Bank Management of Risk Dynamics

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In banks decisions are made in a speedy and complex environment often with huge uncertainty. This risk must be managed proactively on an enterprise level. Thereby a systemic view of the bank is essential. Up to now there is no standardised approach for analysing overall risk dynamics of a bank. Most risk models are constrained by their static view, so that they hardly capture the rapid and discontinuous changes. This paper examines the dynamics by applying system dynamics to enterprisk risk management, with the aim of understanding the banks' risk dynamics. In order to simulate the risk dynamics an enterprise risk model was developed. By combining the disciplines of enterprise risk management and system dynamics, this paper shows how a systemic view can improve structures in bank risk management.

Keywords: Enterprise Risk Management, Dynamic Modelling, Bank Management

"Risk is a choice, not a fate"
Prakash Shimpi (President Fraime LLC)

1. Introduction to Dynamic Risk Management

1.1. The Need for Dynamic Risk Management

Today's bank managers make decisions based on incomplete information, price in volatile markets and use information of complex systems. To accomplish this, risk management helps to deal with uncertainty in the best possible way. The goal is to strike the balance between risk and reward.[1] Financial risk management mainly considers earnings volatility in a bank's credit and trading department. Yet the word risk has two meanings.[2] First it is defined as an exposure to a chance of loss or damage, which is a quite negative connotation. In the same instance, risk is a function of likelihood and consequence. It denotes a revealing positive outlook: to take a risk in expectation of a favourable outcome.[3] We can use our marvellous capabilities to reason on past events and convert the unknown future into an opportunity. In banking the term "risk" is generally used to describe the likelihood of a loss or that an investment return is being lower than expected. However, especially investment banks also make profits by actively taking risks from other counterparties. After all it is not possible to make any gain without taking a risk. Therefore, risk is on equal footing with opportunity and threat.

Each bank has a business specific risk profile and executes decisions with a different risk appetite. The trading division of an investment bank close to Wall Street has a greater risk appetite

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[1] Leslie Rahl: "Lessons learned", *Risk Insights*, 01/2002, available at www.cmra.com
[2] Definition of risk available at http://www.cogsci.princeton.edu/cgi-bin/webwn2.0?stage=1&word=risk accessed 28 January 2005.
[3] The word risk derives actually from "risicare", which in Italian means to dare or to have sufficient courage. It originally meant "to circumnavigate a cliff". In this sense risk is a choice rather than a fate. See also Peter Bernstein: *Against the Gods – The Remarkable Story of Risk*, 1998, Wiley, p. 8.

than a small retail bank in Oslo, for example. Major Banks easily absorb huge risks, either because they have a strong capital basis, or because they possess the expertise to hedge risks following the Markowitz diversification concept.[4] Regardless of their size, banks have to focus on risk management at an enterprise level. In the past, risk managers oversaw hidden hazard and liability risks; internal auditors dealt with accounting issues; business units focused on project risks; and treasury handled foreign exchange and interest rate risks.[5] Although today these functions are united, still risk silos are maintained by single units risk measurements. Risks can be assessed at three levels: at the transaction, business unit and corporate level. ERM shifts the focus of risk management towards a company-wide focus with defined responsibilities. While traditional risk management works best for financial risks (i.e. transferable risks), ERM, by contrast, stresses the management of operational and strategic risks. By the enterprise view we are able to manage a risk portfolio with the tendency to optimise the overall risk. While some risks hedge others, it is essential to capture the correlations between them. Only if all risks are properly integrated can single strategic decisions can be made with a chosen risk appetite. For a CEO to be able to manage the overall risk of a bank, a framework is needed to integrate single risks and business lines.

This paper focuses on enterprise-wide risk management (ERM) as "an *integrated framework* for managing risk and risk transfer of one bank in order to maximize firm value."[6] Therefore, the system boundaries are set like it is shown in the yellow part of figure 1. The reader has to differentiate between the closely related term "*systemic risk*" and the term "risk dynamics" which denotes the stability of a whole banking industry in a geographical region.[7] The main focus of this study is on the risk dynamics of an individual bank. Nonetheless, at some points we will also consider systemic risk for the whole banking industry, since this also has an impact on the risk of each individual bank.

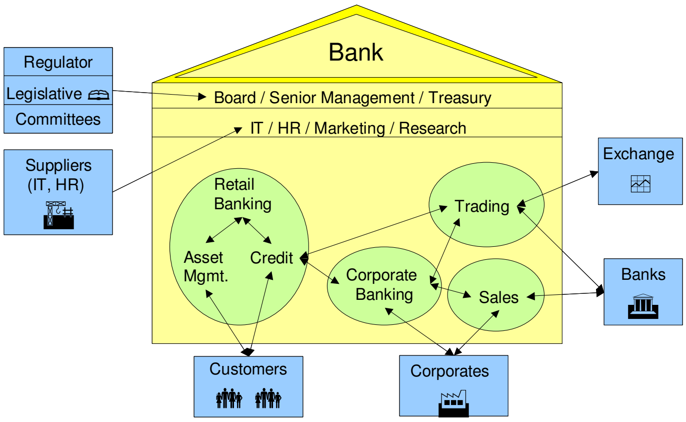

Figure 1: System Boundaries and Sub-systems

The driving force behind ERM initiatives are the regulatory requirements. As Robert Levine notes, "A combination of regulatory and commercial pressures is driving organizations to spend more than ever on technology to manage risks."[8] Enterprise risk management is clearly driven by evolving regulatory requirements such as the modified Basel Capital Accord or the Sarbanes-Oxley Act (SOA). Section 404 of the SOA requires management to attest to the soundness of a company's internal financial reporting. The Basel Committee on Banking Supervision of the Bank for International Settlements (BIS) has introduced more sophisticated requirements for credit and operational risk management in the new accord.[9] This new accord, known as Basel 2, calls for a risk management system with risk sensitivity capabilities and in which eco-

4 Heinz Hockmann and Friedrich Thießen: *Investment Banking*, 2002, Schäfer Poeschel, pp. 74 et seq.
5 Russ Banham: "The Art of Measuring Risk", *Reactions*, 11/2003, Vol. 23, Issue 11, p. 55.
6 James Lam: *Enterprise Risk Management – From Incentives to Controls*, Wiley, 2003.
7 See working papers at the World Bank: http://econ.worldbank.org/view.php?id=39805, accessed 4 March 2005.
8 Robert Levine: "Risk Management Systems: Understanding the Need", Spring 2004, in *Information Systems Management*, p. 31.
9 The Basel II framework can be accessed under http://www.bis.org/publ/bcbsca.htm.

nomic and regulatory capital are aligned. However, as Figure 2 shows, ERM in banking is not only driven by legal requirements, but also internal forces such as technological advances or the finance industry itself.

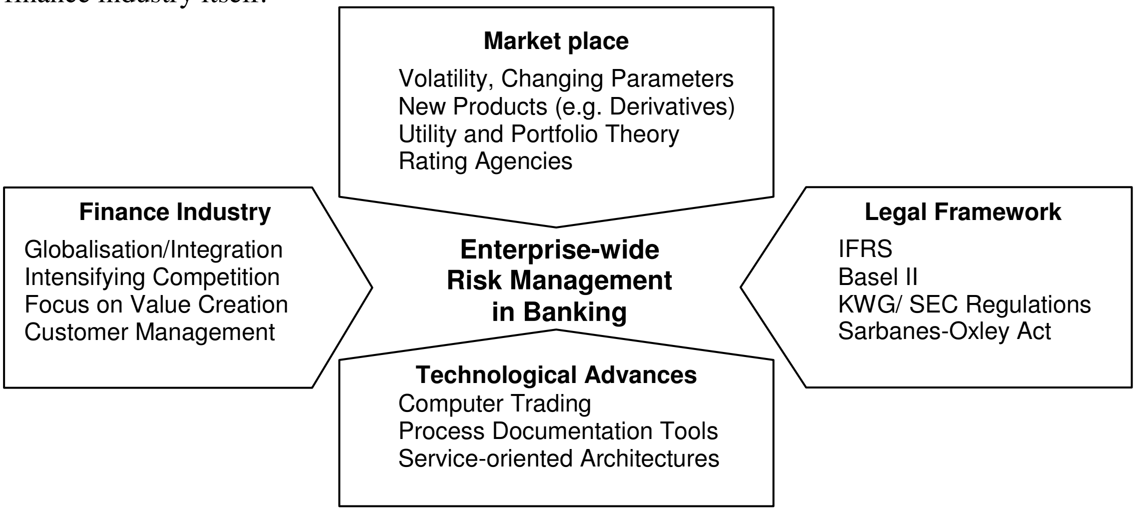

Figure 2: Drivers of Enterprise Risk Management in Banks

ERM improves three essential, closely interlinked parts in banking: value creation, capital structure and capital budgeting. To create value, investments need to be budgeted. If value is created, the capital shifts due to the generated profit. The upcoming revenue stream allows the bank to budget new projects with the aim of creating new value with a certain risk. "Managing risk at the corporate level can increase the value of a bank, because it can reduce […] costs of equity and debt as well as that of transaction costs."[10] Bank managers are able to reduce the cost of capital by better risk management approaches. In order to build such an approach, the bank must select effective strategies of risk elimination, risk transfer and risk taking. Figure 3 lists some of the more recently used risk handling techniques:

Risk Approach	Instruments				
	Hedge/Sell	Diversify	Insure	Set Policy	Hold Capital
Eliminate/Avoid	X	X	X	X	
Transfer	X		X		
Absorb / Manage		X	X		X

Figure 3: Common Risk Approaches and Instruments in the Finance Industry[11]

The dynamic perspective of ERM offers an enormous opportunity not only to make risk optimisation results visible, but also to accomplish sustainable business achievements. ERM is becoming ever more important owing to the increasing complexity of risks. Globalisation, for example, has added new risk components such as country risk to a business. Risk components are also changing, making a risk overview necessary. A bank's risk portfolio is similar to its investment portfolio. The portfolio view of risks allows the bank to make strategic decisions as to which risks should be eliminated and which new ones can be taken on board. Today's banking world is swiftly changing due to innovations in instruments and products. Therefore, ERM has to transform risk management from a rather static activity to a dynamic, proficient process. The Greek root of the word dynamic, *dunamikos,* indeed indicates a powerful or energetic change, marked by continuous or productive activity. The ultimate goal of ERM is to maximise

[10] Gerhard Schröck and Manfred Steiner: "Risk Management and Value Creation in Banks", *Risk Management*, 1st edition, Springer, 2004, pp. 55 et seq..
[11] Partly based on Schröck and Steiner, op. cit., p. 56.

the firm's value by continually optimising risk consumption for a certain return. By improving the dynamic capabilities of enterprise risk systems, a bank can gain valuable insight into the correct level of risk exposure on a flexible and permanent basis.

In the world of finance, models are dynamic in a different way than in the system dynamics view. Most financial models are considered dynamic, and they are indeed designed to contain a certain degree of change over time. However, the structure of the modelled revenue stream is often not changed at all, and financial models remain to a certain extent static, meaning that the full impact of forces is not captured, even though the behaviour changes over time but within the same structure. Systems and especially dynamic models can vary in terms of the degree of dynamism.[12] Dynamic systems behave in a certain way, which means either that they do something, or that interaction is taking place within themselfes. These dynamics are internal and external. As far as the author is aware, this thesis is the first to examine the dynamics in financial risk management from a systemic viewpoint. Taking a systemic view allows to capture complexity, which is hard to model in existing risk models. This paper extends research in two ways:

1. It provides insight into the dynamics of ERM. It is not enough to calculate static risk indicators, since risk changes drastically over time. Banks need to implement these risk dynamics into their models in order to price risk exposure correctly.
2. Strategies, patterns and systems features are examined with regard to how a bank can reduce the overall risk (dynamics). The processes that have to be implemented to absorb risk are also analysed.

A system dynamics model is developed to find answers to questions like: What kind of risk dynamics does a CEO have to face in an ERM framework? What kind of dynamic behaviour is strongest, and what impact does it have? What mostly makes the bank's economic capital increase? By applying system dynamics methods to ERM, we are able to capture risk dynamics.

The purpose of the model is first to discover the dynamics in an exemplary bank within an enterprise risk framework, and then to derive ways to improve the risk system.

1.2. Risk Structures

The most important risks a bank faces are credit, market and operational risk. Alongside these are risk types such as liquidity risk, funding risk or country risk. Figure 4 shows the most important risk categories.

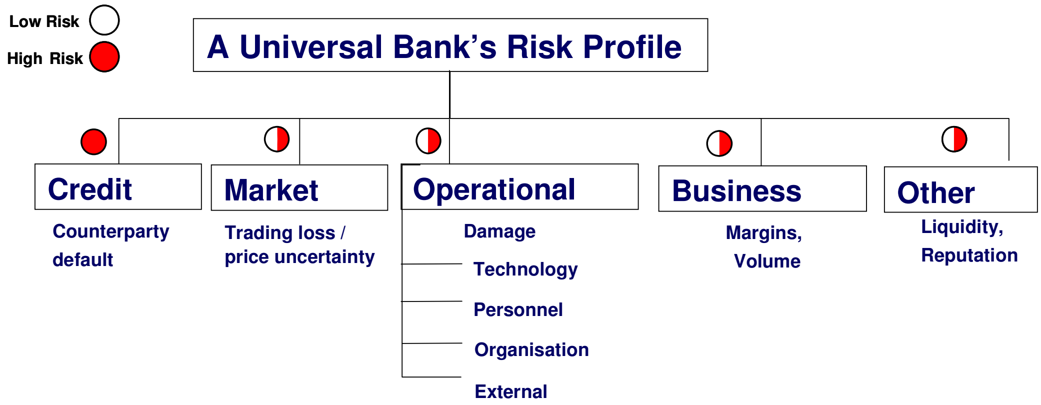

Figure 4: A Universal Bank's Risk Profile

[12] Jürgen Strohhecker: "The Object-oriented Model of a System's Dynamic", in "System- und objektorientierte Simulation betriebswirtschaftlicher Entscheidungen", Issue 53 Scientific papers of the Industrieseminar University Mannheim, Duncker & Humblot, Berlin, 1998.

Risk as an exposure to a chance of loss can be measured in various ways. A loss event occurs when asset values change to the negative. Since Markowitz, the risk of an investment has been measured by the standard deviation of outcomes.[13] In doing so, probabilities of loss are determined from historical data. The probability determines the degree of certainty that can be assigned to certain events (e.g. credit defaults) happening within a specified time interval or within a sequence of events. The most common industry standard is the VaR concept. The value at risk is the value that will not be exceeded (e.g. in the next 10 days) with a probability of 99% (the confidence level= 1-α). For a given portfolio, VaR measures the possible future loss which will not be exceeded with a high probability for a certain period:
$VaR = ([\Phi^{-1}(1-\alpha)\cdot\sigma_{\Delta Value}] - \mu_{\Delta Value})\cdot Value_{current}$, where Φ^{-1}= the inverse standard normal cumulative density function, σ= the standard deviation and μ= the mean (expected return), for 1 day as a holding period.[14]

1.2.1. Credit Risk: Pricing Credit Defaults

Credit risk is the oldest and, in terms of economic capital, the most important risk for banks. It arises from defaults, namely when a debtor does not fulfil a contractual payment obligation to the bank. Often credit risk is the largest single risk a bank has to face. Credit risk is sudden and its potential impact is huge.[15] It is now more important than ever to assess the credit quality of a client (issuer or borrower), an assessment known as rating. Between the actual counterparty risk and the perceived risk is a time delay, as it takes time for the bank to recognise the actual default situation of the customer. At the time of the default, the bank recognises the exposure amount, which can be reduced by selling the collateral (recovery rate). If the exposure is not covered fully, the bank suffers the loss rate of the credit exposure amount.

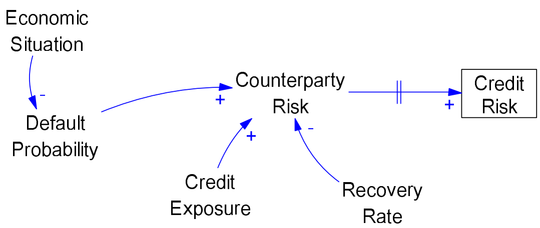

Figure 5: Credit Risk Components[16]

1.2.2. Market Risk: The Known Quant World

Market risk arises from the possibility of losses resulting from uncertainty about changes in market movements (e.g. equity prices, interest rates, exchange rates, commodity prices, etc.). Most of a bank's market risk resides in the trading group.

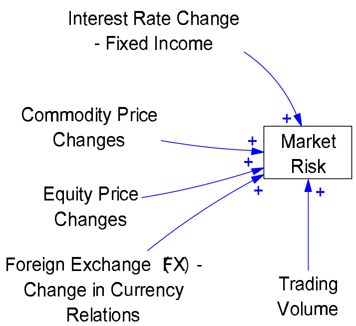

Figure 6: Market Risk Driver

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[13] Harry M. Markowitz: "Portfolio Selection", *Journal of Finance*, 1952, No 7, pp. 77-91.
[14] More information about the VaR concept can for example be found in Kevin Dowd: *Beyond Value at Risk*, Wiley, 1998. This paper gives only an overview of risk measurement methods.
[15] Richard K. Skora: "Modern Portfolio Credit Risk Modeling", available at http://www.skora.com/modern.pdf, accessed 6 March 2005
[16] The two parallel lines "||" in the figure indicate the time delay.

Depending on the transactions, there is more risk either in the trading book or in the bank's book.[17] Market risk emerges from the mismatch of demand and supply, and is also influenced by the correlations of the changes and their levels of volatility. A bank can lose money in a few seconds (e.g. buying currencies high and selling low), but losses also occur due to long-term market trends such as collapsing real estate prices or changes in interest rate levels. Market risk also occurs when, for example, investors are no longer willing to pay a high price for a certain stock. To illustrate this, Figure 7 shows how the Nasdaq index lost 65% of its value between March 2000 and March 2001 as a result of the bursting of the internet stock bubble.

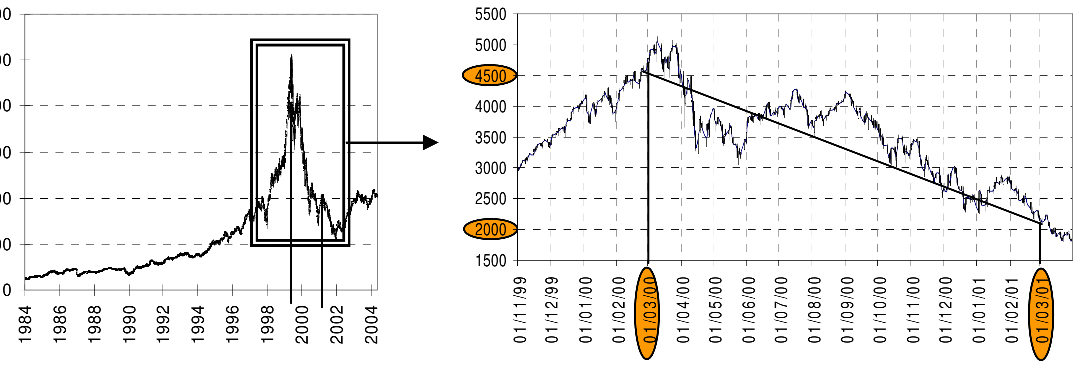

Figure 7: Long-time Chart and Radical Fall Chart from the NASDAQ[18]

1.2.3. Operational Risk: Risk-Resistant Operations

The Basel Committee on Banking defines operational risk as "the risk of direct or indirect losses resulting from inadequate or failed internal *processes*, *people* and *systems* or from *external events*."[19] Operational risk is the threat to the bank's operations. Unmanageable events (such as September 11), insufficiently defined controls and project failures increase operational risk. Business disruption, processing risk as well as fraud and mistakes are included in this risk type, too. In 1997, for example, the National Westminster Bank incurred enormous losses owing to badly handled operational risk. The bank lost $127 million, and "had to greatly reduce its trading operations, because its options traders had been using the wrong data for implied volatility in their pricing models, and was therefore taking risks that they did not see."[20] Operational risks are always industry-specific. Banks handle money, and their business is based on trust and competence. Making mistakes certainly puts off new customers. Financial institutions have to operate accurately, must implement dual controls, must be proactive in combating fraud, and must double-check transactions.

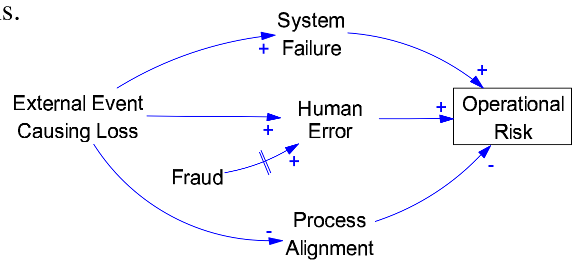

Figure 8: Driver for Operational Risk

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[17] According to Uwe Schulz, Value & Risk AG, mortgage banks tend to keep speculative interest positions in the bank's book, so that no regulatory capital has to be allocated.

[18] Data source: Yahoo Finance: http://finance.yahoo.com/q/hp?s=%5EIXIC&a=00&b=1&c=1984&d=01&e=25&f=2005&g=d, accessed 25 February 2005.

[19] BIS, available at http://www.bis.org/publ/bcbsca.htm

[20] Chris Marrisonop. cit., p. 6.

A challenge for calculating operational risk is the lack of data. Operational risk is typically caused by a variety of factors, including natural events, human errors and technical problems, and the outcomes of these events are often unknown. Some mistakes go completely undetected because they are small enough to hide, but embarrassing enough to admit to. For operational risk, therefore, a more complex and mixed VaR approach is used, because the *loss data* available are insufficient to apply the normal VaR concept.[21]

1.2.4. Business Risk: The Set-up

Business risk is regarded as uncertainty if the bank's (expected) revenues are able to cover its expected fixed cost base and variable expenses. Business risk represents the uncertainty of earnings due to changes in business conditions, namely market environment, client behaviour and technological progress (volume and margins). Risk arises at a time when revenues are for example declining faster than adjustments can be made to the cost base. Business risk reflects the bank managers' decisions. Products, sales and prices have to be managed well to guard against business risk. The three key drivers of business risk are as follows:

1. The volatility of revenues due to intensifying competition, economic cycles and their effects on the customer base or the lifecycle of the bank's products.
2. Business risk tends to grow in proportion to a bank's fixed cost base.
3. The volatility caused by the variable costs.

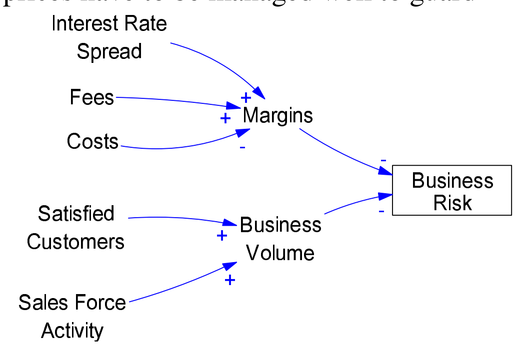

Figure 9: Business Risk Drivers

Business is about people. In a competing environment, financial institutions try to ensure high business volume by pushing and training their sales forces. If a customer is wrongly advised on financial products, however, this will lead to shrinking business volume in the future, since the customer loses confidence and the bank suffers an image loss. It benefits the bank very little if its sales force is ingenious, but they sell the wrong products. Closely connected to Business Risk is also reputation risk. Banks sell liquidity and asset availability to clients. Accurate financial transactions and discretion are a must for the banking business. The minute these business attitudes are called into question, clients loose their confidence, and banks their customers. Reputational risk has an instantaneous impact, as indeed can be observed during a bank run. The concept of Reputation Risk is known in the System Dynamics approach as Word of mouth.

Research conducted by the Royal Bank of Canada found that the stock market tolerates one-off mistakes. Typically, when bad news is announced, the bank's share price drops but recovers within about 90 days. However, there was no tolerance of strategic mistakes or contradictions to a company's formerly chosen risk appetite. It took a year for a bank to re-establish its credibility and to restore its share price.[22] Investors' confidence is also shaken by deficiencies in corporate governance, which can lead to costly fines and legal bills as well as significant damage to the institution's reputation, with the end result invariably reflected in the share price taking a severe pounding. Establishing and maintaining a good reputation requires foresight, but is definitely worth the effort. Therefore, in recent years banks have established communication departments that are responsible for presenting the bank positively in the media.

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[21] Agatha Kalhoff and Marcus Haas: "Operational Risk – Management Based on the Current Loss Data Situation", *Operational Risk Modelling and Analysis*, 2004, pp. 10 et.seq..
[22] Russ Banham: "The Art of Measuring Risk", pp. 55 et seq..

1.3. Risk Aggregation and Integration

The central figure in managing risk is that of the bank's economic capital. This states the amount of equity capital needed to absorb unexpected losses with a high degree of certainty at any given date. The certainty is chosen by each bank individually (normally ≥ 99.95%). Economic capital consists of aggregated risks and mostly takes into account diversification effects. It does not equal the regulatory capital (the minimum which is required by regulation). In contrast, economic capital is the capital that shareholders would choose in the absence of regulation, i.e. the amount that is needed to keep the bank operating during the next year and to maintain a certain rating.[23] It focuses on its buffer function against future unidentified losses. In general, capital is the means to achieving the optimal capital structure, and also provides insurance for the bank's safety.

All stakeholders are collectively interested in not overstepping the critical threshold, where the bank has to discontinue operations (i.e. a bank run). Figure 24 below displays the insurance function of economic capital. The peak of the distribution with the highest probability is where $Gains > 0$, as the bank should be expected to generate profits. In the area where there are no gains, only losses, shareholders lose money because they own the company and the assets in it. The different risk types of credit, market, business and operational risk are aggregated to calculate the overall loss distribution as shown in the next picture.

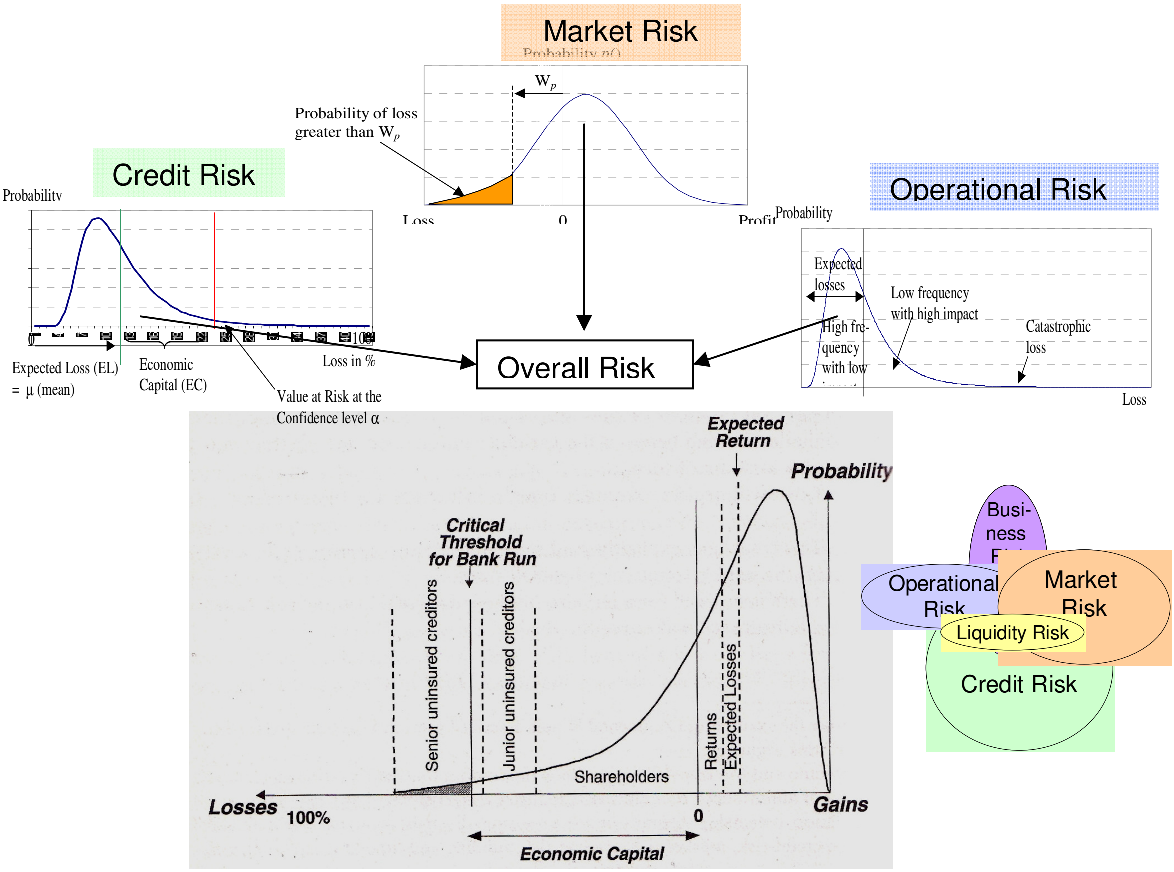

Figure 10: Economic Capital as an Insurance Function[24]

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[23] http://www.defaultrisk.com/pp_super_41.htm, accessed 27 February 2005.
[24] Note: The expected return should be farther to the left than actually depicted. Figure based on Schroeck and Steiner: op. cit., p. 158.

Since VaR measures risk as a negative deviation from the expected outcome, it is a good measure for the bank's total risk and can be used as a common "currency" to quantify each risk type. Economic capital is therefore a function of the riskiness of the bank's activities and the bank's desired likelihood of solvency: $P\left[\left(X - E(X)\right) \geq economic\ capital\right] \leq \alpha$.

This depicts the probability that the distance between the expected outcome X and unexpected deviations E(X) will not exceed the economic capital. This guarantees a certain solvency, with an α until year-end.[25] The overall bank VaR can only be derived indirectly from the different divisions in a bank, since they calculate risk parameters differently. For example, the VaR for market risk is typically calculated for a ten-day holding period[26], while VaR for economic capital is based on a 250 trading day basis. Catastrophic risk with large losses occurring only with a small probability violate the coherence of VaR. VaR is not sub-additive, i.e. $VaR(X+Y) \neq VaR(X) + VaR(Y)$. As Andreas Krause points out: "In many cases the conditions for subadditivity are (at least approximately) fulfilled and VaR is nearly coherent. But remarkably, the payoff distributions of options and similar derivatives mostly violate these conditions. And it was the use of such instruments that caused many of the large losses in the early 1990s and led to the development of VaR."[27]

The economic capital over the single risk types is in practical terms aggregated by adding the capital requirements to determine the overall amount. In actual fact, this practical approach ignores two correlation matrices: the correlation within a risk type, and the correlation matrix across risk types.[28] Given that risk types influence each other, these effects should be considered. Nonetheless, one could argue that even if we neglect the correlation effects, the results are still valid, as shortly before a bank's insolvency, the correlation parameters change drastically. Banks determine correlations for the second matrix by employing macroeconomic simulation models which are also used to enhance the operational risk model. Such models are complex and modelled only with difficulty. Large events are so rare that risk relations cannot be determined on an ad hoc basis. A few more events can quickly invalidate any *a priori* modelling decision. Risk systems in extreme situations show a very different behaviour than during normal events. A natural catastrophe or terrorist act can wipe out a stock market, whereas there is no correlation among the single shares. "Large risks are much more likely to be interconnected because the large-scale processes they unleash will overlap."[29]

There is also a systemic risk in the VaR measurement, which could lead to a self-fulfilling prophecy of doom. Actions taken as the result of a VaR estimate, e.g. an asset liquidation, could themselves precipitate a crisis. In this instance, VaR becomes obsolete as a risk measure because the distribution of outcomes changes significantly. This effect is not taken into account in the VaR estimation. With many market participants acting in the same way, namely trying to sell the asset, VaR may lead to loss realisation and trigger a domino effect.[30] Figure 12 shows the economic capital development at Deutsche Bank. Economic capital is measured from 1998 onwards, first without any information about the components. Between 1998 and 2002 it steadily increased. The drop in 2003 was explained in the annual report by improved credit portfolio quality, better market prospects and the ability to react on the cost side in weak market periods.

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[25] Ibid., p. 169.
[26] The regulatory process requires a confidence level of α=99% and a ten-day holding period. Internal models also use a one-day holding period and a confidence level of α=95% for back-testing reasons, and also because the economic P&L is calculated daily.
[27] Andreas Krause: "Exploring the Limitations of Value at Risk: How Good Is It in Practice?", *Journal of Risk Finance*, Winter 2003, pp. 19 et seq..
[28] Schroeck and Steiner: op. cit., p. 210.
[29] Jim Brander and Sam Manoff: "ERM and DFA Using Active Knowledge Structures", paper available at http://www.casact.org/pubs/forum/03sforum/03sf001.pdf; accessed 15 January 2005.
[30] Andreas Krause: op. cit., pp. 26 et seq..

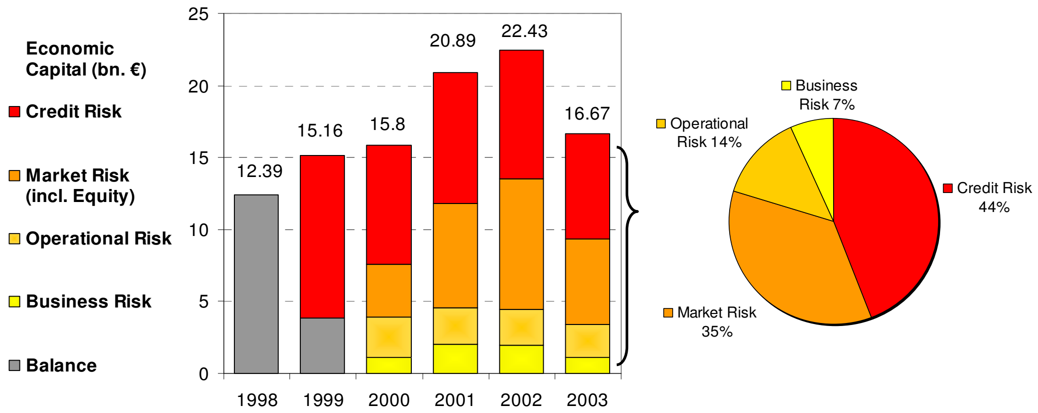
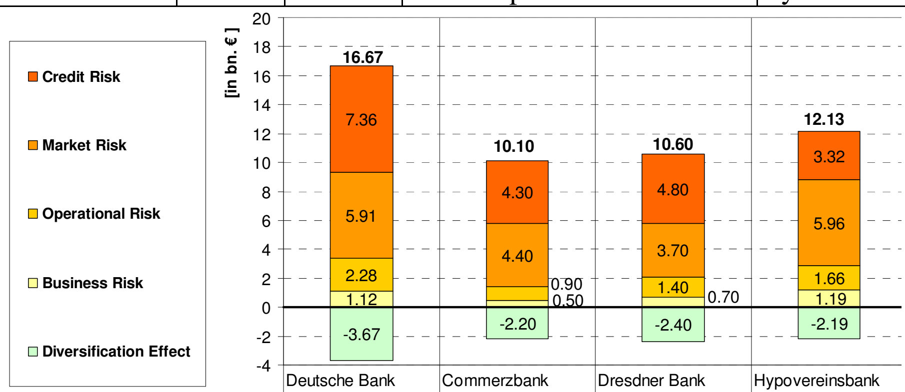


Figure 11: Economic capital development at Deutsche Bank 1998 – 2003

On the next page in figure 13 is the economic capital for 2003 and the parameters for the four leading private banks in Germany pictured. The results are not scaled to an overall confidence level α to show the original data. To make the figures comparable, diversification effects have to be estimated where the necessary information is not provided in the annual risk reports.

	Period	α	Correlation/Diversification	Comment on Figure 13
Deutsche Bank	1 year	99.98%	Will be implemented from 2004 onwards.	Diversification effect estimated at 22%.[31]
Commerzbank	1 year	99.95%	Effects considered.	–
Dresdner Bank	1 year	99.93%	Effects considered.	–
Hypovereinsbank	1 year	99.95%	Annual Risk Report values are published after diversification/portfolio effects.	Values for single risk components scaled up by estimation (22%).



	Deutsche Bank	Commerzbank	Dresdner Bank	Hypovereinsbank
Economic Capital 31.12.2003 (mn. €)	16,674	10,100	10,600	12,128
Credit Risk	7,363	4,300	4,800	3,316
Market Risk	5,912	4,400	3,700	5,956
Operational Risk	2,282	900	1,400	1,664
Business Risk	1,117	500	700	1,192
Diversification Effect	-3,668	-2,200	-2,400	-2,187

Figure 12: Economic Capital Components at the Four Main German Banks[32]

[31] 22% is the average diversification effect of the other two banks. While bearing in mind that this estimation only serves as a first approximation, it nevertheless serves as a good benchmark (see also Figure 26 and explanation).

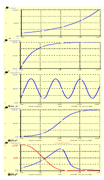
This chapter has considered how to derive economic capital based on the VaR concept. This concept, although not without some minor weaknesses and therefore risks in itself, provides a good approach for measuring the deviation from the expected value. Risk aggregation and correlation have also been considered. To enhance the approach, more dynamic elements such as business cycles, macroeconomic events and investor behaviour are to be added to the model. The next chapter accordingly examines the dynamics inherent in banking risk.

"Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist"
Kenneth Boulding

2. Risk Dynamics: From Equilibrium to Non-linearity

The real impact of risk is often separated by time and space from the event instigating it, so that a risk manager has a hard time quantifying risks appropriately. Risks can develop either quickly or slowly - and can sometimes gang up and have a *cumulative* effect. Risks may hedge, aggregate with, magnify or be uncorrelated with other risks. Risk concentration is one of the most dangerous types of risk, and can cause major insolvencies.

Real estate risks, for instance, tend to mount up over time, e.g. by uniting market, credit, liquidity and business risks. Real estate risks have made many banks insolvent, as sub-section “Bubble Dynamics” demonstrates. Such risks are highly contagious in two ways: first, in case another bank takes over, the assets of the healthy bank will be corrupted; and second, the whole economy can be hit if a real estate bubble bursts, affecting all market participants adversely. One really large risk, or indeed a plethora of small risks, can put a bank out of business.[33] Risk is by definition determined by its severity and frequency and therefore risks have different dynamics. Their severity varies from high impacts (e.g. a wrong strategic decision or all servers down) to minor mistakes (like one incorrect number in a transaction). The frequency ranges from “per second” to “once in a lifetime”. In risk management systems, behaviour such as “exponential growth” and “overshoot and collapse” can be found more often and for a longer period than for instance goal-seeking behaviour, because prices move constantly. These dynamics, as displayed in Figure 14, are considered in the following sub-sections.



System’s Behaviour	Appearance in Risk Management
Exponential growth	Market growth, Overreaction, Reputation, Rating, IT
Goal-seeking	Equilibrium, Laying off until employees are efficient
Oscillation	GDP cycle, Market cycles
S-shaped growth	New product growth period, Efficient capital allocation
Overshoot and collapse	Bank run, Bubble dynamics, Cover up mistakes, IT

Figure 13: System Dynamics in Risk Management

2.1. Unstable Equilibria

A system is said to be in equilibrium when there is no change on the macroscopic level and no net forces on the system.[34] Although there is no perceived change and no process of becoming different, forces can nevertheless still be at work. The change may be too incremental to be perceived, or a powerful negative feedback keeps the state of the system nearly constant despite

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32 Data were derived from the 2003 annual reports of the individual institutions.
33 Mark Carey: “Changed World, New Risks”, presentation in 2003, slide 18, available at: http://www.delcreo.com/delcreo/free/docs/Changed%20World%2C%20New%20Risks.ppt, accessed 7 January 2005.
34 http://www.sasked.gov.sk.ca/docs/chemistry/ksc_b.html, accessed 3 February 2005.

countervailing forces.[35] Efficient market theory argues that all past information about a stock is already inherent in the current market price, and that it does not help to evaluate future performance. Nevertheless, the equilibrium price moves, sometimes without any news or information about the stock, simply because an investor decides to buy a stock at a certain price. In contrast to the efficient market theory, findings from behavioural finance show that charts of the last year's performance still influence actual investor's behaviour.

Charts of stocks with a salient high in the past create expectations that the stock has the potential to perform better in the future. Investors are also more likely to keep these stocks than those with a significant low in their price history. "Past prices exert a stronger influence on investing decisions than trends."[36] This is an overreaction from the efficient market theory point of view. Investors overreact to past information. They face an enormously complex situation when they try to decide where to invest their money. One way to reduce such information complexity is by using charts to compare investments. However, such charts can be a self-fulfilling prophecy for the investor, although they are only based on historical information. By relying on past information, investors become overconfident about future performance. Whether investors behave rationally in pricing stocks or whether they overreact, prices are constantly changing, driven by information and investor decisions.

Figure 31 depicts a system dynamics model of a momentum investor's decision-making. Momentum implies the partial incorporation of information into stock prices. Such investors only care about the price trend in making their decisions. In behavioural finance research, informed investors and herding investors are sometimes distinguished to describe the different behaviours.

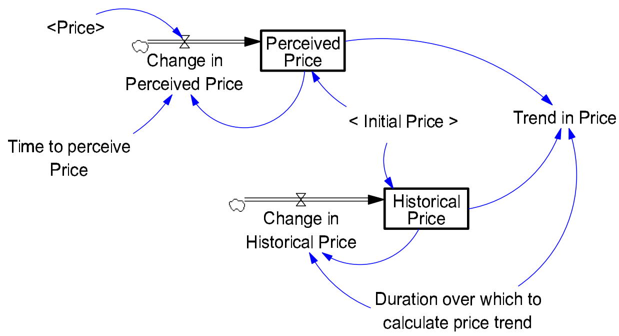

Figure 14: A Momentum Investor's Decision-making[37]

2.2. Exponential Growth and Decay

Unstable equilibria are caused by a force in the market pushing toward a higher or lower price. This behaviour can be shown by a feedback loop. A feedback loop is an element of a system which (in)directly influences itself. Two or more system portions are involved in the loop, one with a correlating effect on the other. A feedback loop with an overall positive correlation leads to reinforcing behaviour, e.g. overreaction and unstable equilibria. Exponential growth patterns can be detected throughout the whole bank system. One famous loop exhibiting such behaviour is that of a bank panic.

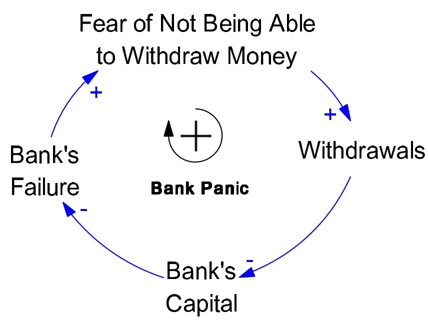

Figure 15: Bank Panic Feedback Loop[38]

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[35] John D. Sterman: "Business Dynamics", 2000, McGraw-Hill, p. 127.
[36] Thomas Mussweiler and Karl Schneller [both psychology professors at the university in Würzburg]: "What Goes Up Must Come Down – How Charts Influence Decisions to Buy and Sell Stocks", *Journal of Behavioral Finance*, 2003, Vol. 4, No 3, pp. 121-30.
[37] Model developed by Getmansky and Papastaikoudi: op. cit.

The fear of not being able to withdraw money leads to panic, in which everyone tries to withdraw their investments. By doing so, the capital basis of the bank is weakened until finally the bank fails. Associated with this loop is reputational and business risk, namely the risk of losing customers. The reinforcing power behind the loop leads to an exponential loss in the number of customers.

The rating cycle creates a very strong feedback loop is, because two positive feedback loops combine forces. A rating can become a self-fulfilling prophecy, as Figure 35 shows. Business partners - like customers or trading partners – perceive the default probability of a bank by its rating. Customers may become more confident based on a good rating, which results in improved turnover. This effect may even increase over the next few years, as customers become better informed about the reputation of a bank. Nonetheless, ratings have a much stronger impact on the refinancing counterparties. The lenders to the bank keenly observe the rating, since this is a clear indicator of the credit quality they are accepting. A bad rating clearly increases the cost of capital since it is interpreted as representing a higher default risk for the counterparty. Turnover and the cost of capital both influence profitability and subsequently liquidity, which is observed again by the rating agencies.

The rating process determines whether a bank faces defeat or will thrive. Further research needs to be conducted into the dynamics in the rating process, to establish whether a bearish economic period leads to worse ratings, and whether rating cycles follow GDP cycles. So far, it has only been observed that hard economic times lead to higher default rates of debtors.[39] By assessing the bank's strength and robustness, rating agencies are extremely interested in establishing whether a bank has implemented a risk management system.

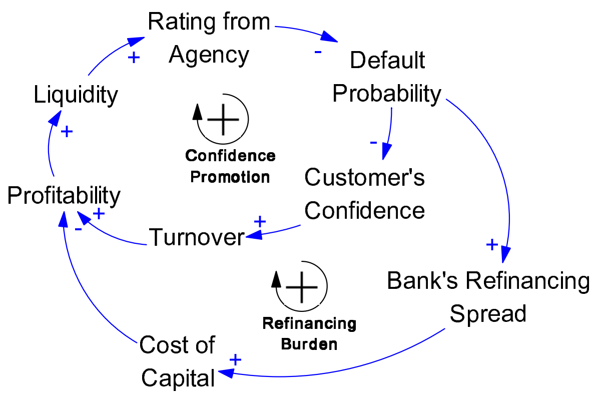

Figure 16: Powerful Loops Concerning the Rating of a Bank

Other examples of exponential growth concerning business and operational risk are cost explosion and technological advancement. According to Moore's law, computational power grows exponentially. The number of transistors on a chip doubles every 24 months. Since a bank basically consists of information valued with money, or as John Reed, Citicorp., put it, "banks may become nothing more than product lines of code in a big computer network", software capabilities are essential. If a bank is to compete in the market, as well as to ensure employee motivation, it has to provide fast data processing, and to manage costs. Mounting costs for software maintenance in particular have become a major challenge for banks.

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[38] Adapted from the System Dynamics Group website: http://www.systemdynamics.org/DL-IntroSysDyn/start.htm, accessed 11 March 2005.
[39] John Frye: "Loss Given Default and Credit Portfolio Risk", presentation at the Symposium on Enterprise Wide Risk Management in Chicago, 26 April 2004, available at http://www.casact.org/coneduc/erm/2004/handouts/fryebw.ppt, accessed 27 January 2005.

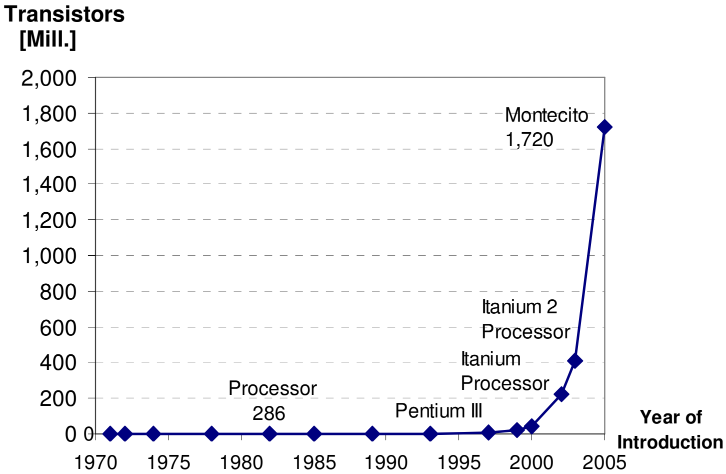

Figure 17: Moore's Law as an Exponential Factor for Bank IT[40]

Exponential growth patterns can also be found with regard to operational risk. Operational risk managers try to minimise the number of mistakes made in operations, because errors increase operational risk. As chaos theory has explained, small mistakes can have huge consequences, so that costs increase exponentially – particularly when mistakes are not recognised for a long period (e.g. calculating VaR with the wrong standard deviation for five years). Risk can also increase through a series of mistakes, when these single mistakes are also interdependent. Mistakes can lead to even more mistakes if the pressure upon a person becomes too high. This feedback loop, as Figure 37 shows, will only be tolerated for a short time, as costs quickly mount.

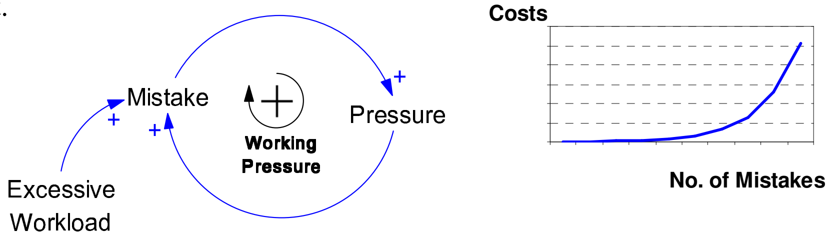

Figure 18: Working Pressure Feedback Loop and the Cost/Mistakes Relationship

Negative feedback loops are associated with a goal, so that the forces at work reach an equilibrium after some time. An example of this is the rate of employee fluctuation. A company lays off a certain percentage of employees as part of cutting back, until it reaches the absolute minimum number of employees needed to function.[41]

Figure 20 shows a negative feedback loop with an associated goal. The desired loan quality influences the default rate, since a bank cannot accept every default rate without becoming bankrupt. The default rate influences the loan quality improvement programme, which hopefully will upgrade the loan quality until the actual loan quality and the desired loan quality will reach the same level and an equilibrium is found.

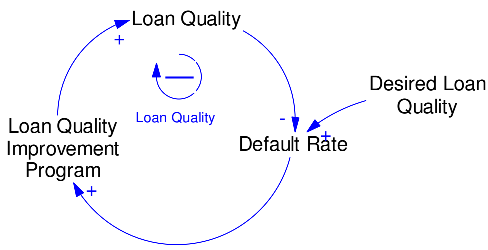

Figure 19: Loan Quality Loop with the Intended Goal

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[40] Intel Research Website, http://www.intel.com/research/silicon/mooreslaw.htm, accessed11 March 2005.
[41] Helen Zhu: "Mental Simulation of Simple Negative Feedback", p. 19, available at http://sysdyn.clexchange.org/sdep/Roadmaps/RM3/D-4536-2.pdf, accessed 12 March 2005.

2.3. Bubble Dynamics: Overshoot and Collapse

A bubble is a self-fulfilling price escalation. Soap bubbles, which the idea of bubbles is based on, usually last for only a few moments and burst on their own or on contact with another object. They will always find the smallest surface area between points or edges. Thus, soap selectively strengthens the weakest parts of the bubble and tends to prevent them from stretching further, and also reduces evaporation to make the bubbles last longer. Thanks to their fragile nature, bubbles have become a favourite metaphor for something that is attractive yet insubstantial.[42] This is very much the case with stock bubbles. These often appear around the turn of a decade and typically exhibit the same psychological pattern: euphoria, greed, and hope at the high point of the bubble, then fear and panic as the bubble bursts. Only after the bursting of the bubble are investors ready for a sober assessment: before that they are caught in self-delusion and blind to the mounting danger. In actual fact, we should be able to judge more accurately based on our past and present experience. However, investors get carried away with excess cash and buy stocks heedless of the consequences. The awareness that everyone is acting the same way takes the form of a devotion to pure play, herding behaviour at its most obvious. Speculation is unpredictable by its intrinsically chaotic nature.[43]

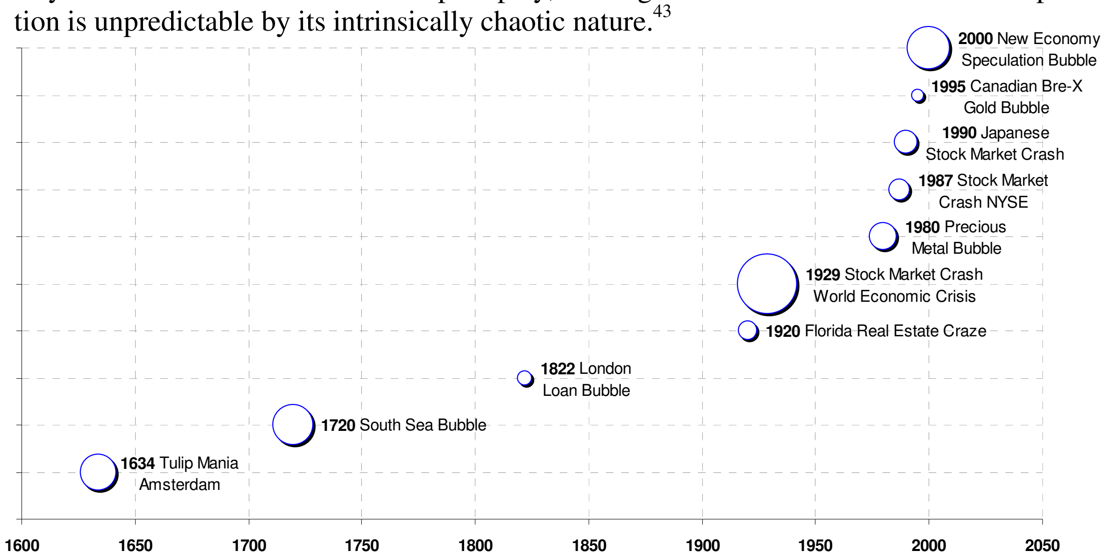

Figure 20: History of Bubbles[44]

Figure 21 shows the main historical bubbles, where the size of the bubble is determined by the geographical (local/continental/global) and monetary impacts. Historically the duration of speculative bubbles has shortened, while the frequency has increased, perhaps owing to the enhanced possibilities investors have nowadays due to the volume of information at hand. Most bubbles appear at a distance of some years, which means that there are no shared memories of past bubbles that could have arrested the momentum of a new bubble. The severity of price bubbles and crashes in the economy is related to inexperience according to hypotheses in behavioural finance.[45] As time passes, new investors enter and old investors exit the market, re-

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[42] http://en.wikipedia.org/wiki/Soap_bubble, accessed 24 February 2005.
[43] Jörg Müllenmeister, available at http://www.wallstreet-online.de/ws/community/board/threadpages.php?&tid=00771850&reverse=1&page=8, accessed 23 February 2005.
[44] Datasource: http://www.caslon.com.au/boomprofile1.htm#railway, and http://www.investopedia.com/features/crashes/crashes1.asp, both accessed 4 March 2005.
[45] Edward Renshaw: "The Crash of October 19 in Retrospect", *Market Chronicle*, 22, 1988.

ducing the proportion of investors who remember the last stock market decline.[46] The objects of bubbles have changed in the course of time. Tulips, real estate, metals and stocks have all been objects of speculation. These bubbles show different behaviours. The website of one investment service company even classifies bubbles into four major types: dollar, ,money supply, stock market and debt bubbles (see Figure 22 on the next page).

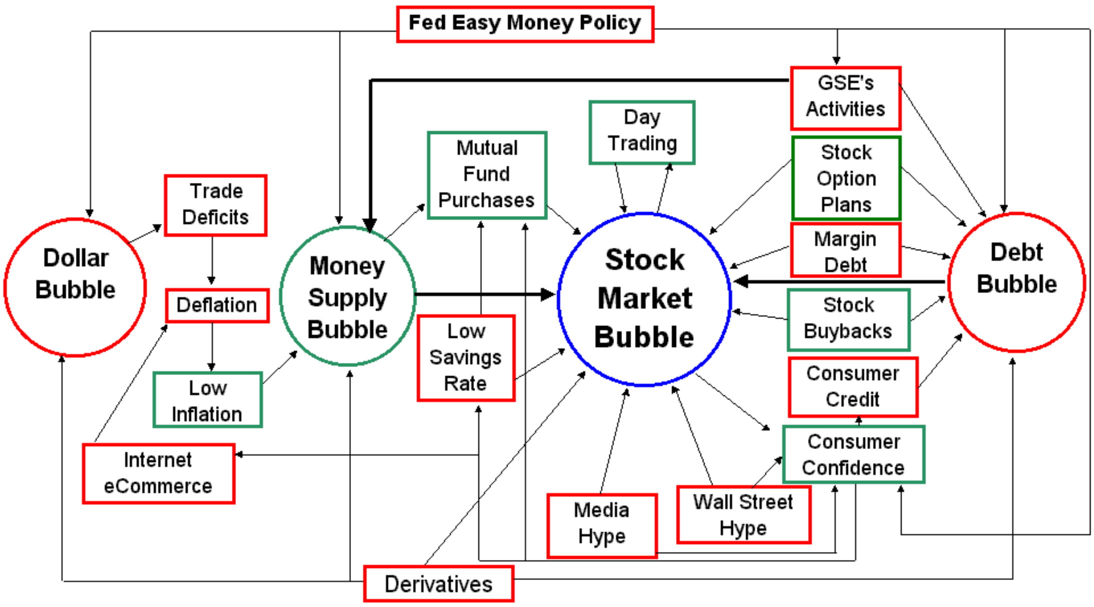

Figure 21: Bubble system[47]

Further research is needed at this point to establish how these different kind of bubbles interact. Rather than focusing on macroeconomic interrelation, this thesis concentrates on micro-market dynamics regarding risk in a single bank.

The behaviour of bubbles can be separated into three phases. First there is extreme exponential growth, followed by a short period of equilibrium, and finally exponential decay. To describe the growth of extreme bubbles, the volume formula for spheres can be used:[48]

$V = \frac{4}{3} \cdot \pi \cdot r^3$, where V is the volume and r the radius.

The volume of a sphere grows by the third exponent, if the radius is increased by only one unit. The volume increases at enormous speed. Although bubbles have another kurtosis than globes, this provides an indication of the speed.

After the escalation period, which is marked by high trading volume, a sudden break sets in, resembling the lull before a storm. Then one person buys/sells at an unusually low price, and the market becomes irritated.[49] These bids occur very suddenly and dramatically, which then leads to a drop in the market. The price continues to rise, sell orders remain open and sellers

[46] Gunduz Caginalp, David Porter and Vernon L. Smith: "Overreactions, Momentum, Liquidity, and Price Bubbles in Laboratory and Field Asset Markets", *Journal of Psychology and Financial Markets*, 2000, Vol. 1/ No 1, pp. 24-48.
[47] http://www.cornerstoneri.com/newpage17.htm, accessed 1 March 2005.
[48] Wolfram Research Inc., http://mathworld.wolfram.com/Sphere.html, accessed 23 February 2005.
[49] An interview on trading experiments with Colin Camerer, Professor of Business Economics at the California Institute of Technology, can be found in: "Market Efficiency of Bubbles", *Journal of Psychology and Financial Markets* 2002, Vol. 3, No 1, pp. 29-36 (32).

become nervous. The market follows the low seller. Panic sets in and then there is no longer any stopping the price. The surface tension grows larger with a declining bubble growth rate. Buy orders dry up near the peak until the bubble bursts. As Colin Camerer notes, "The largest percentage changes are almost always drops rather than increases."[50] After the sudden burst, the asset value drops crucially, sometimes even dragging along other asset classes. A decay pattern mirrors the same behaviour as the growth observed first, but with a negative slope that resembles a radioactive decay pattern. After the bubble has burst, rational behaviour resumes, at least until the advent of the next bubble.

Figure 24 depicts the cause and loop structure. The two feedback loops influence the market price. Speculation causes more and more money to be invested and creates more demand, while some investors withdraw money because they are disappointed by the performance. Some investors try to counteract bad performance by the "when in trouble, double" loop, and buy even though the asset price has failed to meet their expectations. However, the impact such investors have on the demand is much smaller than a bearish market movement. The market volume cannot be influenced by one transaction, unless it is significant enough.

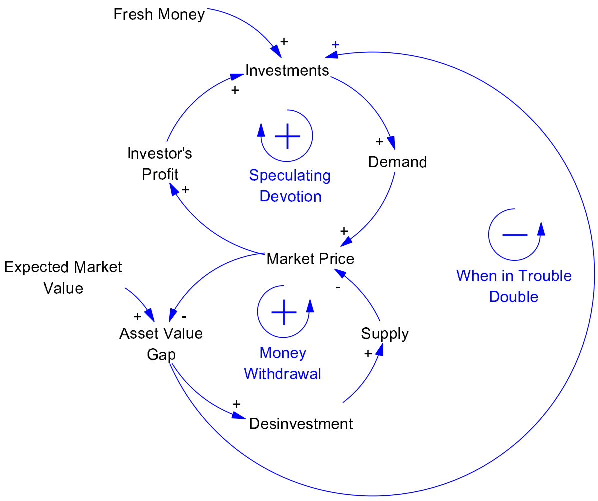

Figure 22: Speculation Market Dynamics

The bubble dynamics show classic overshoot and collapse behaviour. The ability to justify the exorbitant price is eroded or consumed by the speculation itself, which drives the price higher. This type of behaviour can be seen in past cultures which disappeared because they consumed the very resources they were living on. Line 2 in Figure 25 represents the carrying capacity, while line 1 represents the state of the system, which feeds on the capacity.

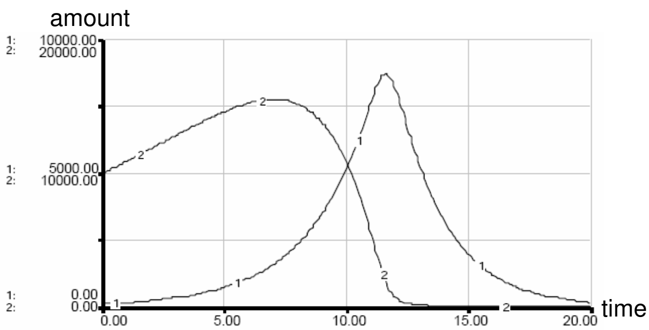

Figure 23: Overshoot and Collapse Behaviour[51]

[50] Colin Camerer,ibid.

[51] Lucia Breierova: "Generic Structures: Overshoot and Collapse", 1997, p.10, available at http://sysdyn.clexchange.org/sdep/Roadmaps/RM9/D-4480.pdf, accessed 12 March 2005.

A bank run illustrates just such an overshoot and collapse structure. It is a panic response that occurs when a large number of people rush to take their assets out of a bank which they believe to be financially unsound and about to collapse. This action, of course, usually causes the very collapse feared in the first place, as no bank has enough reserves to cope with all its investors simultaneously withdrawing their savings.[52] This vicious cycle came into effect during the 1930s, when an overall economic downturn caused the rate of bank failures to increase. "As more banks failed, the public's fear of not being able to withdraw their own money increased. This, in turn, prompted many to withdraw their savings from banks, which further reduced the banking industry's capital reserves. This caused even more banks to fail."[53]

An overshoot and collapse pattern can be detected with regard to credit risk when riskier borrowers borrow more and more money until they become insolvent. This type of borrowing behaviour can be initialised by means of a rigid credit policy. Credit panic sets in, and credit limits are exhausted. This cycle has caused some banks to be perceived to be lenders of last resort, which inherently leads to an undesirable concentration of credit risk.

Operational risk has to deal with crimes of "upholstery", which is a second fraud committed to cover up the first fraud or mistake. The damage caused by the second fraud generally far exceeds that of the original loss. Operational risk managers are fortunate that the ability to hide losses is constantly shrinking and that the transparency increases over time. A mistake has only a limited fault tolerance, since different views on the issue help to detect such ones.

Figure 26 clearly summarises the classic overshoot and collapse patterns for each type of risk. Software maintenance capacity for new software and asset allocation for a holding follow the same patterns.

Risk	Overshoot and Collapse	Carrying Capacity
Market	Stock market bubbles	Price justification
	Holdings	Asset allocation to holdings
Credit	Riskier lenders lend more	Creditworthiness
Operational	Fraud	Hiding capacity
	New software	Time for maintenance
Business	Bank run	Cash available

Figure 24: Overshoot and Collapse Structures in Banking

2.4. The Impact of Oscillating Economic Cycles on Risk Management

A series of bubbles in a row becomes a wave or a cycle. Economic conditions like upswings and downswings result from such dynamics. Investors are mostly not aware of the overall picture and forget the cyclical nature of markets. These swings are repeated over the long-term horizon of decades. The daily noise of the market is thereby irrelevant to the macro-cycle. By reviewing macroeconomic statistics, one can detect the trend and the dynamic impact on bubbles. The model includes the GDP variable, which helps us to capture market cycles. Other cycles depend on the GDP cycle, such as the rating, interest level and stock market cycles.

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52 Wikipedia Online Encyclopedia, "Bank Run" article, , available at http://en.wikipedia.org/wiki/Bank_run, accessed 15 January 2005

53 Example from the System Dynamics Group website: http://www.systemdynamics.org/DL-IntroSysDyn/start.htm, accessed 11 March 2005.

Figures 27 and 28 depict actual German GDP and modelled GDP:

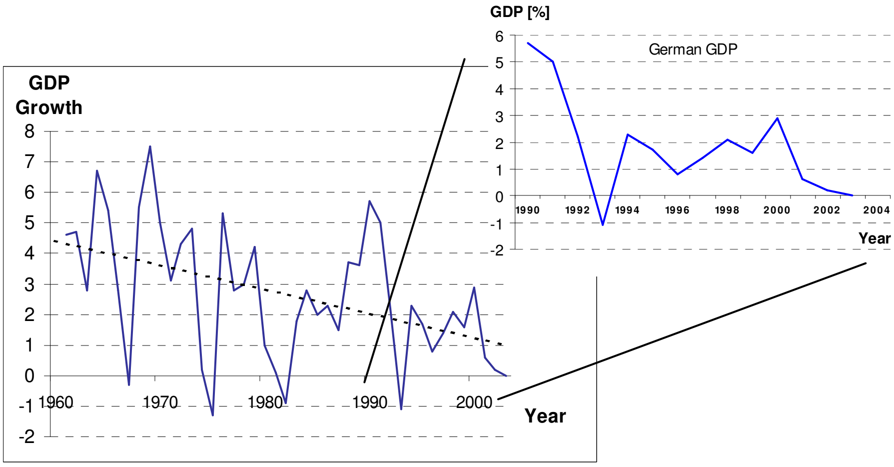

Figure 25: German GDP Cycles of the Last 40 Years[54]

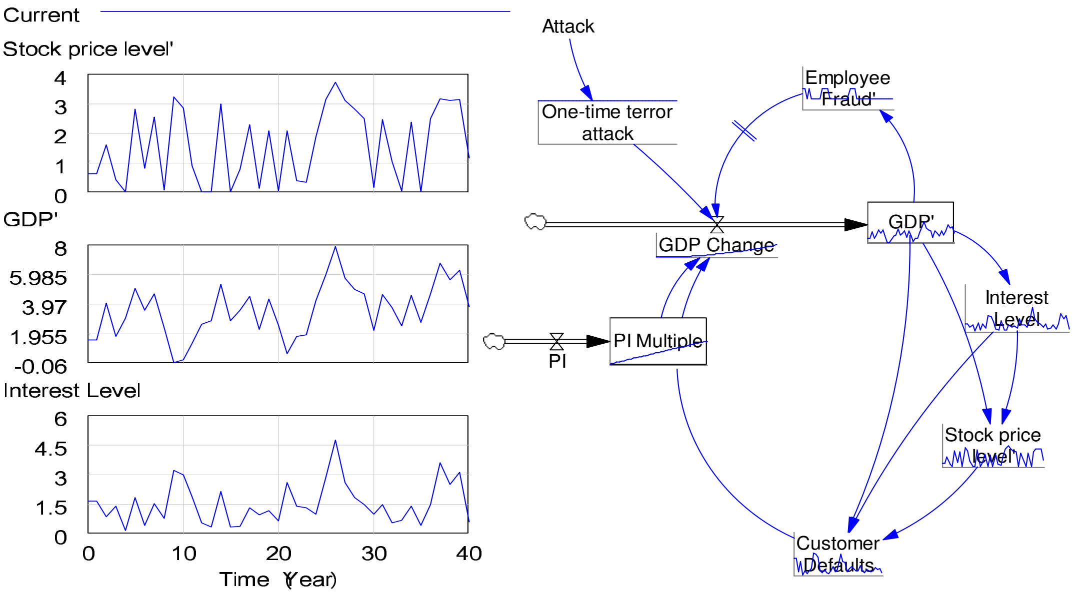

Figure 26: GDP from the Model[55]

The model uses idealised cycles as in Figure 29. They do not fully show the actual movements and shapes of the cycles, but the approximation does include the ebb and flow of the GDP cycle. None of the cycles from historical data are exactly the same as the previous one, because the specific causes of recoveries and downturns were not the same.[56]

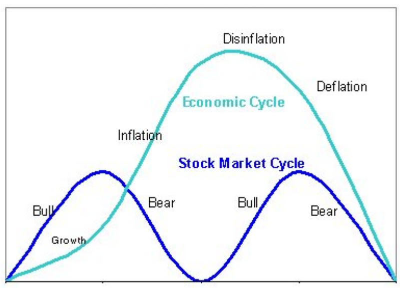

Figure 27: Idealised Cycles[57]

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[54] Datasource: HfB Macroeconomic MasterClass, 2004.
[55] (range: -0.06 to 8% | with GDP(x)= (2.5*sin((x)/2))+1.5), x=z*π| z∈ℜ).
[56] http://www.cornerstoneri.com/home/cycles.htm, accessed 1 March 2005.
[57] Ibid.

The GDP cycle is imitated by the following function: $GDP(x) = 2.5 \cdot \sin((x)/2)) + 1.5$, with $x = z \cdot \pi$, $x = z \cdot \pi \mid z \in \Re$. Two factors that depend on the GDP cycle are the interest level curve and the stock price level, which is a bias factor for the stock market index. The GDP movement impacts the interest spread and the stock market. The standard deviation of each of the two factors is derived to calculate the economic capital of a bank. A risk model modelled without the economic cycle would definitely fail to capture these dynamic qualities.

2.5. Time Concerns

Risk levels change over time due to external and internal dynamics. Risk parameters need to be updated more frequently in times of fast change, since the value function of a risk premium changes with time. Risk management hunts sometimes phantoms. The perception of senior bank management changes as knowledge increases. Bank managers might grow impatient and lose their long-term perspective. Due to advances in technology, the cycle times are shortened. Straight-through processing (STP) allows for automated loans to customers nearly without human interaction. On the one hand, STP minimises risk and increases efficiency because it prevents human error. However on the other hand risk might increase through impacts of mistakes that are more severe, such as wrongly implemented creditworthiness checks or increased cycle time (i.e. more loans are granted in each period, and a greater number of these will default).

Bank managers look at returns and results more frequently within a shorter time horizon, which leads to higher risk premiums. This is a myopic loss aversion experience, a narrow view of results without seeing the GDP cycle or the business environment.[58] It might also have the effect that risk managers get used to high volatilities, so that these are seen as normal. The perception of risks varies across countries and among different age groups, so that common standards have to be set for the measurement of enterprise risk.

Risk	Delays
Credit	To recognise the debtor's default.
Market	Settlement risk: a position could not be settled during a transaction.
Business	Customers are lost because they had to wait too long due to poor service.
Operational	To detect fraud and normal mistakes which are invisible.
	Technology adoption of the bank itself, of the customers and of the staff.
	A non-functioning IT system causes business loss.

Figure 28: Table of Delays in Banking Sorted by Risk Type

Table 30 summarizes the delays appearing in risk management. Delays are fierce and increase overall bank risk, since processes are not executed. Delays minimise the quality of bank operations, because of the formula *Risk = 1-Quality*. Basel II addresses this point in the operational risk section concerning processes. Risk managers therefore consider delays with regard to IT systems and try to prevent a situation whereby a trade cannot be executed because an IT server is down. By no means less severe is a delay in recognising a customer's default or in detecting capital misallocation. The latter is particularly dangerous, for the reason that it has "no immediate impact on company financial statements. However, misallocation will distort ROEs[59] and possibly be a catalyst to incorrect decisions being made on strategy."[60]

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[58] Donald Mango: "Report on CAS Research Working Parties", Risk Preferences Working Party slide, available at http://www.casact.org/coneduc/erm/2004/handouts/mango.ppt, accessed 15 January 2005.
[59] ROE = Return on Equity.
[60] Vinaya Sharma and Randy Tillis: "Implementing & Transitioning ERM", presentation, slide 25, available at http://www.casact.org/coneduc/erm/2004/handouts/sharmatillis.ppt, accessed 15 January 2005.

Real-time risk systems permit quicker risk limit checks in the trading room. However, these systems require data integrity and accuracy. It is necessary to integrate front, middle and back office in order to perform the required tasks and to reduce the risk of errors due to manual data input, data re-keying, and data transformation. The question is: how fast can risk information travel through the whole business to support decision-makers best? A recent article on real-time analytics questions whether “the immediacy may simply make it easier to make more mistakes, faster.”[61] It was encouraged to implement analytical strategies, which are longer lasting than the next up sell.

“Once ERM programs are in place, it is important to make sure the modelling has consistency and validity.”
Mark Puccia (Managing Director - Standard & Poor’s Corp.)

3. The Risk Simulation Model

This chapter shows how the model was developed, what assumptions were made and what insights were gained about risk dynamics. The fundamental steps to build a model are:[62]

- to define a clear-cut purpose for the modelling effort
- to predetermine which factors shall vary and which shall be projected
- to decide, which are the most relevant factors to model.

The modelling process itself as described in figure 31 shows the importance of the problem definition, since it will determine the meaning for the whole model. Also included in figure 31 are already some results from the findings, which will be discussed in chapter 4.5. in more detail.

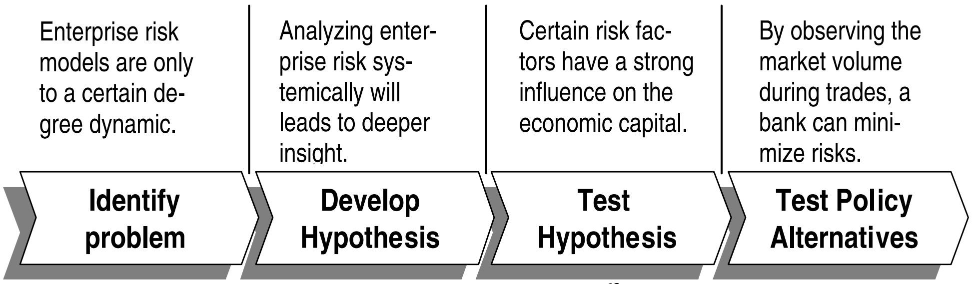

Figure 29: The Modelling Process[63]

3.1. Model Development

A dynamic financial model depends on the following four components:[64]

- people available for system design and programming
- data from which to derive assumptions and with which to initialize the model
- money available to purchase an existing software package
- computer architecture.

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[61] Jason Compton: “Real-time Analytics: Excellent Insight, or Speedier Mistakes?”, available at http://www.destinationcrm.com/articles/default.asp?ArticleID=4785, accessed 22 January 2005

[62] Stephen D’Arcy, Richard Gorvett, Joseph Herbers, Thomas Hettinger: “Steps in Building a DFA Model”, Article available at http://casact.org/coneduc/specsem/98dfa/dfamodel.htm accessed 15 January 2005.

[63] System Dynamics: “The Modelling Process”, available at http://www.systemdynamics.org/DL-IntroSysDyn/start.htm accessed 04 March 2005

[64] Dynamic Financial Analysis Committee: “Dynamic Financial Models”, presentation available at http://casact.org/research/drm/dfahbch2.pdf, page 9, accessed 15 January 2005.

The model was developed by the author from January to March 2005. Thereby, the modelling process was done iteratively following the Rational Unified Process of software development (RUP) as shown in figure 32.

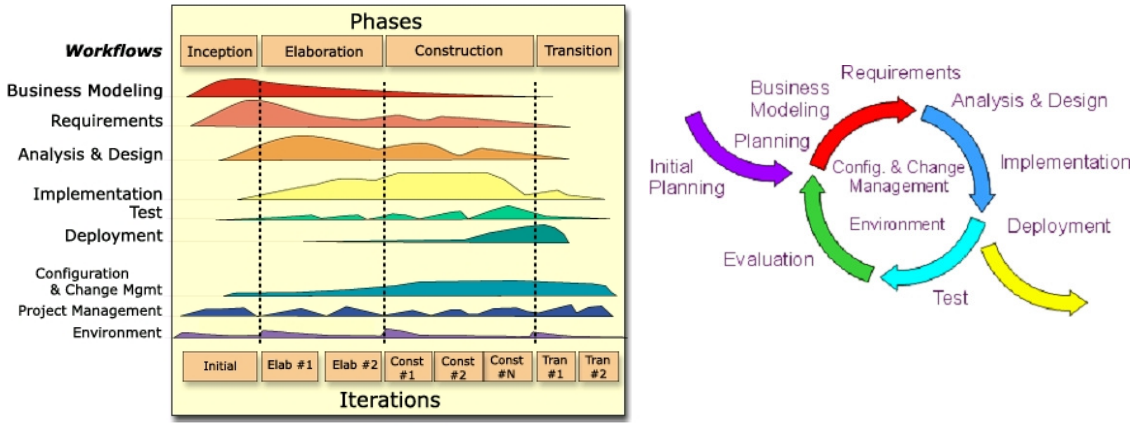


Figure 30: Iterative Development Process according to Rational Unified Process[65]

The main data source for the model was the website of Deutsche Bank AG. The data was enhanced by trading and finance data from Finance Yahoo, rating agencies and Bloomberg. Some distributions and benchmark figures were derived from the ERM literature.

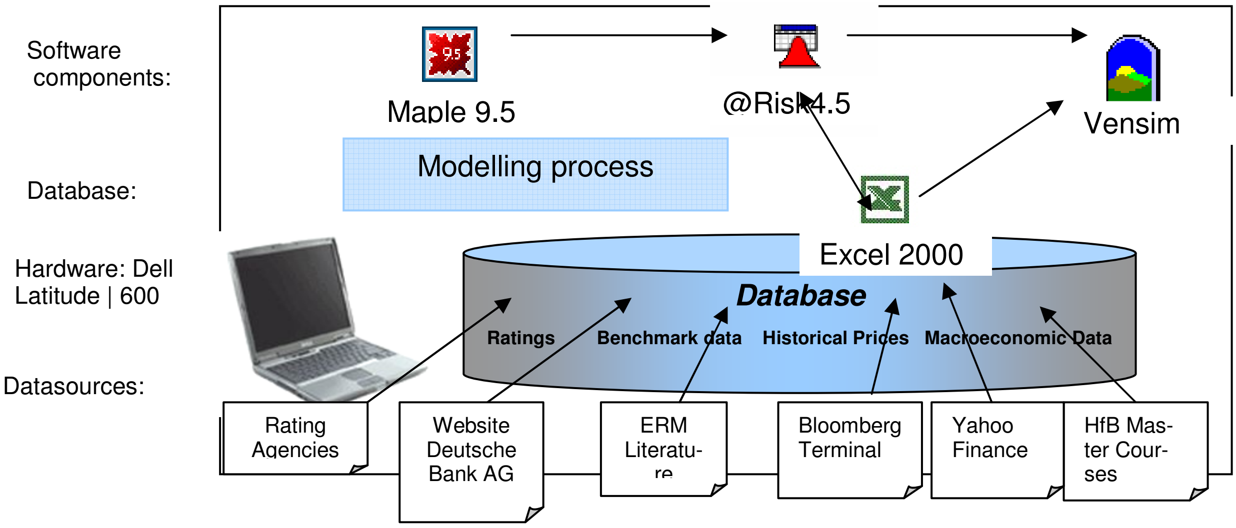


Figure 31: The IT Architecture

To model the GDP and the mathematical formulas, the software Maple was used. This allowed a flexible calculus, since even sophisticated functions can be plotted easily by Maple. The various distributions, their parameters and quantiles were calculated with @Risk developed by the company Palisade. @Risk is an enhancement to excel. After having calculated the assumptions and key data, the formulas were entered into Vensim, a simulation software package, which uses system dynamics notation.

[65] Management Systems Consulting: "RUP Fundamentals Presentation", available at http://www.msc-inc.net/Documents/rup_fundamentals_presentation.htm, accessed 15 March 2005.

3.2. Basic Assumptions

The following variables were used in the model:

Internal/ endogenous	External / exogenous
Number of assets Various standard deviations of distributions Products (number of products, credit, asset) Staff (number of employees) Mistakes made by employees VaR Values for the single Risk types	Customers (number, type of, …) Pricing (interest rate, year-2000-hype,…) GDP: We cannot model a bank's system, which will not influence the GDP.[66] NASDAQ imitated stock price development Terror Attack Function Stock Market Crash Function

The model runs for 40 years in order to integrate the long-term GDP cycles of approximately 10 years. The time steps are measured in years, since the available data of the economic capital is taken from the annual report. One must keep in mind that economic capital is a notional figure and that no real money is involved. Therefore, it might be delusive since the economic capital is measured in monetary terms. The most important risk types are to be modelled, so that the economic capital as overall risk measure can be calculated.

All the data for the universal bank were taken from the Deutsche Bank. The employee structure, profit figures and economical capital segmentation imitate the Deutsche Bank figures in a range of ±20%. Deutsche Bank publishes a risk report in each annual report, which was the main source of information. Where no data were available (e.g. more detailed credit loss provision calculations or complete probability default rates and distributions), assumptions were made to imitate the concern at the best.

Figure 35 shows the simplified balance sheet used in the model:

Assets	**Balance Sheet [in m.€]**		**Liabilities**
Cash	5,000	Saving Accounts	600,000
100 Loans á 500 m€	500,000	Current Accounts	40,000
Shares (speculative)	100,000	Other Liabilities	100,000
Holdings	15,000	Equity	60,000
Real Estate (5 objects)	100,000		
Other Assets	80,000		
TOTAL	800,000	TOTAL	800,000

With a focus on the overall dynamics, flow of single credit payment transactions are aggregated, so that there is no "credit flow", but a growth rate of credits. The portfolio of the 100 loans with an amount of each 500 m€ were modelled with varying default probabilities (in average 10%) and a recovery rate of around 30%.

The market risk is determined by three kind of assets:

- "NASDAQ-like" shares (standard deviation simulates the historical NASDAQ data)
- Holdings, which imitate the historical dax performance
- Real estate assets

Historical simulations were made for up to 15 years (1990 to 2005).

[66] Compare also John D. Sterman: "A Skeptic's Guide to Computer Models" , 1988/1991, available at http://www.millenniuminstitute.net/publications/Skeptics.pdf, accessed 04 March 2005, p. 23 et seqq.

Operational risk data were estimated from the portion of economical capital for the operational risk in the annual report of Deutsche Bank from 2000 to 2005. Benchmark-data from other international banks were used to enhance the estimation.

3.3. Behavioural Relationships and Initial Conditions

The GDP cycle runs differently than the interest and stock market cycles as explained before. The stock market influences the shares and holdings, while the interest curve will have an effect on business revenue and default probabilities.

The indices performance is derived from the long term Dow Jones Industrial average, since it was the index with the longest data history available. Figure 34 illustrates clearly that between 1995 and 2000 the index accelerated in points and high volume (from 5,000 above 11,000).

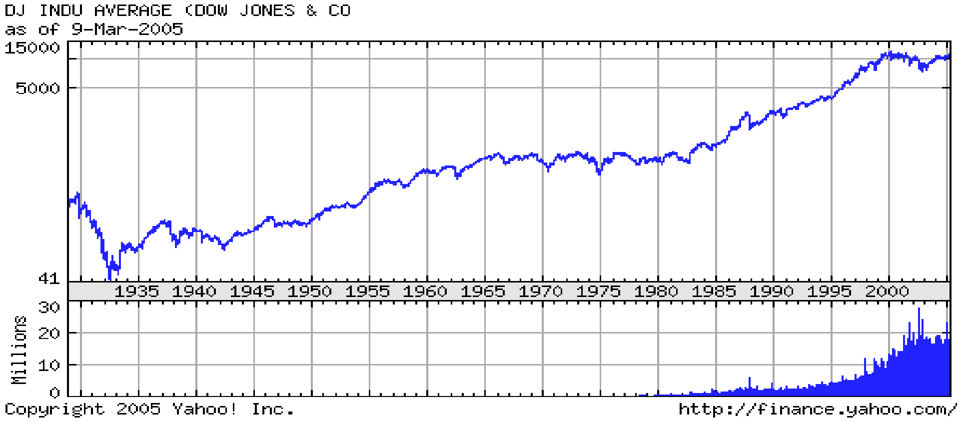


Figure 32: Dow Jones Industrial Average of the last 70 Years

In the model there are certain "IF THEN ELSE" structures implemented regarding two events. One is a terror attack, which will decrease the GDP over a period of 5 years; the other is a stock market crash with an exponential recovery over 8 years.

3.4. Tests for Consistency with Purpose and the Boundary

The purpose of the model is to show the dynamics and the driving factors by means of the development of the economic capital. The development can be seen for a time period of 40 years and the effects of a stock market crash and a terror attack can be simulated. The model is consistent for a period of 40 years, although the economical capital skyrockets, which are the effect of the asset value development. Furthermore, the recovery rate is limited. It cannot exceed 100% and cannot become smaller than 0%. The Economic capital and the VaR figures are not allowed to become smaller than zero.

3.5. Insights gained from the Model

The recovery rate has an exponential effect on the economic capital for the credit risk section. In case banks can recover with a slightly higher rate, they will be able to protect assets. The effect from the default rate is not as strong as the recovery rate impact. Banks should create an "outer loop" to credit risk in order to support riskier lenders by educating companies beforehand how they can avoid financial difficulties.

The strongest impact on the economic capital was the market risk section as it can be seen on the right side in figure 56. This big influence is due to the size of the market position that the imaginary bank holds. The asset values developed so strongly that, as a result, the economic capital increased enormously. To sell holdings would decrease the economic capital, but has no major effect compared with the riskier "NASDAQ position".

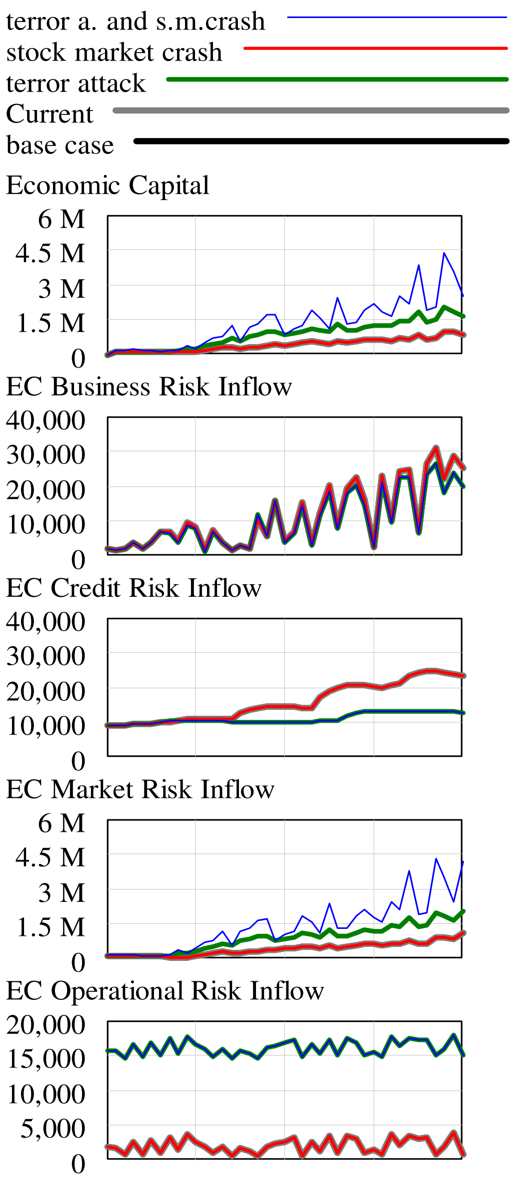


Figure 33: The simulated Results

Operational risk is mainly driven by process failures as it can be seen in figure 36. There is a very high correlation (above 90%) between the development of employees and the operational economical capital. A terror attack led even to higher recoveries in the credit risk, since the GDP change was small after the terror attack. Due to the uncertainty of terrorism, people and corporate clients might become more cautious while the GDP is at lower rates.

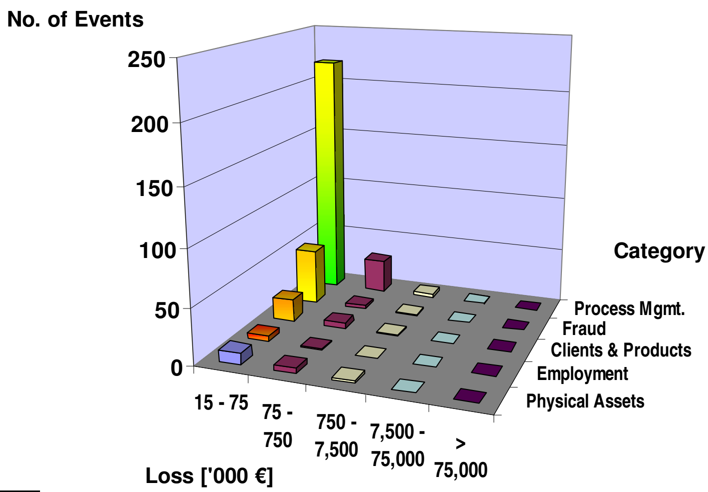


Figure 34: Driver Analysis of the Operational Risk[67]

[67] Marcelo Cruz: "Operational Risk Modelling and Analysis", page 324 Soure: JP Morgan Chase

3.6. Future Extensions of the Model

The model can be extended by distinguishing between corporate and private customers in different countries, since especially concerning credit risk the default probabilities would deviate from each other very much. With enhanced (internal) data, the exploitation of credit lines could be modelled. However, the feedback loop "Riskier lenders lend more" is dependent on the data of customer behaviour. The market risk section can be extended by considering that real estate market prices depend very much on regional price indices and default probabilities. The time series input for estimating the real estate standard deviation could be longer (60 years) to capture whole real estate cycle moves. Not considered were also: yield curve changes in market risk. The asset class is to be added in the next version of the model.

The dependence on single risk factor after having considered correlations would be valuable information to strengthen the risk structure as well. In order to implement this in a future version no lookup functions were used. Instead, "IF THEN ELSE" constructions captured the nonlinearity in the model. An additional questions is what happens in case of a rating downturn: AA- to B or even to such a bad rating, when no issuing of bank products is possible anymore. Models already existing in the system dynamics approach could also be used to enhance the existing model. There have been models for risk assessment of transmission dynamics to calculate how fast epidemics spread among a population.[68] This can be applied to market participants in an economy, which interact by value chains and "infect" each other with financial difficulties. Figure 37 shows an example. The "New Infect" rate could be calculated as:

$$\textit{Infection Rate} = \textit{Market Participants}*\textit{Contact Rate}*\textit{Transmission Probability}*\frac{\textit{Market Participants}}{\textit{Market Participants} + \textit{Infected} + \mathrm{Re}\,\mathrm{cov}\,\textit{ered}}$$

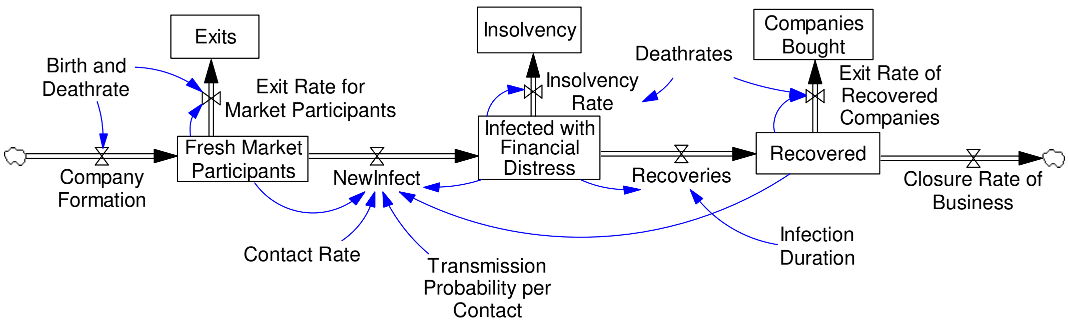


Figure 35: Example of Transmission of Financial Risk in an Economy

This study would give insight, how and why the "financial epidemic" would rise and fall. However, this study would need to take a broader look on the economy. It surely would provide insight about risk concentration as well.

Even a "Risk Management Flight Simulator" could be developed. One cycle or gaming step would be the semi-annual shareholder conference. Initial conditions are to be shown in terms of employees, balance sheet, GDP cycle. Then a decision board can be added, which allows to control the following variables:

- Employee fluctuation (layoff has an impact on service quality and cost base)
- Rating target (from AAA to AA-, a better rating will decrease the cost of capital)
- New product decision (CDO effect is decreasing economic capital)
- Marketing Budget (efforts to work against competition)

[68] James Koopman: "Transmission dynamics" available at http://www.sph.umich.edu/~jkoopman/Web606/RiskAssess/, accessed 16 March 2005

Graphs could illustrate the developments of: P&L, Business Units, Economic Capital, Rating Tendency, Shareholder value, GDP and Credit Defaults. The gaming procedure of the simulated 10 years could include the following events:

Year	Event	Scenarios
1 – 2	Normal mode	To learn the market dynamics
3 – 6	Competition mode	GDP decreases, customer fluctuation up (exponentially), At a random time point: one merger, a takeover of a suffering bank and one joint venture of a successful bank
6 – 8	Every half-year decision about one policy to improve the overall risk structure and EC	(1) Creating a CRO position (it works out, if the company has the necessary size) (2) Implementing a customer education division (will reduce customer defaults, but increases costs) (3) Selling of holdings (smaller returns at the end with rising GDP) (4) Investing more in more riskier assets (could overstretch the EC in year 8 with low GDP)
9 – 10	Normal mode	GDP rises again to first level

Such a "risk flight simulation" would certainly increase the learning experience about risk dynamics. Future simulations might not only cover single values or risk structures, but whole companies and processes. Business war games are one such computerised business simulation. These simulations challenge managers to make decisions that will directly affect their virtual companies. Over several years, tactical and operational decisions can be tested in a risk-free simulation environment. This simulation helps managers to understand the dynamics and interactions of their business. They learn faster how to assess the competition accurately, how to position their company by defining a long-term strategy, and how to make operational cost decisions.[69] Forio Business Simulations, for example, offers a price strategy simulator on their website, showing feedback loops of a price war as depicted in Figure 38.

Figure 36: Feedback Relationships in Pricing used by Forio Business Simulations[70]

[69] http://www.prisim.com/, accessed 10 March 2005.
[70] Michael Bean: "The Price Strategy Simulator – Anatomy of a Price War", available at http://www.forio.com/pcpricesim.htm, accessed 10 March 2005.

"Do today, what others consider doing tomorrow, only change is constant!"
Heraklit, 480 B.C.

4. Conclusion

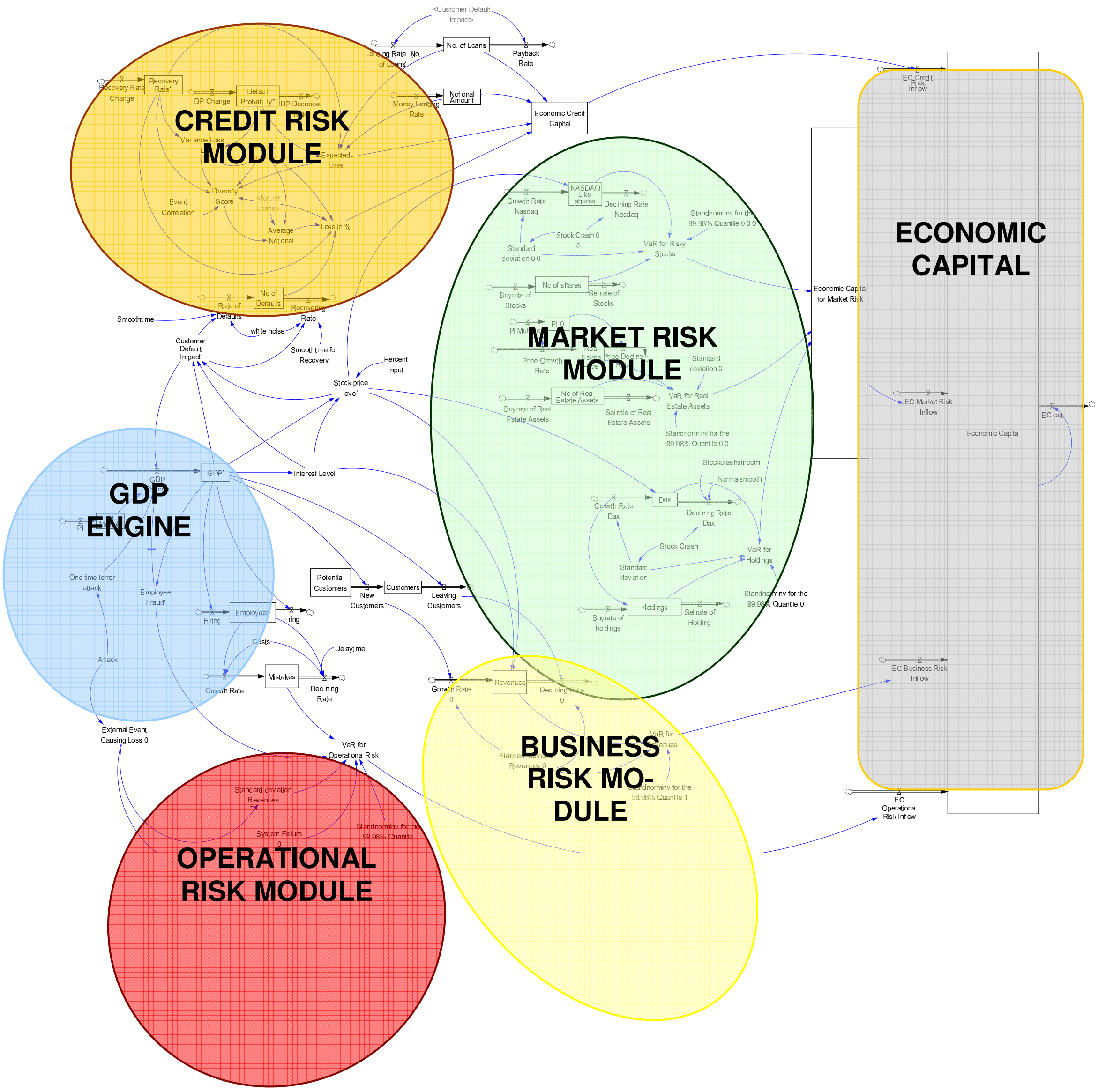
ERM focuses on the bank as a system with the bank's economic capital as notional benchmark for the overall risk. To provide insight into the correct risk exposure and the robustness of the bank's risk structure, the function used to calculate economic capital must be dynamic, as well as capable of integrating the different risk structures. Credit, market, operational and business risk differ greatly from each other in terms of uncertainties, default distributions and inherent potential loss. Only holistic risk management can successfully unite these different types of risk. Risk management itself is not a new science, but its methods improve constantly. The focus on ERM requires risk types to be viewed as a portfolio, and allows the bank to implement an overall risk strategy. However, to gain insight into the risk dynamics and risk interactions, a dynamic risk model is essential. Complex risk/return decisions can be made only if rapid and discontinuous changes are considered.

Integrated processes and the vast amount of incomplete information at hand pose a major challenge to the information architecture of a risk management system. Technology can enhance risk management capabilities enormously by gathering data and supporting the analytical process. Computational power allows more sophisticated scenarios and more accurate modelled distribution functions, so that a set of different risk measurement techniques can be used to manage risk. The diversification of the calculus counteracts the systemic risk that all traders could sell at the same price simply because one benchmark limit has been breached. The enhancement of scenarios can even be extended to real world business scenarios such as flight simulators. This process will become ever more important, as the speed and complexity of the business decision-making process continues to put pressure on the tolerance limit of banks. This faster learning cycle helps bank managers to take decisions with enhanced intuitiveness. Even with the most sophisticated enterprise risk system, a manager will not be able to forecast chaotic dynamics like bubble behaviours or external shocks.

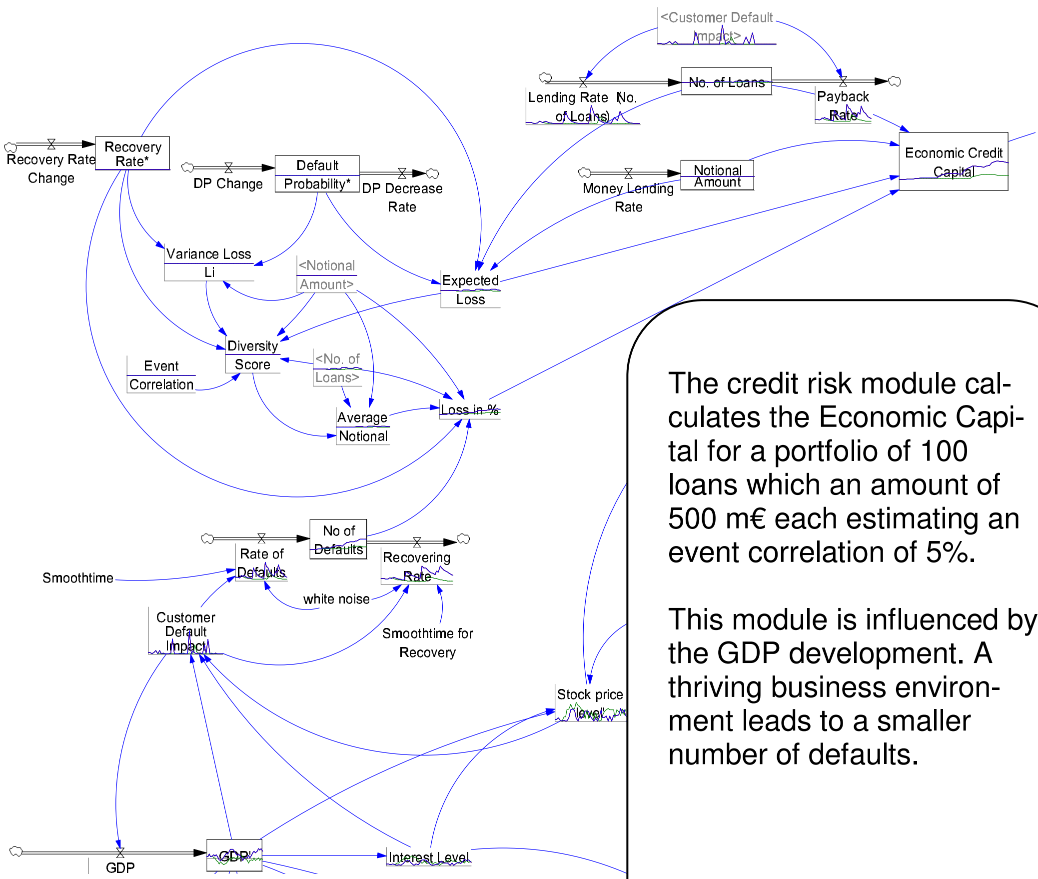
The value added of the system dynamics method is to increase the robustness of the structure in terms of non-linear and dynamic change. The right tools will enhance insights gained diagnostically by focusing on the whole bank as a unified system. By doing so, bank managers more effectively control risk exposures and asset allocations and manage the bank's organisation as well as the triangle of risk, return and liquidity within space and time. In a world of rapid change, dynamic enterprise risk management enables bank managers to see and make proper use of future opportunities.

Appendix: Model Screenshots

The Model Overview



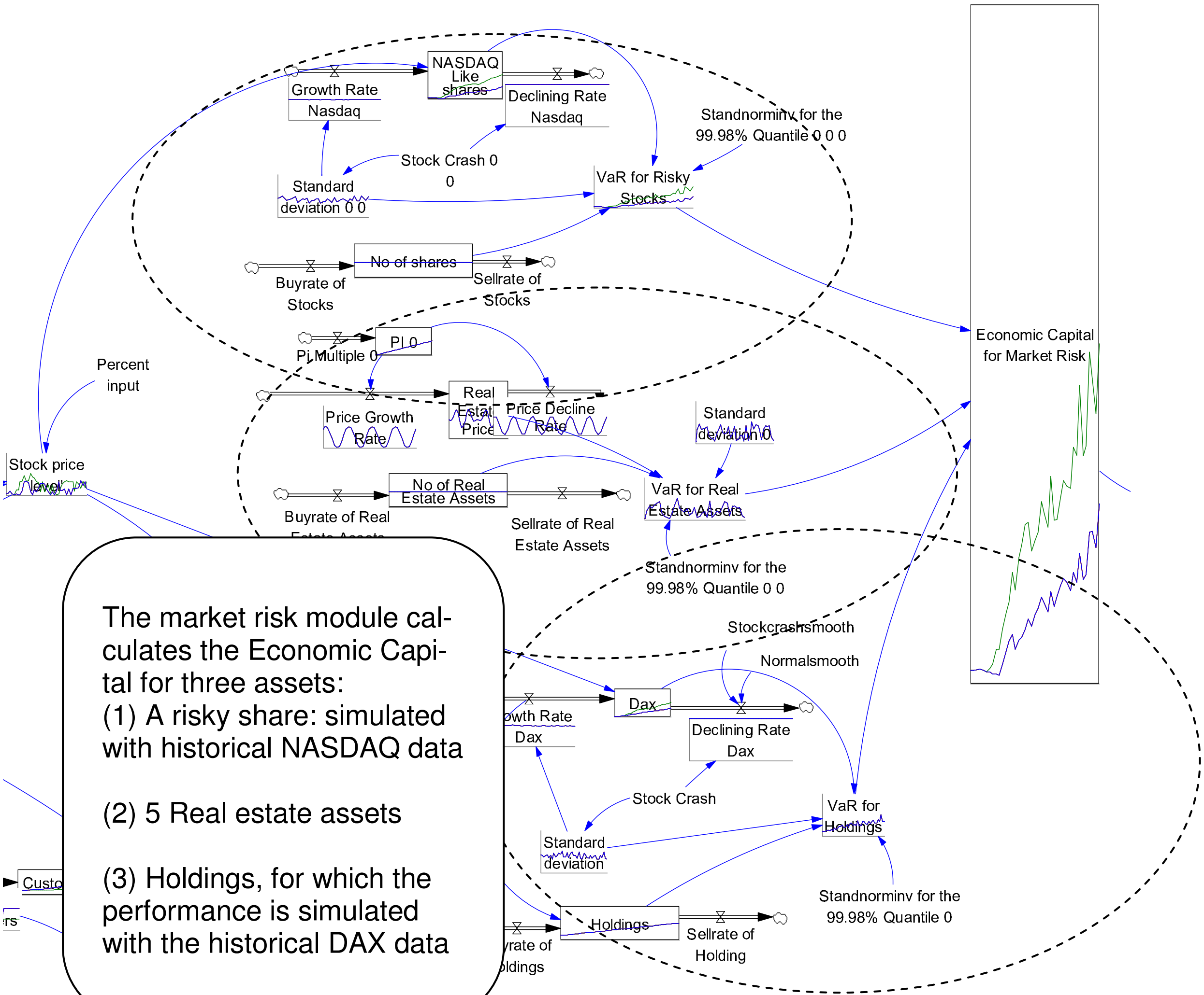
Credit Risk Module



The credit risk module calculates the Economic Capital for a portfolio of 100 loans which an amount of 500 m€ each estimating an event correlation of 5%.

This module is influenced by the GDP development. A thriving business environment leads to a smaller number of defaults.

Market Risk Module

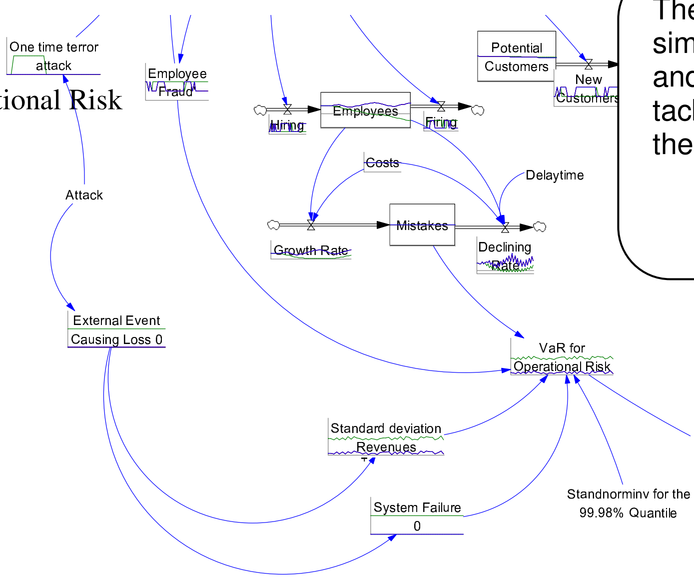


The market risk module calculates the Economic Capital for three assets:
(1) A risky share: simulated with historical NASDAQ data

(2) 5 Real estate assets

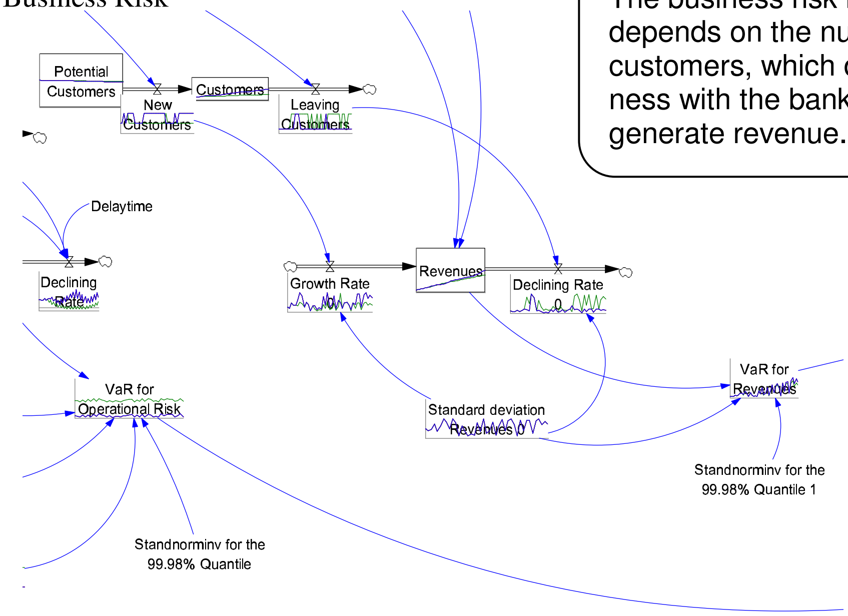
(3) Holdings, for which the performance is simulated with the historical DAX data

Operational Risk



The operational risk module simulates fraud, mistakes and an external terror attack, which is connected to the GDP development.

Business Risk



The business risk module depends on the number of customers, which do business with the bank and generate revenue.

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