



## **An Integrated Approach to Managing Risk and Performance**

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Abstract

This paper provides an integrated and practical approach to managing risk and performance of a bank on an enterprise level. The results show how analytics can be used along with a strategic management organization to formulate a coherent framework to deal with some of the challenges of our current banking environment.

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## **An Integrated Approach to Managing Risk and Performance**

### **Overview**

Managing interest rate risk and maintaining a profitable balance sheet is perhaps one of the most important challenges for banks in today's competitive environment. Recently, we have seen that the integration of global markets, specifically the European markets, has led to higher market volatility and increased competition, with a greater demand from customers and more competitive products on the market. Further, regulators and rating agencies continue to raise their monitoring efforts on the exposure of the banks' balance sheets, resulting in more constraints to balance sheet management strategies. To confront these changes, banks must be able to measure their structural balance sheet risks comprehensively, and, with policies and procedures in place, to produce positive performances on a risk-adjusted basis. It is imperative that banks develop a strategy to meet this challenge.

To meet such a challenge banks are encouraged to implement a management system that complies with Basle International Settlement's (BIS) Principles of Managing Interest Rate Risks, and provides a consistent framework of risk measures and performance valuation across business units, Treasury, ALCO, and Risk Department. As a result, the system will provide the comprehensive risk measures to senior management and the governing board. Therefore, the system becomes an essential tool for implementing and monitoring the policies and procedures in managing market risk determined by the board and senior management.

Managing risk and managing performance in many ways are inseparable. Managing market risk goes beyond measuring risk exposures, setting limits and providing risk reports, but must deal also with the organizational structure of the bank. Policies and procedures must also ensure separation of roles and responsibilities of the different departments in the business process. The management system should provide a framework for robust performance measures. As a result, each department can be held accountable to its own risk and performance, measured against appropriate benchmarks. The purpose of this paper is to describe such a management system.

Distinguished from other risk systems, our management system recognizes the importance of managing risks as a process, tying all departments' risks and performances in one consistent framework. The system also enables the bank to compare prospective risks and retrospective performances. Therefore the approach is based on the principles of quality assurance for a business process in managing the bank's risks and not narrowly confined to risk measurements of the bank's position at a particular time.

In contrast, much of the risk management approaches today focus in two somewhat separate directions. One approach brings all the assets and liabilities together and measures their risk exposure. These efforts tend to concentrate on various models of risk and the validity of risk measures. While this approach is somewhat effective for

managing trading floor risks, it has many limitations for managing the risks of a structural balance sheet. For example, consider the treasury function. Such monitoring the risk can be used for position management but it is not used for structural balance sheet management, formulating funding strategies using balance sheet items like loans and deposits. Applications for senior management are limited because the approach fails to recognize that banking is a process involving separate departments.

Another approach is setting up policies and procedures for the organization. There have been many principles for risk management proposed for strategic management of the organization. But there is a lack of proper measures of performance so that managers can be appropriately compensated for implementing and making profitable decisions on a risk adjusted basis. To date, there are few systematic approaches to measurement and management of risk with a clear understanding of the business process, something that the proposed system possesses.

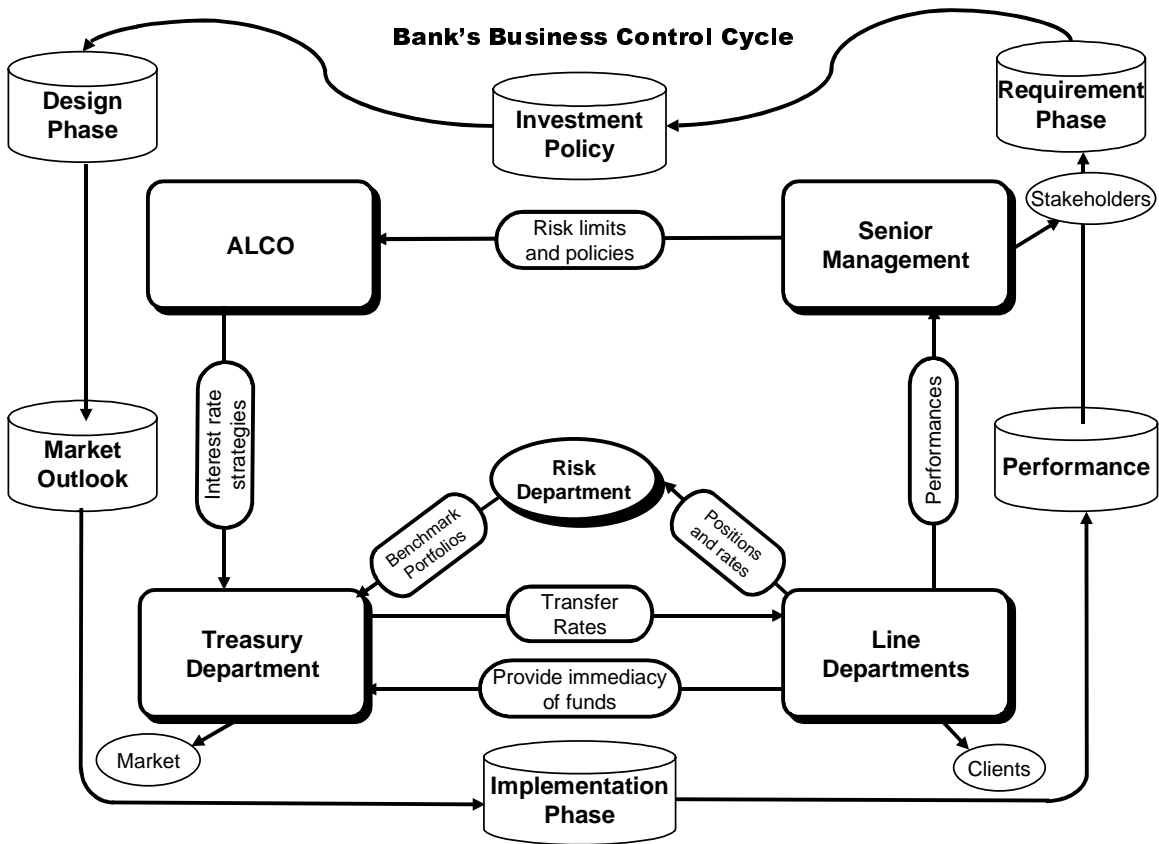
**Section A** describes the integrated approach to managing risk and performance, showing the organization of information flow in the business process. Actionable decisions that a bank can make using the information system are discussed in **Section B**. Finally, **Section C** contains the conclusions.

## **A. Management System for Risk and Performance**

The primary departments with which the System interfaces are: Senior Management, ALCO, the Risk department, the Treasury department, and lines departments. These departments provide the business control of the banking process. (See Ho [1995] for a detailed description of the process.) In brief, *Figure 1* depicts the cycle. Senior management is held accountable to stakeholders, and is responsible for articulating the objectives of the bank. It defines the maximum interest rate risk that the line departments may collectively carry for client business (loans and deposit activity combined) per gap. Given these limits, the realized ex-post profits or losses in the changes in present values resulting from the lines' activities are then attributed to the line profit centers. Specifically, senior managers determine the risk limits and policies for managing the balance sheet, and the target profitability. ALCO takes the performance objective and determines the interest rate strategies.

The Treasury department provides two functions in this process. It implements the ALCO strategies optimally, performing its role as an interest rate risk manager. Also it is a service center in funding and risk hedging of the individual gaps (for the risks beyond senior management limits). It supplies/receives funds from the lines. The transfer rates are determined by using the benchmark portfolios specified by the risk department. Line departments then compensate the treasury department for these services. Finally, line departments conduct businesses with the clients. They are responsible for generating the interest rate margin of the current account period. In the management accounts, they also carry the profits/losses in the changes in present values of their activities. The cycle ends

with providing the performances to senior management, which are used to monitor and adjust the business cycle.



**Figure 1**

In sum, senior management is responsible for the requirement phase, ALCO responsible for the design phase, Treasury department for interest rate risk management, and line departments for the businesses.

This approach provides analytical information along this business cycle. It begins with providing senior management with the economic value of each item of the balance sheet, enabling management to understand the economic value of the bank. This approach does so by first modeling the balance sheet items. The option adjusted spreads and the values of each item are computed and maintained. Such information is then used along the business cycle of banking by each department.

### 1. *Modeling the Balance Sheet Items*

The line departments provide the positions on each item of the balance sheet to the risk department. The items on the balance sheet are then modeled in a way consistent with the system. The basic modeling principles include arbitrage-free modeling (See Rebonato [1996] and Ho [1995] for an extensive discussion on interest rate modeling.) and option adjusted approach to measure the basis spreads of consumer products or

investments. This basis spread is called option-adjusted spread (OAS). The derivation and the use of OAS for securitized items on the balance sheet have been discussed extensively in the literature. OAS is the constant spread off the transfer-pricing curve needed to assure the present value of the interest rate-sensitive cash flows to equal the market observed price. We can extend this OAS concept to the unsecuritized items where no observable market price by using the initial transaction value as the “market price” and keep the OAS number constant over time. For details of this methodology, see Ho [1998] on the market valuation of liability.

Also, the basic modeling includes structured sampling of interest rate scenarios taking consumers’ and investor’s options into account. The valuation is based on the transfer-pricing curve, which may be determined to be the LIBOR/swap curve.

The system begins the valuation by estimating the LIBOR spot rate (and the swap rates) taken real time from the market. An arbitrage-free interest rate process then values the balance sheet items. The system has the interest rate models in place including the interest rate scenario generation process of the LIBOR rate—Linear Path Space (see Ho [1992]), a structured sampling methodology—the variable mortgage rate model and the savings account rated model based on the LIBOR rate. These models then enable the system to simulate future variable mortgage rates and savings rates.

In combining the security valuation models with the interest rate models, we can determine the value and option adjusted spread for each balance sheet item. These items may include on the asset side swaps, caps and floors, loans, variable rate mortgages. On the liability side, the items may include savings account, corporate bonds and deposits. The system analyzes the balance sheet items on a cell level, and not on an aggregate level.

Each derivative position and corporate bond position is calculated separately. The system can then provide the market value, option adjusted spreads, duration, convexity, and eleven key rate durations. The analysis of the entire balance sheet can be computed.

For illustration, we provide the following balance sheet position values for ABC Bank

**Balance Sheet of ABC Bank in Economic Values (in \$'000 )**

<i>Asset</i>		<i>Liability</i>	
Cash and due	4,600	Time deposit	5,341
US Treasury and federal agency obligations	15,800	CD	7,349
Variable Mortgage	5,000	Savings account	13,393
Commercial loans	4,980	Variable rate account	4,392
Consumer loans	7,650	Other liabilities	5,030
Other loans and financing leases	725		
<b>Total balance sheet asset</b>	<b>38,755</b>	<b>Total</b>	<b>35,505</b>
<i>Off Balance Sheet Items</i>		<b>Surplus (Equity)</b>	<b>3,447</b>
Swaps	148		
Swaptions	49		
<b>Total</b>	<b>38,952</b>	<b>Total</b>	<b>38,952</b>

The surplus of the bank is defined as the asset value including the off balance sheet items net of the liability value. Therefore, the surplus is the mark to market value to the equity-holders of the bank if the bank were to be liquidated at the economic value. However, the surplus value is not the shareholders' value because the shareholders' value should be the value of the bank as an ongoing concern taking business growth and taxes into account. This valuation does not include the growth of the loan, mortgages, savings or other items of the balance sheet. The value of the bank may have a higher value taking growth into account. This surplus value is also called equity value or embedded value of the bank. The relationship between this surplus value to the shareholders' value is discussed in Ho [1998]. In this example, the surplus is calculated to be \$3.447 million and is 8.84 percent of the total asset value. We should note that real estate—offices that are used for operations—is not included in this valuation.

The value of the swaps is marked to market at \$197,000, which is the net value of the pay and receive sides of the trade in economic valuation. Since the swaps are used to hedge the balance sheet position, this result shows that the hedging strategy has significant impact on the bank's profitability.

The balance sheet has some option risks. Savings accounts have embedded options as customers can withdraw from their accounts and variable rate mortgages have embedded options because mortgagors have the right to switch from variable rate to fixed rate mortgages. These embedded options should be modeled in this analysis.

One goal for senior management is to manage the balance sheet profitably. Management should seek to increase the surplus value of the bank while managing risk, or downside risk of the surplus. Senior management may also take the shareholders' view, business conditions, bank's potential growth into account, and specify the risk limits and policies. These limits may be specified as VaR numbers. The approach can provide the VaR number for each item of the balance sheet as well as the aggregates. (See

Ho [1996] for the details of the VaR Organizational Map.) The system can also provide the prospective and retrospective profitability of each balance sheet item. This will be discussed in Section A.4. Senior management can use the profitability measures to formulate balance sheet management strategies.

## 2. *Asset Benchmark, Liability Benchmark and Transfer Pricing*

The Risk Department is responsible for the valuation models, specifying the market parameters—which include the daily spot curve—term structure of volatilities, option-adjusted spreads for each product, and verification of market prices. Further, the risk department is responsible for the financial models of the asset portfolio, which is called “the asset benchmark portfolio.” Similarly, the financial model of liability portfolio is called “the liability benchmark portfolio.” The Risk Department maintains these two benchmark portfolios. By definition, the asset benchmark portfolio net of the benchmark liability portfolio is the benchmark surplus portfolio.

Benchmarks are replications of the balance sheet items using marketable securities. As a result, the benchmarks enable the bank to measure the profitability of each line business against the market, adjusting for risks and optionality embedded in the products. Wallace [1996] provides a more detail discussion on this topic. However, it is important to note that these benchmarks are used only for profitability measures on a total return basis, but not on a risk-adjusted basis. It is beyond the scope of this paper to address the use of this profitability measure for relative or absolute performance measures (return on risk-adjusted capital or capital asset pricing modeling. These issues are specifically dealt with in Ho [1998] “Allocate Capital and Measure Performances in a Financial Institution.”

Prospective profitability of an asset portfolio (for example, the portfolio of loans) is measured by the OAS (option adjusted spread) of the benchmark asset net of default premium and appropriate administrative cost adjustments. The net spread is the marginal return of selling the loans. Similarly, the OAS of savings account net of the appropriate administrative cost is the profitability of savings accounts. Therefore, transfer pricing is used to determine the profitability of products and investments. The profitability measure can be summarized by the following equation:

$$\text{profitability} = \text{OAS} - \text{default premium} - \text{administrative costs}$$

The Treasury Department provides and accepts funds from both sides of the balance sheet. The department is compensated for providing such liquidity internally to the bank, and taking market risks in the process. The compensation is a spread in basis off the transfer-pricing curve, and should be determined by risks in providing this immediacy to the demanders and suppliers of funds. This role is referred to “market making” internal to the bank. The spread pays the Treasury Department for their services in providing immediacy to the internal market, taking market risks in the process. The appropriate level of this payment depends on the liquidity of the market, the flow of the

orders and other issues. It is beyond the scope of this project to evaluate these issues, but to note that there has been much research in this subject called “microstructure theory” [see Ho and Stoll (1980)].

Another role of the Treasurer is that of implementing the interest rate risk strategy as formulated by ALCO, using capital market instruments like swaps, caps and floors. In this interest-rate risk-management role, the Treasurer is responsible for taking interest-rate directional bets subject to trading limits and investment policies. The Treasury Department can measure the interest rate risk exposure, using key rate durations of the surplus. (Appendix A provides an overview and Ho [1990] provides further details on key rate durations.) The use of key rate durations for interest rate risk management will be discussed in the next section.

To analyze Treasury as a service center performing the two functions of funding and hedging interest rate risk of gaps, we consider the following four cases:

- a. No mismatch between asset and liability in terms of volume and maturity. In this case, the underlying business has no interest rate risk and the treasury plays no role in the process.
- b. Asset and liability are matched in volume but have different maturities. In this case, the contribution of the treasury is restricted to the management of interest rate risk, isolating the underlying business (the customer margin) from actively managing interest rate risks. There is no funding operation as the volume is identical for loans and deposits.
- c. Asset and liability have the same maturity but different amounts. When asset exceeds liability, the treasury typically needs to raise the funds in the short-term market and swap the exposure into the same maturity of the loan, reducing the spread by the swap transaction. When liability exceeds asset, the treasury has to invest the surplus liquidity. The treasury may buy securities with similar maturity to the liability or enter into a swap transaction depending of the profitability of the trade.
- d. Asset and liability are mismatched in volume and maturity. The treasury combines the activities of case b and case c.

These cases clearly demonstrate the two different roles of the Treasury department. And therefore, when the Treasury department is established as a profit center, the department should be compensated according to the roles the department performs.

### 3. *Interest Rate Management: Static Hedging and Dynamic Hedging*

There are two sources of interest rate risks. The transfer-pricing curve may unexpectedly change (the yield curve risk) and the embedded options in both assets and liabilities may change in value (the option risk). To manage such interest rate risks, the bank can use two complementary interest rate risk management tools: static hedging and dynamic hedging.

Traditionally, banks manage interest rate risks using interest rate buckets or durations. These approaches are not appropriate for banks with balance sheets that have embedded options. Banks can first manage the embedded options strategically by static hedging and then use dynamic hedging for tactical implementations. One tactical implementation is to use the key rate duration for directional bet in the yield curve movement.

The methodology for implementing a static hedge is called arbitrage-free bond canonical decomposition (ABCD). Ho and Chen (1996) describe such a static hedging strategy. In essence, ABCD identifies the embedded options in the balance sheet as caps and floors. ALCO can determine the strategic balance sheet plan in deciding the static hedging strategies, by first using the identification of the embedded options. In so doing, the bank can neutralize the embedded option risk (if so desired), avoiding any liquidity risks in hedging the options using dynamic strategies.

The following provides some of the ABCD results, as we identify the building blocks of the variable rate mortgages, savings account, and the surplus (or alternative saying, the structural balance sheet.)

**Variable Rate Mortgage Static Hedge (in \$'000 )**

Cash	107
Cash flows Generated of the Forward Curves	4,894
12mo forward, 12mo Window, 2.70% strike, 3mo reset Cap	1
36mo forward, 12mo Window, 4.30% strike, 3mo reset Cap	5
6mo forward, 12mo Window, 5.60% strike, 3mo reset 5 year CMS Cap	(2)
60mo forward, 24mo Window, 3.80% strike, 3mo reset 5 year CMS Floor	(5)
<b>Total</b>	<b>5,000</b>

This variable rate mortgage (sold in Switzerland) offers the mortgagors the option to convert from the variable rate to fixed rate over a period of time. The variable rate depends on the mortgage market forces. The optionality of the rate adjustment by the bank and early withdrawal (redemption or convertibility), in principle, for the purpose of illustrating the static hedging, is similar to that in the savings accounts, or mortgages sold in other countries.

The above result can be explained quite intuitively. When a bank buys a \$5 million variable rate mortgage, \$4.894 million goes to purchase the cash flows, but the ability to adjust the rate is a cap (option) to the bank. Further in the future, because the mortgagors have the right to switch to fixed rate, the bank has also sold the options (floors). The decomposition specifies precisely the types of caps and floors embedded in the variable rate mortgages.

This analysis can show that the balance sheet has a net positive (or negative) position in embedded options. As a result, the bank may consider selling or buying some caps and floors to manage option risks.

For the tactical management, the Treasury Department can measure the interest rate risk exposure using key rate durations. The market value, duration, and convexity of the asset, liability and surplus are provided below.

### Key Rate Durations (KRD) for Dynamic Hedging

Types	Market Values	Duration	Convexity
Asset	38,952	1.35	0.51
Liability	35,505	1.98	(1.22)
Surplus	3,447	(5.13)	18.32

These results show that the asset and liability durations are relatively close with the liability duration slightly higher, resulting in a negative duration for the surplus. That is, if the interest rates rise by 100 basis points, then the surplus value will rise by 5.13 percent. The asset portfolio has positive convexity and the liability has negative convexity. As a result, the surplus has significant convexity. In the static hedging results, we have shown that the surplus has a net positive position in options. Using the sensitivity analysis, we can find that the static hedging results should be consistent with this result showing that the surplus has positive convexity.

Next we can analyze the yield curve risk on the surplus. Key rate duration measures the sensitivity of the asset, liability or surplus market value to the changes in each of the points on the spot yield curve.

### Key Rate Durations

KRD terms (yr)	0.25	1	2	3	5	7	10	15	20	25	30
Asset	0.01	0.31	0.35	0.71	0.44	-0.06	-0.10	-0.31	0.00	0.00	0.00
Liability	0.06	0.12	0.41	0.63	0.44	0.32	0.08	-0.04	-0.04	0.00	0.00
Surplus	-0.50	2.26	-0.27	1.53	0.44	-3.97	-12.12	-10.3	0.41	0.00	0.00

While the surplus duration is small (5.13 years), the balance sheet is exposed to significant yield curve risk resulting from the changing shape of the yield curve and not just the parallel shifts of the yield curve. Specifically, the position is sensitive to the ten-year and 15-year rate falling. If the 10-year rate falls 10 basis points, and all other rates remain unchanged, then the surplus value will fall by 1.212 percent. When the yield curve is positively sloped in the short term, the positive key rate durations in the first three years can ensure higher returns, if the yield curve falls or remains unchanged. This is the result of the bonds riding down the curve as the transfer rate falls with the passage of time. As the above discussion shows, key rate durations are useful for managing interest rate risks on an operational basis.

#### 4. *Risk Management*

VaR can be used as a risk measure. VaR can be calculated by several methodologies and is defined in several ways. VaR should be provided for each item as well as for the entire balance sheet. Ho, Abrahamson and Abbott (1996) provide an overview of such a methodology. Further, the results can be used to determine the marginal contribution of risks by each item of the balance sheet to the total risks of the bank. Therefore, we can identify the natural hedges within the balance sheet and the diversification effect of each risk source.

This approach can also provide the risk exposure of the entire balance sheet and, subsequently, the Risk Department can continually enforce the risk limits. Further, the prospective risks are then compared to the retrospective performance of each item of the balance sheet. Risk management must also evaluate the stress scenarios.

The Risk Department can provide risk reports on a regular basis, including:

- (1) the time trend of duration, OAS, and other analytics.
- (2) stress tests for the variable rate and fixed rate positions
- (3) balance sheet items simulated under interest rate scenarios
- (4) key rate duration reports by item and by aggregate
- (5) risk measures with and without option hedging.

These reports are derived in an analytical framework consistent with that of the System. The Risk Department's role is to provide risk measures along the business cycle and independent oversight of each phase of the cycle. Therefore, the risk reports can best be designed within the context of the business cycle. The Risk Department receives balance sheet positions from Economics Department and then calculates the risk measures, risk exposures, and simulated values under stress scenarios.

For the requirement phase, a report can be used to compare with the risk limits and policies determined by senior management to identify the validity or relevance of these limits. Further, the Risk Department can provide the prospective profitability of balance sheet items and their risk contributions to Senior Management. Such information can be used to determine the risk-adjusted capital and compare products' profitability. The use of marginal contribution of risk by each department to the bank's surplus (called VaR-Beta) and relating such information to the shareholders' value to determine the capital allocation are discussed by Ho (1996) "VaR Analytics: Portfolio Structure, Key Rate Convexities, and VaR Beta", and Ho (1998) in "Allocate Capital and Measure Performance in a Financial Institution".

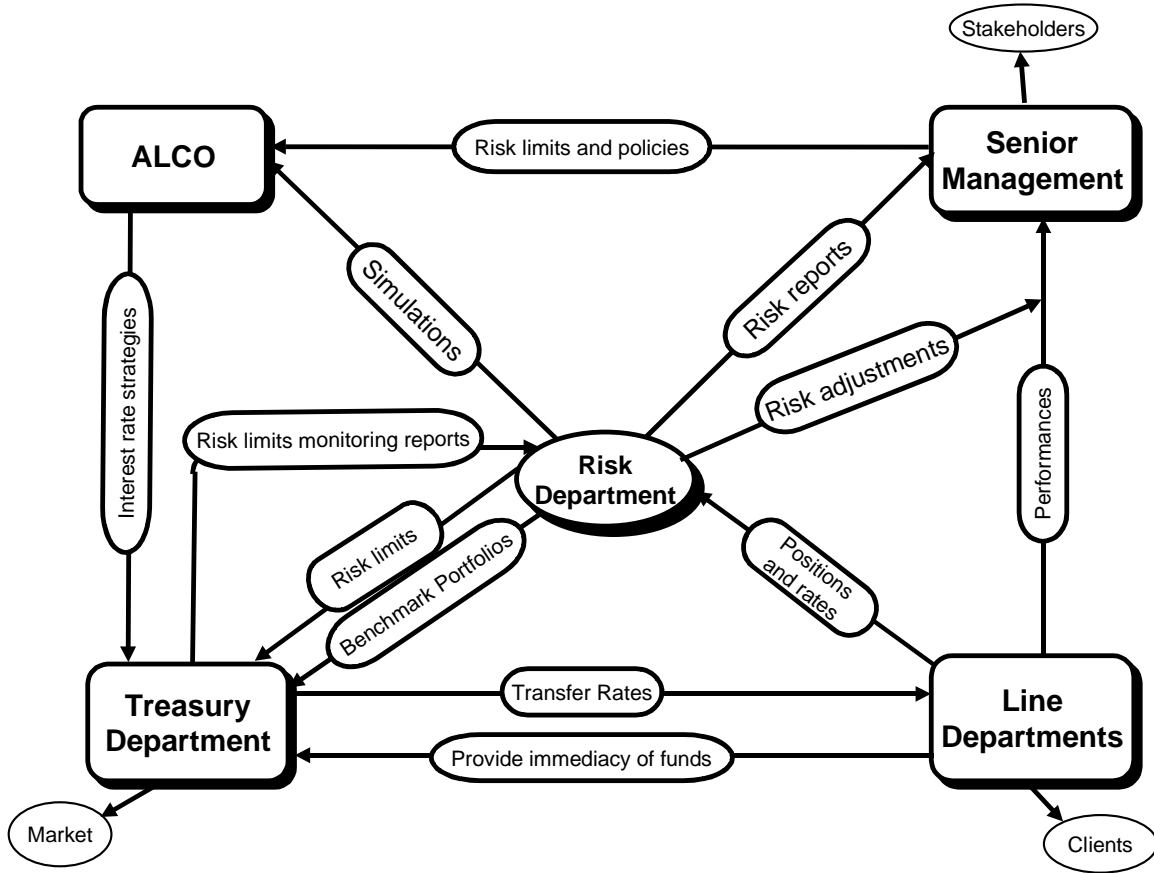
For the design phase, the Risk Department can provide independent verification of the ALCO proposed strategies, assuring that the strategies are within the risk tolerance

level. The static hedge results can also be used to identify the embedded options on the balance sheet.

The Risk Department can provide a comparison of the retrospective and prospective profitability for the line departments. (These measures will be discussed in the next section.) Also, these profitability measures can also be tested against the limits.

Hence for each phase of the business cycle, the Risk Department can provide (1) risk exposures, (2) comparison of prospective and retrospective returns, (3) identification of major risk sources, (4) independent oversight and monitoring of the effectiveness of the risk limits and procedure. This discussion is summarized by *Figure 2*.

### Risk Management Within the Business Control Cycle



**Figure 2**

#### 5. Strategic Balance Sheet Plan

When ALCO determines the strategic balance sheet plan, the management system can be used to provide the “what if” scenarios. This analysis will enable ALCO to weigh the risk and return tradeoff for certain strategic positions. For example, as the yield curve

rises with the short rate lagging the long rate, we may consider implementing a strategy that exploits the steepening of the yield curve. This approach in integrating performance with risk can then evaluate different strategies for such an interest rate scenario.

Senior Management can use the enterprise performance analysis to decide on the growth strategy of the bank. By knowing how each item impacts the balance sheet risk and profitability, Senior Management can better decide on the optimal mix of the business units on the balance sheet.

#### 6. *Return Attribution: Prospective and Retrospective Profitability*

Over each period, daily or weekly, the total return of the surplus of the entire balance sheet can be calculated. This can be accomplished because we can determine the market value of the surplus at the beginning of the period and the end of the period. The total return of the surplus is defined as the change of the surplus value plus the payments released to the shareholders. Now, we can determine the contributions of this total return by departments. This attribution model is called the return attribution model. Ho, Scheitlin and Tam [1992] provide a detail description of this approach.

The total return of surplus can be broken down to its component parts, which are related to each risk source. This decomposition is called “return attribution.” The model is given below:

$$\Delta S / S = r\Delta t - \sum KRD_i \Delta r_i + OAS\Delta t - d_{OAS} \times \Delta OAS + e_i$$

where:

- $r$  = the rate off the transfer pricing curve
- $D_{OAS}$  = OAS duration is the sensitivity to the basis risks
- $\Delta r_i$  = key rate change relative to the forward curve determined at the beginning of the period
- $KRD$  = key rate durations
- $OAS$  = Option Adjusted Spreads
- $\Delta OAS$  = shifts in OAS
- $S$  = surplus
- $e_i$  = error term

If we measure the returns in sufficiently short interval, the option decay value and the impact of convexity may be negligible.

At the beginning of each period  $S$ ,  $KRD_i$ ,  $r$ ,  $OAS$ ,  $D_{OAS}$  can be calculated. At the end of the period, we can calculate  $\Delta r_i$  and  $\Delta OAS_i$ . Therefore, we can determine all the terms of the return attribution operation on both right- and left-hand side, except for  $e_i$ , the residual, which is then implied.

Return attribution is the model that breaks down the total return of the balance sheet to the returns attributed to each profit center (line business or the treasury department). The model shows that the balance sheet returns have the following components. The first term is the return on the surplus (or equity) of the balance sheet. The second term is the returns from the interest rate risk exposures of all the “buckets” measured by key rate duration in taking the embedded options into account. The third term is the expected margins derived from the products. The fourth term is the returns due to the changes of margins. Finally, the last term is the residual term.

This analysis provides a methodology to calculate the interest rate returns using the key rate duration terms both for prospective and retrospective profitability. The practicality of the methodology will depend on the efficiency of its implementation and the accuracy of the return attribution model as measured by the magnitude of the error (residual) term. McCoy [1996] has shown that the return attribution model can be quite accurate. Consider the application of return attribution to one profit center, for example, the Treasury. These returns will be attributable to the Treasury Department for the interest rate risk management function. Specifically, the return attributable to the Treasury Department is given by:

$$\Delta S^* = S - \sum KRD_i \Delta r_i$$

The key rate durations can be calculated as described in Section A.3. Therefore, the daily (or weekly) return can be calculated by the observed shifts of the key rates relative to the forward rates over the time period multiplying the key rate durations. This approach enables the Treasury department to measure their prospective interest rate risk exposure and at the same time the retrospective measure of their performance. This procedure is relatively straightforward and robust.

Similarly, the return attribution model can apply to other profit centers. OAS terms (the terms for the margins and the change of margins resulting in the change in present value of the volume) are attributable to the line departments. The risk-free term is the profit for the shareholders, who own the net value of the asset and liability.

## 7. Summary

In sum, the system collects and provides analytical information to each department. The flow of information is depicted below.

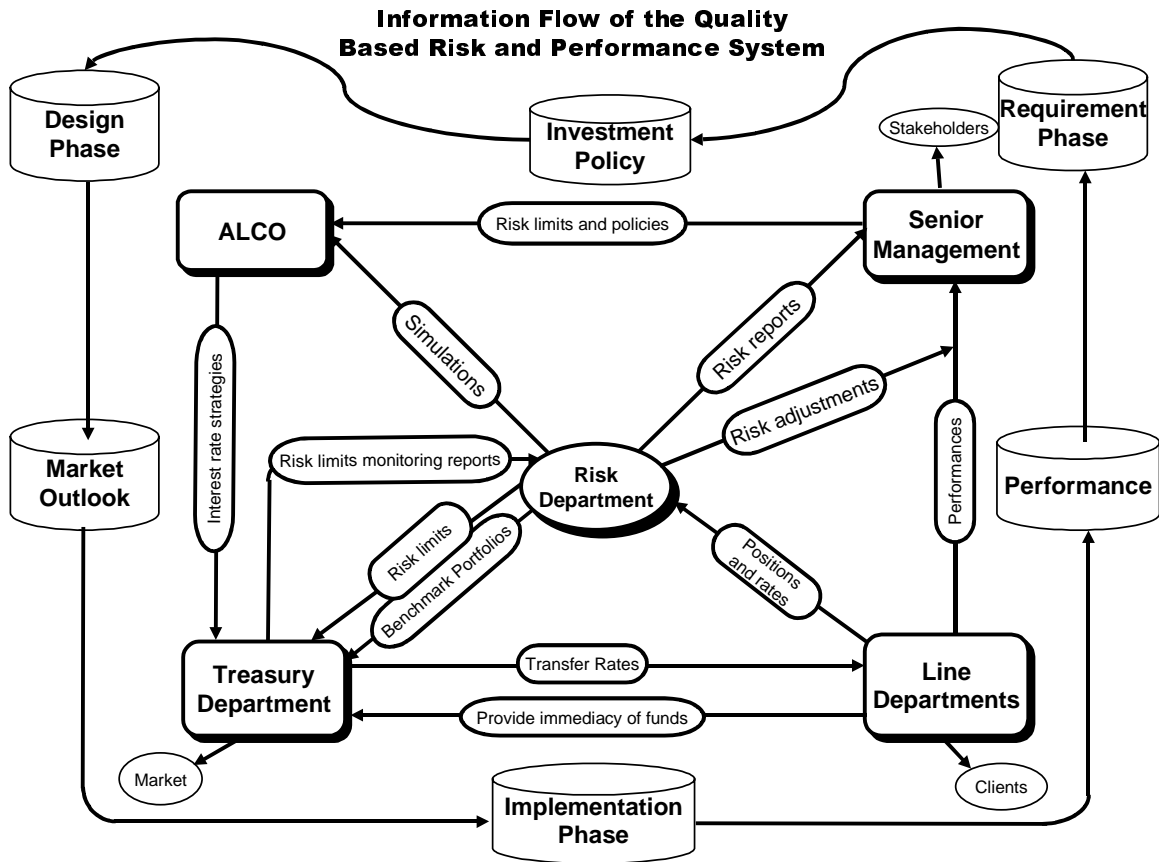


Figure 3

## B. Actionable Decisions that Can be Made Using the System

The System enables the bank to take many actionable decisions, beyond providing the risk reports and the monitoring role of risk management. The following are just some examples:

### 1. *Interest Rate Management Strategies*

In managing the entire balance sheet risks, ALCO can appropriately implement investment strategies, with risks and returns properly quantified. The strategies may involve the use of caps and floors for statically hedge the embedded options in the balance sheet, or taking active bets in exploiting movements of the yield curve.

### 2. *New Product Design*

The system provides the transfer pricing rate and hence the profitability of the products. Further, the system provides the marginal contribution of risks of each product to the balance sheet. Therefore, the system provides comprehensive risk-adjusted profitability of each product. This enables senior management to evaluate the desirability of each product and to design new products.

For example, Stalder and Straub (1997) suggest using strippable mortgages in place of variable rate mortgages. In Section A.3 we have discussed the embedded options in the variable rate mortgages. These options do offer challenges to the management of the balance sheet. The proposed approach provides the platform that can analyze the risks and profitability of such a product on the balance sheet.

### 3. *Treasury Department Profitability*

The Treasury Department can become a profit center since profitability can be measured in a consistent fashion. Also, the system enables the Treasury Department to evaluate the cheapness and richness of the hedging instruments to decide on the optimal risk management strategies.

### 4. *Line Departments Profitability*

The line departments' profitability can also be measured on an economic valuation basis. Therefore, line departments can change product designs and set rates in an optimal manner that can be consistent with the economic valuation approach. The transfer pricing approach can enable us to take into account the embedded options within our core accounts or within other liabilities.

### 5. *Risk Management Based on the Business Cycle*

In building risk management based on the business cycle, the risk system can assure the separation of roles and responsibilities of the different phases of the business cycle. As a result, the bank can better determine the profitability of the phases on a risk-adjusted basis. Also, the risk department can proceed to measure the operational risks of the business cycle.

## **Conclusions**

The approach described in this paper provides benefits to the Board, Senior Management, ALCO, Risk Management, and the Treasury. It provides a flow of analytical information across these departments in a consistent manner. In so doing, the bank can manage the entire structural balance sheet risks and its performance. As a result, investment strategies and new product designs can be implemented to enhance the bank's profitability.

### Key Rate Durations

Effective duration is a standard measure of the interest rate risk exposure of a bond or a portfolio, which has come to have many applications in managing interest rate risk. Its main assumption is that the spot yield curve shift is parallel. Parallel shifts of the spot curve can capture much of the nature of term structure movements, although the returns of two securities with the same effective duration can be significantly different if the yield curve undergoes nonparallel shifts, such as steepness or curvature.

Key rate durations define the risk of the changing shape of the spot curve. Key rate durations are not a single measure as is effective duration. As a set (or a vector of numbers), the key rate durations define the price sensitivity of a security over the entire domain of possible movements of the yield curve. The sum of the key rate durations is identical to the effective duration.

To define key rate durations, first we need to develop the model of yield curve movements. Let  $R(\cdot)$  be the initial spot yield curve, where  $R(t)$  is defined to be the (continuously compounded) yield to maturity of the default-free zero-coupon bond maturing at time  $t$ . Let  $R^*(\cdot)$  be the spot yield curve shifted from the initial yield curve instantaneously. The shift need not be parallel. Therefore if we define the shift  $W(\cdot)$  to be the difference between the shifted spot curve and the initial spot curve,

$$S(t) = R^*(t) - R(t) \quad (1)$$

The  $S(t)$  is not necessarily a constant function. In principle, the shift can be any function. We want to find a simple representation of the shift by assuming that the shift can be approximated by a piecewise linear function.

Consider a spot yield curve ranging from zero to thirty years. We define a set of key rates in this range. For purposes of exposition in the article, we choose a set of eleven key rates of three months, one two, three, five seven, ten fifteen, twenty, twenty-five, and thirty years. Other sets can be defined that differ in both the number and the term of the key rates. For example, one could specify 360 key rates, one month apart.

Our choice of these eleven is motivated by market practice, because most market professionals closely watch the movements of these rates. We denote these key rates by  $t(i)$  where  $i = 1 \dots 11$ . By definition, the shift at each key rate is  $S[t(i)]$ . Then the yield curve shift along the maturity range  $S(t)$  can be approximated by linear interpolation of the shifts of each key rate.

Linear interpolation, as opposed to other interpolation, is used for reasons of simplicity. Note that the linear interpolation is used to model the change of the yield curve, not the yield curve itself. It enables the shifted yield curve to capture a curvature similar to the underlying yield curve.

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