have negative risk adjustments. Because the aim of active managers is to outperform, such adjustments may be difficult to implement. It is usually appropriate therefore when supervising risk levels to assume that fund managers will not outperform. The general rule that those fund managers with the greatest perceived skill should have the most relaxed risk constraints may be a practical way of allowing for skill. Downside risk is discussed further in section 4.4.

4.3 Using Mean Variance Optimisation for Traditionally Managed Portfolios

Mean variance analysis facilitates the movement towards an optimal mix of risk and return. As we have discussed, it is advisable to perform various safety checks to confirm the robustness of the results from such an analysis and make suitable adjustments if required. There are several problems associated with the use of the same techniques to produce optimised portfolios for traditional actively managed funds. The optimiser requires the input of expected returns (alphas) for each asset. The error margins in the estimates are assumed to be the same but this, however, is seldom if ever the case. The relationship between some asset returns can be predicted with a fair degree of certainty whereas other assets that are less closely linked (or perhaps covered by different analysts) have expected relative returns that are estimated with a far lower level of confidence. This can be partially compensated for by the associated correlation statistic but the degree of relative certainty is not directly allowed for. In some cases small differences in projected returns for a group of stocks may not be considered significant by the analyst but treated in an opposite manner by the optimisation process. Some software packages attempt to allow for this by producing implied returns for different investments on the assumption of optimality of the portfolio.

A second and perhaps more fundamental problem is that investments selected by an
optimisation procedure are likely to be subject to the largest estimation errors with respect to return variance and covariance (Michaud, 1989) and the actual variance of the portfolio can be considerably higher than the computed value. In effect the optimiser selects the portfolio that happened to have the lowest variability over the base time period rather than calculate the typical variability of portfolios similar to that selected. Optimisers tend to exacerbate the inaccuracies of the risk estimates - large switches are suggested when the error margins are at their greatest. This can occur, for example, when expected returns reflect a future risk that did not exist historically. The risk matrix can incorrectly then predict a lower risk than exists. These problems can be eased somewhat by installing constraints as already discussed. This has the effect of reducing the impact of errors in the risk factor estimates.

For traditional fund managers we suggest portfolios which are acceptable from an expected return standpoint are produced. The risk should then be checked to ensure it remains acceptable. As the fund manager becomes more familiar with risk analysis the impact of stock switches on portfolio risk will become more predictable.

4.4 Using Performance Statistics to Control Risk

Accurate and timely information on a fund's performance relative to its benchmark is an important element of risk control. If calculated on a frequent, even daily basis, the historical performance deviations can be used as predictors of future relative risk assuming the fund's past risk level persists in the future. Return statistics also provide a check on the validity of the risk model applied to the fund; the risk predicted by the model is compared to the variability of actual performance. Consistent underestimation, for example, implies an adjustment should be incorporated into the prospective risk measure.

Although this type of risk analysis is retrospective one benefit of performance data is that statistics such as downside risk, and therefore risk measures that allow for the skill of the fund manager, can be calculated with ease. The reliability of such numbers depends crucially on the amount and frequency of available performance data. Many funds' performance is calculated on only a monthly or even quarterly basis and even then there are production delays. This periodicity severely hampers the effectiveness
of this type of risk analysis.

An example of performance deviation as a means of risk assessment is shown in the chart below.

Over the one year period the fund outperformed the benchmark FT-SE-A All Share Index by 3.93%. The standard deviation, variance and downside risk statistics have been calculated on alternative periodic returns over the same year and are tabulated below. In order to reduce any distortions to the historic risk statistics it is important to remove where possible those performance deviations that are exaggerated by valuation discrepancies.

<table>
<thead>
<tr>
<th>Periodicity of Returns Over Year</th>
<th>Daily</th>
<th>2 Days</th>
<th>Weekly</th>
<th>Monthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annualised Standard Deviation (%)</td>
<td>2.80</td>
<td>2.29</td>
<td>2.26</td>
<td>2.06</td>
</tr>
<tr>
<td>Downside Variance/Total Variance (%)</td>
<td>43.4</td>
<td>41.1</td>
<td>34.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Downside risk x √2 (%)</td>
<td>2.67</td>
<td>2.08</td>
<td>1.86</td>
<td>1.19</td>
</tr>
<tr>
<td>Negative return periods/Total number of periods (%)</td>
<td>45.5</td>
<td>42.1</td>
<td>44.2</td>
<td>25.0</td>
</tr>
</tbody>
</table>
The table illustrates three features of the risk measures. Firstly, the periodicity of the returns used can affect the standard deviation estimate. Errors in the security prices, either as a consequence of inaccuracies in the market quotes used in the valuation, or due to inconsistencies between the pricing of the fund and the benchmark can have an influence here. These errors generally lead to an overestimation of daily relative portfolio performance. The impact of the overestimation on the standard deviation reduces as the periodicity of returns increases.

The second feature is that the downside variance is less than half the variance and is a direct consequence of the outperformance of the fund. This demonstrates how good performance can reduce risk if the downside risk measure is used. Lastly, the downside risk as a percentage of total risk decreases as the return calculation period increases. Again this is a result of the outperformance the benchmark and can be explained with reference to the normal return distribution. The standard deviation of the relative return increases in proportion to the square root of the return periodicity, but the incremental expected return increases in proportion to it. The percentage of the return distribution that falls below the benchmark rate therefore diminishes. The relationship between the downside risk measures based on different time periods of return depends on the assumed return distribution and the level of fund outperformance.

The risk of the portfolio was also assessed using an MFM. The predicted standard deviation of relative return was 1.89% at the beginning of the year and 1.93% after six months. This appears to be an underestimate of the actual portfolio risk and suggests that on the assumption that the fund manager has no skill the recorded outperformance occurs approximately once every 50 years.

If there is belief that a fund manager's selection process is likely to lead to outperformance in the future, then downside variance is a useful indicator of fund risk. Conversely, if it is uncertain whether the manager will add value in the future (or if it is deemed prudent not to assume expected outperformance) then the standard deviation of the relative return is likely to provide a better indication of risk.
4.5 Other Fund Management Statistics

To obtain a greater understanding of how a fund is managed it is useful to consider additional statistics that do not necessarily have an effect on risk but provide further insight into the fund's characteristics.

Turnover levels can indicate the style of an investment manager. Research in the UK infers there is a tenuous positive link between high turnover and outperformance but once the costs of dealing are included the incremental performance disappears. Upper limits may be set on activity if greater volumes of trades are not rewarded with superior performance.

A further simple indicator of risk is the number of stocks held in a fund. Whilst a large number of stocks is not necessarily indicative of a low risk strategy, a small number of stocks usually implies a high risk position. For example, in the UK a twenty stock equity portfolio has a minimum expected standard deviation of return (otherwise called the tracking error) around the FT-SE-A All Share Index of c.2.95%; increasing the number of stocks to sixty brings this figure down to c.1.40% on the basis of conventional mean variance risk assessment. The number of stocks required to produce a given tracking error depends, however, on the number of stocks in the benchmark index and the characteristics of that index.

4.6 Competitor Risk Calibration

The comparison of fund returns with competitor funds' returns is the most common method of evaluating fund performance. Fund managers who are judged against a peer group are keenly aware of their league table ranking and in this context portfolio risk is commonly defined as the risk of deviating from the median or average fund performance. Studies show that funds categorised within the same universe can have extremely different investment characteristics (eg. Robinson, 1994) and consequently produce diverse performance returns and exhibit different volatilities (Borland, 1994).

A common approach to calibrating this risk is as follows: first measure the portfolio risk of a fund relative to its benchmark; then determine the similar risk taken by other
funds in its peer group. By comparing the fund's risk with that typically taken by competitor funds, a relative risk level can be determined. This can be achieved by analysing historic performance statistics. For example, in the UK segregated pension funds industry the average inter-quartile range of the WM Total Assets returns (which is a universe of balanced discretionary funds) over the period 1984 to 1993 was 3.4%. This range is reasonably stable over time and can be used as a yardstick to decide the level of relative risk appropriate for a fund measured against this peer group. Some further research along similar lines has attempted to provide the link between portfolio risk and business risk (eg. County NatWest, 1992).

Where possible it is useful to check this crude analysis using current peer group data. The asset allocations of competing funds are collated for most types of funds by a number of organisations. Armed with this information a fund manager can review his relative position. A simplistic approach is to sum the total absolute deviations of his fund's asset allocation from the average weightings and compare this with the similar figure for the other funds. Although this ignores the impact of the relative risks of the asset classes it provides a straightforward indication of the level of competitor risk being taken. More complex financial economics methods can also be used (and their assumptions tested). By comparing the risk of a fund with the average of the peer group on each basis the level of adopted league table risk can be gauged. This is discussed more fully in section 5.

Competitor fund information should always be treated with caution and any anomalies can distort a risk analysis. A peer group's average asset allocation can be misrepresented by the presence of funds which adopt strategies that differ significantly from the consensus. These funds may either be willing to accept a higher level of competitor risk or do not truly benchmark themselves against the peer group (they may be marketed on a particular investment strategy for example). One approach to reducing the impact of such funds, if they cannot be readily identified, is to adopt the median asset allocation weights as the benchmark.

Information on competitor funds is published often a long time after the date of the analysis. For example, pooled pension fund data is produced quarterly with a six week lag after each quarter end, whereas unit-linked individual pensions' data is available
monthly with an approximate four week delay. These problems, however, may not be profoundly disadvantageous. Although the asset allocations of individual funds may often change markedly, it is extremely unusual for a peer group average asset allocation to significantly drift over a three month period for reasons other than relative market performance.

Stock selection risk relates to the probability of underperforming the peer group within a specific asset class. The control mechanism is much weaker in this area because stock level information is not made publicly available in a timely fashion. Mutual funds' stock holdings are published in their annual (and sometimes quarterly) reports and this information can at best provide a flavour of the type of investment policies followed by competitors. Some attempts have been made by the leading performance analysis organisations to compile universe information on the stock and sector holdings of contributing pension funds but so far this has related solely to UK equities where the problems of identifying an appropriate benchmark are least. Even when this occurs, the delay between the date of analysis and time of publication can be too long for it to be of any meaningful use.

The alternative is to gauge stock selection risk relative to a market index that acts as a proxy for the average competitor fund. This is not a problem for UK equity portfolios which are usually structured relative to the FT-SE-A All Share Index but is more difficult for overseas portfolios (for example, unit linked Japanese equity funds tend to follow the TSE1 index but with a much lower weighting to the Financial sector). In these cases, best estimate hybrid indices can be constructed and cautiously applied.

To assess the overall risk of a portfolio the asset allocation and stock selection risks must be consolidated. Whilst an integrated risk analysis can be performed for an individual fund, a similar and timely analysis for competing funds is currently impracticable. Alternatively, the relative risk of the asset allocation and the sector selection stances can be assessed separately and an overall relative risk profile estimated. This can then be checked by comparing the risk of the fund with the historic inter-quartile performance range of the peer group for the same period from which the fund risk is derived.
Even when a fund has a liability-driven benchmark, peer group risk measures are also of benefit if a group of similar funds can be identified. These risk comparisons can enable risk constraints to be more objectively set. Also, some categories of funds obtain only scant or tardy industry analyses. In these situations it is possible to draw some tentative conclusions about the way competitors run their funds, for example, by analysing the data available on those investment funds run by the same companies in other product areas. In the UK the obvious source is the pension fund industry for which considerable data is available.

The problems associated with identifying an exact benchmark introduces an element of benchmark risk to the risk analysis and can increase the error in the results. This problem is most severe for funds that invest in a wide variety of markets (eg. overseas equity funds).

4.7 Other Fund Management Risks and Competing Constraints

The risks associated with some investment funds are linked to other aspects of the affiliated company and the use of competitor risk calibration as the sole performance control is often inappropriate. One example is general insurance funds for which the company's solvency affects the asset mix and risk stance adopted. Nevertheless the above method of risk assessment provides a conceptual framework to address fund risk in any area where competitor outperformance is important. There are very few funds that fall outside this category.
5. Competitor Risk Analysis

5.1 The Calculation of Variability

To illustrate some of the techniques discussed in section 4.6 we have performed a simple analysis of asset allocation risk. In practice the risk of future deviation from benchmark performance is usually analysed at two levels - asset allocation and stock selection - and then an attempt is made to combine the two risks.

Portfolio variance can be calculated, if the expected variances and covariances of the investments are known, by the formula:

\[ \sum_{i=1}^{n} \sum_{j=1}^{n} X_i X_j \sigma_{ij} \]

Where \( X_i \) and \( X_j \) are the weights of the \( i^{th} \) and \( j^{th} \) asset in the portfolio, and \( \sigma_{ij} \) the expected covariance between the \( i^{th} \) and \( j^{th} \) asset.

In matrix algebra,

\[
\text{Variance} = XCSI \\
\text{where } X \text{ is the vector of asset weights, } C \text{ the covariance matrix for } X \text{ and } X^T \text{ is the transpose of } X.
\]

The above formulas hold for any assumed return distributions for the asset classes - except for very special cases - and do not require the presence of normality. However, if the individual return distributions are not normal the other characteristics of the overall distribution may be difficult to determine.

The above computation is straightforward but the variance and correlation parameter inputs are usually at least partly subjective. For example, if (as is usual) estimates are derived from historic relationships, the choice of time horizon is open to debate. To provide an indication of the sensitivity of a risk analysis to different correlation
assumptions it is helpful to calculate risk on a number of different bases. Three
methods are described below:

1. **Historic Mean Variance (1)** This is the standard approach. The historical
   variances and correlations over a specified period are applied to the above formula

2. **Adjusted Mean Variance (2)** Similar to the above but assumes zero
   correlation between the assets. The above formula simplifies to:

   \[ \sqrt{\sum_{i=1}^{n} x_i^2 \sigma_i^2} \]

3. **Adjusted Mean Variance (3)** Similar to the above but assumes perfect
   correlation between the overweight assets and also between the underweight assets and
   perfect negative correlation between underweight and overweight assets. The
   formula simplifies to:

   \[ \sum_{i=1}^{n} |x_i| \sigma_i \]

Each method places a different value on portfolio variance. If the asset weights in the
formulae are replaced with the weights relative to a benchmark then the expected
standard deviation of future relative performance (commonly known as the portfolio
tracking error) can be derived. The third method is the most conservative and (if the
individual asset variances are appropriate) acts as the maximum expected deviation
from the benchmark return. There is no single definitive method of measuring risk
and interpreting the results of an analysis on three separate bases may lead to a more
meaningful conclusion.
5.2 Potential Annual Performance Shortfall against a Benchmark

To be of practical use these tracking errors should be translated from a quantitative format to one that can be easily understood by fund managers and other investment personnel. Instead of the standard deviation (or tracking error) of a portfolio's expected relative return we suggest the use of a more descriptive epithet of risk. The measure we propose is the Potential Annual Performance Shortfall Against the Benchmark (PAPSAB), which is defined as the portfolio return relative to the benchmark that will be exceeded with a probability of 0.975. For portfolios with normally distributed returns this equates approximately to the expected return (relative to the benchmark) minus twice the standard deviation. However the PAPSAB measure does not assume a normal distribution and can be applied when the returns follow a different distribution or are generated by Monte Carlo simulation.

To determine peer group risk we propose a second but related measure which we call Relative PAPSAB. This is defined as the ratio of a portfolio's PAPSAB to the median PAPSAB of the peer group. A relative PAPSAB greater than one implies high risk, lower than one low risk relative to the peer group average.

The use of an annual period to calculate portfolio risk in PAPSAB may seem extreme because offsetting action may well be taken to reduce risk if significant adverse performance occurs. However an annual period may allow for worst case scenarios and also to some extent model risk such as fatter tails in the distribution of returns if normality was previously assumed in the analysis. The approach can easily be adjusted for analyses over shorter (or longer) time periods. If very short periods are used on the basis that a fund manager may take offsetting action then an adjustment to the PAPSAB should be made to reflect the illiquidity of the portfolio in extreme market conditions.

We have calculated the PAPSAB using the three methods outlined in section 5.1 on three unitised pensions products currently available in the marketplace. Each fund deviates from the peer group asset allocation to a different extent and their returns are assumed to be normally distributed. The calculations follow the formulae on the previous page but the asset weights are calculated relative to the peer group average.
The cumulative absolute deviations (described in section 4.6) for each fund are also included. The analysis is based on data at 31st October 1994 and the variance and correlation data (where not overwritten) derived from the five years 31st October 1989 to 31st October 1994.

<table>
<thead>
<tr>
<th>Fund</th>
<th>Cumulative absolute deviation</th>
<th>Historic Correlation</th>
<th>Correlation = 0</th>
<th>Correlation = 1 &amp; -1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>47.11</td>
<td>5.22</td>
<td>7.12</td>
<td>14.96</td>
</tr>
<tr>
<td>M</td>
<td>17.10</td>
<td>1.88</td>
<td>2.20</td>
<td>5.42</td>
</tr>
<tr>
<td>Y</td>
<td>7.53</td>
<td>0.56</td>
<td>0.76</td>
<td>1.58</td>
</tr>
</tbody>
</table>

For example, based on historic data fund A has a 2.5% chance of underperforming the peer group by more than 5.22% over the next year. Funds M and Y, on the other hand, have lower potential underperformance of 1.88 and 0.56% respectively.

Discarding historic correlations paints a different picture. Under both of the alternative correlation assumptions the risk measures increase for all funds but the differential between them also increases, particularly between the average and high-risk funds. The sharp rise in the risk level under assumption (3) suggests further analysis is required to consider whether in extreme conditions or scenarios the portfolios A and M could be subject to greater risk than that predicted under assumption (1). The analysis implies that fund Y can be more relaxed about its initial estimate of asset allocation risk relative to its competitors. The assumption of zero correlation has less impact on the results. It does indicate, however, that if those asset classes that have been closely correlated in the past become more independent, the risk of portfolio A may increase significantly.
5.3 Relative Risk Analysis

The most commonly used method of risk analysis is the mean variance analysis based on both historic asset variances and covariances. We have already suggested that financial economic methods can be unreliable, often due to the instability of the risk matrix over time. The selection of the time period on which to base the matrix is arbitrary and can lead to misleading conclusions. By calculating the variances and covariances over, say, the previous five years the risk assessment is implicitly based on the view that future relationships between asset price movements will replicate those in that historic period. In theory, the investment characteristics of the selected historic time period should mirror as far as possible those conditions that are expected to occur in the future time period under consideration. In practice it is usual to use the most recent period as a base case, but also to calculate the results based on different time periods to understand the matrix's sensitivity. This is particularly pertinent when the base period includes a large market movement.

To highlight the instability of the historical covariance matrix and the conflicting signals it can send to a fund manager, the PAPSAB method has been applied to a wider subset of the same unit-linked pensions product universe used in 5.2. The exercise has been repeated on two bases. Both use historical covariance matrices but one draws on data from 31/10/84 to 31/10/89, the other on the subsequent five year period to 31/10/94.

The table on the next page summarises the portfolio risk profiles of 25 leading unit-linked pension fund products available today in the marketplace. Their relative PAPSABs are listed alongside.

The diversity of asset allocation risk borne by the funds is clear. The highest risk fund has a PAPSAB of 4.58%pa, whereas the lowest has a risk of 0.58%pa based on the 1984-1989 matrix.
The results on both bases contrast quite significantly. Not only are there significant differences between individual PAPSABs depending on the historic period chosen but the relative PAPSABs of some funds shift markedly. By applying a covariance matrix
based on more recent data, three funds' relative PAPSABs move from less than one to greater than one (or vice versa). Hence a fund can be judged as either high or low risk depending on the risk matrix used. Given the importance of the inference from this analysis, appropriate application and interpretation of these risk measures is vital. In practice the full range of risk statistics should be calculated for all portfolios.

The high PAPSABs of many portfolios and the significant deviations from the benchmark in virtually all asset classes (not shown) suggest that either their objective is very high league table rankings or, perhaps more likely, they are not peer group benchmark orientated. The persistency of these features for some funds over time suggests the latter. While one or two funds market themselves on a special asset distribution, the remainder are most probably adopting peer group risk without any associated reward. This additional risk is redundant or passive risk which if eliminated would result in more consistent relative performance.

This approach to asset allocation risk can be applied not only on a discrete time basis but also to evaluate the impact of proposed switches on portfolio risk. A spreadsheet can simply recalculate the PAPSAB (on the preferred base(s)) and the marginal effect of a switch on risk can be thus determined. Alternatively for a given base portfolio and benchmark, a two-dimensional matrix can be constructed along similar lines showing the effect on the PAPSAB of simultaneously moving long and short in two asset classes to the same extent. This acts as a reference table for the manager and highlights the relative impact of alternative tactical asset allocation switches on portfolio risk. Combinations of movements, however, become more problematical because of the large number of possible permutations.
6. An Overall Risk Framework

6.1 Objectives

The design of a portfolio risk management framework should reflect two key objectives. Senior management need to be assured that the risks taken by a fund manager are consistent with both his fund's objectives and those of the investment management organisation. A framework which facilitates the constant supervision of fund managers in a simple manner and can demonstrate to investors and their advisors that the risk of falling short of agreed performance objectives is constrained is highly desirable. The second primary objective is to enhance fund managers' understanding of their portfolios' risk characteristics and help them to construct portfolios with improved risk and return profiles.

6.2 Overall Framework

A risk management system can easily fall short of its objectives if all facets of the control process are not addressed in detail prior to design and implementation. A structured and transparent approach is the key to success and the ability of all interested parties (senior management, fund managers, investors and advisors alike) to understand the risk measures and their application is of paramount importance. The desirable features of an effective risk control process are briefly documented below.

(i) Transparent and Practical Application

A "black box" system can severely limit the understanding and thereby the appropriate use of a risk control system. If individuals are able to understand the conceptual framework then this will increase its use as an aid to fund management. Similarly, ease of practical application by fund managers will facilitate its inclusion in portfolio design.
(ii) Coherent, and Comprehensive Risk Measurement

The layers of control (eg. asset allocation and stock selection risk) must be comprehensive and allow aggregation into an overall risk monitoring process, both in absolute terms and where appropriate relative to competitors.

The risk measures and the factors which influence their value should be understandable. Risk measures that are common across all portfolios, where possible, are preferable (we recommend PAPSAB) and enable inconsistencies across funds to be identified. They also increase the likelihood of comprehension by all relevant individuals.

Risk assessment has to be comprehensive yet justifiable. The needs of relatively small parts of portfolios should not disproportionately influence the risk framework design.

(iii) Accurate, Succinct and Timely Reporting

Estimates of fund risk should be accurate and incorporate prudent adjustments as deemed necessary (see section 4). Stress analysis, worst case scenarios and sensitivity analysis will allow more robust risk estimates to be produced. The inclusion of a checking procedure to compare actual risk and that predicted by the risk models will help to isolate any biases in the measurement techniques.

Reporting can be voluminous for a large number of funds and important issues consequently overlooked. While monitoring risk in detail it is usually appropriate to report only on those funds which have breached their predefined risk limits. Regular analysis allows prompt attention to "problem areas" that may otherwise only be revealed by poor performance.
(iv) Independent and Sufficiently Qualified Personnel

The development of an effective risk management system is dependent on the attraction and retention of appropriately qualified personnel. To facilitate objective risk monitoring, risk controllers should ideally be independent of fund managers. There must also be defined lines of responsibility for managing risk.

(v) Documented Control Guidelines and Procedures

The risk tolerance and constraints of individual funds must be consistent with the overall philosophy of the organisation towards investment risk. This is facilitated if it is fully documented and agreed by all parties. For consistency any changes to allowable risk profiles and measurement processes should similarly be documented.

(vi) Regular Reviews

Fund management methods evolve, market conditions change and risk measurement techniques develop. Similarly, a risk monitoring process requires continuous review and improvement as necessary. Flexibility to incorporate new investment instruments into the process and prudently control their (often initially unknown) impact on overall risk are desirable features.

6.3 System Design

6.3.1 General

The specification of a control system is unique to each fund management organisation. No two organisations manage money in identical fashions and the range of potential funds is very large. It is not, therefore, possible to provide a detailed pro-forma risk monitoring process that is applicable to all investment firms. We can, however, provide an illustration of a risk process with particular reference to the control of equity portfolio risk.
6.3.2 Equity Portfolios

The risk characteristics of an equity portfolio are moulded by the active (to buy/sell stock) and passive (to retain or refrain from holding stock) investment decisions taken by the fund manager. The first step in the monitoring process is to evaluate the initial risk position of the portfolio relative to the stated benchmark (using PAPSAB for example). Once this is deemed to be acceptable the task is then to monitor daily transactions and the impact of market movements to ascertain how the risk profile relative to the benchmark is changing on a real-time basis. This can be achieved using daily and weekly reporting processes. Daily reports address the impact of individual trades on portfolio risk whereas a weekly profile report summarises any significant changes to the risk characteristics of the portfolio over the preceding week.

Equity risk control is, in practice, a combination of risk modelling and the enforcement of empirical constraints (discussed in section 4). Whether multi-factor models are used or not, the influences on portfolio risk can be controlled. Their identity varies but generally they come under four headings: market, industry, thematic and stock-specific. The control of a portfolio's exposure to each of these risk factor groups by applying upper and lower limits helps to restrict overall risk and hence the deviation from benchmark performance.

(A) Weekly Risk Review Report

This report highlights changes to industry and theme factor exposures. The weekly review confirms how a fund manager has changed the stance of his portfolio relative to the benchmark over the preceding week. There is no summary of individual transactions made over the period, to avoid the duplication of information already produced by the daily reports (see below). The objective is to highlight changes in portfolio biases that may have a material impact on the overall risk of the fund.

The risk review report documents exceptional changes to portfolio and factor risk by considering the following:
(i) Increase/decreases in sector biases
(ii) Increase/decreases to theme exposures
(iii) Changes to overall portfolio risk (PAPSAB)

It must be emphasised that, similar to the daily report, this is an exceptions sheet and filter rules apply. This avoids the production of insignificant movements. Hence a shift in an under/overweight position is only highlighted if this causes the position to exceed a predefined limit.

These filter limits are often difficult to determine. Effectively, the fund manager needs to know which sector and theme exposure constraints will, when fully exploited, cause the portfolio risk to breach its maximum permitted level. The problem is analogous to that discussed in section 7. Past experience, knowledge of the market and quadratic optimisation procedures can all help to find the answer.

(B) Daily Transactions Report

For any portfolio this highlights any significant changes to industry, theme and specific-risk exposures that are caused by transactions effected the preceding day. Only those changes deemed to be of material interest are reported.

A primary objective of this report is to be concise yet succint. In most fund management organisations, a list of trades completed the preceding day is generated each working day and placed on senior managers' desks. This is a factual report and does not attempt to assess the impact of the trades on the risk profiles of their associated portfolios. It is clearly counterproductive to also produce voluminous daily reports analysing the impact of all individual transactions on each portfolio's risk characteristics. The recommended daily transactions report is more concise. Purchases and sales which are not "significant" in their own right and have no material impact on a portfolio's exposure to the risk factors are not flagged up. These "exceptions" reports highlight the following situations:

(i) "Significant" transactions that have caused a portfolio to deviate from its industry and theme risk factor benchmark weightings by predefined limits (plus
or minus).

(ii) "Significant" transactions even if these limits have not been breached

(iii) Changes to risk factor exposures which exceed these limits and result from the cumulative impact of "insignificant transactions".

The definition of a "significant" trade is clearly subjective. A common approach is to look at the effect of a trade on that stock's weight in the portfolio relative to its weight in the benchmark index. The resulting load ratio or load difference is then deemed significant if it breaches some predefined range. For example stock load-differences are often limited to plus or minus 2%. The stipulated range for a stock is subjective and should be derived by considering its impact on all other risk factor exposures (and not just the stock's market capitalisation).

6.3.3 Bonds

Different risk measures are appropriate for bond portfolios. In addition to maturity band constraints, risk can be controlled by constraining the portfolio duration relative to that of the benchmark index. To reduce yield curve risk, the convexity of the portfolio can be constrained in a similar way.

For international bond portfolios risk can be measured using a conventional risk matrix again with maturity band, duration and convexity constraints.

6.3.4 Derivatives

Risk control for derivatives is a far more complex process. Option values depend on the underlying variability of the asset to which they relate. However their value can also be affected by other factors such as changes in the expected future volatility of the related asset. The price movements of options often be estimated by considering their average effective exposure over the predicted price movement of the related security. However, the segmentation of the options market means that liquidity problems are more significant. Prices may consequently deviate from their fair value.
Due to their greater sensitivity to price changes, the problems associated with inaccurate specification of underlying return distributions are increased for options. Whilst these characteristics are most pronounced in options they also apply to convertibles and warrants. Further research in this area is required.

6.3.5 Direct Property

Direct property and other illiquid assets require special treatment. An estimate of the risk of a property portfolio relative to its benchmark on the basis of historic returns needs to be adjusted to reflect the possible mispricing when transaction levels are low.
7. Integrating Fund Risk Control and Balance Sheet Management

Pension fund trustees and fund sponsors normally decree a specific benchmark for their fund against which their investment manager's performance is judged. This can be the average of a peer group or based on the conclusions of an asset and liability study. Trustees are particularly concerned that deviations from a target strategy may result in adverse performance over a predetermined time horizon. An active fund manager is likely to deviate from such a benchmark but it is unclear how such deviations affect total risk. Investment switches may add to the risk of underperforming a benchmark but may be less risky when considered from the liability risk perspective. In this way risk for a fund manager may not be consistent with the risk for his investors.

Asset switches away from a benchmark strategy are effected by an investment manager to enhance relative performance and only the risk of poor performance relative to the benchmark is considered. An alternative approach for a manager is to evaluate the merits of different asset portfolios in the context of the resulting change in risk to the fund's associated balance sheet. This form of asset and liability management integration is desirable but currently impractical. Focusing on asset risk in isolation may not be the optimal risk control process for a fund's sponsor and beneficiaries. This segregation of the total risk that a fund bears between its benchmark and the deviations from that benchmark - where it is well defined- is artificial.

Nevertheless, attempting to control asset risk in this way creates some difficulties. If it is possible to relate risk to actual liabilities rather than a chosen benchmark, then it would still be useful to measure the performance of the fund manager. While choosing a benchmark asset distribution to gauge the success of the fund manager can lead to sub-optimal asset selection, measuring his performance against the growth in liabilities leaves too much to chance. If there is no set of assets that exactly matches the liabilities, the fund manager is forced to take a mismatched position. The incremental performance caused by the necessity of mismatching and that resultant on the skill in choosing the mismatched assets is difficult to disentangle. It may be appropriate, however, to make some risk adjustment so that the fund manager's decisions reflect the true risk rather than the benchmark risk.
In order to illustrate the above, we have tried to measure the risk of a fund with a conventional benchmark and an allowable set of asset ranges. In order to do this we have used the Wilkie stochastic model (Wilkie 1986, 1992, 1994). The published parts of the model include only two foreign equity markets and so we have used them together, with the related foreign exchange exposure for those countries, as the surrogate for a wider overseas equity exposure. As a property model has not been published, property has been excluded from the exercise. We have taken what we believe to be a broadly typical pension fund asset mix and examined the effect on the risk of the fund (using a simple measure) of utilising the stated asset ranges.

The real returns on a fund maintaining the benchmark distribution (and rebalanced annually) has been stochastically projected over 5, 10, 20, 30 and 40 years on the basis of 1,000 simulations. Projections were also run for two alternative portfolios; one with high overseas equity, low UK fixed interest and zero cash weightings and the other maintaining low overseas equity, high UK fixed interest and high cash allocations. These are shown in the table overleaf.

The initial conditions for the model were the neutral conditions suggested in Wilkie 1986.

<table>
<thead>
<tr>
<th>Fund Asset Allocation (%)</th>
<th>Benchmark</th>
<th>High Equity</th>
<th>Low Equity</th>
<th>Allowable range</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK Equities</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>50-70</td>
</tr>
<tr>
<td>UK Bonds</td>
<td>10</td>
<td>5</td>
<td>15</td>
<td>5-15</td>
</tr>
<tr>
<td>US Equities</td>
<td>12.5</td>
<td>17.5</td>
<td>7.5</td>
<td>7.5-17.5</td>
</tr>
<tr>
<td>French Equities</td>
<td>12.5</td>
<td>17.5</td>
<td>7.5</td>
<td>7.5-17.5</td>
</tr>
<tr>
<td>Cash</td>
<td>5</td>
<td>0</td>
<td>10</td>
<td>0-10</td>
</tr>
</tbody>
</table>

The risk of each asset stances is investigated by examining the mean and standard deviation of returns and considering the estimated probability of the fund achieving
real returns below various levels. The results are shown below.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Projection Term (Years)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Equity</strong></td>
<td>Real Return</td>
<td>5.0</td>
<td>5.2</td>
<td>5.1</td>
<td>5.2</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>Std Deviation</td>
<td>5.0</td>
<td>3.1</td>
<td>2.0</td>
<td>1.6</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>Low Equity</strong></td>
<td>Real Return</td>
<td>4.2</td>
<td>4.3</td>
<td>4.4</td>
<td>4.4</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Std Deviation</td>
<td>4.7</td>
<td>3.0</td>
<td>2.0</td>
<td>1.6</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>Benchmark</strong></td>
<td>Real Return</td>
<td>4.6</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>Std Deviation</td>
<td>4.8</td>
<td>3.0</td>
<td>2.0</td>
<td>1.6</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Perhaps not surprisingly the higher real returns are obtained by following the high equity allocation. The standard deviation of returns is broadly the same for each asset mix. This suggests that on the basis of real returns the high equity portfolio has the lowest risk over all periods. This is confirmed by considering the probability of each strategy not achieving various threshold real returns.

(i) **Probability of a Real Return Less Than Zero**

<table>
<thead>
<tr>
<th>(%)</th>
<th>Projection Term (Years)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Equity</td>
<td>16.1</td>
<td>5.4</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Low equity</td>
<td>19.9</td>
<td>6.6</td>
<td>1.4</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Benchmark</td>
<td>17.7</td>
<td>5.5</td>
<td>0.6</td>
<td>0.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>
(ii) Probability of a Real Return Less Than 2%

<table>
<thead>
<tr>
<th>(%)</th>
<th>Projection Term (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>High Equity</td>
<td>28.5</td>
</tr>
<tr>
<td>Low equity</td>
<td>33.4</td>
</tr>
<tr>
<td>Benchmark</td>
<td>31.1</td>
</tr>
</tbody>
</table>

(iii) Probability of a Real Return Less Than 4%

<table>
<thead>
<tr>
<th>(%)</th>
<th>Projection Term (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>High Equity</td>
<td>42.5</td>
</tr>
<tr>
<td>Low equity</td>
<td>49.7</td>
</tr>
<tr>
<td>Benchmark</td>
<td>45.8</td>
</tr>
</tbody>
</table>

The high equity portfolio has the lowest probability of not achieving the threshold rates over each projection term. The differences in the probabilities are quite large for longer periods if, as assumed, the asset allocations are continuously maintained. While the assumption of a persistently high or low overseas equity position is perhaps an extreme and unrealistic one, partial utilisation of the asset allocation bands will still have a significant effect on some of the probabilities.

There are also reasons to expect the actual variability created under the above scenarios to be greater than that shown. No allowance has been made for the variability of performance around the specified market indices; threshold returns more appropriate for funds with a mature membership are likely to be more sensitive to the effects of higher equity weightings and some of the more volatile markets such as the Japanese and Other Far Eastern markets have not been included. The time ranges
shown begin from a fairly short 5 years, although if the current Government Pension Reform legislation is enacted, even shorter time scales may be considered.

From a fund manager's viewpoint, any deviation from the benchmark incurs some risk because it introduces a chance of underperformance. The results show that the risk assessed by a fund manager and the risk relative to the liabilities may not be the same. In fact for funds supporting immature liabilities (for which the real return criteria may be appropriate) and maintaining a conventional asset mix the risks work in opposite directions. This is because a higher equity weighting produces benchmark risk for the fund manager but reduces risk relative to the liabilities.

The results also show that the risks taken by a fund manager can have a significant effect on the overall risk profile of a fund (if this were not the case then it might be argued that there is little value to be gained from attempting to identify superior fund managers). This suggests, therefore, that a quantitative determination of risk control constraints is appropriate.

It may however be difficult for consultants who have chosen fund managers on their ability to outperform a benchmark then to establish risk controls (or bands) on the assumption that the manager's might not outperform. Nevertheless, prudence is unlikely to permit any credit for expected superior performance in the inevitable absence of statistical support.

If asset allocation constraints are implemented on the basis of quantitative analysis it is necessary to undertake an investigation analogous to the optimisation used to produce mean-variance efficient portfolios. In this case, however the advisor seeks to identify the portfolio with the most adverse attributes possible under the allowable constraints rather than the most attractive. The analysis must allow for performance deviations from the benchmark within each asset class. Assumptions regarding the variability of the relative returns and correlations between benchmark and fund performance (on a cautious basis) are therefore also required.
8. Conclusion

Portfolio risk control is a wide subject and this paper attempts a broad coverage of the issues covering both the basic problems relating to the identification of risk and the practical methods for its estimation.

For portfolio risk many of the problems associated with identifying risk can be resolved by choosing a risk measure appropriate for the funds under management. We suggest an appraisal of downside risk is usually most appropriate and recommend the application of a measure which we call the "Potential Annual Portfolio Shortfall Against a Benchmark" (or PAPSAB). When determining portfolio risk we conclude that while it is appropriate for a fund manager to allow for expected outperformance when reviewing his own risk, this is not an appropriate assumption from the portfolio risk controllers' perspective. Attempts to adjust prospective returns for the risks taken should in theory be made to allow for elements of incremental non-diversifiable risk. However, the problems associated with identifying this component of risk unfortunately remain unresolved.

In this paper we have highlighted the pitfalls of the current approaches to risk control. The introduction of empirical constraints, sensitivity analysis of the chosen risk model and the analysis of actual risk and that predicted by the adopted risk models can reduce or eliminate many of these shortcomings. Competitor risk is a central risk for almost all fund managers but can be addressed and controlled using measures of the peer group risk profile as described. The risk as identified by a fund manager in relation to his benchmark and that gauged with reference to the liabilities may be different. Also, it appears appropriate for advisors to set risk limits based on quantitative analysis (as outlined) as part of their role of controlling the overall risk of a pension fund or company.

In addressing both the theoretical underpinning and practical application of risk control techniques we have only briefly discussed some of the topics. These include the more accurate measurement of risk through the application of appropriate return distributions and Monte Carlo simulation; varying the assumptions of the risk matrix; risk control for portfolios incorporating options and other derivatives; analysis of competitor risk;
risk-adjusted returns and the integration of fund risk and balance sheet management. Further discussion and analysis seems appropriate and likely to be of considerable benefit.

It was over 40 years ago that Markowitz provided the method to determine the risk characteristics of a portfolio. Implementation of his approach was not practicable for most institutional portfolios for many years and it is only recently that computing costs have fallen to a level which has enabled systems based on his general theory to be developed and used in practice. The increasing efficiency of computers has now largely removed all the barriers to effective risk analysis and control. Over the next few years it is almost inevitable that the types of risk control processes described in this paper will become an integral part of the fund management business.
Appendix

The two well known examples below illustrate important characteristics of investors' risk return preferences. The first, the St Petersberg Game, is from Daniel Bernoulli and appeared in a paper published in 1738. This shows that expected return is insufficient by itself to order preferences for different investment portfolios. The second first appeared in a paper by Allais (1953) and shows that expected utility of return cannot be applied as a universal measure to derive investor preference.

1. St Petersberg Game

The St Petersberg Game is a game of chance where the payout is determined by a series of spins of a coin. For payment of a fee an unbiased coin is spun, and if the coin comes up as heads it is spun again. The coin continues to be spun as long as heads occur. Once a tail occurs the game ends and the payout determined.

The payout is calculated in the following way: if no heads occurred then the payout is £1; if one head occurred then the payout is £1 + £2 = £3; if two heads occurred then the payout is £1 + £2 + £4 = £7; and if n heads occurred then the payout is £1 + £2 + £4 +,...,+£2^n ( = 2 x £2^n-1).

What is the appropriate fee to play the game? The probabilities associated with various payouts are as follows:

With a probability of 1 a pound will be paid out.

With a probability of 1/2 a further £2 will be paid out.

With a probability of 1/4 a further £4 will be paid out.

With a probability of 1/8 a further £8 will be paid out

and so on. The expected value for the game is therefore given by:
Expected value  = \[1 + \frac{1}{2} \times 2 + \frac{1}{4} \times 4 + \frac{1}{8} \times 8 +, \ldots\]
= \[1+1+1+1+\ldots\]
= Infinity

Various probability thresholds can also easily be calculated for example:

The probability of the payout exceeding £255 is \[\frac{1}{2^7} = 0.00781\]

The probability of the payout exceeding £8071 is \[\frac{1}{2^{12}} = 0.00024\]

And generally the probability of the payout exceeding \[2 \times £2^n - £1\] is \[\frac{1}{2^n}\]

The distribution is extremely skew and the chances of winning large amounts increasingly minuscule. The fee most people would be prepared to pay would be fairly low. As the expected return is infinite this shows that the expected return of a venture is not the sole determinant of its utility.
Allais

Utility theory assumes that the 'worth' of a prize is independent of the probability with which that prize is received. Allais produced an example where this was found not to be the case.

Allais asked his students to consider the following choices:

Choice A: receive £1,000,000 with certainty

Choice B: receive £5,000,000 with probability 0.1
receive £1,000,000 with probability 0.89
receive nothing with probability 0.01

Choice C: receive £1,000,000 with probability 0.11
receive nothing with probability 0.89

Choice D: receive £5,000,000 with probability 0.10
receive nothing with probability 0.90

When presented with the alternatives of choice A or choice B he found that choice A was preferred, and when presented with choices C and D that D was preferred. This was then analysed using utility theory.

If U(O), U(1) and U(5) are the utilities of receiving nothing, £1m and £5m respectively.

Then as A is preferred to B, U(1) > 0.1 U(5) + 0.89 U(1) + 0.01 U(0)

Adding 0.89 U(0) - 0.89 U(1) to each sides this implies:

0.11 U(1) + 0.89 U(0) > 0.1 U(5) + 0.9 U(0).
This implies that utility (C) > (D)

As in practice utility (D) > (C) this contradicts utility theory principles.

It can be argued that for equivalent positions in investment markets the parts of the various choices can effectively be split out and traded at values close to their expected value. This may then remove the anomaly. Nevertheless if the utility of a return changes as the associated probability of occurrence changes then this significantly complicates analysis based on utility maximisation.

There are many other examples of investor behaviour that are not consistent with theories based solely on the expected utility of return (eg Crum et al 1980).
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