Currency risk management -Hedging-
optimalization of the hedging policy

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-Hedging-

Optimization of the hedging policy

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Foreword

This thesis describes the final results of my graduation assignment within Philips Innovative Applications NV, division Lighting in Turnhout (PLT). This is the final project to finish my Master's degree program in Industrial Engineering and Management Science at the Technische Universiteit Eindhoven. My main interest is Management Accounting, which means I liked to graduate at the department of Business Economics and Marketing, in the field of Management Accounting. The topic of this thesis, currency risk management, typically belongs to the field of Financial Management. The internship should provide experience with analysis and problem solving in practice, using scientific knowledge in a justified way.

This report handles currency risk management (hedging) within PLT, especially within the Business Unit (BU) UHP. Since UHP has worldwide responsibilities with its manufacturing mainly in Europe and most of its sales in the United States and Japan, it has a very high currency exposure. For this reason, hedging is a major issue within UHP and a lot of attention is paid to its hedging policy. The main goal of this thesis is analyzing and improving this hedging policy.

In this foreword I would like to thank everybody who contributed to a successful execution of my graduation assignment. It was a great pleasure and a very valuable experience to work within PLT.
In particular I would like to thank my company supervisor Geert van Bockstal (BU UHP Controller), who was always willing to discuss about all subjects. His input was essential in order to fulfill my assignment.
Also I want to thank the other (ex-)Controllers, Emiel Jongerius, Nelle Machiels, Johan Naten, Wim Rombaut and Rob Verbeek, Chief Finance and Accounting Roelof van Langen and Chief Accounting Guy Ruts. They were always willing to discuss issues related to my assignment.
Next to that particularly Bart van Tiggelen assisted me with some operational and Microsoft Excel issues. In the Microsoft Excel context I want to thank Harrie Bouwens as well.

I also want to thank my two university supervisors, Fred van Bel and Peter Sander for their helpfulness when I needed some advice.

Further I want to mention the cooperation with Philips Corporate Treasury, in particular Onno van de Griend, and with the Bank of America, represented by Emmanuel Acar, David Cowley and particularly Joakim Lidbark. Their contribution to this thesis has played a vital role.

A friend of mine, Joep Aerts, as well as Benjamin Jansen, both working at the Centre for Quantitative Methods (CQM) B.V., played a vital role in critically analyzing my modeling activities.

Last but not least I want to thank the secretary Tinne van Deun, the printing establishment (particularly Constant Vermeiren) and all employees within PLT, specifically within the Finance & Accounting department, for their support and creation of a very nice working environment.

Thank you all for this great experience!

John van der Linden

Abstract

Currency risk management (hedging) plays a vital role to most multinationals. This thesis handles the analysis and optimization of the hedging policy, in order to minimize currency risks within Philips' Business Unit UHP. The influence of uncertainties in both its sales and the foreign exchange market on the (optimal) combination of forward and option contracts, that minimizes the Value at Risk, is analyzed and modeled. Based on the results of the model, recommendations are proposed.

Summary

Chapter 1 Company description

Royal Philips Electronics is a multinational electronics company active in the areas of lighting, consumer electronics, domestic appliances, components, semiconductors and medical systems. Philips Innovative Applications NV, division Lighting in Turnhout (PLT) is an entity of Philips Lighting. It is specialized in the development and manufacturing of HID (high-intensity gas-discharge) lamps, metal components for lamps and special lighting products. The most important special lighting product is UHP (Ultra High Power); a high-performing lamp applied in data and digital TV projectors. This thesis is executed within the Business Unit (BU) UHP.

Chapter 2 Problem and assignment formulation

Decisions within organizations are based upon forecasts, or budgets. These budgets are made using forecasted sales and purchases volumes and forecasted foreign currency rates. The currency rate forecasts are made on a global level within Philips. Currency rate fluctuations can lead to big risks, therefore the management of currency risks is very important and this is what this thesis is about.

Financial techniques and instruments are designed to hedge these currency risks. Hedging techniques are split into natural en transactional techniques. Natural hedging involves changing something within the business, or altering the financial structure of the business, such that the exposure is eliminated without actually needing to undertake further transactions. Natural hedging should have priority in each company, but if it cannot fully reduce the currency risk other hedging techniques have to be used as well, namely transactional hedging techniques.

Transactional hedging techniques undertake transactions that are designed to protect a particular exchange rate and are available from a number of sources, primarily the commercial banks but increasingly from financial future markets and, sometimes, stock exchanges. The basic instruments are forwards and futures, options and swaps. Only forwards and options are used within UHP.
In currency forward contracts an agreement, usually with a bank, is made that at a certain moment in time one has the obligation to buy or sell a certain amount of foreign currency for an agreed amount of one's own currency.
A currency option contract gives you the right to buy or sell a foreign currency at a pre-arranged price within or at the end of a given period. An option premium has to be paid for the option. An option reduces the downside loss and has an unlimited upward gain. A put option is used to hedge sales and receivables.

The BU UHP uses both forward and option contracts to hedge its sales exposures of the next 15 months. The ratio forwards/options is 50%/40%, which means that 90% of the forecasted sales exposure is being hedged. An optimization[1] of this ratio is the main goal of this thesis.

The following problem definition resulted:
The BU UHP in Turnhout is exposed to currency risks and uses a policy to hedge these risks. This policy may not be optimal with regard to the following aspects (research questions):

- *Up to what level should UHP hedge its currency risks?*
- *Which combination of forward and option contracts is optimal in order to minimize the risk of losing money, leading to the optimal hedging policy?*
- *How exactly should these instruments be used?*

Under some relevant preconditions and boundary lines, the following assignment was defined:

[1] The criterion to optimize the hedging policy is minimizing the Value at Risk (95%), the risk of losing money.

Optimizing the current hedging policy within the BU UHP in order to minimize currency risk exposures. The assignment can be subdivided into the following sub assignments:

1. *Analyzing the current hedging policy*
2. *Setting up a currency risk model*
3. *Optimizing the current hedging policy*
4. *Recommendations*

Chapter 3 Currency risk modeling

Many factors influence the optimal hedging policy. Firstly an analysis was made to understand the effect of price fluctuations on economic and transaction exposures, by analyzing the relationship between market prices and currency rate fluctuations.
Secondly both the influence of the uncertainty in the sales and the uncertainty in the foreign exchange (FX) market on currency risk exposures and on the optimal hedging policy was modeled. Three different models were developed. The first two of them proved to be invalid because of some lacks and unreasonable assumptions underlying these models. Finally a valid model resulted, solving the invalidity of the previous two models. This final model, which is based on a Monte Carlo simulation, is an extension of the existing scientific literature.

A couple of variables, i.e. the sales forecast accuracy, the volatility of the FX market and the option premium, determine two substantial aspects of the optimal hedging policy. These are the combination of forward and options contracts and the total percentage of the forecasted exposure to be hedged. The Monte Carlo model optimizes both of them.

Contrary to forward contracts, option contracts only protect the downward risk of exchange rate movements. This means that, though the obligation to pay an option premium, one can benefit from an exchange rate movement in one's advantage. And on the other side, if the exchange rate moves in an unfavorable direction, one does not have the obligation to buy or sell the underlying value (sales). Therefore option contracts might be preferable to forward contracts in case of very unstable sales, illustrating the importance of the sales forecast accuracy towards optimizing the hedging policy.

Chapter 4 Monte Carlo simulation model

This chapter discusses a Monte Carlo simulation being used to model both the uncertainties in the sales and in the FX market. A Monte Carlo simulation is useful if there is no relevant historical time series available, like in UHP's situation. Furthermore it can provide confidence intervals around the optimal hedge. Therefore the Monte Carlo simulation, instead of a covariance method, correlation method or historical simulation, is chosen.

The model overcomes the lacks and disadvantages of the previous 'invalid' models and furthermore it is very flexible. The model generates Value at Risk (VaR) percentages for different hedging policies, based on which the optimal hedging policy (combination of forward and option contracts) is chosen.

VaR is a statistical technique that combines sensitivity and probability analysis. It values market sensitive instruments under various scenarios and attaches a probability of incurring a loss. In the model being explained below, the VaR is used as the criterion to determine the effectiveness of different hedging scenarios. By examining the left tail of the distribution of outcomes for a certain hedging policy, one can get an estimation of the downside risk associated with that particular policy. In fact it is the risk of losing money in a particular policy with a defined confidence interval, which is set at 95%.

The VaR percentage is calculated by generating the range of profit and loss values resulting from the simulation. These are then ranked and the appropriate percentile, in this case the 5^{th}, is selected. For

example, if the VaR(95%) is 7,5%, one can say that there is only a 5% chance that the cash flow will fall by more than 7,5% over a defined time period. In this analysis this time period is 15 months.

Microsoft Excel is used to execute the simulation. The first part of the spreadsheet uses two separate simulations, one representing the uncertainty in the sales and the other the uncertainty in the FX market. This means that situations can occur when UHP is under- or over-hedged at the same time as the FX market moves against UHP, so including a 'worst-case' analysis.

The input variables are the mean of the standardized sales, the standard deviation of the standardized sales, the mean of the currency rate fluctuation, the hedging horizon, the 1-year volatility of the underlying currency pair (from which the standard deviation of the standardized sales is calculated, begin equal to the 15-months volatility), the 15-months option premium percentage and the hedge ratio, split up into a percentage of forwards and options.

Since the BU UHP does not have clear evidence supporting a specific distribution, it assumes the sales to be normally distributed, which is reasonable. The mean of the standardized sales is assumed to be 1. Actually this means that the average sales forecast accuracy is 100%. This is very reasonable, because if the mean of the standardized sales differs from 1 it would imply that the sales are structurally being under- or over-hedged. If this turns out, the new sales forecasts would be changed in order to try not to over- or under-hedge the future exposures. Sales forecasts are made based on the most recent market information, so in fact no better predictor is available. Because (a direction of) deviations cannot be forecasted, on average the sales forecast is assumed to be right and therefore the mean of the standardized sales is 1. The deviation from the sales forecast is represented by the standard deviation of the standardized sales, which depends on different business characteristics; in particular differences in sales forecast accuracy.

Together with simulating the uncertainty of the FX market (in a similar way), the simulation of the sales uncertainty can be used to evaluate how well different hedged and un-hedged strategies perform. Both uncertainties are simulated 10.000 times by a random simulation in order to create valid results.

The second part of the spreadsheet calculates the returns of the 'un-hedged part – forward – option + option premium'. Based on the 10.000 random simulations, 10.000 returns are calculated and the 'summary' of them generates amongst others the VaR(95%). By creating a table, which automatically calculates the VaR(95%) percentages for all possible forward/option combinations, the (optimal) hedging policy leading to the lowest VaR(95%) is determined.

The results show that the optimal hedging policy in order to hedge UHP's sales, under the set of current FX market variables and conditions that fit to the UHP business, is to hedge using 70% forward contracts and 60% option contracts. So this optimal policy states 30% over-hedging to be risk minimizing. As chapter 6 of this summary extensively explains, it makes sense to hedge more than 100% of the expected exposure. However, according to FAS 133 (the accounting standard) the criterion for effectiveness of a hedge is that the hedged amount should be in between 80% and 125% of the underlying sales, if UHP wants to defer the results on hedging instruments. In this respect implementing the (optimal) outcome of this study makes it much more difficult not to be in contradiction with the FAS 133 regulations.

There are two methods to execute a sensitivity analysis based on the VaR(95%). These are handled in the conclusions (chapter 6), together with the results of the sensitivity analysis.

Chapter 5 Hedging: operational issues

Two operational issues that are strongly related to this graduation assignment are relevant to discuss in this chapter, because they are considered as very valuable within PLT. These are the ways of performance measurement and how to forecast the hedging result.

Towards both compliance with FAS 133 and KPMG Auditing, the hedging effectiveness should be measured both monthly and quarterly according to the FAS 133 standards. These measuring methods should be standardized throughout all PLT.

The monthly effectiveness is measured by dividing the total realized sales and supplies in a specific currency by the amount of the 100% committed forward sales contract in that currency.
The goal of the quarterly effectiveness check is to quarterly monitor the situation with regard to all outstanding anticipated exposures. In this way possible changes in these forecasted exposures can be followed up on a rolling basis, by concluding additional hedging contracts.

Besides these measurements, PLT uses an internal performance indicator calculating the percentage of the currency result compensated by hedging. This is roughly calculated by dividing the result on hedging contracts by the potential gain or loss due to currency effects.

Obviously, accurately forecasting the hedging result is an important aspect in the quarterly planning and yearly budgeting processes within PLT, because the hedging result takes up a big part of the total result. A format was introduced in order to be able to forecast the future hedging result on a monthly basis, based on all outstanding anticipated hedging contracts.

Chapter 6 Conclusions and recommendations

Conclusions:

- The current hedging policy within the Business Unit UHP states that 50% forward contracts and 40% option contracts should be used in order to hedge future sales exposures. As the results of the Monte Carlo simulation model show, the Value at Risk (95%) in this situation equals –6,3%. This means that there is a 5% chance that the cash flow will fall by more than 6,3% over a 15-months period.

- The results of the Monte Carlo simulation show that the optimal hedging policy for UHP, under the set of current market variables and conditions that fit to the UHP business, is to hedge using 70% forward and 60% option contracts in order to minimize the Value at Risk (95%). This leads to a VaR(95%) of –3,5%.

- Over-hedging proves to be risk reducing. This is a very interesting aspect that argues with existing literature and visions, which mainly states that over-hedging means speculating, which is absolutely forbidden within Philips. But the results of the Monte Carlo model are based on the VaR(95%), a decision variable indicating risk. This means that by minimizing the VaR(95%), one can determine a maximum loss, expressed in a percentage of the cash flow, with a certainty of 95%. This is no speculation, but minimizing risk and loss of cash flow.

- Economically it can make sense to hedge more than 100%. For example, assume a series of exposures with an average of 1. For each exposure the final (realized) number could be 0,8 or it could be 1,2. If you only hedge 1 and you realize 1,2, this means that you will have an unlimited downside risk on the 0,2 that is left un-hedged. This should be compared to the loss that you could make on the hedge if the final exposure is only 0,8, which means that you are over-hedged by 0,2. The most you can lose in this case is the option premium on this amount. Due to the fact that the payout of an option is not symmetrical, you may find that the optimal hedge ratio is higher than 1. This might lead to complications with regard to FAS 133. The recommendations in this summary discuss this issue.

- The first sensitivity analysis of the Monte Carlo model results shows the relationships between the input variables and the VaR(95%) under a specific hedging policy. Firstly, the VaR(95%) approximately increases linearly if the standard deviation of the sales increases. Secondly, the

VaR(95%) is minimal if the mean of the standardized sales is around 0,75. This corresponds to the conclusion that it is optimal to over-hedge future sales exposures with about 30%. Thirdly, the VaR(95%) approximately increases linearly if the volatility increases, as well as if the option premium increases. The second sensitivity analysis of the Monte Carlo modeling results shows the relationships between the input variables and the optimal hedging policy. Firstly, if the sales forecast accuracy decreases, relatively more options should be used and the hedge ratio increases. Secondly, the higher the volatility of the FX market, the more options should be used. Finally, if the option premium increases, the amount of options in the optimal hedging policy decreases. The influence of the volatility on the option premium is taken into account as well.

Recommendations:

- It is recommended to change the hedging policy of the BU UHP by increasing the hedged percentage of the forecasted sales exposure (currently 90%) in order to reduce foreign currency risks, based on the results of the Monte Carlo model. However, this may lead to complications with regard to FAS 133. Namely, if one wants to defer the results on hedging instruments, one should be in compliance with FAS 133, stating that the hedged amount should be in between 80% and 125% of the underlying sales, resulting in "effectiveness".
  Therefore the exposure might be split in two parts. The first part may consist of 50% forwards and 30% options, which will lead to effectiveness without many problems. The second part may consist of 30% options. In case of ineffectiveness the results on the second exposure can be taken into the profit and loss (P&L) account directly. So this would only be the result on a 30% hedge instead of a 110% hedge, which leads to much smaller fluctuations in the P&L than taking the result on the 110% hedge into the P&L directly. However, both exposures are still related to the same underlying sales and it is not sure whether this is allowed according to FAS 133.
  Obviously the results of the model differ from business to business, amongst others due to differences between business' sales and purchases forecast accuracies. Due to the fact that this is a crucial variable in the Monte Carlo model, the optimal hedging policy can be calculated for each business.

- In order to hedge more than 100% of the exposure, extra checks related to compliance with FAS 133 need to be executed. These checks will be done in close cooperation with the KPMG auditors.

- Improving the sales forecast accuracy changes the optimal outcome from the Monte Carlo simulation from hedging 130% closer to 100%. The recommendation is therefore not only to increase the hedged percentage (currently 90%), but also to try to further improve the sales forecast accuracy, and by that to reduce the costs of hedging. In the 'perfect' situation this results in a hedge of 100% forwards at zero cost and zero risk.

- PLT should keep going on measuring the monthly and quarterly effectiveness and the percentage of the currency result compensated by hedging, indirectly leading to risk reduction and mapping of the sales forecast accuracy of the sales in foreign currencies. All these performance indicators have already been implemented successfully. Currently more and more Philips organizations contact PLT in order to get more knowledge about its hedging work method (see appendix 10) and both its monthly and quarterly effectiveness measurement.

- PLT should keep going on to use the format (see appendix 23) to forecast the monthly hedging result. This format has already been implemented successfully. It turns out to be a great assistance for the quarterly forecasting and yearly budgeting process. It might be possible to use this format throughout all Philips organizations hedging its foreign currency exposures.

The results of this thesis might be used to improve the hedging policy in 2004, not only for the BU UHP but also within a further range. However, in order to change a hedging policy, approval by product division management is needed. Therefore the contents, conclusions and recommendations of this thesis will be presented to higher management in the beginning of December 2003.

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Introduction

This report is the result of an internship within Philips Innovative Applications NV, division Lighting in Turnhout (PLT). Due to currency rate fluctuations currency risk management (hedging) plays a vital role to most multinationals. This thesis handles the analysis and optimization[2] of the hedging policy, in particular within the Business Unit UHP (Ultra High Power), in order to minimize currency risks.

Chapter 1 describes the environment in which the assignment took place. An overview of the multinational Royal Philips Electronics, its Lighting division, the organization in Turnhout and specifically its Business Unit UHP is given. This creates an impression of the organization and its products, processes, competitors, customers and business situation.

Chapter 2 provides the reader with an extensive explanation of the context of the assignment. Different types of currency risks and the techniques and instruments to hedge them are explained, before the hedging policy within UHP is considered in detail. After having provided this information, the problem and assignment are formulated, as well as the preconditions and boundary lines. A project strategy is provided in order to be able to execute a well-planned assignment in a scientifically justified way.

The problem within UHP is the fact that its hedging policy may not be optimal with regard to the following aspects (research questions):

- Up to what level should UHP hedge its currency risks?
- Which combination of forward and option contracts is optimal in order to minimize the risk of losing money, leading to the optimal hedging policy?
- How exactly should these instruments be used?

Globally described the assignment is to optimize the current hedging policy in order to minimize currency risk exposures, by analyzing the current hedging policy, setting up a currency risk model, optimizing the current hedging policy and proposing recommendations.

Chapter 3 handles the modeling of the currency risk. It describes the modeling process and explains the most important variables influencing the optimal hedging policy. These are the volatility of the foreign exchange (FX) market, the option premium, and particularly the sales forecast accuracy. One will see that under some specific market and/or business conditions, option contracts are preferable to forward contracts.

Chapter 4 is the most essential part of this thesis. It describes the Monte Carlo simulation model, which is the basis for the conclusions and recommendations. It simulates both the uncertainty in the sales and in the FX market. Using these two random simulations an analysis of different hedging policies is executed. The decision variable Value at Risk is used to assess them and to determine the optimal hedging policy.

Chapter 5 pays attention to some operational issues, i.e. hedging performance measurement and the hedging result forecast.

Finally chapter 6 handles the conclusions and recommendations resulting from the graduation assignment. In particular the Monte Carlo model contributed to this. Besides that, some attention is paid to possible further research and implementation of the outcomes of this thesis.

[2] The criterion to optimize the hedging policy is minimizing the Value at Risk (95%), the risk of losing money.

Chapter 1 Company description

This chapter will start with an overview of Royal Philips Electronics, followed by more specific sections about the division Lighting, Philips Innovative Applications NV, division Lighting in Turnhout (PLT) and the Business Unit (BU) UHP. After getting more familiar with the company, the recent business field developments will be highlighted and the strengths, weaknesses, opportunities and threats of the company will be analyzed using a SWOT analysis.

1.1 Royal Philips Electronics

The foundations for Royal Philips Electronics, what was to become one of the world's biggest electronics companies, were laid in 1891 when Gerard Philips established a company in Eindhoven, the Netherlands, to manufacture incandescent lamps and other electrical products.
Philips is one of the world's biggest electronics companies and Europe's largest, with sales of € 31.8 billion in 2002 [1]. It is a global leader in color television sets, lighting, electric shavers, medical diagnostic imaging and patient monitoring, and one-chip television products. Its 170.000 employees in some 160 factories, covering more than 60 countries, are active in the areas of lighting, consumer electronics, domestic appliances, components, semiconductors, and medical systems.

Royal Philips Electronics consists of five product divisions (PDs), which are:
- Consumer Electronics
- Domestic Appliances & Personal Care
- Lighting (the division PLT belongs to)
- Medical Systems
- Semiconductors

The 2002 sales by division are presented in figure 1.1.

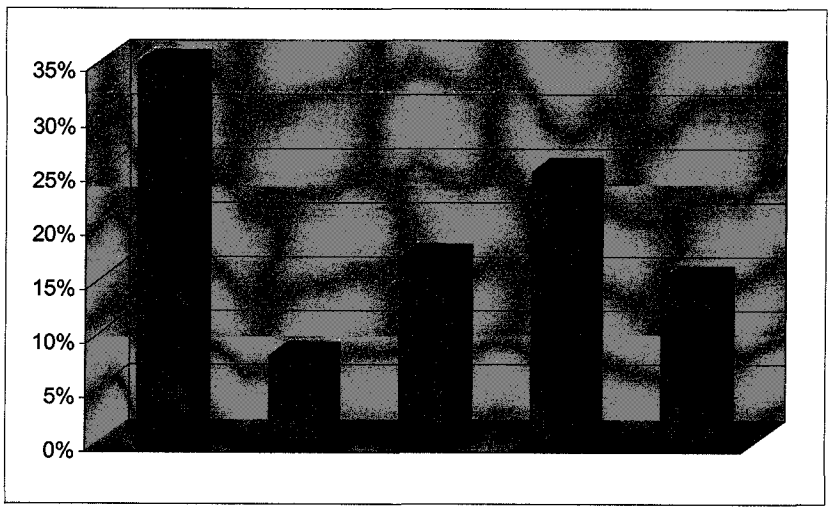


Figure 1.1 2002 sales by division

The strength of Philips' global operations is reflected in its (value-based) leadership position in many of the markets in which it is active, shown in table 1.1 [1].

Table 1.1 Market positions Royal Philips Electronics [1]

Market	World	Europe
Lighting	1	1
Consumer Electronics (audio/video)	3	1
Monitors (units)	4	3
Shavers	1	1
Steam irons	2	2
Semiconductors	9	4
Color picture tubes	3	1
DVD recorders	1	1
Medical imaging equipment	2	1
Dental care (electric toothbrushes)	2	2

Philips is quoted on the New York Stock Exchange (NYSE), London, Frankfurt, Amsterdam and other stock exchanges. The list of biggest electronics concerns all over the world shows that Philips takes the eleventh position[3] [2].

1.2 Philips Lighting

As mentioned before, Lighting is one out of totally five product divisions. The sales of this division amount to 15% of the total Royal Philips Electronics sales. As shown before in table 1.1, Philips is number one in the global lighting market, a position supported by leadership in innovation combined with a systematic approach to seeking out new market opportunities. Its strategic ambition is to set the pace in the lighting industry as the first-choice innovative partner for the supply of creative and cost-effective lighting solutions.

The division's products are found all around the world; not only everywhere in the home, but also in a multitude of professional applications, for example 30% of offices, 65% of the world's top airports, 30% of hospitals, 35% of cars and 55% of football stadiums.
Products include a full range of incandescent and halogen lamps, compact and normal fluorescent lamps, high-intensity gas-discharge (HID) and special lamps, fixtures, ballasts, lighting electronics and automotive lamps.

The Lighting division consists of four business groups (BGs), namely:
- Lamps
- Luminaires
- Lighting Electronics
- Automotive, Special Lighting and UHP

The business within PLT belongs to both the BGs Lamps and Automotive, Special Lighting and UHP.

The 2002 Lighting sales by business group are as presented in figure 1.2.

[3] Source: Fortune, July 2002

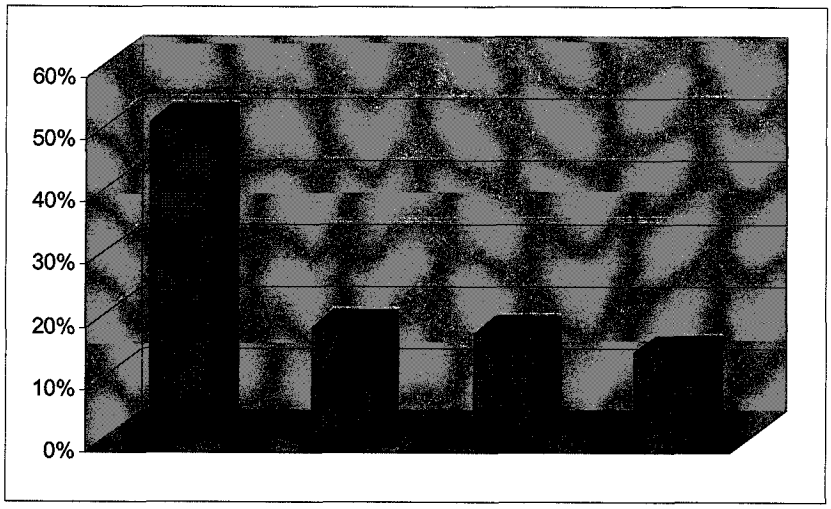


Figure 1.2 2002 Lighting sales by business group

Philips Lighting employs some 48,000 people worldwide. Manufacturing operations are located in the Netherlands, Belgium, Germany, France, the United Kingdom, Poland, the United States, Canada, Brazil, India, Indonesia, Thailand, the People's Republic of China, South Korea, Spain, and Mexico.

Important market introductions of recent years within the Lighting division can be found in appendix 1.

1.3 Philips Innovative Applications NV, division Lighting in Turnhout

PLT is one of the most important competence centers of the Lighting division. It is specialized in the development and manufacturing of HID lamps, metal components (MECO) for lamps (amongst others filament and coils) and special lighting products.

The HID lamps developed and produced in Turnhout are used in general, professional lighting projects like outdoor lighting of roads and indoor lighting of buildings, stores and industrial lighting. An example of an HID lamp is shown in figure 1.3.

PLT is worldwide market leader in the area of HID lamps. The most important ones are:

- Mastercolour CDM, a compact metal halide lamp with a ceramic burner used to light stores.
- Another product is the SON-lamp, a high-pressure sodium lamp mainly applied in street lighting.
- The QL, a lamp without electrodes but with an especially long life expectancy up to 100.000 burning hours.

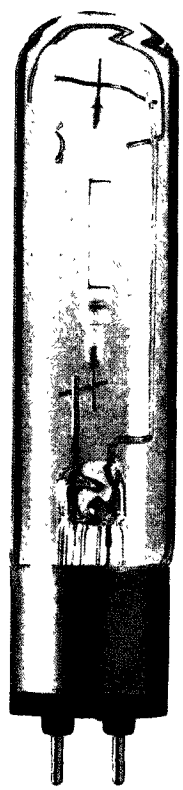


Figure 1.3 HID lamp

An overview of HID products can be found in figure 1.4.

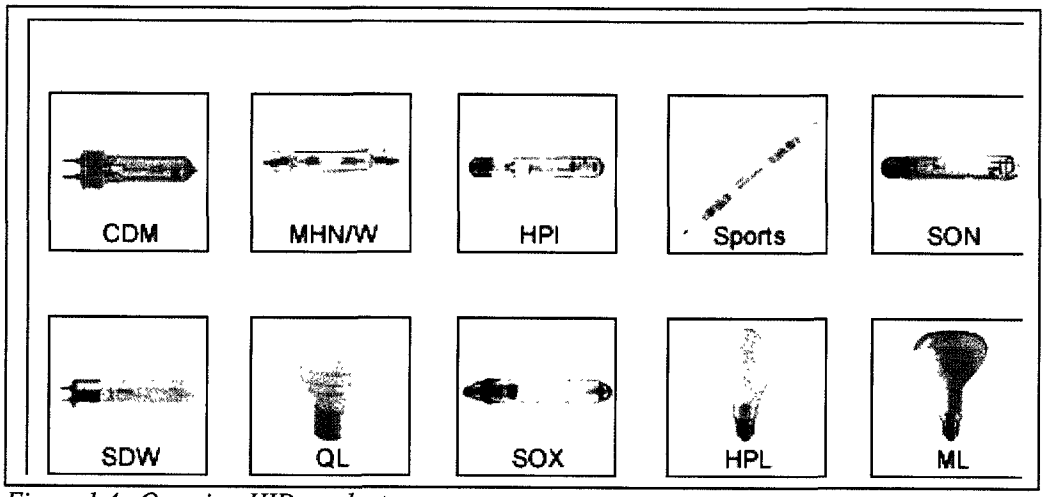


Figure 1.4 Overview HID products

Besides HID, Turnhout is also a major competence center for special lighting products. The most important one is the UHP lamp; a high-performing lamp applied in data and digital TV projectors.

PLT was one of the first companies in Belgium acquiring, besides an ISO9001 certificate, an ISO14001 label for environmental care as well.

In Belgium some 7000 employees work for Philips, of whom some 2500 for Philips Turnhout. Appendix 2 shows the company structure of PLT using an organization chart, while appendix 3 shows the Finance & Accounting department, of which I was a member during the project.

1.4 Business Unit UHP

Like mentioned before, the business within PLT belongs to both the BGs Lamps and Automotive, Special Lighting and UHP. The business is subdivided into the Business Unit UHP and the Business Lines (BLs) Lamps Europe (HID), Lighting Components (MECO), Global Technology Development (GTD), UV and Optics. In appendix 4, displaying the structure of Royal Philips Electronics, all these PLT businesses, frequently called profit centers further on in this thesis, are shown in bold.
The graduation assignment is specifically related to the BU UHP within the BG Automotive, Special Lighting and UHP, while on operational level it covers most profit centers as well. The reason for this will be explained in section 2.2. After having described Philips Turnhout extensively, now some attention will be paid to the BU UHP, of which the organization chart is shown in appendix 5. The BU UHP is the fastest growing business within PLT.

1.4.1 Mission and vision

The mission and vision of UHP will be described to illustrate its goals.

The mission of UHP is:
"Committed to creative and reliable lighting solutions for digital projection."

The vision of UHP is:
"UHP shines a new light on the digital visual resolution. Recognized leader in illuminating infotainment for every projection screen."

1.4.2 Competitors and customers

In the UHP market Philips is the worldwide market leader with a market share of 45%. There are 3 major competitors, namely Osram (Europe), Eye (Japan) and Ushio (Japan). Graphically this is shown in figure 1.5.

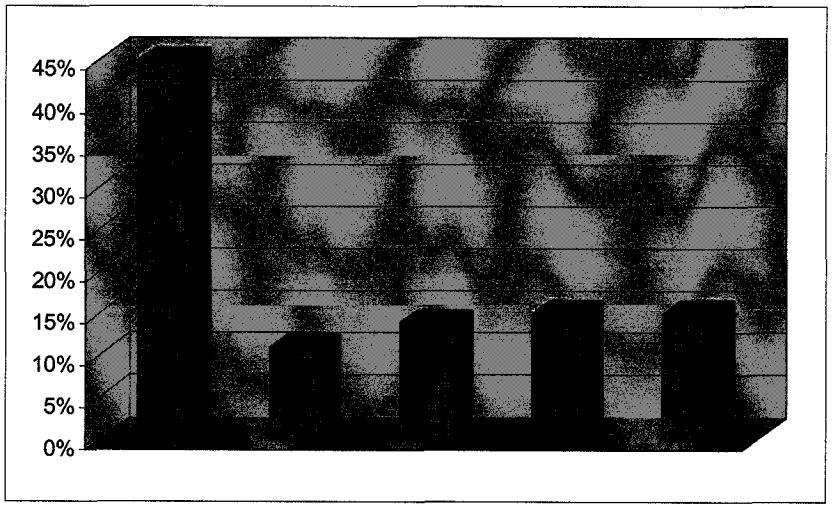


Figure 1.5 UHP competitors

Customers of the BU UHP are located worldwide, which is shown in figure 1.6.

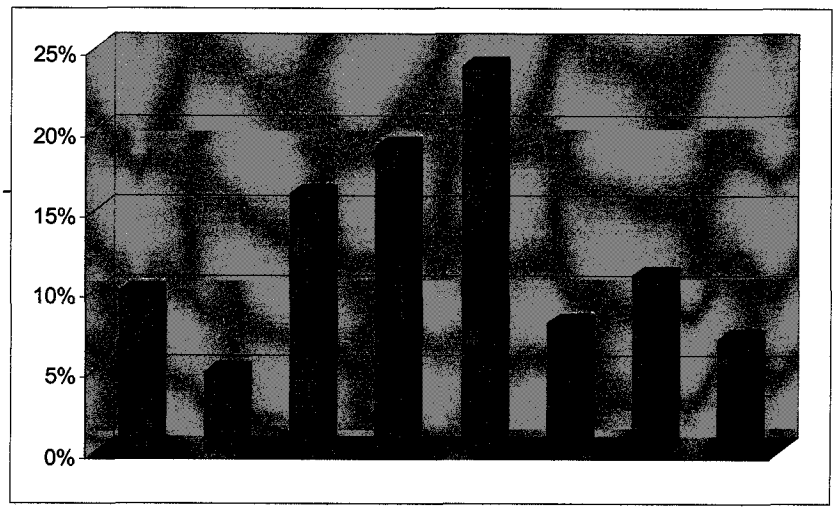


Figure 1.6 UHP customers

1.4.3 Recent business field developments

The Lighting division is one of the most profitable Philips divisions with positive future perspectives. The Business Group Special Lighting has even better perspectives. Especially within the projection field an extensive growth is observed and can be expected in the near future. Lamps being used for projection can possibly be used as replacement of the much more room-taking cathode-ray tubes in televisions within a couple of years.

The new technology of a digital LCD (Liquid Crystal Display) projector (see figure 1.7) is based on a breakthrough in both LCDs and light sources technology. The UHP lamp is the light source with the highest light intensity in the beam. Therefore it can be used in optical applications. The light source is bundled through optical lenses, split into three colors and sent through a LCD display, before it is optically projected onto the screen. This way of working is presented in figure 1.8.

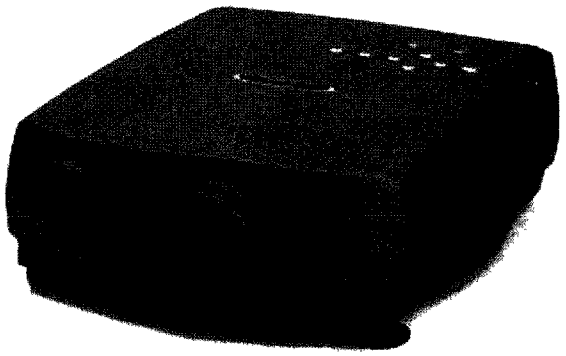


Figure 1.7 LCD projector

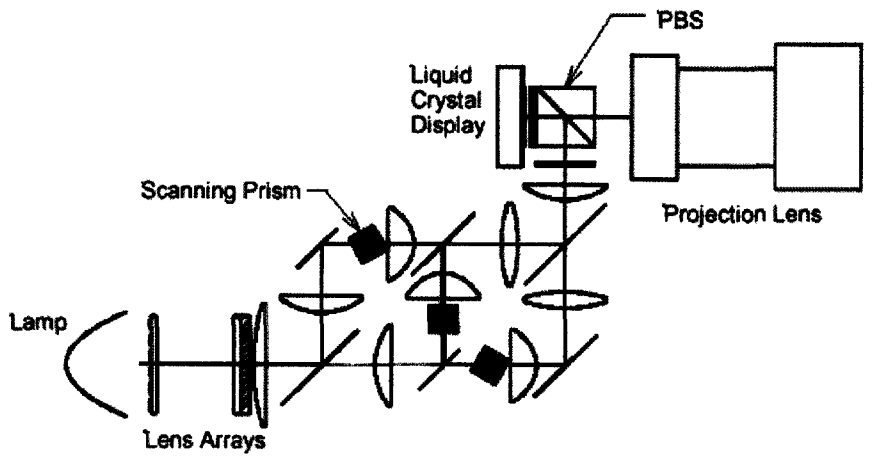


Figure 1.8 Way of working UHP lamp in optical applications

1.4.4 SWOT analysis

Partly based on subsection 1.4.3, the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of PLT / UHP can be summarized as follows:

- Strengths
  - High technology capabilities
  - High Research and Development (R&D) knowledge
  - Leading market position at the European and worldwide lighting market

- Weaknesses
  - High production costs compared to low-wage countries

- Opportunities
  - High growth within the special lighting projection field
  - Opportunities in the consumer market: the lamp which can possibly be used as replacement of the room-taking cathode-ray tubes in televisions
  - Increasing profitability by relocation of production facilities to China

- Threats
  - Increasing know-how in low-wage countries
  - Possible threat of the leading market position at the European and worldwide lighting market (however, there are no indications for this)

The next chapter will amongst others describe the problem and formulate the graduation assignment.

Chapter 2 Problem and assignment formulation

This chapter will successively describe the context of the graduation assignment, the situation within the Business Unit UHP in Turnhout, and the problems/challenges within UHP being subject of the graduation assignment. Based on this problem/challenge definition, the original assignment is formulated and refined. The assignment will be subdivided into four sub assignments, which are based on three research questions derived from the main problem. The sub assignments are:

1. Analyzing the current hedging policy
2. Setting up a current risk model
3. Optimizing the current hedging policy
4. Recommendations

To restrict the scope of the graduation project, preconditions and boundary lines are defined.

2.1 Context of the assignment

First of all it should be mentioned that financial techniques and instruments could be designed from two perspectives [3]:

- For purely speculative purposes
- For the purpose of risk management (hedging)

As will be mentioned in the preconditions in subsection 2.5.1, this thesis deals with the second aspect, in particular currency risk management, or hedging. The basic idea behind setting up a hedge is identifying and quantifying a currency risk and subsequently taking an opposite position to minimize the financial risk [4].
This can be explained using an example. Assume that the BU UHP expects to sell lamps worth $ 5 Million (Mio) one year later. Because the €/$ rate one year later is not yet known, there is a risk that this rate is much lower than currently, causing a "loss" compared to the budget. In order to minimize this loss/risk, UHP can conclude hedge contracts with the bank. These contracts oblige or give UHP the right (this depends on the kind of contract, which will be extensively in subsection 2.1.2.2) to buy or sell $ against a contracted rate to compensate a gain or loss when the sale takes place.

The financial techniques and instruments discussed below are designed to manage two main types of financial risk, namely currency and interest risk. This thesis will only handle currency risk. The reason for this will be explained in subsection 2.5.2.

2.1.1 Types of currency risk

Currency risks/exposures can be classified into three categories [3]:

- Transaction risk
- Translation risk
- Economic risk

Transaction risk stems from the possibility of incurring future exchange gains or losses on transactions in currencies other than its own functional currency, and will therefore have a direct cash effect [5]. It relates to the short to medium term (< 15 months) exposure from committed and anticipated transactions.

Committed transaction exposures are exposures related to transactions that are committed in terms of pricing, volumes and time of payment [5].

Anticipated transaction exposures are related to forecasted transactions, which are not yet committed on any one of the terms pricing, volume and time of payment [5].

Translation exposure arises when the value of profits, losses, assets and liabilities is translated from one currency to another [5]. Translation does not involve actually undertaking a foreign exchange deal in the market place, and therefore does not give rise to immediate cash effect. Translation does, however, change values reported in the domestic currency, such as consolidated net worth. These resulting adjustments can alter a company's borrowing capacity and may therefore affect its cash flow. There are two types of translation risk, namely balance sheet and profit and loss account.

Economic exposures are also known as strategic exposures. They arise from the structure, currencies and geographical composition of commercial activities, production activities and purchasing activities of UHP compared to its competitors and the manner in which costs, prices and therefore profits respond to exchange rate movements [5].
Economic exposures are usually complex, often hidden and frequently not even identified, let alone measured or managed. Businesses that fail to identify economic exposures run the risk of undertaking pointless, or even counterproductive, hedging transactions.

This thesis specifically handles transaction and economic risks. Translation risks are left out of the scope because they do not cause immediate cash effects, only reported values.

2.1.2 Hedging techniques and instruments

When a foreign currency exposure has been identified and a management policy determined, it might be appropriate to protect (or hedge) it. It then becomes necessary to choose the appropriate hedging technique. Hedging techniques can be split into two types [3]:

- Natural
- Transactional

2.1.2.1 Natural hedging techniques

Natural hedging involves changing something within the business, or altering the financial structure of the business, such that the exposure is eliminated without actually needing to undertake further transactions [3]. Natural hedging has the advantage in many cases that it is 'fail-safe' and once in place may not require active management. Examples of natural hedging are:

- Partly financing a company in the (foreign) currency in which a proportion of that company's assets are financed and cash flows take place.
- Because exposures on a payable or receivable are no longer exposures once they have been paid (settled), the negotiation of a settlement discount and prompt paying will naturally eliminate the exposure much more simply than, for example, buying a currency forward.
- Leading and lagging, actually this means changing the payment schedule. If an increased volatility is expected in the currency markets, a treasurer can instruct companies to pay each other promptly. Similarly, he can manage individual currency risk by speeding up (leading) or slowing down (lagging) particular settlements if currency rate fluctuations are expected.

Two other examples of natural hedging are mentioned below. These are used within UHP:

- Purchasing reflectors from Okamoto. Okamoto is a Japanese supplier, paid by UHP in Japanese Yens (¥). On the other side UHP sells many products in ¥, resulting in a natural hedge.
- Partly moving its production facilities to China, resulting in costs in the Chinese currency. Recently this currency has been strongly related to the $ and because UHP sells many products in $, this is a natural hedge as well.

Natural hedging should have priority in each company, but if it cannot fully reduce the currency risk other hedging techniques have to be used as well, namely transactional hedging techniques.

2.1.2.2 Transactional hedging techniques/instruments

Transactional hedging techniques undertake transactions that are designed to protect a particular exchange rate, and are available from a number of sources, primarily the commercial banks but increasingly from financial futures and, sometimes, stock exchanges [3].
The basic instruments are forwards and futures, options and swaps. Many so called new financial techniques/instruments are actually not new. They are merely derived from products that already existed or combinations of forwards/futures, options and/or swaps.
Because this thesis will only pay attention to currency risk management, specific attention is paid to the currency risk management variants of these instruments, which will be explained below:

- Currency forwards and futures
- Currency options
- Currency swaps

Currency forwards and options are the only instruments that are allowed to use according to UHP's hedging policy, therefore this thesis will only handle these two hedging instruments.

2.1.2.2.1 Currency forwards and futures

In currency forward contracts an agreement, usually with a bank, is made that at a certain moment in time one has the obligation to buy or sell a certain amount of foreign currency for an agreed amount of one's own currency [6]. Both delivery and payment take place at a later date. Forward contracts are not standardized nor are they traded on an organized market. The difference between the forward rate and the spot rate is based on the difference between the interest rates of the two currencies and should be considered the fair value of a certain cash flow to be received at that date. If the interest rate of the foreign currency is lower than that of your own currency, the forward rate of the foreign currency will be higher than the current rate and vice versa.

The disadvantage of forward contracts is that everything is fixed. For example, if you have a forward contract to sell $ and buy € at a certain moment in the future, and you do not have the contracted amount of $ at the moment you agreed to sell, than you will be exposed to a risk, since you have a duty to deliver at a pre-arranged rate. If the real rate at that moment is higher, you will have to buy $ at a high rate, and sell at a low rate, causing a loss. This is the reason that forward contracts are not particularly suited for uncertain, anticipated, cash flows and why UHP's hedging policy does not allow to hedge more than 50% of the anticipated exposures with forwards.

An example of a forward contract deal confirmation can be found in appendix 6.

The risk reduction of a forward contract can be explained graphically using figures 2.1 and 2.2. If UHP does not hedge its exposures, the risk can be graphically explained as in figure 2.1. Assume that UHP budgets her $-sales at a €/$ rate of 1,05 (this means that $ 1,00 equals to € 1,05), it will lose money if the $-sales occurs against a €/$ rate which is lower than 1,05. In contrary, UHP will gain money if the $-sales occur against a €/$ rate which is higher than 1,05.

A forward contract works exactly in the opposite way of not hedging an exposure. If UHP agrees on a forward contract of €/$ 1,05 with the bank, this means that UHP will receive € 1,05 for each $ when the sale occurs. If the current €/$ spot rate is higher/lower at the moment of sale, Philips loses/wins money due to the contract obligation. The net position leads to no risk if the forecasted exposure is fully hedged with a forward contract.

Actually a forward contract is nothing else than a combination of selling a call option and buying a put option. Together with the exposure this leads to a net position without any risk. This construction is a variant of a zero-cost collar, in which the bandwidth is zero, and is graphically explained in appendix 7.
The described situation of using a forward is very hypothetical because hedging 100% of the exposure using forward contracts is only efficient if sales are predictable with an accurateness of 100%. This is unrealistic, which is the reason to hedge more or less than 100% of the exposure and/or to use option contracts as well.

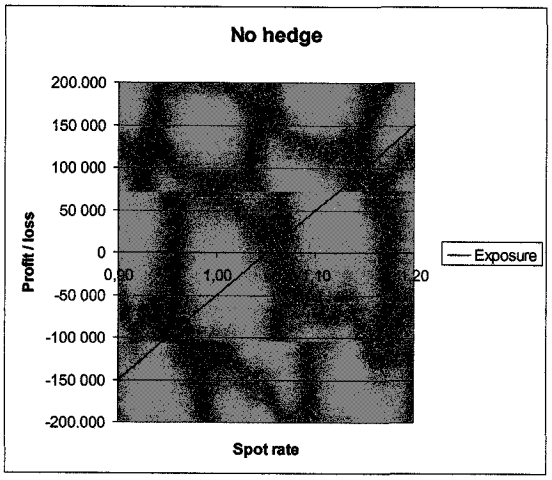


Figure 2.1 Risk in case of no hedging

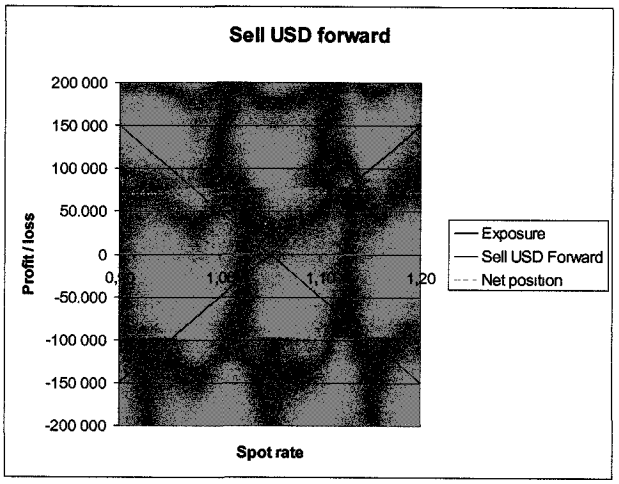


Figure 2.2 Risk reduction using a forward contract

Currency futures are standardized currency forward contracts which are traded on markets specialized in these instruments [3].

2.1.2.2.2 Currency options

A currency option contract gives you the right to buy or sell a foreign currency at a pre-arranged price within or at the end of a given period. The particular exchange rate at which the option holder can buy or sell the currency is known as the strike price. If the option can be exercised at any time during its life it is known as an 'American Style' option. If the option can be exercised only on its expiry date, then it is known as a 'European style' option. UHP makes use of 'European style' options. When options are mentioned further in this thesis, 'European style' options are meant.

The advantage of a currency option over the most other methods of currency hedging is that only one side of an exchange rate movement can be protected. This enables the company to benefit if the exchange rate moves in the company's advantage. On the other side, an option premium has to be paid for the option, being the maximum loss.

There are two kinds of options:
- A call option gives you the right to buy a particular currency at a specified price at a specified future date.
- A put option gives you the right to sell a particular currency at a specified price at a specified future date. UHP uses put options to hedge its exposures.

An example of an option contract deal confirmation can be found in appendix 8.

The risk reduction of a put option contract can be explained graphically using figure 2.3 on the next page. A (put) option contract reduces the downside loss and has an unlimited upward gain.

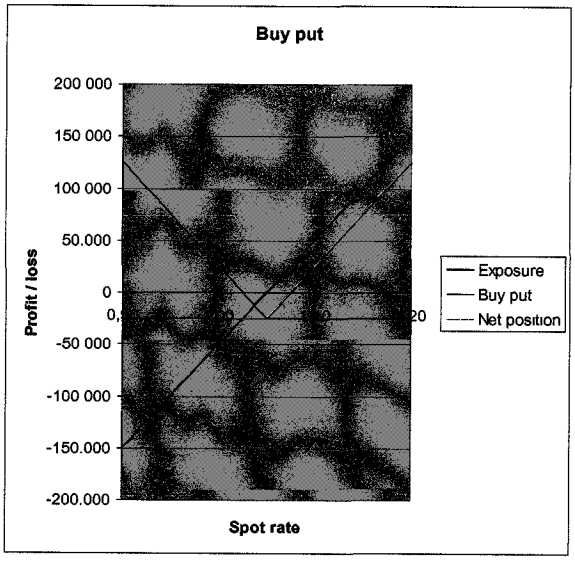


Figure 2.3 Risk reduction using an option contract

The price of an option (the option premium) is composed of two elements, intrinsic value and time value.

Intrinsic value is the profit that can be realized if the option is immediately exercised. The premium is, therefore, never lower than the current level of the intrinsic value. Where the intrinsic value is positive, the option is referred to as being "in the money". If the intrinsic value is nil, the option is referred to as being "at the money". An option is "at the money" if the exercise price and the spot rate when the option is written, are identical. An option is referred to as being "out of the money" when immediate exercise of the option would give rise to a loss.

The time value of an option is the difference between the premium and the intrinsic value, and is related to the following factors:

- The expiry date: options with a long lifetime will be valued higher than options with a short lifetime, since more (or certainly as much) can happen in a long time period than in a short, partly overlapping, time period. At the end of the contract the option no longer has any time value and is valued exclusively at its intrinsic value.
- The volatility of the underlying asset: a greater volatility of the rate of the underlying asset provides greater profit possibilities.
- The time cost of money (interest rates)
- The spot rate of the underlying value
- The strike rate of the underlying value

Appendix 9 shows an option price calculator, filled in for a 13 month €/$ option.

2.1.2.2.3 Currency swaps

A currency swap is in essence a long-dated currency forward contract. It involves the swapping of one currency for a comparable amount in another currency. The main difference is that the interest rate differentials are paid during the period of the swap.

2.1.3 'Summary' context of the assignment

Figure 2.4 indicates the context of the graduation assignment. The highlighted parts are considered in this thesis.

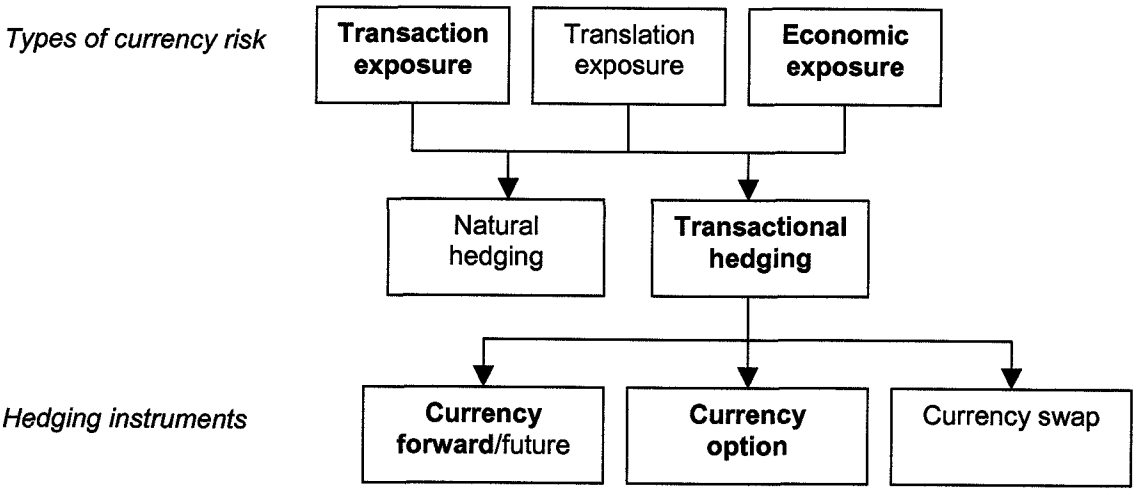


Figure 2.4 Currency risk management overview

2.2 Situation within the BU UHP in Turnhout

Decisions within organizations are based upon forecasts, or budgets. These budgets are made using forecasted sales and purchases volumes and forecasted foreign currency rates. The currency rate forecasts are made on a global level within Philips. If currency rates in reality differ dramatically from forecasts it might be possible that planned investments cannot be realized anymore. Therefore it is important to hedge these currency risks.
Intuitively one can say that only if the currency rates move against you, currency risks have negative impacts and that hedging these risks eliminates the possibility to profit from currency rates moving in a positive direction. But the issue is the fact that negative impacts on the short term might be disastrous for a company, which means that not only long-term influences should be considered. Namely on the long term, currency rates are seen as stable. It is important to know that the goal of hedging is to minimize downward risks and not to speculate.

About fifteen years ago, when Philips started introducing hedging policies, it applied one and the same worldwide policy. Due to the different business characteristics of the divisions, Philips noticed that one worldwide policy is far from optimal. Currently each division and sometimes even a business group within Philips has its own hedging policy. The BU controller in cooperation with the PD Treasurer will jointly determine the hedging policy for the specific organization. The BU controller has the final responsibility. Since the BU UHP has worldwide responsibilities with all its actual manufacturing in Europe and most of its sales in $ and ¥, this BU has a very high currency exposure. Because of this, UHP has very high currency exposures in relation to many other Philips entities. Therefore UHP pays a lot of attention to its hedging policy and benchmarking within Royal Philips Electronics is difficult.

As mentioned in chapter 1, the business within PLT belongs to both the BGs Lamps and Automotive, Special Lighting and UHP, and consists of six profit centers.
On operational level the hedging policy for all profit centers is optimized during the graduation project. However, this thesis specifically handles the currency risk management policy of the Business Unit UHP due to the complexity of this policy and the volume of UHP's currency exposures. It is relatively easy to extend the policy to all profit cetners, but the added value for this thesis is nil so this will not be described.

The hedge contracts being used within UHP are aligned with the hedging policy used within the business group Automotive & Special Lighting [5]. The business has different currency exposures. On the one hand on the revenues side, where some 70% of the sales takes place in foreign currency and on the other hand on the purchasing side, where some 8% of the costs of goods sold is in foreign currency.

UHP uses both forward and option contracts to hedge its exposures of the coming 15 months. Subsection 2.2.2 pays more attention to this 15 months hedging horizon. The actual ratio forwards/options for the BU UHP is 50%/40%, which means that 90% of the forecasted sales exposure is being hedged. An optimization of this ratio is the main goal of this study and will be discussed in chapter 4.

2.2.1 Hedging policy

This subsection describes the basic process being used within UHP.

Hedges will be performed at least on a quarterly rolling basis. All hedges are concluded with Philips Corporate Treasury, who concludes the contracts one by one externally with banks. This means that not only on local level exposures are not netted, and neither on corporate level. Note that an individual currency contract has to be at least the equivalent of € 50.000.

The basic process can be divided in actions when starting the policy, monthly and quarterly actions.

- Actions when starting the policy:

  Start with a hedge horizon of 15 months. Hedge all committed sales/supplies flows for 90% using forwards. Hedge all committed cash receivables for 100% using forwards. All anticipated flows within 15 months should be hedged for 50% with forwards and for 40% with options.
  The hedging policy within Philips Lighting starts from 50% forwards. In order to cover all currency exposures it was decided to cover a remaining part of the exposure with options. According to FAS 133 (the accounting standard) the hedged amount should be in between 80% and 125% of the underlying sales, so 40% instead of 50% is chosen. It can be concluded that the argumentation of this ratio is not business related and therefore an analysis and possible optimization is needed.

- Quarterly actions:

  Every quarter the time horizon is extended with an extra quarter. This means that after the new quarterly forecast is made, new information about the exposures is available, with a horizon of 15 months. This exposure should then be hedged using 50% forwards and 40% options.

- Monthly actions:

  During the month the sales/supplies become committed and the 40% option will expire. The committed sales/supplies should then be hedged for 100% using forwards, for the remaining part of the month. For this actual sales and supplies are important, since 50% of the original amount was already hedged with forwards and the other 40% was hedged with options. The total amount of the option (actual sales – hedged sales) should be hedged using forwards.
  At the end of the month a separate forward hedge is made for the receivable position that is always committed and amounts to 100% of the extrapolated sales amount of the month.

2.2.2 Hedging horizon

Another issue with regard to the hedging policy is the hedging horizon, currently being 15 months. This period is based on the budgeting process. It is questionable whether the 15 months horizon is optimal. It could be a separate assignment to analyze and possibly improve this 15 months period, so a quantitative analysis of the hedging horizon is left out of the scope of this assignment. However, a qualitative argument is stated:

- The forecast accuracy turns out not to improve linearly by shortening the hedging horizon, but roughly as plotted in figure 2.5. Therefore the possible advantages of a shorter hedging horizon are greatly undone.

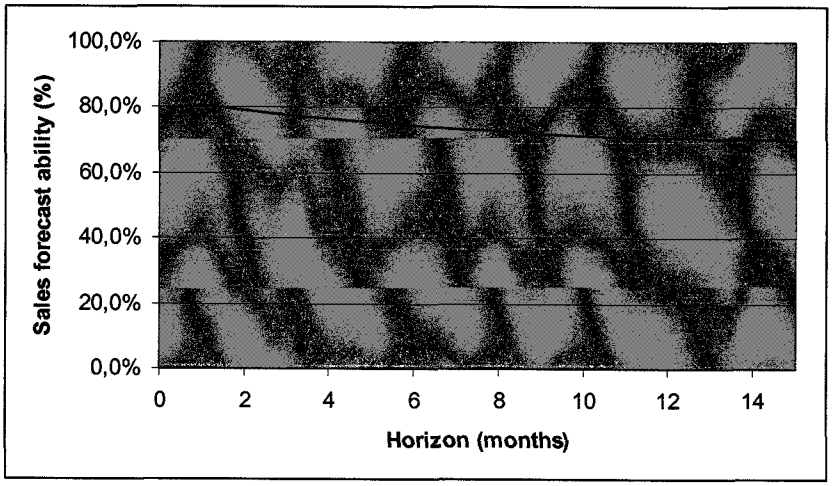


Figure 2.5 Influence hedging horizon on sales forecast accuracy

2.2.3 Documentation

Besides structural improvements, the assignment also concerns improving and standardizing the documentation of all hedging activities, which is subject to the FAS 133 accounting standard. Once a year KPMG (Klynveld, Peat, Marwick and Goerdeler) Auditing checks the way of working and all hedging documentation. Due to complaints from KPMG these processes have to be improved.

Appendix 10 shows the work instruction that I developed after having gained more in-depth knowledge about the subject. This work method has three main functions:

- It is a requirement of KPMG
- Development and documentation of the standard way of working; one and the same documentation standard throughout all the factory
- A useful base to analyze the situation within PLT and particularly within the BU UHP

The work method states that a Microsoft Excel file has to be filled in, which gives an overview of all contracts and its values. By creating two pivot tables, one related to forwards and one related to options, the hedging results can be calculated and this is a check whether the accounting is executed in the right way. If not, this can still be changed in time.

This file also includes the effectiveness measurement, an important requirement of FAS 133. The effectiveness of a hedge is defined as the 100% committed hedged amount divided by the total sales of the month. This should be between 80% and 125% if PLT wants to defer its results on hedging instruments. In this file the effectiveness can be calculated using the hedged amount from the hedging overview and the realized sales in the month.

2.3 Problem definition

Because the forward/option ratio has not been investigated extensively before, the hedging policy that is currently used may not be optimal.

Based on section 2.2, the problem can be defined as follows:

The BU UHP is exposed to currency risks and uses a policy to hedge these risks. This policy may not be optimal with regard to the following aspects (research questions):

- *Up to what level should UHP hedge its currency risks?*
- *Which combination of forward and option contracts is optimal in order to minimize the risk of losing money, leading to the optimal hedging policy?*
- *How exactly should these instruments be used?*

2.4 Assignment formulation

Originally, the assignment generally consisted of two parts:
1. Determine UHP's business risk, paying attention to competitors, market price evolution, etc.
2. Analyze both the current hedging policy and possible improvements of this policy. Eventually, the goal is obtaining an optimal model in which the business risk is minimized against acceptable costs.

After having had discussions with all for the assignment relevant persons, and a thorough analysis of the current situation, the following definite assignment was stated:

Optimizing the current hedging policy within the BU UHP in order to minimize currency risk exposures. The assignment can be subdivided into the following sub assignments:

1. *Analyze the current hedging policy:*
   - *Literature research related to currency risk management tools*
   - *Compliance with FAS 133*
   - *Describe the current way of working in order to understand, criticize, execute, follow up and document all hedging activities*
2. *Setup a currency risk model to:*
   - *Analyze the influence of sales forecast accuracy on the optimal hedging policy*
   - *Analyze the influence of foreign exchange market uncertainties on the optimal hedging policy*
   - *Quantify the currency risk*
3. *Optimize the current hedging policy by minimizing the risk of losing money*
4. *Recommendations related to:*
   - *The optimal hedging policy: optimal combination of forwards and options*
   - *The level up to what level the currency risk is hedged*
   - *Minimizing the risk of losing money using this policy*

Due to the fact that I am studying Industrial Engineering and Management Science, it is important to take a look at the assignment using a "helicopter view". This is realized by not only paying attention to analyzing and optimizing the hedging policy, but also to the currency risk model.

2.5 Preconditions and boundary lines

It is absolutely important to have a clear view on the preconditions and boundary lines of the assignment. First of all, by defining the preconditions the chance to spend time on possible problem solutions that are not accepted is restricted. Secondly, by stating the boundary lines the complexity of the assignment is limited and side issues can be left out of the scope of the analysis and design phases.

2.5.1 Preconditions

The first and most important precondition is the fact that hedging may only be used to minimize currency risk and not to speculate. Philips does absolutely not allow its BUs to hedge based on speculation because the risk of losing money due to speculation is not acceptable.

The second precondition is the fact that the hedging policy should be in compliance with FAS 133. FAS 133 (Statement 133 or SFAS 133) establishes accounting and reporting standards for derivative instruments, including certain derivative instruments embedded in other contracts and for hedging activities. Every company quoted on the NYSE is obliged to follow up the regulations stated in FAS 133. For example, FAS 133 does not allow netting of incoming and outgoing flows in the same currency in the same period. Incoming and outgoing exposures should therefore be assessed separately.

Finally, the hedging policy of the business group Automotive and Special Lighting is a guideline for the UHP hedging policy, which does not mean that this policy cannot be changed. Namely, if proposals to change the policy are made with a good foundation, the product division management within Philips might approve these.

2.5.2 Boundary lines

To mark out the assignment, these boundary lines are made:

- Management of interest risks is not considered. Attention is only paid to the management of currency risks due to the following reasons:
  - With regard to currency risk management a point of interest is the interest difference between currencies, in contrary to interest risk management, which is about interest fluctuations of an individual currency. Individual currency interest risks are related to financing and financing takes place centrally within Royal Philips Electronics. This means that only interest differences between currencies are important and considered in this thesis.
  - Besides that, most financial derivatives to hedge interest risks can be used to hedge currency risks as well.

- Only hedging of incoming and outgoing cash flows is taken into account. Hedging of assets and liabilities is not considered.

- It is the sales and purchases that are being hedged. There are possibilities of hedging market share or profit instead of the sales and purchases, but these are not considered.

- Roughly said the currency result consists of two components:
  - The results on hedging contracts (hedging results)
  - The balance sheet revaluation: payable/receivable positions related to the sales/purchases transactions

  The balance sheet revaluation involves complicated SAP entries. These are not straightforward and an analysis is needed in order to fully understand them. It is decided to leave the balance sheet

revaluation out of the scope of the analysis because it does not affect the hedging results. Therefore it is not directly related to the optimization of the hedging policy.

- The only transactional hedging instruments that will be analyzed are forwards and options. Swaps are not used within PLT and will not be considered in the further analysis.

- The possible improvement of the 15-months hedging horizon will not be analyzed.

2.6 Project strategy

In order to have a scientifically justified project strategy, according to [7] the following four phases are followed during the project:

- Orientation
- Analysis
- Design
- Reporting

These phases are graphically represented in figure 2.6, including the most important project deliverables.

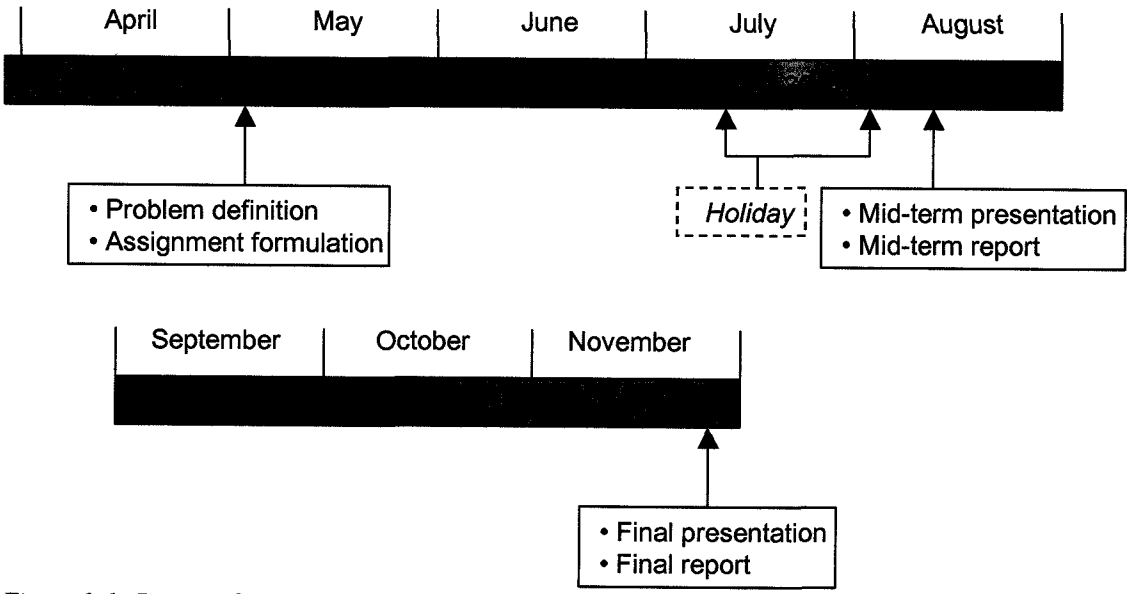


Figure 2.6 Project planning with deliverables

Table 2.1 summarizes the activities needed in order to fulfill the graduation assignment, in compliance with the four phases mentioned above. It should be mentioned that this is a rough planning because most phases overlap and some of them take more time than expected.

Table 2.1 Project activities

	Phase	Activities
	Orientation	➢ Get familiar with the company (market, products, processes, etc.) ➢ Get familiar with hedging (definitions, techniques, policy, contracts, documentation, results) ➢ Analyze and describe the current situation related to hedging ➢ Define the problem and formulate the assignment ➢ Literature research related to currency risk management techniques
	Analysis	➢ Analyze the current hedging policy ➢ Setup of a standard hedging work method

	➢ Literature research related to currency risk modeling ➢ Analyze the sensitivity of Philips' sales prices to currency rate fluctuations ➢ Setup of a currency risk model ➢ Analyze the influence of the sales forecast accuracy on the optimal hedging policy ➢ Analyze the influence of FX market uncertainties on the optimal hedging policy ➢ Quantify the currency risk ➢ Continue literature research (FAS 133, currency risk modeling, etc.) ➢ Write the mid-term report ➢ Prepare the mid-term presentation
Holiday	
Design	➢ Improvement of the currency risk model ➢ Analyze the results of the model ➢ Based on these results: optimize the hedging policy with regard to risk and costs ➢ Execute a sensitivity analysis ➢ Recommendations about improving the current hedging policy ➢ Propose these recommendations to higher management ➢ If approved by higher management: implement the proposed improvements
Reporting	➢ Write the final report ➢ Prepare the final presentation

Chapter 3 Currency risk modeling

3.1 Modeling process

As mentioned before, economic exposures arise from the structure, currencies and geographical composition of commercial activities, production activities and purchasing activities of UHP compared to its competitors and the manner in which costs, prices and therefore profits respond to exchange rate movements.
All these aspects should be understood and analyzed in order to get a complete overview of the business and to be able to model the currency risk exposures.

Great amounts of time were spent on analyzing and trying to model all above-mentioned factors. Firstly a separate analysis was made to understand the effect of price fluctuations on economic and transaction exposures, by analyzing the relationship between market prices and currency rate fluctuations. This will be explained in section 3.6.

Secondly an analysis of the influence of the sales forecast accuracy and FX market fluctuations on both currency risk exposures and on the optimal hedging policy, is made. This part of the graduation assignment is vital. I went into a couple of different directions, each resulting in different models. After experimenting with them the first two models proved to be invalid because of some lacks and unreasonable assumptions underlying these models. Finally a valid model resulted, solving the invalidity of the previous two models. The final model, which is based on a Monte Carlo simulation, is an extension of the existing scientific literature.

The first two 'invalid' models will not be described in detail in the main text of this thesis, because they cannot be used to determine optimal hedging policies. However, subsections 3.5.1 and 3.5.2 will briefly discuss them in order to create a complete overview of the process I went through and the difficulties I met before realizing the final model. For the interested reader these two models are placed in the appendices 11 and 12. No conclusions are drawn because they would not be valid anyway, but the lacks of these models are highlighted. These lacks are important because they gave cause to improve the modeling process, by which the final model has been realized. The final model will be discussed in chapter 4.

3.2 Modeling context

In order to define a founded and valid currency risk management policy, one should be able to execute the following steps:

1. Quantify the various currency exposures
2. Aggregate all exposures to the same underlying parameter, even though they may come from different aspects of the business
3. Select the appropriate financial instruments and policy to offset the risk
4. Layout the anticipated performance of the various instruments as a function of the underlying and create a system for monitoring that performance

The first step, quantifying the various currency exposures, is basically forecasting the sales and purchases in foreign currency. Visualizing the sales forecast accuracy is extremely useful in this context because knowledge about historical forecast accuracies might influence future sales forecasts. Section 3.3 pays attention to this issue.

The second step is a boundary line that is used throughout the complete thesis, namely that the sales are the parameter based on which hedging is executed.

With regard to the third step: the possible financial instruments to offset the risk are forward and option contracts. No other instruments will be discussed as indicated in subsection 2.5.2. Two aspects are substantial in this context:

- The combination of forward and options contracts
- The total percentage of the forecasted exposure being hedged

These aspects are explained in subsections 3.2.1 and 3.2.2. Chapter 4 describes the final modeling and optimization of them. One will see that both aspects are combined into one model, while originally they were separately modeled.

Chapter 5 (section 5.1) pays attention to the fourth step, creating hedging performance indicators.

3.2.1 The combination of forward and option contracts

A couple of variables influence the optimal combination of forwards and options:

- The option premium: the lower the option premium, the more attractive it is to use options instead of forwards.
- The volatility of the FX market.
- The sales forecast accuracy: this is a quite complicated and important factor that will be explained in section 3.3.

These variables are successfully included in the Monte Carlo model in chapter 4.

3.2.2 The total percentage of the forecasted exposure to be hedged

Chapter 4, which amongst others analyzes the results of the Monte Carlo model, extensively pays attention to the issue of the total percentage of the exposure being hedged. A couple of variables influence the optimal percentage of the exposure to be hedged, amongst others the sales forecast accuracy, handled in section 3.3.

If a high percentage (for example more than 100%) of the forecasted exposure is hedged, a conflict with the restrictions of the FAS 133 regulations could arise easily. These regulations do not allow deferring results of hedge instruments if the amount of the hedge contract is not in line with the sales amount within a bandwidth of 80-125%.

The model presented in chapter 4 excellently shows the issues mentioned in the subsections 3.2.1 and 3.2.2.

3.3 Sales forecast accuracy and its effect on the optimal hedging policy

Hypothetically assume that UHP's sales in month *m+15* are with 100% certainty forecast able in month *m*. Like figure 2.2 shows, in this situation hedging 100% of the exposure with forwards results in total currency risk reduction. There would be no doubt about the optimal hedging policy.

Unfortunately, the sales are not 100% predictable on a 15-months horizon. Now assume that in month *m*, UHP forecasts a $ 5Mio sale in month *m+15* and that UHP hedges this exposure for 100% using forwards. Assume that the realized sales in month *m+15* turn out to be only $ 3Mio. However, UHP has the obligation to deliver $ 5Mio according the forward contract. If the €/$ rate is very high in month *m+15*, UHP loses money on its forward contract. Regarding $ 3Mio this is no problem because

gaining money on its realized sales compensates this. But regarding the other $ 2Mio the loss on the forward contract is NOT compensated by a gain on its realized sales.

So it seems to be logical that in this situation UHP hedges a part of its exposure with option contracts instead of forward contracts because they give UHP the right, instead of the obligation, to exercise them. As said before, option contracts only protect the downward risk of exchange rate movements. This means that, though the obligation to pay an option premium, one can benefit from an exchange rate movement in one's advantage. And on the other side, if the exchange rate moves in an unfavorable direction, one does not have the obligation to buy or sell the underlying value (sales). Therefore option contracts are preferable to forward contracts in case of a very unstable underlying value.

Besides that, as will become clear in chapter 4, the total amount to be hedged depends on the sales forecast accuracy as well.

The two above-described situations proof that an imperfect sales forecast accuracy has an influence on the optimal hedging policy. Namely, it would be optimal to use, besides forward contracts, option contracts as well. This also means that the optimal hedging policy for $ sales may differ from the optimal ¥ sales hedging policy, amongst others due to differences in sales forecast accuracy of the $ and ¥ sales.

After having mentioned the sales forecast accuracy throughout this whole chapter, it is useful to display it for the BU UHP. Because hedging takes place quarterly the hedging horizon is 13, 14 and 15 months, leading to an average horizon of 14 months. Table 3.1 shows the sales forecast accuracy from January '02 until September '03, with the average sales forecast made 14 months before the actual sales take place.

Table 3.1 Sales forecast accuracy

	Realized $ sales	Forecasted $ sales	Deviation	Absolute deviation	Realized ¥ sales	Forecasted ¥ sales	Deviation	Absolute deviation
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	292.419.560	422.887.772	109%	109%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	362.850.350	422.887.772	17%	17%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	335.434.980	422.887.772	26%	26%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	436.881.400	533.034.714	22%	22%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	342.577.750	533.034.714	56%	56%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	563.914.941	587.905.986	4%	4%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	417.942.500	548.862.096	31%	31%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	451.168.350	460.515.460	2%	2%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	682.794.700	546.862.096	-20%	20%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	561.659.021	639.627.552	14%	14%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	597.990.305	639.627.552	7%	7%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	482.630.958	639.627.552	33%	33%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	530.209.936	601.249.900	13%	13%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	388.956.141	601.249.900	55%	55%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	303.268.200	601.249.900	98%	98%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	525.180.840	525.000.000	0%	0%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	331.840.357	525.000.000	58%	58%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	384.868.989	525.000.000	36%	36%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	369.900.744	525.000.000	42%	42%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	274.053.731	525.000.000	92%	92%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	327.005.521	525.000.000	61%	61%
Average	4.314.774	3.130.556		25%	422.481.345	540.452.889		38%
SD	2.042.595	884.073		14%	120.285.608	67.943.761		32%

The average absolute deviation of the sales forecast accuracy of the $ sales is 25%, while for the ¥ this is 38%, which means that sales are difficult to forecast accurately on a 14-months time horizon.

In one way or another one would like to include the following variables into a model:

- Sales forecast accuracy
- Volatility of the FX market
- Option premium
- Percentage of forwards and options in the hedging policy

Section 3.5 discusses the two 'invalid models' that included the variables mentioned above, but not in a valid way. The next chapter shows the successful and valid Monte Carlo model.

3.4 Scientific literature

With regard to literature research especially the modeling part of the assignment has been hard. About currency risk management in general, different types of currency risk and currency risk management techniques, plenty of literature is written and the basics have hardly changed in recent years. On the other hand you would expect that, due to the enormous amounts of risk being carried when not hedging currency risks, a lot of literature is written about issues as the percentage of the forecasted exposure to be hedged and optimal hedging policies influenced by currency rate fluctuations, sales forecast accuracy and (FX) market situations. The opposite turns out to be true. Besides that, if some models may exist, these are probably developed for specific companies and not publicly available. This makes it difficult to use existing scientific knowledge for the modeling part of my assignment.

The above does not imply that no literature has been found. In contrary, besides articles in journals Corporate Treasury introduced me to several international banks, especially the Bank of America, familiar with currency risk management. They sent (links to) articles, but like said before most of them were not usable for the assignment.

3.5 Modeling in order to optimize the hedging policy

Like explained before, uncertain exposures can range from variable sales due to a fluctuating economy and/or due to variations caused by consumer behavior. Brown [8] investigates the foreign exchange risk management program of an industry-leading manufacturer of durable equipment with sales in more than 50 countries. This includes quantification of the exposure forecast errors and correlations between exposure forecast errors (or revisions) and changes in exchange rates. One of the challenges is not only to assess quantity risk and its relationship, if any, to market risk but more importantly to design an effective hedging program [9]. This is the goal of the modeling process.

Totally three models are developed in order to find the interrelationships between sales forecast accuracy, currency rate fluctuations and the optimal hedging policy, more specific the optimal combination of forwards and options. Two of these models proved to be quite invalid, and one is very valid. This one includes a Monte Carlo simulation. The next chapter is spent on this model, while the other two models are shortly discussed in this chapter. Further explanation of them can be found in the appendices.

3.5.1 First model

In order to be able to determine the influence of the sales forecast accuracy and FX market fluctuations on the optimal hedging policy, a model is set up.

First it is necessary to explain the meaning of an optimal hedging policy. An optimal hedging policy consists of the forward/option combination leading to the lowest risk under a specified set of variables.

Secondly the sales forecast accuracy should be defined. It is defined as the realized sales divided by the forecasted sales with a horizon of 15 months. In formula (1):

$$salesfc.ab. = (sales_{realized} / sales_{forecasted}) * 100\%$$

The sales forecast accuracy can be defined as ($sales_{forecasted}$ / $sales_{realized}$)*100% as well, but this turns out not to make a substantial difference in the results of the model.

Thirdly it is important to know more about the distribution of the sales forecast accuracy. Because there is no clear evidence supporting a specific distribution, the sales forecast accuracy is assumed to be normally distributed with a mean of 100% and a standard deviation being equal to the average absolute deviation of the realized sales from the forecasted sales (based on a 15-months horizon) over the last two years. Assuming the average forecast accuracy to be 100% is realistic because the direction of the deviation of the realized sales from the forecasted sales cannot be predicted.
A big advantage of this (model) is the fact that the risk of under- and over-hedging is evenly distributed and weighed.

Fourthly, including a currency rate fluctuation distribution in the model is realized as follows. Again, because there is no have clear evidence supporting a specific distribution, the currency rate fluctuation is assumed to be normally distributed with a mean of 0% and a standard deviation being equal to the average 15-months volatility over the last 5 years. Assuming the average currency rate fluctuation to be 0% is realistic because the direction of the fluctuation cannot be predicted. However, interest differences might be a reason to deviate from 0%, which is explained in chapter 4 (subsection 4.3.3)
The currency rate fluctuation is assumed to be independent of the sales forecast accuracy.

The model, which will be explained below, has the following additional assumptions:
- Maximal 100% of the forecasted exposure is allowed to be hedged. This means that the sum of the percentage of the forecasted exposure being hedged with forwards and the percentage of the forecasted exposure being hedged with options, should not exceed 100%.
- The only goal of hedging is to reduce risk and not to gain money. This means that options are not exercised if the exposure is already over-hedged with forwards, although exercising the options might provide a gain. The only goal is to reduce risk.

Further explanation of the model is the following:
- It is possible to exercise a part of the option instead of being obliged to exercise the full option. This is realized by reversing a part of the original option contract.
- Only At-the-Money put options with a lifetime of 15 months are used, as the hedging policy implies.
- The option premium depends on the volatility of the underlying currency pair.
- This draft paper is based on an example of a $ exposure, but exposures in each foreign currency can be analyzed with this model.

The variables in the model are:
1. Average currency rate fluctuation
2. Standard deviation currency rate fluctuation
3. Option premium percentage
4. Forecasted $ sales in $
5. Average sales forecast accuracy
6. Standard deviation of the sales forecast accuracy

By changing the sixth variable and leaving all other variables constant, the influence of the sales forecast accuracy on the optimal hedging policy can be analyzed.

The definition and results of the model are placed in appendix 11.

It is very important to know the lacks of the model, in order to be able to compare it with other models and to find points of improvement. The lacks are:

- The impossibility of including the full possible advantage of options under the set of assumptions in this model.
- The extremely sizeable calculation method in order to calculate VaR percentages for a specific set of input variables, due to the fact that two normal distributions have to be multiplied. This leads to inflexibility of the model.
- The discrete nature of both the currency rate fluctuation and foreign exchange market.

The Monte Carlo model presented in the next chapter overcomes all these lacks.

3.5.2 Second model

It should be noted that the model in this section uses the present value of this month's sales as a predictor of the sales in the next month. This is totally different from the hedging policy that is currently used within PLT, namely hedging based on a 15-months forecast. Therefore, this model cannot be used yet, but the challenge is to change the model in a way that historical data, based on a 15-months forecast, can be used to determine the optimal hedging policy. This might be a challenge for further research.
Please refer to appendix 12 to read about this model.

The model presented in the next chapter overcomes the lack of this model.

3.6 Effect of price fluctuations on economic and transaction exposures

Like mentioned in section 3.1, this section pays attention to the effect of price fluctuations on economic and transaction exposures, by analyzing the relationship between market prices and currency rate fluctuations.
For example, it might be true that €/$ rate fluctuations have a bigger influence on the total exposure in € than €/¥ rate fluctuations have, or the opposite. This would imply that the optimal hedging policy for $ sales might be different from the optimal ¥ sales hedging policy.

It should be said that this is a separate analysis not to be combined with the results of the other models. Namely, the Monte Carlo model in the next chapter indirectly includes all factors/variables included in this model, like the market data and exchange rate fluctuations. But due to the insights given by the results of this analysis the model is explained shortly here and it is completely discussed in appendix 16.

The effect of price fluctuations on economic and transaction exposures is influenced by many factors:
1. Market prices
2. Market shares
3. Competitors
4. Suppliers
5. Customers
6. End customers
7. Exchange rate fluctuations

In fact the factors 1 up to and including 6 give a rough indication of a business's currency position. An overview of this position for the BU UHP is created in table 3.2.

Table 3.2 Rough indication of the UHP business currency position

Lamp			**Projector**				**Consumer**	
Price	*100*		*Price*	*1000*			*Price*	*1500*
Name	**Market share**	**Cost driver**	**Name**	**Market share**	**Cost driver / invoicing**			**Market share**
Philips	45%	EUR	Sony	10%	EUR	20%	USD	60%
Osram	11%	EUR			USD	20%	EUR	25%
Eye	14%	JPY			JPY	60%	JPY	15%
Ushio	15%	JPY	Epson	5%	JPY	80%		
Others	15%				USD	20%		
			Sanyo	16%	JPY	100%		
			Other Japanese	19%	JPY	100%		
			Infocus	24%	USD	100%		
			Philips	8%	EUR	100%		
			Taiwan	11%	USD	100%		
			Korea	7%	USD	100%		

3.6.1 Input data model

Trying to model the relationship between currency rate fluctuations and sales prices, a model is set up. I have tried to do this using the historical sales price and currency rates data, but this proved to be useless due to two reasons:

- It is impossible to separate €/$ and €/¥ rate fluctuation influences on the sales prices because historical sales prices are only available based on both a €/$ and €/¥ rate fluctuation.
- Currency-independent factors cannot be separated from the currency-dependent factors because historical data are only available based on both factors, so it impossible to determine the currency rate fluctuation influences.

Next I tried to analyze the relationship using the UHP sales manager's forecasts, being the input data for the model. It should be noted that the fact that only one person provided these data, is an absolute restriction of the model. But the reasoning behind the numbers is grounded and stems with the reasoning of others as well. The data are shown in table 3.3 and will be explained below.

Table 3.3 Forecasted price erosions

	A	B	C	D	E	F	G	H	I	J	K	L
1			Forecast									
2			$ +/- 0%				$ + 10%	$ - 10%	$ +/- 0%	$ +/- 0%	$ - 10%	$ + 10%
3			¥ +/- 0%				¥ +/- 0%	¥ +/- 0%	¥ + 10%	¥ - 10%	¥ - 10%	¥ + 10%
4	**Customer**	**Currency**	**Average Quarterly Price Erosion Q3 2003-Q4 2005**	**Customer Adjustment Percentage**	**Adjusted Quarterly Price Erosion**	**Adjusted Yearly Price Erosion**	**Adjusted Yearly Price Erosion**	**Adjusted Yearly Price Erosion**	**Adjusted Yearly Price Erosion**	**Adjusted Yearly Price Erosion**	**Adjusted Yearly Price Erosion**	**Adjusted Yearly Price Erosion**
5	Infocus	$	-4,1%	0,35%	-3,8%	-14,2%	-10,6%	-14,2%	-10,6%	-17,7%	-17,7%	-6,9%
6	Philips CDS	€	-4,7%	0,95%	-3,8%	-14,2%	-14,2%	-14,2%	-14,2%	-14,2%	-14,2%	-14,2%
7	Sanyo	¥	-2,8%	-0,95%	-3,8%	-14,2%	-10,6%	-19,4%	-22,8%	-10,6%	-15,8%	-19,1%
8	Sony	¥	-3,4%	-0,35%	-3,8%	-14,2%	-10,6%	-21,1%	-24,4%	-10,6%	-17,5%	-20,8%
9			**-3,8%**									
10	Infocus	€				-14,2%	-1,6%	-22,8%	-10,6%	-17,7%	-26,3%	2,0%
11	Philips CDS	€				-14,2%	-14,2%	-14,2%	-14,2%	-14,2%	-14,2%	-14,2%
12	Sanyo	€				-14,2%	-10,6%	-19,4%	-15,0%	-19,5%	-24,7%	-11,4%
13	Sony	€				-14,2%	-10,6%	-21,1%	-16,8%	-19,5%	-26,4%	-13,2%

The sales manager made well-founded estimations of the quarterly sales price erosion from the third quarter (Q3) of 2003 until Q4 2005, for four customers of UHP (see table 3.2) which are representative for the UHP sales in $, € and ¥. Firstly, these quarterly price erosions are reported in the customer's invoicing currency and in case the €/$ and €/¥ rates do not fluctuate. These percentages are shown in cells C5 until C8.

Because the only interest is the currency rate fluctuation effect in these price erosions, the customer-dependent factor should be eliminated. In order to do this, the average of cells C5 until C8 is

calculated in cell C9. The difference between cells C5 until C8 and cell C9 is shown in cells D5 until D8, being the percentage by which customer-dependent factors can be eliminated. Using this percentage the adjusted quarterly price erosion is calculated (cells E5 until E8), followed by the yearly price erosion (cells F5 until F8). Besides the price erosion in the customers' invoicing currency, the price erosion in € is shown in cells F10 until F13. Due to stable €/$ and €/¥ rates, these percentages are the same.

Besides the price erosions in case of stable €/$ and €/¥ rates, I asked the sales manger to forecast the quarterly price erosion in case of a €/$ rise and fall of 10% and a €/¥ rise and fall of 10%. These percentages are adjusted by the customer adjustment percentages from cells D5 until D8 and translated into yearly price erosions. These scenarios are shown in columns G until J, both in the customers' invoicing currency as well as in €.
An assumption is that the customer adjustment percentages are fixed percentages, being used for all scenarios.

Finally columns K and L show the price erosions if both the €/$ and €/¥ rates rise and fall 10%. An important assumption here is that if both the €/$ and €/¥ rates rise 10%, the price erosion is the added effect of the separate effects of a 10% €/$ and €/¥ rate increase. In case of falling €/$ and €/¥ rates, the same reasoning holds.

Some comments should be made on the above:
- The data in table 3.3 are forecasts made by the sales manager. These will not be exact and accurate, but because UHP cannot get more accurate data and because UHP only wants to estimate directions and rough amounts of influences, these data are useful.
- The way in which the customer-dependent factor is calculated is just a hypothetical way, being an assumption of the model developed below.

3.6.2 Relationships

It might be helpful to explain the reasoning behind the data in table 3.3 in order to create a better understanding of the outcomes of the model that will be developed.

The percentages in column F represent the non-currency-dependent price erosion, namely the yearly price erosion in case of stable €/$ and €/¥ rates. Using the columns F until L it is tried to determine the influence of currency rate fluctuations on sales prices.

In fact two variables are responsible for the difference between the non-currency-dependent and the currency-dependent price erosion:
- UHP's competitors: which currency is their cost driver, who are their customers, etc
- UHP's sales: who are UHP's customers, in which currency are they invoiced, etc

These variables are graphically shown in figure 3.1 on the next page.

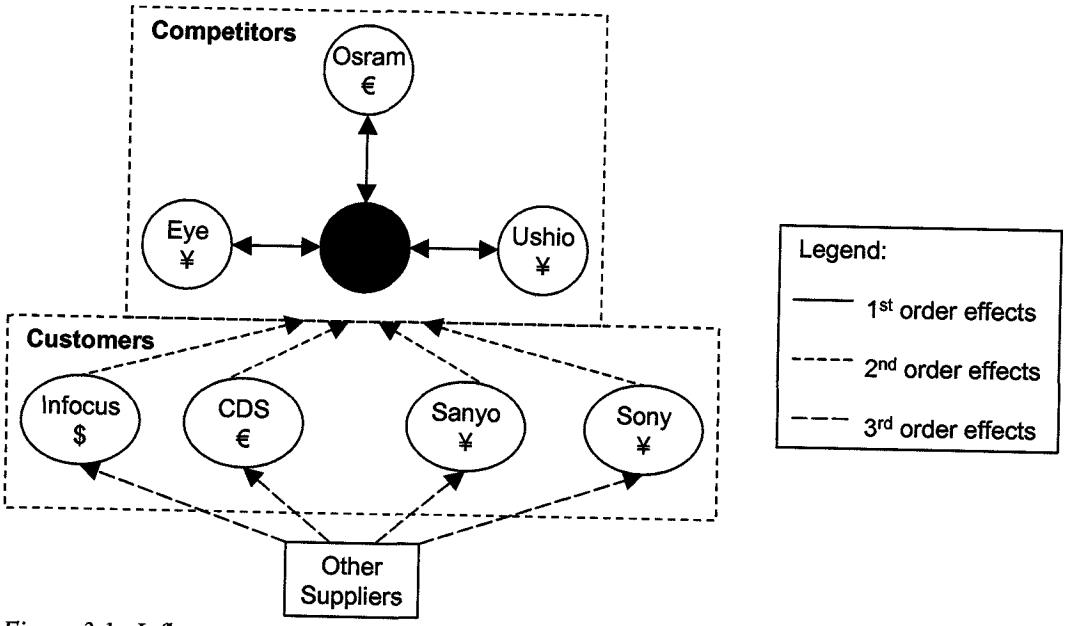


Figure 3.1 Influences on currency-dependent price erosion

The influences of these variables on the data in table 3.3 (and consequently on the model being developed) are explained in appendix 16, together with the modeling process.

3.6.3 Conclusions

From section 3.6.2 and the data in appendix 16 it can be concluded that €/$ rate fluctuations have a higher influence on UHP's $ customer sales prices than €/¥ rate fluctuations have.
For ¥ customers it can be said that €/$ rate fluctuations have approximately the same effect on their sales prices as €/¥ rate fluctuations have.

Linking the results of the model to the historical data proves to be extremely difficult. Historical sales prices show much smaller price erosions, especially for Infocus, Sanyo and Sony. With a yearly €/$ fall of 18,7% and a €/¥ fall of 7,4%, the price erosions according to the model would be much higher then in reality. For this reason it is extremely difficult to verify the model.

The goal of this thesis is to analyze and possibly improve the existing hedging policy. The next chapter presents the model on which the conclusions and recommendations of this thesis are based, the Monte Carlo simulation model.

Chapter 4 Monte Carlo simulation model

This chapter discusses a Monte Carlo simulation being used to model both the uncertainties in the sales and in the foreign exchange (FX) market. The model generates Value at Risk (95%) values for different hedging policies, based on which the optimal hedging policy (combination of forward and option contracts) can be found. This model overcomes the lacks and disadvantages of the models handled in chapter 3 and furthermore it is very valid and flexible.

Firstly some attention is paid to the definition of the Value at Risk. Secondly various ways how to measure the VaR will be explained. Monte Carlo simulation is one of them. Subsequently the Monte Carlo simulation model is described and the results are extensively analyzed by a sensitivity analysis.

4.1 Definition of Value at Risk

VaR is a statistical technique that combines sensitivity and probability analysis. It values market sensitive instruments under various scenarios and attaches a probability of incurring a loss [10]. In the model being explained below the VaR is used as the criterion to determine the effectiveness of different hedging scenarios. By examining the left tail of the distribution of outcomes for a certain hedging policy, one can get an estimation of the downside risk associated with that particular policy. In fact it is the risk of losing money in a particular policy with a defined confidence interval, which is set at 95%. Figure 4.1 [10] graphically shows the VaR(95%).

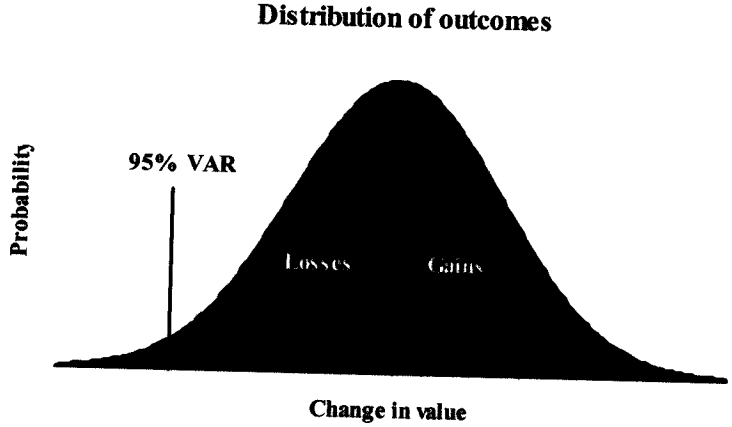


Figure 4.1 Distribution of outcomes [10]

The VaR percentage is calculated by generating the range of profit and loss values that results from the simulation. These are then ranked and the appropriate percentile, in this case the 5th, is selected. Now one can say that there is only a 5% chance that the cash flow will fall by more than x% over a defined time period. x% Represents the VaR(95%) percentage and in this analysis the time period is 15 months. The benefit of this approach is that by capturing the actual relationships between historical market prices, it can help to incorporate the changing correlations between market prices through time. The drawbacks of the approach are the need to hold a huge amount of historical data and its computer-intensive nature because a simulation must be performed each time VaR is calculated.

It is possible to look at VaR as a coefficient of proportionality to the underlying FX market, instead of a percentage. The VaR coefficient is calculated by dividing the VaR percentage by the volatility of the underlying FX market. The benefit of this approach is that the VaR coefficients presented can be applied to many different currency pairs simply by multiplying the coefficient by the FX market volatility. For example, if the implied 15-months volatility of a particular currency is 10,0% and the

VaR(95%) coefficient is –0,75, there is only a 5% chance that the cash flow will fall by more than 7,5% (10,0% * 0,75) over a 15-months period.

However, in this thesis only two currency pairs are handled. Therefore the VaR percentage, instead of the VaR coefficient, is set as the decision variable because it is easier to interpret. For example, a VaR(95%) of –7,5% means that there is only a 5% chance that the cash flow will fall by more than 7,5% over a 15-months period.
If one wants to calculate the chance how much the cash flow will fall over a 1-year period with a 95% confidence interval, this is calculated as follows: {7,5% * sqrt(12/15)} = 6,71%, because standard deviation is a statistical term assumed to increase with the square root of time.

4.2 Measurement of Value at Risk

There are three commonly used ways to measure VaR [3]:
- Covariance or correlation method
- Historical simulation
- Monte Carlo simulation

Whichever method is used, certain issues need to be resolved [3]:
- The time period over which the instrument is held. Within UHP this is the hedging horizon of 15 months.
- The confidence interval (the statistic probability that values will only fluctuate between designated bands). The confidence interval is set to 95%, which is a generally accepted and commonly used confidence interval.
- The length of the historical time horizon over which the data are observed. Because the historical time horizon regarding the BU UHP's sales data is quite short, it is determined that sales data partly based on the history, but on a future forecast as well, are more valid.

The most common VaR method used is the covariance or correlation method, which calculates VaR as a multiple of a portfolio's standard deviation. It uses historical volatilities to describe the uncertainty in future market prices. In order to measure risk, the method also describes, usually in terms of covariance, the relationship between these market prices. The covariance method, though, has a number of drawbacks. It assumes that market prices are log normally distributed and that combinations of prices have one fixed or linear relationship between them as expressed by the one set of correlation coefficients in the correlation matrix. Secondly, it is less effective for a portfolio including significant optionality or convexity. As a consequence of this, this method is less useful in UHP's situation. Its strength, however, is its simplicity and ease of calculation [3].

Where extensive use of options is made and exposure to theta (this is the rate of change of the option price to time) is high, then the covariance model is seriously inadequate. More banks are moving away from it towards using simulation models, either historical or Monte Carlo. The historical covariance method assumes that sensitivity of the option price to changes in the underlying remains static over the life of the option. However, this is clearly not the case. Historic simulation and Monte Carlo simulations are able to revalue portfolios using either historic or simulated market prices incorporating these sensitivities [3].

The historical simulation method uses the historically observed changes in market prices to simulate the VaR of a security or portfolio. The technique assumes that future market price changes are drawn from the same empirical distribution as the actual changes generated by the historical data. This addresses the weakness of the covariance approach: the assumption that there is one description for the distribution of market variables and one description for the relationships between them. In other words, the historical movements are applied to the current positions [3].

A Monte Carlo simulation randomly generates values for uncertain variables over and over to simulate a model [11]. In this situation it is a numeric probability approach to VaR. It generates a random distribution of market rate movements by approximating the market's price-generating process [3]. It is useful if there is no relevant historical time series available, like in UHP's situation. As a consequence of this, this simulation method is executed. Furthermore it can provide confidence intervals around the optimal hedge on the grid [10].

The next section describes the definition of Value at Risk.

4.3 The Monte Carlo simulation model

Like said in the introduction of this chapter, the Monte Carlo simulation model overcomes the lacks and disadvantages of previous models. Namely, contrary to the model explained in subsection 3.5.1 and appendix 11, it includes all possible advantages of options compared to forwards.
Furthermore it is a flexible model because all relevant variables can be changed in order to execute a (valid) sensitivity analysis of the results.
Moreover, using two random distributions, for the sales as well as for the currency rate fluctuation, solves the drawback that not enough (historical) data are used. This means that 'worst-case' scenarios, extremely low sales combined with a currency rate moving against you, are included in the model.
Another advantage compared to the models described in subsections 3.5.1 and 3.5.2 and appendices 11 and 12, is that the other models give one and only optimal solution for a specified set of input variables, while the Monte Carlo simulation model creates slightly different results every time a new simulation is ran, due to the random generation of data. The bigger the simulation, the more random draws, and the less variation on results arises. Once more this proofs the flexibility of the model, which matches the market situation.
Also the distribution of the sales and FX market is continuous instead of discrete and finally, the 15-months hedging horizon is incorporated.

The spreadsheet on the next page (table 4.1) shows the use of a Monte Carlo simulation to analyze the hedging of uncertain exposures. The spreadsheet uses two separate simulations, one representing the uncertainty in the sales and the other the uncertainty in the FX market. The simulation is executed based on 10.000 simulation runs to guarantee validity. Table 4.1 only displays 22 out of the 10.000 simulations.

The construction of the spreadsheet will be explained now.

4.3.1 Input variables

The yellow cells contain the input variables, the blue cells in the rows 11 up to and including 16 display the outputs of the Monte Carlo simulation and the rows from 19 onwards actually include the simulation. The input variables are:

- The mean of the standardized sales (cell C4)
- The standard deviation of the standardized sales (cell C5)
- The mean of the currency rate fluctuation (cell D4)
- The hedging horizon (in number of days) (cell H4)
- The 1-year volatility of the underlying currency pair (cell H5), which determines the standard deviation of the currency rate fluctuation (being the 15-months volatility specified in cell D5, which in fact is an input variable as well)
- The 15-months option premium percentage (cell H6)
- The hedge ratio, split up into:
  - The percentage of forwards in the hedging policy (I4)
  - The percentage of options in the hedging policy (J4)

Next the way in which these input variables are used in the simulation will be explained.

Table 4.1 Monte Carlo simulation spreadsheet

	A	B	C	D	E	F	G	H	I	J
1										
2		**Simulation parameters**					**Input**			
3			Normal Sales	Normal FX Returns					Hedge forward	Hedge option
4		Mean	1,00	0,00%			Days	457	0,50	0,50
5		Stdev	0,25				Implied vol	10,5%		
6							Option premium	4,5%		
7										
8										
9										
10										
11		Mean					Mean			
12		Stdev					Stdev			
13		Skewness					Skewness			
14		Kurtosis					Kurtosis			
15							VaR(95%)			
16							VaR(95%)/Stdev			
17										
18			Amount	Market				Forward & option	Unhedged	
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										

4.3.2 Simulation of the uncertainty in the sales

Column C simulates the uncertainty in the standardized sales. Because UHP does not have clear evidence supporting a specific distribution, it assumes the sales to be normally distributed. This normal distribution has a standardized mean (cell C4) and a specified standard deviation (cell C5), depending on the business characteristics (of the BU UHP).

The mean of the standardized sales is assumed to be 1,00. Actually this means that the average sales forecast accuracy is 100%, so in fact column C can be seen as the sales forecast accuracy. This is very reasonable, because if the mean of the standardized sales differs from 1,00 it would imply that the sales are structurally being under- or over-hedged. If this turns out, the new sales forecasts would be changed in order to try not to over- or under-hedge the future exposures. Sales forecasts are made based on the most recent market information, so in fact no better predictor is available. Because (a direction of) deviations cannot be forecasted, on average the sales forecast is assumed to be right and therefore the mean of the standardized sales is 1,00.
However, usually deviations from the sales forecast occur, but as mentioned in the previous paragraph, the direction cannot be predicted on forehand. Therefore the standard deviation of the sales is defined as this deviation. Because the historical time horizon regarding UHP's sales data is quite short, UHP

determined that these data are partly based on the historical data, but on a future forecast as well. Table 3.1 gives an indication of the standard deviation of the standardized sales. This number presents the average absolute deviation of the realized sales from the forecasted sales (based on a 15-months horizon) and for UHP the standard deviation of the standardized sales is set at 0,25 (see table 4.1).

Separately modeling the influence of the various market factors on the optimal hedging policy is useless due to two reasons. First of all, there are too many interdependencies between these factors which makes it extremely hard to model them correctly and secondly all these factors are included in the sales forecast.

An advantage of the definition of the sales (forecast accuracy) is the fact that historic sales trends are indirectly included in the model. Namely, historic trends are taken into account when sales are being forecasted. For your information, Appendix 17 shows both the $ and ¥ sales over the last 28 months. However, correlations between the future sales between month *m* and month *m+15* influence the realized sales in month *m+15* as well. This trend cannot be taken into account in the Monte Carlo simulation model because 10.000 random simulations are executed, instead of 10.000 successive months. Therefore, in the sales forecast only historical, and no future sales trends, are included. This might be a lack of the model.

The goal of the simulation is to generate a lot of data with a mean of 1,00 and a standard deviation of 0,25. It is decided to execute 10.000 independent simulation runs and therefore the 'normsinv(rand())' distribution is used. The 'normsinv' function returns the inverse of the standard normal cumulative distribution. This distribution has a mean of zero and a standard deviation of one. The 'rand' function returns an evenly distributed random number, greater than or equal to 0 and less than 1. This 'rand' function actually holds the simulation, namely it generates a new random draw each time by hitting 'F9' on the keyboard.
By multiplying the 'normsinv(rand())' function by the standard deviation of the standardized sales and subsequently adding the average of the standardized sales, a simulation scenario of the uncertainty of the sales, with a mean of 1,00 and a standard deviation of 0,25, is created.

The rows 11 up to and including 14 show the results of one simulation run of 10.000 random distributions.
Due to the large simulation run, one can see that both the mean and standard deviation of the standardized sales (cells C11 and C12) are around the specified input variables (cells C4 and C5).
The skew-ness of a distribution is a characterization of the degree of its asymmetry around its mean [18]. If the skew-ness deviates from zero this implies a crooked distribution. A perfectly normal distribution has a skew-ness of zero. The skew-ness proves to be around zero (cell C13). This fact, together with the fact that both the mean and standard deviation of the standardized sales are around the specified input variables, proofs that 10.000 simulation runs satisfy.
Cell C14 returns the kurtosis of the dataset, being around zero. Kurtosis characterizes the relative peaked-ness or flatness of a distribution compared with the normal distribution [18]. Positive kurtosis indicates a relatively peaked distribution. Negative kurtosis indicates a relatively flat distribution.

Together with simulating the uncertainty of the FX market, this simulation can be used to evaluate how well the hedged and un-hedged strategies perform.

4.3.3 Simulation of the uncertainty in the FX market

The uncertainty of the FX market (column D) is simulated in the same way as the uncertainty of the sales, also by using a 'normsinv(rand())' distribution, multiplying this by the 15 months volatility of the currency rate and then adding the average of the currency rate fluctuation over the specified time period.
The average currency rate fluctuation over the specified time period is 0% (cell D4). It is assumed that the FX market has zero drift and no interest differential. Note that the interest differential for each

currency pair is different and it is very easy to include this in the model, just by changing the average FX market fluctuation. However, this turns out not to make a substantial difference in the results of the model, so the mean is set at 0%.
The 15 months volatility of the currency rate (cell D5) is calculated by taking the square of (15 months /12 months), multiplied by the 1-year volatility, because standard deviation is a statistical term assumed to increase with the square root of time.

Both the mean and standard deviation of the simulation run (cells D11 and D12) are around its input values and the skew-ness and kurtosis of the results (cells D13 and D14) are around zero, again proving that 10.000 simulation runs are satisfying.

The columns H and I analyze the returns of a hedging policy specified by cells I4 and J4 (forwards and options), under the specified set of all input variables in the yellow cells. Both columns will be explained in the next subsection.

Note that the underlying exposure (sales) and the FX market are assumed to be independent of each other. This means there is no correlation between them.

4.3.4 Returns of different hedging policies

From row 19 onwards column H displays the returns for the in column C and D generated sales and FX market movement, as well as for specified volatility and option premium data, and in case of a forward/option combination given in the cells I4 and J4.

Cell H4 contains the number of days in 15 months. This is just a formula being used to calculate the standard deviation of the currency rate fluctuation, which is equal to the 15-months volatility. Cell H5 contains the 1-year volatility of the underlying currency pair. Cell H6 contains the option premium percentage for a 15 months vanilla option, being roughly 4,5% for the €/¥ currently. A vanilla option is a 'normal' option with no special or unusual features [12].

Column H calculates the returns of the 'un-hedged part – forward – option + option premium'. The return of the un-hedged part is calculated by multiplying the standardized sales by the FX market fluctuation. The return of the forward is the market fluctuation multiplied by the percentage hedged using forwards (cell I4). The return of the option includes a constraint, namely that the option will not be exercised if it implies a loss, so if the FX market moves upwards. If the option is not exercised the return equals 0, else the return equals the market fluctuation multiplied by the percentage hedged using options (cell J4). Finally the option premium equals the percentage hedged using options multiplied by the option premium percentage.

Column I calculates the returns if the exposure is not being hedged. The un-hedged situation multiplies two normal distributions, namely those of the standardized sales and the currency rate fluctuation.

Analyzing the results of both the hedged (50% forwards and 50% options) and un-hedged strategies in rows 11 up to and including 16, one can see that in both situations the mean return approximately equals zero (cells H11 and I11), which implies that overall the hedging policy does not incur no loss, as well as no gain. This is because of the facts that the mean of the standardized sales is 1,00, the mean of the FX market is zero and 100% of the exposure is being hedged in the hedge strategy.

The standard deviation of the returns of the hedged situation (H12) is much smaller than in the un-hedged situation (I12). This shows the use of hedging, namely that hedging of currency exposures leads to smaller variations in a company's returns compared to its budget.

Additionally, the standard deviation of a product of two normal distributions (in this case the un-hedged situation) equals:

$$\sigma_{unhedged} = \sigma^2_{st.sales} * \sigma^2_{market} + \mu^2_{st.sales} * \sigma^2_{market} + \mu^2_{market} * \sigma^2_{st.sales}$$

This formula proves to be right by comparing its results with cell I12.

Adding options in a hedging policy will increase the skew-ness because the symmetry around an average return of zero increases. Comparing cells H13 and I13 proves this.

Since the VaR(95%) is the decision variable, this is the most important number resulting from the Monte Carlo simulation.
As one can see, the VaR(95%) in the un-hedged situation equals –20,06% (cell I15). This means that there is only a 5% chance that the cash flow will fall by more than 20,06% over a 15-months period. On the other hand the spreadsheet shows that there is only a 5% chance that the cash flow will fall by more than 5,33% (cell H15) over a 15-months period if the exposure is hedged with 50% forwards and 50% options. This proves the risk reduction of the hedging policy. Graphically this risk reduction is shown in figure 4.2. The first bar shows the return if the exposure is hedged by 50% forwards and 50% options, while the second column displays the VaR(95%) if the exposure is left un-hedged.

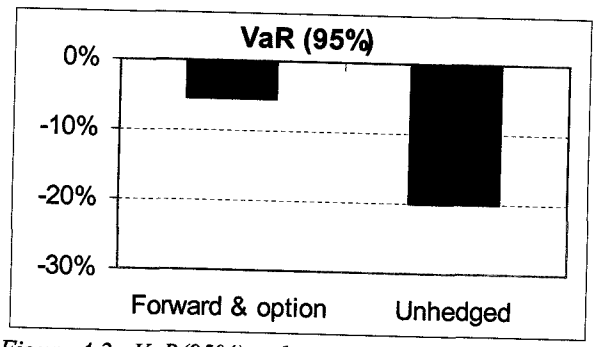


Figure 4.2 VaR(95%) reduction of hedging with 50% forwards and 50% options

Looking at the kurtosis of the returns in cells H14 and I14, one can see that the kurtosis of the hedged situation is 4,39, being only 0,78 in the un-hedged situation. This can be directly related to the VaR(95%), because the value of 4,39 implies that the distribution of the returns is much more peaked than the normal distribution. Therefore the VaR(95%) will be closer to zero because of the small tails of the distribution of the returns.

The VaR(95%)/SD coefficient has already been explained before. This represents the VaR(95%), independent of an underlying currency pair. However, because only two currency pairs are analyzed in this thesis, on no attention will be paid to this coefficient.

The above analysis is related to a hedging policy of 50% forwards and 50% options. The goal of this thesis is to determine the optimal combination of options and forwards. The next subsection pays attention to this.

4.3.5 Determining the optimal hedging policy

Finally, figure 4.3 on the next page shows the VaR(95%) for different forward / option combinations for the set of variables, specified on top of the table. The black numbers represent hedging policies in which the total percentage of the exposure hedged is smaller than or equal to 100%, while the gray numbers represent hedging policies in which the total percentage of the exposure hedged exceeds 100%.

The VaR(95%) when hedging with 50% forwards and 50% options is –5,2%, while table 4.1 showed –5,33%, although exactly the same input variables are used. The reason for this is that each number in

the grid above is based on another random distribution. Therefore it is decided to represent the VaR(95%) with an accuracy of one instead of two numbers behind the comma. Pasting 'values' instead of 'formulas' in the columns C and D can prevent the variation in results, but it is more realistic not to take 'values' because real-life is dynamic as well. This makes it hard to say that there is only one optimal solution.

Indicating a boundary with a specific confidence interval improves the validity of the results. The green cells in figure 4.3 contain the optimal VaR(95%) with a boundary of 5% upwards and downwards, under the restriction that the total percentage of the exposure being hedged is smaller or equal to 100%. The red cells do not hold that restriction, but have a confidence interval of 5% around the optimum as well.

Thoroughly analyzing the outcomes in figure 4.3, one notices that the optimal solution without the restriction of hedging maximally 100% of the exposure (hedge ratio exceeds 1), is to hedge using 70% forwards and 60% options. This results in the lowest VaR(95%), namely –3,5%, and it means that over-hedging the exposure leads to risk reduction. The next subsection pays attention to over-hedging.

Mean sales	1,00
SD sales	0,25
Volatitlity	10,5%
Option premium	4,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-20,0%	-18,3%	-16,9%	-15,7%	-14,7%	-13,2%	-12,1%	-10,6%	-9,6%	-8,4%	-7,6%
wards	10%	-18,4%	-16,9%	-15,7%	-13,9%	-12,8%	-11,3%	-10,3%	-8,9%	-7,8%	-7,0%	-6,4%
	20%	-16,3%	-15,0%	-13,7%	-12,3%	-10,9%	-9,8%	-8,5%	-7,4%	-6,7%	-5,9%	-5,2%
	30%	-14,4%	-13,1%	-12,1%	-10,3%	-9,2%	-8,1%	-7,2%	-6,2%	-5,3%	-4,9%	-4,6%
	40%	-12,6%	-11,6%	-10,0%	-8,5%	-7,7%	-6,6%	-5,6%	-5,1%	-4,4%	-4,2%	-4,4%
	50%	-10,8%	-9,6%	-8,5%	-7,5%	-6,3%	-5,2%	-4,5%	-4,0%	-3,9%	-4,0%	-4,4%
	60%	-9,1%	-7,9%	-6,8%	-5,9%	-5,2%	-4,2%	-3,8%			-4,0%	-4,4%
	70%	-7,8%	-6,2%	-5,5%	-4,8%	-4,0%				-3,8%	-4,2%	-4,6%
	80%	-6,0%	-5,3%		-4,0%	-3,7%		-3,8%	-4,1%	-4,5%	-4,9%	-5,4%
	90%	-5,0%		-4,2%	-4,1%	-4,1%	-4,2%	-4,5%	-5,1%	-5,3%	-5,8%	-6,3%
	100%		-4,3%	-4,4%	-4,7%	-5,0%	-5,5%	-5,6%	-6,3%	-6,8%	-7,2%	-7,5%
	110%	-5,2%	-5,3%	-5,4%	-6,0%	-6,2%	-6,7%	-7,2%	-7,7%	-8,1%	-8,5%	-8,9%
	120%	-6,1%	-6,5%	-6,8%	-7,3%	-7,6%	-7,9%	-8,5%	-9,0%	-9,6%	-10,2%	-10,2%
	130%	-7,5%	-8,1%	-8,5%	-8,8%	-9,4%	-9,7%	-10,1%	-10,8%	-11,2%	-11,6%	-11,9%

Figure 4.3 Grid of VaR(95%) outcomes

4.3.6 Hedging more than 100% of the exposure

From an accounting point of view it could be okay to hedge more than 100% of the forecasted exposure. This is assuming that the exposures you hedge are net exposures. Simply elect to hedge a slightly larger amount than the net number.

Economically it can also make sense to hedge more than 100%. In a VaR framework it has all to do with the 95% worst outcome of each alternative. For example, assume the series of exposures with an average of 1. For each exposure the final (realized) number could be 0,8 or it could be 1,2. If you only hedge 1 and you realize 1,2, this means that you will have an unlimited downside risk on the 0,2 that is left un-hedged. This should be compared to the loss that you could make on the hedge if the final exposure is only 0,8, which means that you are over-hedged by 0,2. The most you can lose in this case is the option premium on this amount. Due to the fact that the payout of an option is not symmetrical, you may find that the optimal hedge ratio is higher than 1.

In other words and graphically, the economic sense to hedge more than 100% can be explained as follows. Imagine that a cash flow can be divided in two parts, as shown in figure 4.4 [10]:

- Recurrent part

➢ Variable part

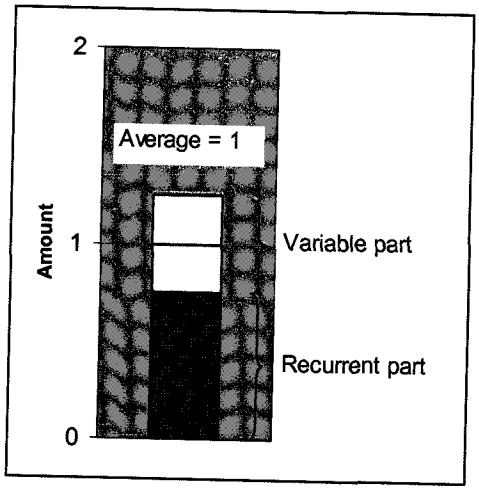


Figure 4.4 Hedging more than 100% of the exposure (this chart is purely for illustrative purposes and is not derived from any analysis) [10]

Forward contracts are the most suitable hedge for the recurrent part. However, options may be more suitable to deal with uncertain cash flows. Since the cash flow can be larger than the average (in this simulation the average equals 1,0), it may make economic sense to hedge an amount larger than the average, as long as the option premium paid to do so is less than what you stand to lose should you not hedge more than 100% of the exposure and the spot rate moves against you.

The above argumentations clarify why it is preferred, given UHP's sales forecast accuracy, to hedge up to 130% of the underlying exposure, being the sales. Unfortunately there is a very clear restriction from FAS 133, which states that the hedged amount should be in between 80% and 125% of the underlying sales, resulting in "effectiveness". Otherwise, in case of ineffectiveness, results on hedging contracts may not be deferred but should be taken into the profit & loss account (P&L) directly. Hedging more than 100% of the exposure will easily lead to ineffectiveness according to FAS 133, which means that one should directly take the results into the P&L. This leads to unpredictable and unacceptable shifts in the P&L on the short term because of currency rate fluctuations and sales forecast inaccuracies. Therefore the solution is found to split the exposure in two parts. The first part may consist of 50% forwards and 30% options, which will lead to effectiveness without many problems. The second part may consist of 30% options and in case of ineffectiveness the results on the second exposure can be taken into the P&L directly. This would only be the result on a 30% hedge instead of a 110% hedge, which leads to much smaller fluctuations in the P&L. However, both exposures are still related to the same underlying sales and it is not sure whether this is allowed according to FAS 133. Therefore another possibility is to always take the results on the second exposure into the P&L directly, instead of in case of ineffectiveness only. Then it is preferable to hedge the second exposure with forwards instead of options because otherwise the option premium will be taken into P&L each time, being a high initial amount. In this way the policy will be as follows: hedging the first part with 20% forwards and 30% options and hedging the second part with 30% forwards. Also about this issue additional checks with FAS 133 have to be executed.

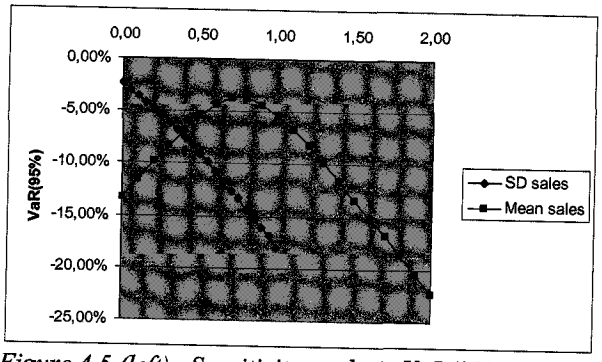
4.4 Sensitivity analysis

Like mentioned before, besides the hedging policy (percentage forwards and options), the four variables are:

1. Mean of the standardized sales
2. Standard deviation of the standardized sales
3. Volatility of the FX market
4. Option premium

4.4.1 First method

There are two methods to execute a sensitivity analysis based on the VaR(95%). In the first method, the combination of forwards and options is kept constant and the above variables are changed one by one.
Figures 4.5 and 4.6 show the results of this sensitivity analysis for the four variables mentioned above, assuming a hedging policy of 50% forwards and 50% options.



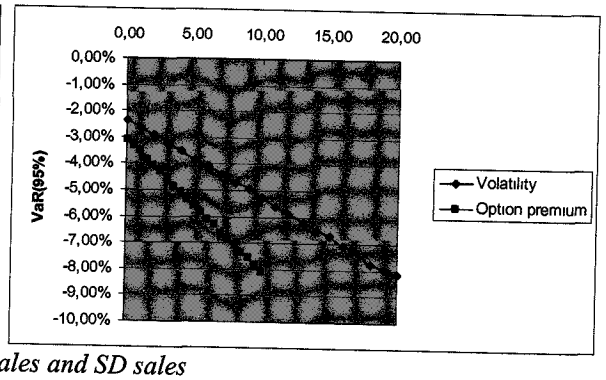


Figure 4.5 (left) Sensitivity analysis VaR(95%) mean sales and SD sales
Figure 4.6 (right) Sensitivity analysis VaR(95%) volatility and option premium

In figure 4.5, the graph of the standard deviation of the sales confirms the expectations, namely that the VaR(95%) increases if the standard deviation of the sales increases. This approximately proves to be a linear relationship on the considered section.
On the other hand one can see that the VaR(95%) is minimal if the mean of the standardized sales is around 0,75. This corresponds to the results in the previous section, namely that it is optimal to over-hedge an exposure. If the mean of the sales equals 0,75 instead of 1,00, the sales are structurally under-hedged with 25%.

In figure 4.6, both graphs confirm the expectations that the VaR increases if the volatility increases as well as if the option premium increases. Both relationships turn out to be approximately linear on the considered section.

4.4.2 Second method

The second method to execute a sensitivity analysis is by creating a table like in figure 4.3 and changing the value of the input variables one by one, while the others are kept constant. In this way the relation between the input variables and the optimal hedging policy is evaluated.

The three input variables that will be changed are the standard deviation of the sales, the volatility and the option premium, each of which will be handled in a separate subsection. The fourth variable, the mean of the sales, will not be changed because that would assume structurally under-/over-hedging of the exposure and it is assumed that this does not happen.

All figures in this section show both the optimal solution if maximal 100% of the exposure is being hedged (green), as well as the optimal solution if there is no restriction of the hedge ratio (red). All optimums are calculated with a confidence interval of 5%. For this reason more cells may be colored.

4.4.2.1 Standard deviation sales

Intuitively one would assume that if the standard deviation of the sales increases, which means that the sales forecast accuracy decreases, more options are used in the optimal hedging policy. Besides that, the optimal hedge ratio increases. Figures 4.7, 4.8 and 4.9 proof this.

Mean sales	1,00
SD sales	0,15
Volatitlity	10,5%
Option premium	4,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-19,6%	-18,2%	-16,9%	-15,0%	-14,0%	-12,4%	-10,9%	-9,8%	-8,5%	-7,3%	-6,3%
wards	10%	-17,3%	-16,1%	-14,5%	-13,6%	-12,0%	-10,6%	-9,1%	-8,0%	-6,8%	-5,9%	-5,1%
	20%	-15,6%	-14,1%	-12,9%	-11,3%	-10,0%	-8,7%	-7,7%	-6,3%	-5,4%	-4,7%	-4,5%
	30%	-13,7%	-12,4%	-11,3%	-9,6%	-8,3%	-7,0%	-5,8%	-4,9%	-4,3%	-4,0%	-4,3%
	40%	-12,0%	-10,4%	-9,3%	-7,9%	-7,0%	-5,6%	-4,5%	-3,8%	-3,6%	-3,9%	-4,2%
	50%	-10,1%	-8,9%	-7,3%	-6,2%	-4,9%	-4,1%	-3,4%	-3,1%	-3,4%	-3,8%	-4,2%
	60%	-8,2%	-7,0%	-5,9%	-4,6%	-3,6%	-2,9%	-2,7%	-3,0%	-3,4%	-3,8%	-4,2%
	70%	-6,5%	-5,3%	-4,0%	-3,2%	-2,4%	-2,3%	-2,6%	-3,0%	-3,4%	-3,9%	-4,3%
	80%	-4,7%	-3,8%	-2,8%	-2,2%	[redacted]	-2,3%	-2,7%	-3,1%	-3,6%	-4,0%	-4,5%
	90%	-3,5%	[redacted]	-2,3%	-2,3%	-2,5%	-2,9%	-3,4%	-3,8%	-4,2%	-4,7%	-5,1%
	100%	-2,8%	-2,7%	-2,8%	-3,2%	-3,6%	-4,2%	-4,4%	-5,1%	-5,5%	-5,9%	-6,4%
	110%	-3,6%	-3,8%	-4,2%	-4,7%	-5,0%	-5,4%	-6,0%	-6,4%	-7,0%	-7,4%	-7,8%
	120%	-4,9%	-5,2%	-5,8%	-6,2%	-6,6%	-7,1%	-7,7%	-8,0%	-8,6%	-9,0%	-9,5%
	130%	-6,5%	-7,0%	-7,4%	-8,0%	-8,6%	-8,6%	-9,4%	-9,7%	-10,1%	-10,4%	-11,1%

Figure 4.7 Sensitivity analysis standard deviation sales = 0,15

Mean sales	1,00
SD sales	0,25
Volatitlity	10,5%
Option premium	4,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-20,0%	-18,3%	-16,9%	-15,7%	-14,7%	-13,2%	-12,1%	-10,6%	-9,6%	-8,4%	-7,6%
wards	10%	-18,4%	-16,9%	-15,7%	-13,9%	-12,8%	-11,3%	-10,3%	-8,9%	-7,8%	-7,0%	-6,4%
	20%	-16,3%	-15,0%	-13,7%	-12,3%	-10,9%	-9,8%	-8,5%	-7,4%	-6,7%	-5,9%	-5,2%
	30%	-14,4%	-13,1%	-12,1%	-10,3%	-9,2%	-8,1%	-7,2%	-6,2%	-5,3%	-4,9%	-4,6%
	40%	-12,6%	-11,6%	-10,0%	-8,5%	-7,7%	-6,6%	-5,6%	-5,1%	-4,4%	-4,2%	-4,4%
	50%	-10,8%	-9,6%	-8,5%	-7,5%	-6,3%	-5,2%	-4,5%	-4,0%	-3,9%	-4,0%	-4,4%
	60%	-9,1%	-7,9%	-6,8%	-5,9%	-5,2%	-4,2%	-3,8%	[redacted]	[redacted]	-4,0%	-4,4%
	70%	-7,8%	-6,2%	-5,5%	-4,8%	-4,0%	[redacted]	[redacted]	[redacted]	-3,8%	-4,2%	-4,6%
	80%	-6,0%	-5,3%	[redacted]	-4,0%	-3,7%	[redacted]	-3,8%	-4,1%	-4,5%	-4,9%	-5,4%
	90%	-5,0%	[redacted]	-4,2%	-4,1%	-4,1%	-4,2%	-4,5%	-5,1%	-5,3%	-5,8%	-6,3%
	100%	[redacted]	-4,3%	-4,4%	-4,7%	-5,0%	-5,5%	-5,6%	-6,3%	-6,8%	-7,2%	-7,5%
	110%	-5,2%	-5,3%	-5,4%	-6,0%	-6,2%	-6,7%	-7,2%	-7,7%	-8,1%	-8,5%	-8,9%
	120%	-6,1%	-6,5%	-6,8%	-7,3%	-7,6%	-7,9%	-8,5%	-9,0%	-9,6%	-10,2%	-10,2%
	130%	-7,5%	-8,1%	-8,5%	-8,8%	-9,4%	-9,7%	-10,1%	-10,8%	-11,2%	-11,6%	-11,9%

Figure 4.8 Sensitivity analysis standard deviation sales = 0,25

Mean sales	1,00
SD sales	0,35
Volatitlity	10,5%
Option premium	4,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-20,6%	-19,4%	-17,9%	-16,7%	-14,7%	-14,4%	-12,7%	-11,8%	-10,9%	-9,6%	-8,8%
wards	10%	-18,6%	-17,3%	-16,3%	-14,9%	-13,5%	-12,5%	-11,4%	-10,4%	-9,2%	-8,3%	-7,4%
	20%	-16,5%	-15,9%	-14,4%	-13,3%	-12,4%	-11,5%	-9,9%	-9,0%	-8,0%	-7,1%	-6,6%
	30%	-15,6%	-13,9%	-12,5%	-11,4%	-10,4%	-9,5%	-8,3%	-7,6%	-6,9%	-5,9%	-5,5%
	40%	-13,1%	-12,4%	-11,1%	-9,8%	-9,0%	-7,8%	-7,3%	-6,2%	-5,7%	-5,2%	-5,0%
	50%	-11,7%	-10,8%	-9,8%	-8,4%	-7,7%	-6,8%	-6,0%	-5,3%	-5,1%	[redacted]	[redacted]
	60%	-10,4%	-8,8%	-8,3%	-7,4%	-6,5%	-5,8%	-5,3%	-5,1%	[redacted]	[redacted]	-5,1%
	70%	-9,0%	-7,5%	-7,3%	[redacted]	-5,7%	-5,4%	-5,1%	[redacted]	[redacted]	-5,1%	-5,6%
	80%	-7,7%	-7,0%	[redacted]	-5,6%	-5,5%	-5,1%	-5,3%	-5,5%	-5,6%	-6,0%	-6,8%
	90%	-6,7%	[redacted]	-5,9%	-5,7%	-5,6%	-5,8%	-6,0%	-6,4%	-6,6%	-7,1%	-7,7%
	100%	-6,7%	-6,2%	-6,1%	-6,2%	-6,4%	-6,6%	-7,0%	-7,3%	-8,0%	-8,1%	-8,8%
	110%	-6,9%	-6,8%	-6,9%	-7,1%	-7,6%	-7,8%	-8,6%	-8,8%	-9,1%	-9,7%	-9,8%
	120%	-7,6%	-7,7%	-8,1%	-8,5%	-9,0%	-9,6%	-9,9%	-10,0%	-10,7%	-10,7%	-11,7%
	130%	-8,8%	-9,0%	-9,6%	-9,9%	-10,5%	-10,9%	-11,3%	-11,7%	-12,3%	-12,4%	-13,4%

Figure 4.9 Sensitivity analysis standard deviation sales = 0,35

4.4.2.2 Volatility

The volatility and the option premium are two input variables being inputted in the model independently of each other. In fact they strongly depend on each other, namely the volatility is an important determinant of the option premium (see subsection 2.1.2.2.2 and appendix 9). However, both data are publicly available and therefore it is easy to manually input them to the model to prevent including a formula, which would make the model slightly more invalid.
Only realistic volatility / option premium combinations are considered. For example, a rising volatility leads to a higher option premium, which means that an extremely high volatility combined with a very low option premium will not be considered.

The higher the volatility of the foreign exchange market, the more options will be used in the optimal hedging policy and the VaR(95%) increases. Figures 4.10, 4.11 and 4.12 proof this.

Mean sales	1,00
SD sales	0,25
Volatitlity	9,5%
Option premium	4,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-17,8%	-16,9%	-15,2%	-14,6%	-13,4%	-12,1%	-11,1%	-10,0%	-9,1%	-8,1%	-7,2%
wards	10%	-16,4%	-15,1%	-14,0%	-12,8%	-12,0%	-10,4%	-9,5%	-8,5%	-7,6%	-6,8%	-6,1%
	20%	-14,8%	-13,5%	-12,4%	-11,0%	-9,9%	-9,2%	-8,1%	-7,3%	-6,3%	-5,6%	-5,2%
	30%	-13,2%	-11,9%	-10,9%	-9,7%	-8,5%	-7,6%	-6,6%	-6,0%	-5,3%	-4,8%	-4,6%
	40%	-11,6%	-10,3%	-9,2%	-8,2%	-7,2%	-6,4%	-5,4%	-4,7%	-4,4%	-4,2%	-4,4%
	50%	-10,0%	-8,6%	-7,9%	-6,8%	-5,9%	-4,9%	-4,3%	-4,0%	-3,8%	-4,0%	-4,4%
	60%	-8,4%	-7,3%	-6,2%	-5,5%	-4,5%	-4,0%	-3,7%		-3,6%	-4,0%	-4,4%
	70%	-6,9%	-6,1%	-4,9%	-4,3%	-3,7%				-3,8%	-4,1%	-4,6%
	80%	-5,4%	-4,8%		-3,6%			-3,7%	-4,0%	-4,4%	-4,8%	-5,3%
	90%	-4,6%		-3,8%	-3,6%	-3,8%	-4,2%	-4,4%	-4,8%	-5,3%	-5,7%	-6,0%
	100%		-4,1%	-4,0%	-4,3%	-4,7%	-5,1%	-5,4%	-5,9%	-6,5%	-6,7%	-7,4%
	110%	-4,5%	-4,8%	-5,1%	-5,3%	-5,6%	-6,3%	-6,6%	-7,3%	-7,6%	-8,0%	-8,5%
	120%	-5,5%	-5,6%	-6,3%	-6,9%	-7,1%	-7,6%	-8,1%	-8,4%	-9,1%	-9,5%	-9,8%
	130%	-6,9%	-7,3%	-7,6%	-8,2%	-8,8%	-9,2%	-9,5%	-9,8%	-10,5%	-10,9%	-11,5%

Figure 4.10 Sensitivity analysis volatility = 9,5%

Mean sales	1,00
SD sales	0,25
Volatitlity	10,5%
Option premium	4,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-20,0%	-18,3%	-16,9%	-15,7%	-14,7%	-13,2%	-12,1%	-10,6%	-9,6%	-8,4%	-7,6%
wards	10%	-18,4%	-16,9%	-15,7%	-13,9%	-12,8%	-11,3%	-10,3%	-8,9%	-7,8%	-7,0%	-6,4%
	20%	-16,3%	-15,0%	-13,7%	-12,3%	-10,9%	-9,8%	-8,5%	-7,4%	-6,7%	-5,9%	-5,2%
	30%	-14,4%	-13,1%	-12,1%	-10,3%	-9,2%	-8,1%	-7,2%	-6,2%	-5,3%	-4,9%	-4,6%
	40%	-12,6%	-11,6%	-10,0%	-8,5%	-7,7%	-6,6%	-5,6%	-5,1%	-4,4%	-4,2%	-4,4%
	50%	-10,8%	-9,6%	-8,5%	-7,5%	-6,3%	-5,2%	-4,5%	-4,0%	-3,9%	-4,0%	-4,4%
	60%	-9,1%	-7,9%	-6,8%	-5,9%	-5,2%	-4,2%	-3,8%			-4,0%	-4,4%
	70%	-7,8%	-6,2%	-5,5%	-4,8%	-4,0%				-3,8%	-4,2%	-4,6%
	80%	-6,0%	-5,3%		-4,0%	-3,7%		-3,8%	-4,1%	-4,5%	-4,9%	-5,4%
	90%	-5,0%		-4,2%	-4,1%	-4,1%	-4,2%	-4,5%	-5,1%	-5,3%	-5,8%	-6,3%
	100%		-4,3%	-4,4%	-4,7%	-5,0%	-5,5%	-5,6%	-6,3%	-6,8%	-7,2%	-7,5%
	110%	-5,2%	-5,3%	-5,4%	-6,0%	-6,2%	-6,7%	-7,2%	-7,7%	-8,1%	-8,5%	-8,9%
	120%	-6,1%	-6,5%	-6,8%	-7,3%	-7,6%	-7,9%	-8,5%	-9,0%	-9,6%	-10,2%	-10,2%
	130%	-7,5%	-8,1%	-8,5%	-8,8%	-9,4%	-9,7%	-10,1%	-10,8%	-11,2%	-11,6%	-11,9%

Figure 4.11 Sensitivity analysis volatility = 10,5%

Mean sales	1,00
SD sales	0,25
Volatitlity	11,5%
Option premium	4,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-21,9%	-20,4%	-19,1%	-17,4%	-15,9%	-14,4%	-12,7%	-11,3%	-10,3%	-8,9%	-7,8%
wards	10%	-19,9%	-18,2%	-17,3%	-15,5%	-13,6%	-12,2%	-10,8%	-9,5%	-8,5%	-7,5%	-6,5%
	20%	-17,8%	-16,5%	-14,9%	-13,2%	-12,2%	-10,3%	-9,3%	-8,1%	-6,9%	-6,0%	-5,3%
	30%	-15,8%	-14,4%	-13,0%	-11,3%	-10,4%	-8,6%	-7,4%	-6,5%	-5,6%	-4,9%	-4,6%
	40%	-14,3%	-12,2%	-10,8%	-9,5%	-8,4%	-7,2%	-5,9%	-5,1%	-4,5%	-4,2%	-4,4%
	50%	-12,0%	-10,4%	-9,1%	-7,6%	-6,4%	-5,6%	-4,7%	-4,2%	-3,9%	-4,0%	-4,4%
	60%	-9,4%	-8,7%	-7,2%	-6,0%	-5,3%	-4,4%	-3,9%			-4,0%	-4,4%
	70%	-8,4%	-7,0%	-5,9%		-4,2%	-3,8%			-3,8%	-4,2%	-4,6%
	80%	-6,9%	-5,8%		-4,1%	-4,0%		-3,9%	-4,1%	-4,3%	-4,9%	-5,4%
	90%	-5,4%		-4,1%	-4,3%	-4,2%	-4,5%	-4,6%	-5,1%	-5,7%	-6,0%	-6,5%
	100%	-5,1%	-4,9%	-4,7%	-5,0%	-5,1%	-5,7%	-6,2%	-6,6%	-6,9%	-7,3%	-7,9%
	110%	-5,5%	-5,6%	-5,8%	-6,2%	-6,7%	-7,4%	-7,4%	-8,1%	-8,4%	-8,9%	-9,4%
	120%	-6,8%	-7,1%	-7,7%	-7,9%	-8,2%	-8,9%	-9,3%	-9,6%	-10,3%	-10,7%	-11,2%
	130%	-8,3%	-8,7%	-8,9%	-9,5%	-9,9%	-10,6%	-10,9%	-11,5%	-12,0%	-12,2%	-12,8%

Figure 4.12 Sensitivity analysis volatility = 11,5%

4.4.2.3 Option premium

The third variable to be changed is the option premium. If the option premium increases, the amount of options in the optimal hedging policy logically decreases. This proofs to be true in figures 4.13 up to and including 4.15.

Mean sales	1,00
SD sales	0,25
Volatitlity	10,5%
Option premium	3,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-19,5%	-18,2%	-17,0%	-15,8%	-14,0%	-12,6%	-11,3%	-10,0%	-8,8%	-7,5%	-6,6%
wards	10%	-18,1%	-16,4%	-15,3%	-13,6%	-12,6%	-10,7%	-9,9%	-8,2%	-7,2%	-6,2%	-5,4%
	20%	-16,5%	-14,9%	-13,6%	-12,3%	-10,8%	-9,3%	-7,9%	-6,8%	-5,8%	-4,9%	-4,3%
	30%	-14,7%	-13,5%	-11,8%	-10,4%	-9,2%	-7,8%	-6,4%	-5,5%	-4,6%	-3,9%	-3,6%
	40%	-12,9%	-10,8%	-10,0%	-8,5%	-7,2%	-6,2%	-5,1%	-4,3%	-3,6%	-3,2%	-3,4%
	50%	-10,9%	-9,6%	-8,1%	-7,2%	-5,7%	-5,1%	-4,0%	-3,3%	-3,1%	-3,1%	-3,4%
	60%	-9,3%	-8,0%	-6,9%	-5,5%	-4,5%	-3,6%	-3,1%			-3,1%	-3,4%
	70%	-7,7%	-6,2%	-5,1%	-4,5%	-3,6%	-3,1%			-3,0%	-3,2%	-3,6%
	80%	-6,1%	-5,1%		-3,6%	-3,2%	-3,2%	-3,2%	-3,4%	-3,6%	-3,9%	-4,3%
	90%	-5,2%		-3,8%	-3,6%	-3,7%	-3,6%	-4,0%	-4,3%	-4,5%	-5,0%	-5,4%
	100%	-4,6%	-4,4%	-4,3%	-4,2%	-4,6%	-4,9%	-5,2%	-5,6%	-6,0%	-6,3%	-6,6%
	110%	-5,1%	-5,0%	-5,3%	-5,5%	-5,9%	-6,0%	-6,6%	-6,8%	-7,1%	-7,7%	-7,9%
	120%	-6,2%	-6,1%	-6,8%	-7,2%	-7,5%	-7,9%	-8,1%	-8,4%	-8,8%	-9,0%	-9,6%
	130%	-7,4%	-7,9%	-8,5%	-8,5%	-8,7%	-9,6%	-9,7%	-9,7%	-10,3%	-10,8%	-11,0%

Figure 4.13 Sensitivity analysis option premium = 3,5%

Mean sales	1,00
SD sales	0,25
Volatitlity	10,5%
Option premium	4,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-20,0%	-18,3%	-16,9%	-15,7%	-14,7%	-13,2%	-12,1%	-10,6%	-9,6%	-8,4%	-7,6%
wards	10%	-18,4%	-16,9%	-15,7%	-13,9%	-12,8%	-11,3%	-10,3%	-8,9%	-7,8%	-7,0%	-6,4%
	20%	-16,3%	-15,0%	-13,7%	-12,3%	-10,9%	-9,8%	-8,5%	-7,4%	-6,7%	-5,9%	-5,2%
	30%	-14,4%	-13,1%	-12,1%	-10,3%	-9,2%	-8,1%	-7,2%	-6,2%	-5,3%	-4,9%	-4,6%
	40%	-12,6%	-11,6%	-10,0%	-8,5%	-7,7%	-6,6%	-5,6%	-5,1%	-4,4%	-4,2%	-4,4%
	50%	-10,8%	-9,6%	-8,5%	-7,5%	-6,3%	-5,2%	-4,5%	-4,0%	-3,9%	-4,0%	-4,4%
	60%	-9,1%	-7,9%	-6,8%	-5,9%	-5,2%	-4,2%	-3,8%	[redacted]	[redacted]	-4,0%	-4,4%
	70%	-7,8%	-6,2%	-5,5%	-4,8%	-4,0%	[redacted]	[redacted]	[redacted]	-3,8%	-4,2%	-4,6%
	80%	-6,0%	-5,3%	[redacted]	-4,0%	-3,7%	[redacted]	-3,8%	-4,1%	-4,5%	-4,9%	-5,4%
	90%	-5,0%	[redacted]	-4,2%	-4,1%	-4,1%	-4,2%	-4,5%	-5,1%	-5,3%	-5,8%	-6,3%
	100%	[redacted]	-4,3%	-4,4%	-4,7%	-5,0%	-5,5%	-5,6%	-6,3%	-6,8%	-7,2%	-7,5%
	110%	-5,2%	-5,3%	-5,4%	-6,0%	-6,2%	-6,7%	-7,2%	-7,7%	-8,1%	-8,5%	-8,9%
	120%	-6,1%	-6,5%	-6,8%	-7,3%	-7,6%	-7,9%	-8,5%	-9,0%	-9,6%	-10,2%	-10,2%
	130%	-7,5%	-8,1%	-8,5%	-8,8%	-9,4%	-9,7%	-10,1%	-10,8%	-11,2%	-11,6%	-11,9%

Figure 4.14 Sensitivity analysis option premium = 4,5%

Mean sales	1,00
SD sales	0,25
Volatitlity	10,5%
Option premium	5,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-19,8%	-18,2%	-17,5%	-16,4%	-14,8%	-13,6%	-12,5%	-11,2%	-10,3%	-9,5%	-8,6%
wards	10%	-18,3%	-17,4%	-15,7%	-14,6%	-13,5%	-12,0%	-10,6%	-9,9%	-9,0%	-8,1%	-7,3%
	20%	-16,2%	-14,8%	-14,0%	-12,3%	-11,4%	-10,3%	-9,4%	-8,4%	-7,5%	-6,9%	-6,2%
	30%	-14,4%	-13,1%	-12,1%	-10,7%	-9,8%	-8,6%	-7,7%	-6,9%	-6,3%	-5,7%	-5,6%
	40%	-12,5%	-11,5%	-10,2%	-9,3%	-8,3%	-7,1%	-6,4%	-5,7%	-5,3%	-5,1%	-5,4%
	50%	-10,8%	-9,8%	-8,5%	-7,7%	-6,8%	-5,8%	-5,3%	-4,8%	-4,6%	-4,9%	-5,4%
	60%	-9,2%	-8,5%	-7,1%	-6,0%	-5,3%	-4,9%	-4,4%	-4,3%	-4,4%	-4,9%	-5,4%
	70%	-7,5%	-6,3%	-5,9%	-5,0%	-4,4%	-4,2%	[redacted]	-4,3%	-4,6%	-5,1%	-5,5%
	80%	-6,3%	-5,2%	-4,6%	-4,2%	[redacted]	[redacted]	-4,3%	-4,7%	-5,2%	-5,9%	-6,2%
	90%	-5,4%	[redacted]	-4,3%	-4,2%	-4,3%	-4,8%	-5,3%	-5,7%	-6,2%	-6,8%	-7,2%
	100%	-4,8%	-4,6%	-4,7%	-5,0%	-5,3%	-5,8%	-6,6%	-6,9%	-7,5%	-8,0%	-8,5%
	110%	-5,0%	-5,3%	-5,6%	-6,2%	-6,7%	-7,1%	-7,6%	-8,4%	-8,9%	-9,5%	-9,7%
	120%	-6,1%	-6,3%	-7,1%	-7,5%	-8,3%	-8,6%	-9,0%	-9,6%	-10,3%	-10,9%	-11,4%
	130%	-7,6%	-8,0%	-8,7%	-9,1%	-9,7%	-10,5%	-10,7%	-11,3%	-11,9%	-12,2%	-13,4%

Figure 4.15 Sensitivity analysis option premium = 5,5%

4.4.2.4 Worst-case analysis

Because the option premium depends on amongst others the volatility, some variables should be changed simultaneously in order to analyze the results of realistic worst-case scenarios. In the previous three subsections, the input variables were changed one by one, while the others were kept constant.

This leads to the following results. If the standard deviation of the sales, the volatility and the option premium are high, relatively more options will be used and the total optimal hedge ratio increases (figure 4.16). The situation to which the results are compared is the result under the current set of market and UHP business conditions, shown in figure 4.3.

Mean sales	1,00
SD sales	0,35
Volatitlity	12,5%
Option premium	5,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-25,0%	-22,4%	-21,9%	-20,1%	-18,5%	-16,2%	-15,7%	-14,5%	-12,5%	-11,9%	-10,6%
wards	10%	-21,8%	-20,8%	-19,4%	-17,6%	-16,4%	-14,4%	-13,4%	-12,3%	-11,1%	-10,1%	-9,0%
	20%	-20,5%	-18,9%	-16,8%	-15,7%	-14,5%	-12,9%	-11,8%	-10,5%	-9,5%	-8,6%	-7,8%
	30%	-18,2%	-16,7%	-15,4%	-13,6%	-12,2%	-11,2%	-10,1%	-8,8%	-8,0%	-7,6%	-6,9%
	40%	-15,9%	-14,7%	-13,1%	-12,1%	-10,6%	-9,7%	-8,6%	-7,9%	-6,9%	-6,5%	
	50%	-14,4%	-12,6%	-11,3%	-10,0%	-8,9%		-7,2%	-6,5%	-6,3%		
	60%	-12,2%	-10,8%	-9,9%	-8,8%		-7,0%	-6,5%				-6,2%
	70%	-10,7%	-9,4%	-8,3%		-7,0%	-6,5%	-6,2%		-6,3%	-6,5%	-6,9%
	80%	-9,0%	-8,2%		-6,9%	-6,5%	-6,5%	-6,3%	-6,6%	-6,9%	-7,3%	-7,7%
	90%	-8,6%		-7,0%	-7,1%	-6,7%	-6,9%	-7,1%	-7,4%	-7,8%	-8,6%	-9,2%
	100%		-7,3%	-7,7%	-7,7%	-7,5%	-8,0%	-8,7%	-9,1%	-9,9%	-10,2%	-10,3%
	110%	-8,7%	-8,2%	-8,4%	-8,8%	-9,1%	-9,7%	-9,9%	-10,5%	-11,1%	-11,8%	-11,9%
	120%	-9,2%	-9,5%	-9,7%	-10,0%	-10,8%	-11,5%	-11,6%	-12,8%	-12,8%	-13,5%	-14,3%
	130%	-10,9%	-10,8%	-11,3%	-11,7%	-13,0%	-12,7%	-13,8%	-13,7%	-14,8%	-15,4%	-15,5%

Figure 4.16 Sensitivity analysis sd sales = 0,35, volatility = 12,5%, option premium = 5,5%

If the standard deviation of the sales is low and both the volatility and the option premium are high, relatively fewer options will be used and the total hedge ratio decreases (figure 4.17).

Mean sales	1,00
SD sales	0,15
Volatitlity	12,5%
Option premium	5,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-23,0%	-22,1%	-20,0%	-17,9%	-16,7%	-14,8%	-13,0%	-11,8%	-10,3%	-8,8%	-7,6%
wards	10%	-20,7%	-19,4%	-17,5%	-16,0%	-14,5%	-13,0%	-11,2%	-9,7%	-8,3%	-7,0%	-6,2%
	20%	-19,0%	-16,8%	-15,3%	-13,9%	-12,1%	-10,6%	-8,7%	-7,8%	-6,4%	-5,8%	-5,5%
	30%	-16,2%	-14,8%	-13,1%	-11,7%	-10,0%	-8,5%	-7,3%	-6,0%	-5,2%	-4,9%	-5,3%
	40%	-14,4%	-12,3%	-11,2%	-9,5%	-8,0%	-6,6%	-5,4%	-4,7%	-4,4%	-4,7%	-5,1%
	50%	-12,0%	-10,4%	-8,8%	-7,3%	-6,2%	-4,9%	-4,2%	-3,8%	-4,2%	-4,7%	-5,1%
	60%	-9,8%	-8,5%	-6,9%	-5,4%	-4,3%	-3,6%	-3,3%	-3,7%	-4,1%	-4,6%	-5,2%
	70%	-7,8%	-6,3%	-4,9%	-3,8%	-3,0%	-2,8%	-3,2%	-3,7%	-4,2%	-4,7%	-5,3%
	80%	-5,8%	-4,5%	-3,4%	-2,7%		-2,8%	-3,3%	-3,8%	-4,4%	-4,9%	-5,5%
	90%	-4,3%			-2,7%	-3,0%	-3,6%	-4,0%	-4,6%	-5,2%	-5,7%	-6,3%
	100%		-3,0%	-3,4%	-3,8%	-4,5%	-5,0%	-5,5%	-6,0%	-6,6%	-7,1%	-7,6%
	110%	-4,2%	-4,5%	-4,9%	-5,7%	-6,2%	-6,8%	-7,3%	-7,6%	-8,4%	-8,8%	-9,4%
	120%	-5,8%	-6,3%	-6,7%	-7,3%	-7,9%	-8,5%	-9,2%	-9,6%	-10,1%	-10,8%	-11,3%
	130%	-7,7%	-8,3%	-8,7%	-9,3%	-10,0%	-10,4%	-11,1%	-11,8%	-12,1%	-12,9%	-13,2%

Figure 4.17 Sensitivity analysis sd sales = 0,15, volatility = 12,5%, option premium = 5,5%

If the standard deviation of the sales, the volatility and the option premium are low, relatively fewer options will be used and the total hedge ratio decreases (figure 4.18).

Mean sales	1,00
SD sales	0,15
Volatitlity	8,5%
Option premium	3,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-15,9%	-14,5%	-13,8%	-12,5%	-11,2%	-10,1%	-9,0%	-7,7%	-6,6%	-5,8%	-5,1%
wards	10%	-14,2%	-13,1%	-11,8%	-10,5%	-9,2%	-8,7%	-7,3%	-6,3%	-5,4%	-4,6%	-4,1%
	20%	-12,3%	-11,5%	-10,5%	-9,1%	-8,1%	-7,1%	-6,0%	-5,0%	-4,3%	-3,7%	-3,5%
	30%	-11,3%	-10,1%	-8,9%	-7,9%	-6,7%	-5,5%	-4,7%	-3,9%	-3,3%	-3,1%	-3,4%
	40%	-9,8%	-8,5%	-7,5%	-6,4%	-5,4%	-4,3%	-3,6%	-3,1%	-2,8%	-3,0%	-3,3%
	50%	-8,0%	-6,9%	-6,1%	-5,0%	-4,0%	-3,2%	-2,6%	-2,4%	-2,7%	-2,9%	-3,2%
	60%	-6,7%	-5,6%	-4,7%	-3,6%	-2,9%	-2,3%	-2,1%	-2,4%	-2,6%	-2,9%	-3,3%
	70%	-5,4%	-4,4%	-3,3%	-2,6%	-2,0%	-1,8%	-2,0%	-2,3%	-2,7%	-3,0%	-3,3%
	80%	-3,9%	-3,0%		-1,8%		-1,8%	-2,1%	-2,4%	-2,8%	-3,1%	-3,5%
	90%	-2,6%		-1,8%	-1,8%	-2,0%	-2,3%	-2,6%	-3,0%	-3,4%	-3,7%	-4,1%
	100%	-2,3%	-2,1%	-2,3%	-2,5%	-2,9%	-3,3%	-3,6%	-4,0%	-4,3%	-4,7%	-5,0%
	110%	-2,8%	-3,0%	-3,3%	-3,8%	-4,0%	-4,5%	-4,7%	-5,1%	-5,4%	-5,8%	-6,2%
	120%	-3,9%	-4,3%	-4,7%	-4,9%	-5,3%	-5,6%	-6,1%	-6,3%	-6,7%	-7,1%	-7,4%
	130%	-5,3%	-5,6%	-6,0%	-6,2%	-6,6%	-7,0%	-7,5%	-7,8%	-8,1%	-8,5%	-8,8%

Figure 4.18 Sensitivity analysis sd sales = 0,15, volatility = 8,5%, option premium = 3,5%

If the standard deviation of the sales is high and both the volatility and the option premium are low, more options will be used and the total hedge ratio increases (figure 4.19).

Mean sales	1,00
SD sales	0,35
Volatitlity	8,5%
Option premium	3,5%

		Options										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
For-	0%	-16,4%	-15,2%	-14,7%	-13,4%	-12,3%	-10,9%	-10,1%	-9,7%	-8,8%	-7,8%	-6,9%
wards	10%	-15,3%	-14,4%	-13,0%	-11,9%	-11,2%	-9,9%	-9,3%	-8,0%	-7,6%	-6,4%	-5,9%
	20%	-13,6%	-12,9%	-11,7%	-10,7%	-9,9%	-8,8%	-8,0%	-6,9%	-6,4%	-5,5%	-5,0%
	30%	-12,2%	-11,2%	-10,4%	-9,4%	-8,2%	-7,9%	-6,8%	-5,9%	-5,3%	-4,8%	-4,3%
	40%	-11,0%	-9,5%	-9,2%	-8,0%	-7,1%	-6,5%	-5,6%	-5,0%	-4,4%	-4,2%	
	50%	-9,6%	-8,6%	-7,7%	-7,1%	-6,4%	-5,4%	-4,7%	-4,5%	-4,0%		
	60%	-8,3%	-7,4%	-6,4%	-5,9%		-4,7%	-4,3%	-4,0%			-4,0%
	70%	-7,5%	-6,3%	-5,6%		-4,5%	-4,3%	-4,0%			-4,1%	-4,4%
	80%	-6,4%	-5,4%		-4,7%	-4,4%	-4,2%	-4,2%	-4,5%	-4,5%	-4,7%	-5,0%
	90%	-5,5%	-5,2%	-4,6%	-4,8%	-4,6%	-4,6%	-4,8%	-5,0%	-5,2%	-5,7%	-6,0%
	100%	-5,4%	-5,1%	-4,9%	-5,0%	-5,2%	-5,3%	-5,7%	-5,9%	-6,2%	-6,6%	-6,9%
	110%	-5,5%	-5,5%	-5,7%	-5,8%	-6,2%	-6,4%	-6,6%	-6,9%	-7,6%	-8,0%	-8,0%
	120%	-6,2%	-6,2%	-6,7%	-6,9%	-7,1%	-7,5%	-7,7%	-8,3%	-8,4%	-8,9%	-9,4%
	130%	-7,2%	-7,4%	-7,6%	-8,2%	-8,3%	-9,0%	-9,0%	-9,2%	-9,7%	-10,2%	-10,2%

Figure 4.19 Sensitivity analysis sd sales = 0,35, volatility = 8,5%, option premium = 3,5%

As one can see the standard deviation of the sales, in other words the sales forecast accuracy, is an extremely important variable in order to determine the optimal hedging policy.

4.5 Validity of the model

Due to the fact that only a few assumptions are underlying the model and that these assumptions are realistic, it is fair to say that the model is quite valid. However, some assumptions and limitations undermine the validity of the model:

- Both the sales forecast accuracy and the FX market are assumed to be normal distributed, which might not perfectly fit. Besides that, the correctness of these normal distributions is not proved.
- Future sales trends are not included in the model. The Monte Carlo model is not built to include these because 10.000 random simulations, instead of 10.000 successive months, are simulated. On the other hand, historic sales trends are included because they are (assumed to be) included in the sales forecast.

- The historic dataset in order to determine the standard deviation of the sales (forecast accuracy) is quite short. However, not only this dataset determines the standard deviation, but an estimation of the controller as well.

Chapter 5 Hedging: operational issues

Two operational issues that are strongly related to this graduation assignment are relevant to discuss in this chapter, because they are considered as valuable within PLT. These are the ways of performance measurement and how to forecast the hedging result.

5.1 Performance measurement

Towards both compliance with FAS 133 and KPMG Auditing, the hedging effectiveness should be measured both monthly and quarterly according to the FAS 133 standards. These measuring methods should be standardized throughout all PLT. The subsections 5.1.1 and 5.1.2 describes them.

On the other hand, PLT uses an internal performance measurement method, calculating the percentage of the currency result compensated by hedging. Subsection 5.1.3 explains this method and the aspects influencing it.

5.1.1 Monthly hedging effectiveness

This measurement method is quite straightforward, namely dividing the total realized sales and supplies in currency i (o_i) by the amount of the 100% committed forward sales contract in that currency i (n_i) in a specific month.

In formula:

$$E = (o_i / n_i) * 100\%$$

s.t.

$$i = 1....5(1 = eur, 2 = jpy, 3 = usd, 4 = gbp, 5 = chf)$$

In which:

E	hedging effectiveness
o_i	total outgoing flows (sales and supplies) in currency i
i	currency
n_i	amount of the 100% committed forward sales contract in currency i

Note that:

- Within PLT hedging only occurs for \$ (i=3) and ¥ (i=2) flows.
- The percentage will not exceed 100% because the hedging documentation states that "The first ... amount" of an exposure is being hedged. This is a trick approved by KPMG in order to be effective in case of under-hedging.

An example of this calculation is shown in appendix 18.

5.1.2 Quarterly hedging effectiveness

According to FAS 133 PLT not only requires a monthly effectiveness check, but a quarterly check as well in order to monitor the situation with regard to all outstanding anticipated exposures. In this way possible changes in these forecasted exposures can be followed up on a rolling basis, by concluding additional hedging contracts. For example, if nine months before expiration of the original exposure additional orders for the specific expiry month are acquired, the hedged amount should be adjusted. By quarterly monitoring and checking all outstanding anticipated exposures PLT meets this FAS 133 requirement. Appendix 19 shows a setup of the quarterly effectiveness check, which is currently used by all profit centers. It shows that an exposure update for the months September '03, October '03 and December '03 took place at the end of August '03.

5.1.3 Percentage of currency result compensated by hedging

Besides these measurements, PLT uses an internal performance indicator (PI) to judge hedging performance every month. This PI is the percentage of the currency result compensated by hedging (y) and is part of the Business Balanced Score Card (BBSC). y Is calculated by dividing the result on hedging contracts (x) by the potential EBIT (Earnings Before Income Tax) gain/loss due to currency effects (z) every month.
The result on hedging contracts is basically the settlement of forward and option contracts, minus the original option premium paid, plus the Fair Value of the cash flow hedges that hedge the term of payment by customers.
Forward contract settlements are calculated using appendix 20, option settlements by appendix 9 (exactly in the same way as option premiums are calculated because in fact an option settlement is a receipt of an option premium).

Appendix 21 displays the formula being used to calculate the results. An example of this PI for the BU UHP is shown in appendix 22, in which all underlying indicators are incorporated as well.

Actually the PI y exists of many aspects influencing its value, some of which have to be analyzed separately in order to be able to control and improve specific actions within the business. Namely, that is the goal of a BBSC.
Firstly, y can be subdivided into two different PIs, namely:

1. The settlements of hedging contracts versus the result due to currency rate differences between AOP (Annual Operations Plan or budget) and activity rates.
2. The balance sheet revaluation versus the Fair Value of cash flow hedges. Because the balance sheet revaluation is left out of the scope of this thesis (see subsection 2.5.2), no further attention will be paid to this PI.

There are a couple of issues influencing the value of the first PI, namely:

1. Different hedging policies exist amongst the profit centers. Therefore, for profit centers that only hedge 50% instead of 90% of its exposures, the PI is expected to be lower.

2. Sales and purchases forecast accuracy; as discussed extensively before, if the sales are not forecasted accurately, it might be possible that the percentage is much higher or lower due to currency rate fluctuations and differences in the forecasted and realized sales. The forecast accuracy should be separately analyzed for sales and purchases.

3. Sales in foreign currencies that are not being hedged. If these currencies have risen during the last 15 months, sales result in a gain compared to the budget. In this case, not hedging these exposures results in a relative gain, compared to hedging these exposures. If these currencies have fallen during the last 15 months, the opposite reasoning holds.

4. Purchases in currencies that are not being hedged. Hereby the opposite of the reasoning in the previous issue is applicable. If these currencies have risen during the last 15 months, purchases result in a loss compared to the budget. In this case, not hedging these exposures results in a relative loss, compared to hedging these exposures. If these currencies have fallen during the last 15 months, the opposite reasoning holds.

5. The difference between the contract settlement rate (the spot rate against which contracts are settled) and the activity rate (the rate against which invoices are charged). The activity rate in month *n* equals the balance sheet rate in month *n-1*. The higher the contract settlement rate, the more profitable the hedging contracts are, increasing the PI. The higher the activity rate, the less € will be received for future sales, which decreases the PI. Note that for purchases the opposite reasoning holds.

6. The difference between the budget (AOP) rate and the rate against which contracts are concluded. If the contract rate is higher than the AOP rate this implies a relative gain because PLT will eventually receive more money than budgeted. This means an increase of the PI. Again, for purchases the opposite reasoning holds.

The monthly value of the PI is influenced by a very important factor, that makes is more reasonable to take a look at the Year-To-Date (YTD) value of the PI. Namely, the settlement of hedging contracts includes results on sales hedging contracts expiring in month *n* as well as cash flow contracts expiring in month *n*, being rolled on sales hedges that expired in month *n-2*. This has a great influence on the monthly PI results, while this is greatly reduced when looking at the YTD percentage.

Besides that, cash flow hedges are 100% forward contracts, but you are not sure whether and/or when you will actually receive the cash flow. This difference is not measured because it is too complicated and the added value is small.

5.2 Forecasting the hedging result

Obviously, accurately forecasting the hedging result is an important aspect in the quarterly planning and yearly budgeting processes within PLT, because the hedging result takes up a big part of the total result (EBIT).

I have set up a file with all outstanding anticipated hedging contracts with its contract rates. Using these data the weighed average contract rates are calculated and then it is quite straightforward to calculate the Fair Value of all forward and option contracts. It is important to forecast the hedging result in the right way. This means that only the forecasted results on the sales hedging contracts should be calculated and NOT those on the cash flow hedging contracts because it is assumed that these Fair Values will be approximately outweighed by the balance sheet revaluation.
Adding these Fair Values minus the option premiums paid, results in the Net Fair Value of all hedging contracts. This is the most accurate forecast of the hedging result in the future because no better forecasted foreign currency rate data than the current rate is available.

Appendix 23 shows the Excel file that is used to execute this forecast.

This operational activity can be classified as action-research. It has no direct impact on the graduation assignment, but it is strongly related to hedging and besides that it strongly enhanced my insights in the ins and outs of currency risk management.

Chapter 6 Conclusions and recommendations

This chapter successively discusses the conclusions and recommendations of this thesis. Furthermore some aspects for possible further research are mentioned and attention is paid to the implementation of the results of this thesis.

6.1 Conclusions

Based on the previous chapters the final conclusions of this thesis are drawn. Especially the Monte Carlo model in chapter 4 contributed a lot to these conclusions:

- The current hedging policy within the Business Unit UHP states that 50% forward contracts and 40% option contracts should be used in order to hedge future sales exposures. As the results of the Monte Carlo simulation model show, the Value at Risk (95%) in this situation equals –6,3%. This means that there is a 5% chance that the cash flow will fall by more than 6,3% over a 15-months period.

- The results of the Monte Carlo simulation show that the optimal hedging policy for UHP, under the set of current market variables and conditions that fit to the UHP business, is to hedge using 70% forward and 60% option contracts in order to minimize the Value at Risk (95%). This leads to a VaR(95%) of –3,5%.

- Over-hedging proves to be risk reducing. This is a very interesting aspect that argues with existing literature and visions, which mainly states that over-hedging means speculating, which is absolutely forbidden within Philips. But the results of the Monte Carlo model are based on the VaR(95%), a decision variable indicating risk. This means that by minimizing the VaR(95%), one can determine a maximum loss, expressed in a percentage of the cash flow, with a certainty of 95%. This is not speculation, but minimizing risk and loss of cash flow.

- From an accounting point of view it could be okay to hedge more than 100% of the forecasted exposure. This is assuming that the exposures you hedge are net exposures. Simply elect to hedge a slightly larger amount than the net number.
  Economically it can also make sense to hedge more than 100%. In a VaR framework it has all to do with the 95% worst outcome of each alternative. For example, assume a series of exposures with an average of 1. For each exposure the final (realized) number could be 0,8 or it could be 1,2. If you only hedge 1 and you realize 1,2, this means that you will have unlimited downside risk on the 0,2 that is left un-hedged. This should be compared to the loss that you could make on the hedge if the final exposure is only 0,8, which means that you are over-hedged by 0,2. The most you can lose in the case is the option premium on this amount. Due to the fact that the payout of an option is not symmetrical, you may find that the optimal hedge ratio is higher than 1. This might lead to complications with regard to FAS 133. The recommendations in this summary discuss this issue.

- The first sensitivity analysis of the Monte Carlo model results showed the relationships between the input variables and the VaR(95%) under a specific hedging policy. Firstly, the VaR(95%) approximately increases linearly if the standard deviation of the sales increases. Secondly, the VaR(95%) is minimal if the mean of the standardized sales is around 0,75. This corresponds to the conclusion that it is optimal to over-hedge future sales exposures with about 30%. Thirdly, the VaR(95%) approximately increases linearly if the volatility increases, as well as if the option premium increases.

- The second sensitivity analysis of the Monte Carlo modeling results shows the relationships between the input variables and the optimal hedging policy. Firstly, if the standard deviation of the sales increases, which means that the sales forecast accuracy decreases, relatively more options should be used and the hedge ratio increases. Secondly, the higher the volatility of the foreign exchange market, the more options should be used in the optimal hedging policy. Finally, if the option premium increases, the amount of options in the optimal hedging policy decreases. The influence of the volatility of the FX market on the option premium is taken into account as well.

- Performance indicators, both towards KPMG and internally, were implemented successfully. The monthly effectiveness measurement realizes compliance with FAS 133 and KPMG. The quarterly effectiveness measurement not only realizes compliance with both FAS 133 and KPMG. Besides that, sales and purchases information based on the most recent forecast should be compared with the original hedges, which might result in a timely update of the exposure, leading to risk reduction.
  Thanks to the internal performance indicator described in subsection 5.1.3, a detailed analysis of the percentage of the currency result compensated by hedging is performed. The most important result hereof is the mapping of the sales forecast accuracy of the sales in each foreign currency.

- The format (see appendix 23) in order to forecast the hedging result by month has been implemented successfully. This format turns out to be a great assistance for the quarterly and yearly forecasting/budgeting processes.

6.2 Recommendations

Mainly based on the conclusions in the previous section the following recommendations are made:

- It is recommended to change the hedging policy of the BU UHP by increasing the hedged percentage of the forecasted sales exposure (currently 90%) in order to reduce foreign currency risks, based on the results of the Monte Carlo model. However, this may lead to complications with regard to FAS 133. Namely, if one wants to defer the results on hedging instruments, one should be in compliance with FAS 133, stating that the hedged amount should be in between 80% and 125% of the underlying sales, resulting in "effectiveness".
  Therefore the exposure might be split in two parts. The first part may consist of 50% forwards and 30% options, which will lead to effectiveness without many problems. The second part may consist of 30% options. In case of ineffectiveness the results on the second exposure can be taken into the profit and loss (P&L) account directly. So this would only be the result on a 30% hedge instead of a 110% hedge, which leads to much smaller fluctuations in the P&L than taking the result on the 110% hedge into the P&L directly. However, both exposures are still related to the same underlying sales and it is not sure whether this is allowed according to FAS 133.
  Therefore another possibility is to always take the results on the second exposure into the P&L directly, instead of only in case of ineffectiveness. Then it is preferable to hedge the second exposure with forwards instead of options because otherwise the option premium will be taken into P&L each time, being a high initial amount. In this way the policy will be as follows: hedging the first part with 20% forwards and 30% options and hedging the second part with 30% forwards. Also about this issue additional checks with FAS 133 have to be executed.
  Obviously the results of the model differ from business to business, amongst others due to differences between business' sales and purchases forecast accuracies. Due to the fact that this is a crucial variable in the Monte Carlo model, the optimal hedging policy can be calculated for each business.

- In order to hedge more than 100% of the exposure, extra checks related to compliance with FAS 133 need to be executed. These checks will be done in close cooperation with the KPMG auditors.

- Improving the sales forecast accuracy changes the optimal outcome from the Monte Carlo simulation from hedging 130% closer to 100%. The recommendation is therefore not only to increase the hedged percentage (currently 90%), but also to try to further improve the sales forecast accuracy, and by that to reduce the costs of hedging. In the 'perfect' situation this results in a hedge of 100% forwards at zero cost and zero risk.

- PLT should keep going on measuring the monthly and quarterly effectiveness and the percentage of the currency result compensated by hedging, indirectly leading to risk reduction and mapping of the sales forecast accuracy of the sales in foreign currencies. All these performance indicators have already been implemented successfully. Currently more and more Philips organizations contact PLT in order to get more knowledge about its hedging work method (see appendix 10) and both its monthly and quarterly effectiveness measurement.

- PLT should keep going on to use the format (see appendix 23) to forecast the monthly hedging result. This format has already been implemented successfully. It turns out to be a great assistance for the quarterly forecasting and yearly budgeting process. It might be possible to use this format throughout all Philips organizations hedging its foreign currency exposures.

6.3 Further research

Like mentioned before, hardly any scientific literature is written about issues as the level of the exposure to be hedged and optimal hedging policies influenced by currency rate fluctuations, sales forecast accuracy and market situations. I am sure about the fact that this thesis can be a base to fill these lacks in the existing scientific literature.

Some further research on the following aspects might happen:

- With regard to the second 'invalid' model, which uses the present value of this month's sales as a predictor of the sales in the next month, further research might be interesting. Namely, this model is totally different from the hedging policy currently used within PLT, namely hedging based on a 15-months forecast. However, it is questionable whether this is worth the effort because of the successfulness of the Monte Carlo model, which will be difficult to beat.

- Subsection 2.5.2 explains why the balance sheet revaluation was left out of the scope of this thesis. Further analysis of it, in order to reach full understanding, is useful. Another student did this analysis and the results were interesting. However, I will not discuss them here.

- Like said in subsection 2.5.2, the only transactional hedging instruments that have been analyzed in this thesis are forwards and options. Further research might be to analyze the possibilities to use other transactional hedging instruments, like swaps, as well.

- The possible improvement of the 15-months hedging horizon has not been analyzed, being an important possible future research aspect.

- The sales forecast accuracy is a very important aspect in this thesis. Splitting it up into a price and a volume forecast accuracy might be an issue to analyze as well.

- An analysis of a flexible hedging policy might be interesting, which means increasing the amount of forwards and decreasing the amount of options during as the expiry date of an exposure comes closer. The reason is that the sales forecast accuracy (slightly) increases as the expiry date of the exposure approaches, implying that forwards become more attractive than options.

- Analyzing the influence of currency rate fluctuations on the sales (forecast accuracy) is an interesting aspect for future research. This is left out of the scope of this thesis.

6.4 Implementation

The execution of this study has been a great opportunity to quantify, analyze and model the currency risks within the BU UHP in order to improve the hedging policy. The results of this thesis might be used to improve the hedging policy in 2004, not only for the BU UHP but also within a further range. However, in order to change a hedging policy, approval by product division management is needed. Therefore the contents, conclusions and recommendations of this thesis will be presented to higher management in the beginning of December 2003.

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[18] Microsoft Excel help function

Used abbreviations

AOP	Annual Operations Plan
BBSC	Business Balanced Score Card
BG	Business Group
BL	Business Line
BU	Business Unit
CCY	Currency
CHF	Swiss Franc
EBIT	Earnings Before Income Tax
EUR	Euro (€)
FX	foreign exchange
GBP	Great British Pound
GTD	Global Technology Development
HID	High-intensity gas-discharge
JPY	Japanese Yen (¥)
KPMG	Klynveld, Peat, Marwick and Goerdeler
LCD	Liquid Crystal Display
LED	Light-emitting diode
MECO	Metal components
Mio	Million
NYSE	New York Stock Exchange
P&L	Profit and loss account
PCLC	Philips Corporate Local Currency
PD	Product Division
PI	Performance Indicator
PLT	Philips Innovative Applications NV, division Lighting in Turnhout
Q	Quarter
R&D	Research & Development
SWOT	Strengths, Weaknesses, Opportunities and Threats
TC	Transaction Currency
UHP	Ultra High Power
USD	American Dollar ($)
VaR	Value at Risk
YTD	Year-To-Date

Vocabulary

Term	Definition
Anticipated transaction exposure	Exposure relating to identified transactions, which are not yet committed on any one of the terms pricing, volume and time of payment [5].
Committed transaction exposure	Exposures relating to transactions that are committed in terms of pricing, volumes and time of payment [5].
Contract rate	The rate/price at which the owner of a forward has to purchase or sell the underlying value of the forward contract.
Currency call option	The right to buy a particular currency at a specified price at a particular time in the future [13].
Currency forward contract	An agreement to buy or sell a specified currency amount at a specified price at a specified future date [6].
Currency future contract	Standardized currency forward contracts, traded on a market specialized in these instruments [3].
Currency option contract	The right to buy or sell a specified currency amount at a specified price at a specified future date [6].
Currency put option	The right to sell a particular currency at a specified price at a particular time in the future [13].
Currency swap	It is in essence a long-dated currency forward contract, involving the swapping of one currency for a comparable amount in another currency [3].
Economic exposure	This arises from the structure, currencies and geographical composition of commercial activities, production activities and purchasing activities of PLT compared to its competitors and the manner in which costs, prices and therefore profits respond to exchange rate movements [5].
Expiry date	- Of an option: the date after which an option is void. An option buyer must decide whether or not to exercise on or before this date. - Of a forward: the final settlement date of a futures or forward contract [14].
Fair value	The option/forward value computed by a probability-type valuation model [14].
Hedging	Currency risk management by identifying and quantifying the currency risk and then taking the opposite position in order to minimize the risk [4].
Hedging instrument	A contract, security, or other instrument that can partially or fully offset some type or element of risk [14].
Monte Carlo simulation	A simulation that randomly generates values for uncertain variables over and over to simulate a model [10].
Natural hedging technique	Natural hedging involves changing something within the business, or altering the financial structure of the business, such that the exposure is eliminated without actually needing to undertake further transactions [3].
Netting	Adding incoming and outgoing flows in the same currency in the same period [5].
Settlement	The process by which a trade is entered onto the books and records of all the parties to the transaction including brokers or dealers, a clearing house, and any other financial institution with a stake in the trade [14].
Spot rate	The current market rate [14].
Strike rate	The rate/price at which the owner of an option can purchase (call) or sell (put) the underlying value if the option is exercised [15].
Transaction exposure	This stems from the possibility of incurring future exchange gains or losses on transactions in currencies other than its own functional currency and will therefore have a direct cash effect [5].
Transactional hedging	Techniques, in order to undertake transactions that are designed to protect a

technique	particular exchange rate, are available from a number of sources, primarily the commercial banks but increasingly from financial futures and, sometimes, stock exchanges [3].
Translation exposure	This arises when the value of profits and losses, and assets and liabilities are translated from one currency to another [5].
Value at Risk	VaR is a statistical technique that combines sensitivity and probability analysis. It values market sensitive instruments under various scenarios and attaches a probability of incurring a loss [10]. In the model being explained below the VaR is used as the criterion to determine the effectiveness of different hedging scenarios. By examining the left tail of the distribution of outcomes for a certain hedging policy one can get an estimation of the downside risk associated with that particular policy. In fact it is the risk of losing money in a particular policy with a defined confidence interval.
Value date	The date on which parties to a financial instrument calculate and exchange payments to settle their respective obligations [14].
Vanilla option	A 'normal' option with no special or unusual features [12].
Volatility	A statistical measure of the tendency of a market price or yield to vary over time. Volatility, usually measured by the variance or annualized standard deviation of the price, rate, or return, is said to be high if the price, yield, or return typically changes dramatically in a short period of time. Volatility is one of the most important elements in evaluating an option, because it is usually the only valuation variable not known with certainty in advance. [16] The measure of the expected movement of the exchange rate predicted over the term of the option [13]. The standard deviation of daily percentage changes in the underlying exchange rate [17].
Kurtosis	It characterizes the relative peaked-ness or flatness of a distribution compared with the normal distribution [18].
Skew-ness	A characterization of the degree of asymmetry of a distribution around its mean [18].

Appendices

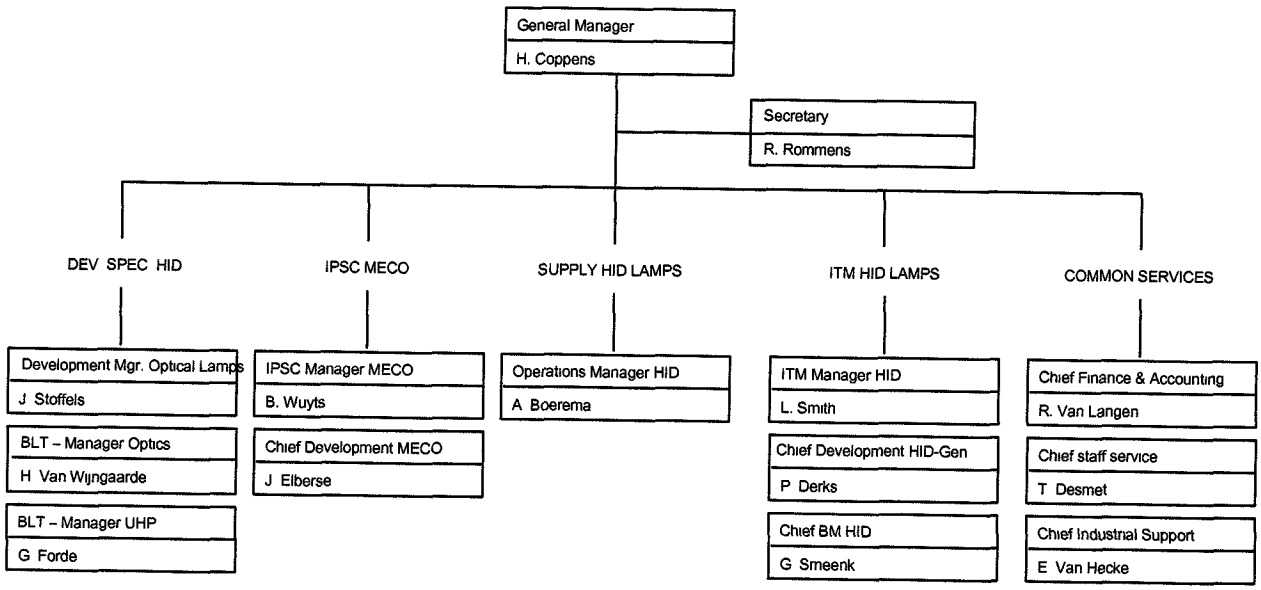
Appendix 1 Important market introductions of recent years

Important market introductions of recent years within the Philips Lighting division are:

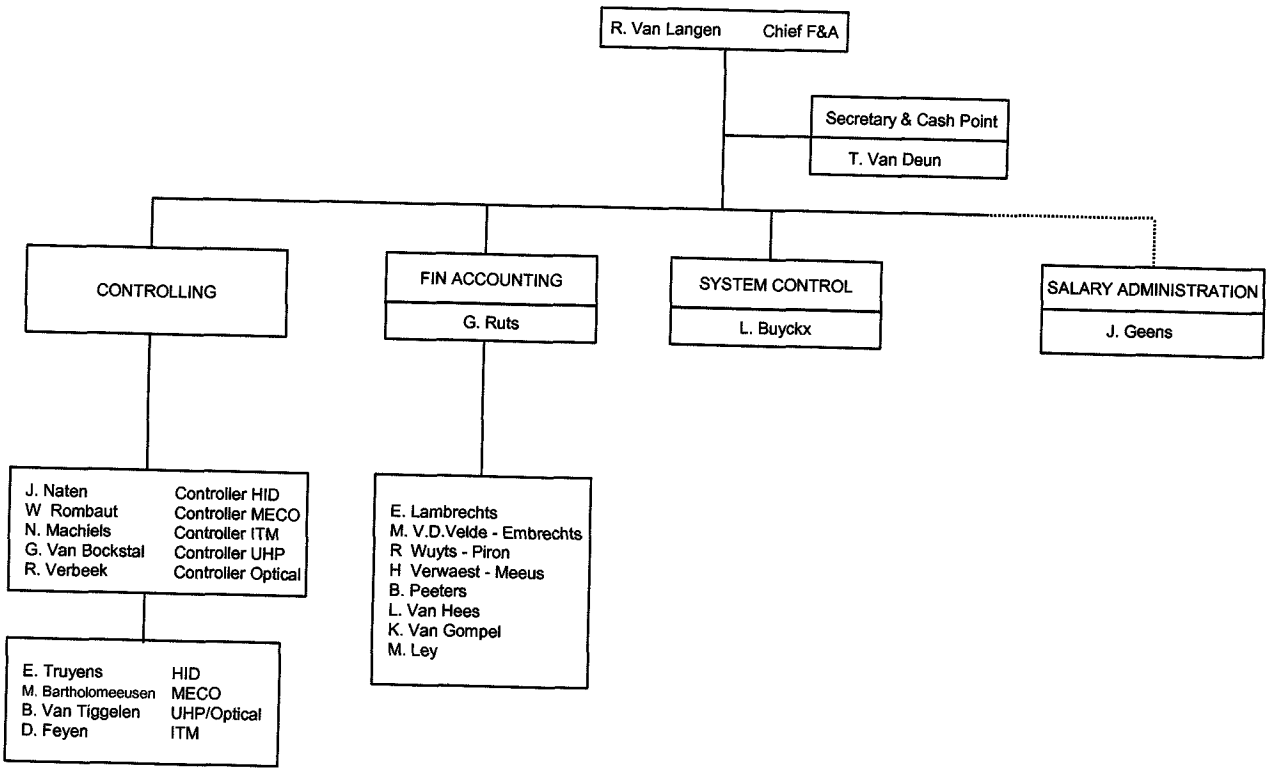
- Halogená offers consumers in the United States (U.S.) whiter light and a lifetime about three times longer than standard incandescent lamps; it introduces the added benefit of a two-year guarantee.
- The ALTO T8 fluorescent lamp, which contains the least mercury of all comparable lamps on the U.S. market while maintaining its superior performance, is being installed in all newly constructed WalMart stores in the U.S.
- Ecotone Ambiance, a compact, energy-saving lamp on the European consumer market, has the same shape and gives the same natural soft light as the Philips Softone.
- The CLEO Natural range of tanning lamps applying the latest scientific and medical knowledge in providing a sensible, effective tan in a soft and gentle way.
- MasterColour CITY extends to outdoor applications the excellent "white light" color properties and high efficacy of the existing MasterColour indoor range.
- Metronomis outdoor luminaires reflect a modern vision of architectural urban lighting, in which leading-edge technology is combined with a clear and elegant design.
- The TL5 office lighting system, consisting of the T5 small-diameter (16mm) fluorescent lamp along with efficient TL5 fixtures incorporating sophisticated lighting controls, provides high-quality lighting and minimizes energy demands.
- The UHP (Ultra High Power) lamp is currently the leading product in the market for digital data projection in beamers connected to PCs.
- Electronic ballasts for TL5 and PL-T/C lamp circuits (e.g. miniature HF-Matchbox), and electronic gear for operating HID lamps.
- The recently launched e-Kyoto electronic ballast weighs 58% less and uses 20% less energy than electromagnetic ballasts.
- VisionPlus lamps increase road safety by giving 50% more light on the road, a 10 to 20 meter longer beam and better reflections from roads and signs; Xenon automotive lamps give more than twice as much light as conventional halogen lamps while using only half of the energy.

The division's extension of its LumiLeds JV with Agilent Technologies in the field of LEDs (light-emitting diodes) strengthens its leading position in this field and underlines its confidence in this technology being applied to an increasing range of applications.

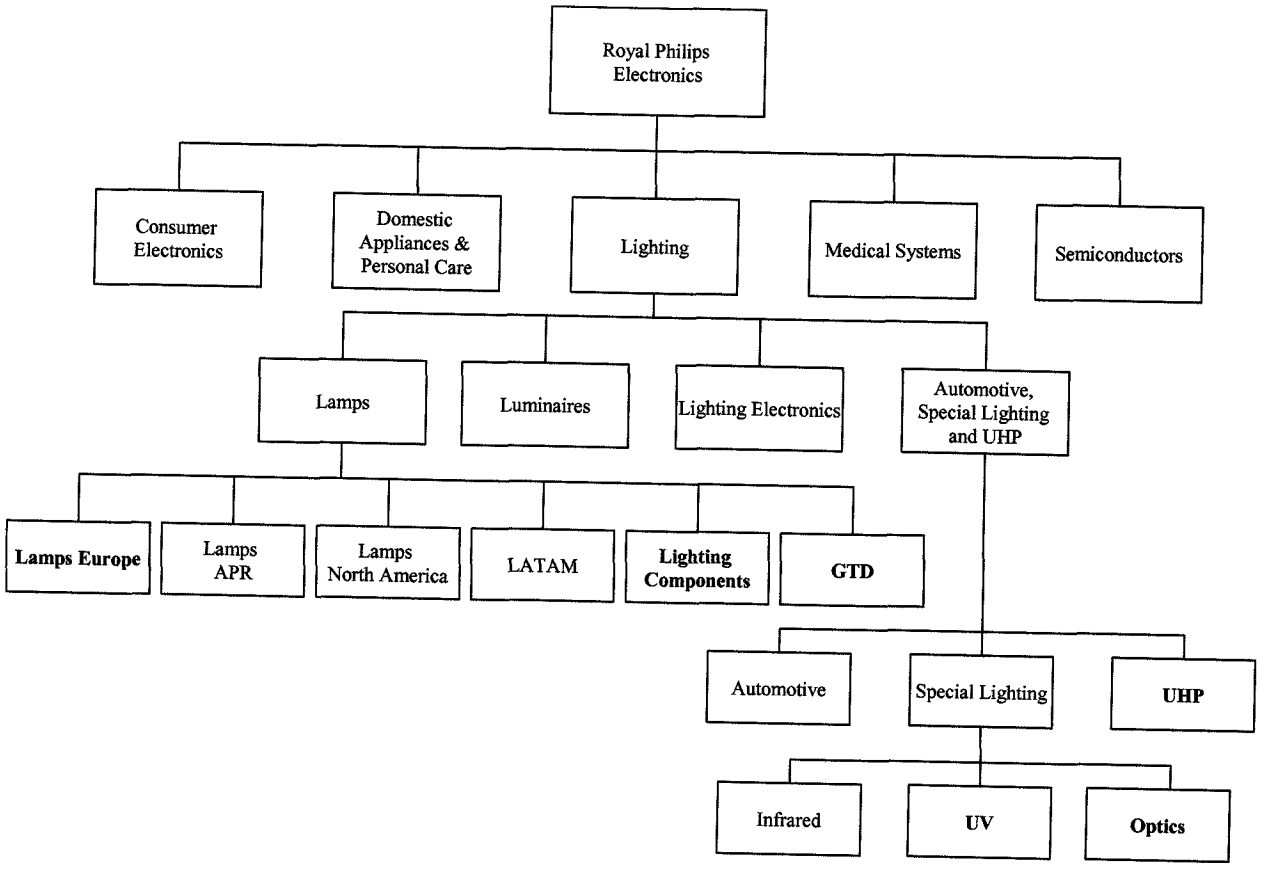
Appendix 2 Organization chart Philips Innovative Applications NV, division Lighting in Turnhout



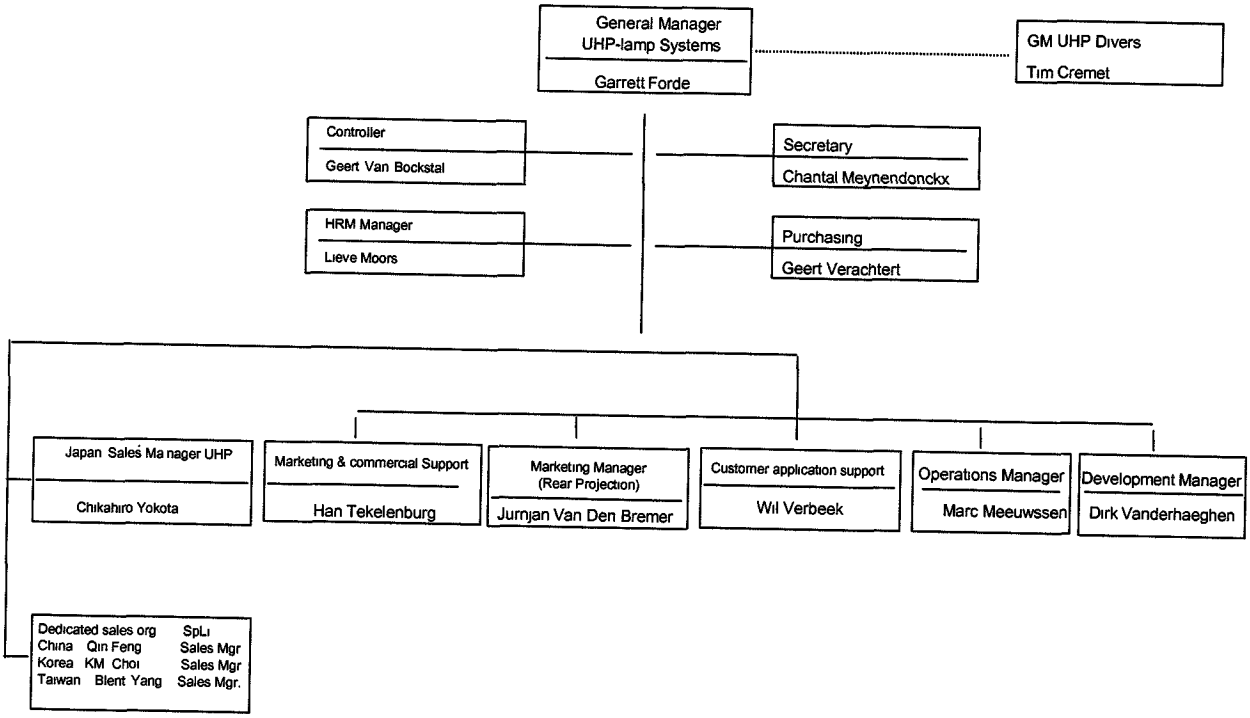
Appendix 3 Organization chart Finance & Accounting



Appendix 4 Organization chart Royal Philips Electronics



Appendix 5 Organization chart BU UHP



Appendix 6 Currency forward contract deal confirmation

NDF DEAL CONFIRMATION

On Behalf of:

PI Corporate Treasury
Philips Electronics - Corporate Treasury
Back Office, VO-p 41
P.O. Box 218
5600 MD Eindhoven

Tel No:
Fax No:
Funloc: 673165

For the attention of: Guy Ruts

1720549013 Lighting NV UHP
Tel No:
Fax No:
Funloc: 1720549013

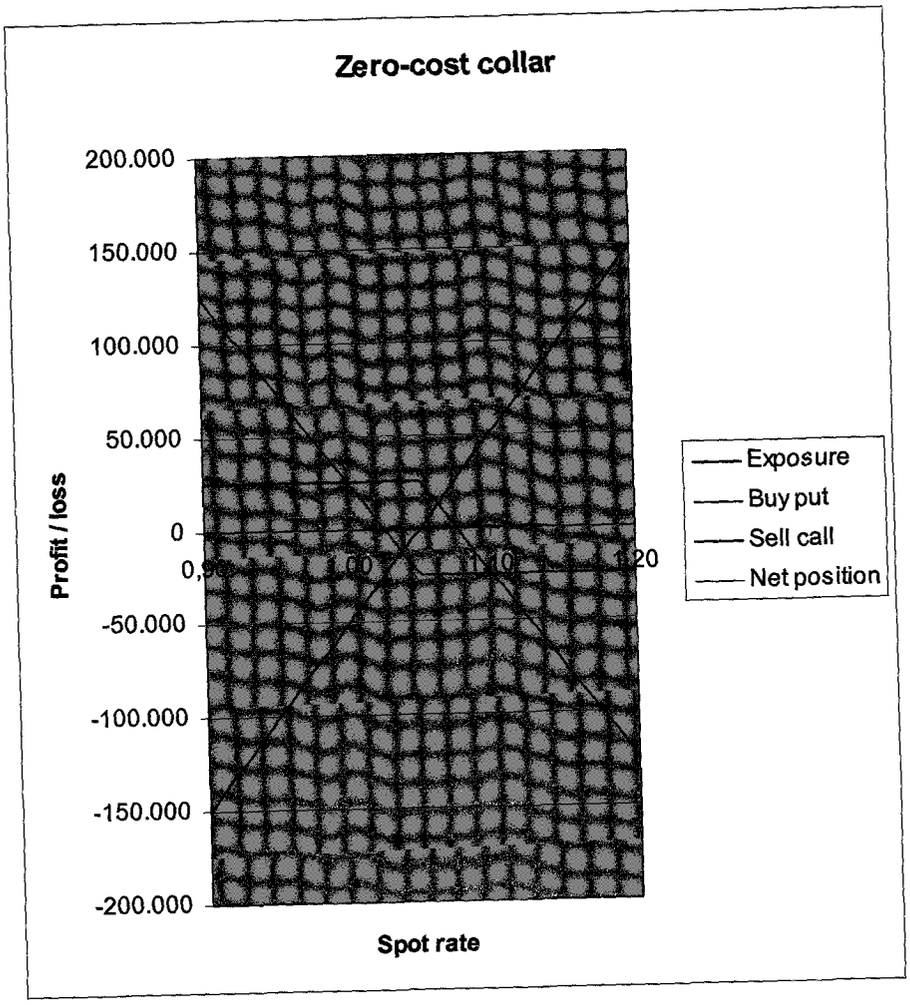
We confirm details of the following transaction:

Deal No:	352911
Deal Date:	20-Jun-2003
We buy:	USD 2,906,500.00
We Sell:	EUR 2,511,600.98
Spot Rate:	1.16939
Forward Points:	(0.0122)
Contract Rate:	1.15723000
Value Date:	25-Aug-2004
Currency Option Deal No:	0

Settlement Details

This transaction will be net settled via the In House banking system.

Appendix 7 Zero-cost collar



Appendix 8 Currency option contract deal confirmation

Currency Option Deal Confirmation

On behalf of:

PI Corporate Treasury
Philips Electronics - Corporate Treasury
Back Office, VO-p 41
P.O. Box 218
5600 MD Eindhoven

Tel No:
Fax No:
Funloc: 673165

For the Attention of:

Guy Ruts
1720549013 Philips Lighting NV UHP

Tel No:
Fax:
Funloc: 1720549013

We confirm details of the following transaction:

We SELL a EUROPEAN style USD PUT Option

Deal No:	352922
We buy:	EUR 2,518,004.34
We Sell:	USD 2,902,000.00
Spot rate:	1.16440000
Strike rate:	1.15250000
Volatility rate:	9.8800
Deal date:	20-Jun-2003
Expiry date:	28-Jul-2004
Value date:	30-Jul-2004
Premium date:	24-Jun-2003
Premium points:	
Premium percentage:	
Premium Amount :	102,545.73

Settlement Details

This transaction will be settled via the In House banking system.

Appendix 9 Option price calculator

	Option 329765
Type Option (C/P):	
Buy/Sell (B/S):	
Today:	wo/26/mrt/03
Expiration Date:	
Strike:	
Face in CC1:	
Lifetime option:	1,09863
Spot Rate:	
Interest CC1:	
Interest CC2:	
Volatility:	
Value in CC2 points:	-0,0398
Value in CC2:	-119.470,33

[redacted]

Legend:

C	Call option
P	Put option
CC	Currency
Value in CC2 points	Option premium percentage
Value in CC2	Option premium in EUR (CC2)

Appendix 10 Work method hedging Philips Innovative Applications NV, division Lighting in Turnhout

➢ *Business Lines HID, MECO, Optics/UV and Business Unit UHP*

If a currency exposure exists, one should follow specified Currency Risk Management policies in order to hedge these exposures. The Business Lines (BLs) HID and MECO should adopt the Lighting division policy, in which only forward contracts are allowed, while the BL Optics/UV (combined) and the Business Unit (BU) UHP should follow the BU Special Lighting regulations, in which both forward and option contracts are allowed.

The operational actions of the hedging policy are described below. These actions can be subdivided into quarterly and monthly steps. Note that both receivables and payables might have to be hedged[4] and that each step has to be taken for each relevant currency (CCY). For each BL/BU the relevant currencies are the following:

- HID: USD and JPY receivables, USD payables
- MECO: USD receivables, USD payables
- Optics/UV: USD receivables, no payables
- UHP: USD and JPY receivables, JPY payables

HID and UHP hedge both USD and JPY exposures, while MECO and Optics/UV only hedge USD exposures.

Note that:

1. Hedging activities with regard to forward contracts have to be taken within Deal Station, which will be marked by **(DS)** below. Authorization is needed in order to get access to Deal Station.
2. For HID and MECO forward contract requests within Deal Station have to be approved by Mr. Roelof van Langen (Chief F&A), while for UHP Mr. Geert van Bockstal (controller UHP), and for Optics/UV Mr. Rob Verbeek (controller Optics/UV) are responsible for this.

➢ At the end of ***quarter m*** *(for HID this happens on a* ***monthly*** *basis)*:

1. Forecast the quarterly *m+5* sales/purchases by month, based on the strategic plan
   - Print and save this survey (1)

2. Conclude "anticipated receivables/payables" forward contracts **(DS)**
   - Within Deal Station: choose to create new exposure numbers for each month in quarter *m+5*. The exposure type is an "anticipated cash flow" with value date in the specific month *n* in quarter *m+5*. Set the date to PMC date! Fill in the total amount being exposed; Deal Station "knows" that forward contracts worth 50% of this total amount should be concluded.
   - Print the "Exposures to be approved" overview (2)
   - Approve the requests
   - Only for HID and MECO: attach the "Exposures to be approved" overview to the sales/purchases forecast created in step 1 and register this

This step only to hedge the receivables of UHP and Optics/UV:

3. Conclude option contracts
   - Fill in the "FX Option Request" form (3); buy put options worth 40% of the total amount to be hedged for each month in quarter *m+5* (file "Standard FX Option Request")
   - Print and save this request

[4] One should hedge when the Euro-equivalent value of the sum of future (committed + anticipated) transactions for the next 15 months, in that currency, exceeds Euro 2.5 million.

- Send this request by e-mail to the approver
- The approver has to electronically sign the request, use the 'return receipt' option and send it by e-mail to Corporate Treasury (e-mail: Dealingroom.Treasury@Philips.com)
- Attach this request, the 'return receipt' confirmation (4) and the "Exposures to be approved" overview to the sales/purchases forecast created in step 1 and register this

One day later:

4. Documentation "anticipated receivables/payables" forward contracts **(DS)**
   - Receipt of the forward "NDF DEAL CONFIRMATION" (5)
   - Print out the Deal Station forward documentation (6)
   - In step 4 of the documentation the word "receipt/payment" has to be changed to "sale/purchase"
   - Attach these two documents for each contract and register this by exposure number

This step only for UHP and Optics/UV:

5. Documentation option contracts
   - Receipt of the option contracts confirmation (7)
   - Fill in, print and save the option contract documentation form (file "Standard Option contract documentation expiry date deal no CCYOpt") (8)
   - Attach these two documents for each contract and register this by exposure number

This step only for HID and MECO:

6. Update "anticipated receivable/payable" contracts from 50% to 70% **(DS)**
   - The in step 2 anticipated "anticipated receivable/payable" forward contracts will automatically be update to a 70% hedge three months before the expiration date of the contract. This means that step 4 has to be repeated for these contracts at that time.

➢ At the end of ***month n*** *(Wednesday in the week before month closing)*:

1. Extrapolate the sales/purchases in month *n*
   - Open the sales/purchases report of month *n* in SAP
   - Use this report to create a pivot table showing:
     - Currenc(y)/(ies)
     - Quantity of sales/purchases
     - Value of sales/purchases in local currency (= PCLC = EUR)
     - Value of sales/purchases in transaction currency (= TC = USD or JPY)
   - Extrapolate the TC values by currency, covering the whole month *n* and add occasional overdue if necessary. This leads to a total amount by currency.
   - Print and save this survey (9)

2. Change the forward contracts which expire in month *n* from "anticipated receivables/payables" to "committed receivables/payables" **(DS)**
   - Within Deal Station: choose to update the exposure number for the corresponding month *n*. The exposure type is a "committed cash flow" with value date in month *n*. Fill in the in step 1 extrapolated total amount (this may deviate dramatically from the originally anticipated amount); Deal Station "knows" that forward contracts worth the difference between this amount and the amount of the last "anticipated receivable/payable" hedge should be concluded. If the extrapolated amount is lower than the last "anticipated receivable/payable" hedged amount, then fill in the amount of the last "anticipated receivable/payable" hedge.
   - Print the "Exposures to be approved" overview (10)
   - Approve the requests
   - Only for HID and MECO: attach the "Exposures to be approved" overview to the extrapolated sales/purchases forecast created in step 1 and register this

This step only for UHP and Optics/UV:

3. Reverse the option contracts which expire in month *n*
   - Fill in the "FX Option reversal Request" form (11): sell the put options which expire in month *n* against the same amount and strike price as concluded in the original contract, with the maturity date to be the expiry date of the original contract (file "Standard FX Option reversal Request")
   - Print and save this request
   - Send this request by e-mail to the approver
   - The approver has to electronically sign the request, use the 'return receipt' option and send it by e-mail to Corporate Treasury (e-mail: Dealingroom.Treasury@Philips.com)
   - Attach this request, the 'return receipt' confirmation (12) and the "Exposures to be approved" overview to the extrapolated sales/purchases forecast created in step 1 and register this

One day later:

4. Documentation "committed receivables/payables" forward contracts **(DS)**
   - Receipt of the forward "NDF DEAL CONFIRMATION" (13)
   - Print out the Deal Station forward documentation (14)
   - In step 3 of the documentation the words "The first" have to be added in front of the hedged amount
   - Attach these two documents for each contract and register this by exposure number

5. Roll on the forward contracts to a receivable/payable position **(DS)**
   - Within Deal Station: choose to update the exposure number for the corresponding month *n*. The exposure type is a "committed cash flow" with value date in month *n+2*. Set the date to PMC date! Fill in the in step 1 extrapolated total amount; Deal Station "knows" which forward contracts should be created: reversals of the contracts created before and a new contract against 100% of the total amount to be hedged
   - Print the "Exposures to be approved" overview (15)
   - Approve the requests
   - Register the "Exposures to be approved" overview

6. Documentation "rolled on" forward contracts **(DS)**
   - Receipt of all forward "NDF DEAL CONFIRMATION", from both the "rolled on" and reversed "anticipated receivables/payables" and "committed receivables/payables" contracts (16)
   - Print out the Deal Station forward documentation (17)
   - In step 3 of the documentation the words "The first" have to be added in front of the hedged amount
   - Attach these two documents for each contract register this by exposure number
   - Print "Report F2: Exposures and Related Hedges Funloc Level Specification" in Deal Station and register this (18)

This step only for UHP and Optics/UV:

7. Documentation option contracts
   - Receipt of the option contracts confirmation (19)
   - Fill in, print and save the reversal option contract documentation form (file "Standard Option contract reversal documentation expiry date deal no CCYOpt reversal") (20)
   - Attach these two documents for each contract and register this by exposure number
   - The receipt of the forward "NDF DEAL CONFIRMATION" (21) which are related to the option contracts, and which are created due to the reversal of the original option contract before the expiry date, should be registered as well
   - Register these documents by exposure number

After month closing:

8. Update the contracts overview, calculate the currency results and fill in the effectiveness check (file "Hedging overview")
   - Print the Fair Value and Settlement overviews in Deal Station (22)
   - Update the contracts overview
     - Add the contract data of the in step 2, 3 and 4 concluded contracts
     - Add/replace the Fair Values of the contracts that expire in months *n+1* and *n+2*
     - Add the Settlements of the contracts that expire in month *n*
   - Refresh the pivot tables of the forwards by selecting the dates in months *n+1* and *n+2*
   - Refresh the pivot tables of the options by selecting the dates in month *n*
   - Calculate the currency results using the refreshed pivot tables
     - Settlement Forwards CCY = CCY Sum of Settlement Value Date (Pivot table forwards)[5]
     - Only for UHP and Optics/UV: settlement Options CCY = CCY Total (Pivot table options)[6]
     - Only for UHP and Optics/UV: correction option premiums is used if a mistake is encountered and a correction is needed
     - Fair Value New Month Forwards CCY = CCY Sum of Fair Value (Pivot table forwards)[7]
     - The balance revaluation can be filled in using data from SAP
   - Fill in the effectiveness check
     - Fill in the total hedged amount
     - Determine the sales/purchases of month *n* using SAP
     - The effectiveness should be between 80% and 125%[8]
   - Save the file "Hedging overview" (23), print all sheets and register them together with the Fair Value and Settlement overviews from Deal Station

9. Determine the BBSC PI: % currency results compensated by hedging

Remarks:
- Hedging is based on SALES/PURCHASES
- Rolling on is based on CASH FLOWS

Note: payables may be hedged as well!

Eventually each exposure will have the following documentation:
- The "NDF DEAL CONFIRMATION" (5, 13 and 16) and Deal Station forward documentation (6, 14 and 17) for each contract: "anticipated receivables/payables" (HID and MECO both 50% and 70%), "committed receivables/payables", reversed "anticipated receivables/payables", reversed "committed receivables/payables" and "rolled on" contracts
- Only for UHP and Optics/UV: the option contract confirmation (7 and 19) and the option contract documentation form (8 and 20) for each contract, both original and reversal contracts
- Only for UHP and Optics/UV: the extrapolated sales/purchases survey (9), the "FX Option reversal Request" (11), the 'return receipt' confirmation (12) and the "Exposures to be approved" overview (10)
- Only for HID and MECO: the extrapolated sales/purchases survey (9), and the "Exposures to be approved" overview of the 100% committed contracts (10)

[5] The settlement of forwards in month *n* consists of the settlement values of the forward contracts which expire in month *n*.
[6] When an option contract is concluded an option premium *x* is paid. When this contract is reversed (against exactly the same strike price in order to let the fair value be 0) an option premium *y* is received or paid. The settlement of options in month *n* consists of the amounts of option premiums $x + y$ for all option contracts which expire in month *n*.
[7] The fair value of forwards in month *n* consists of the fair values of the committed forward contracts that expire in the months *n+1* and *n+2*.
[8] The effectiveness in month *n* is calculated by dividing the total sales by the total hedged amount.

- The "Exposure to be approved" overview of the "rolled on" contracts (15)
- Only for UHP and Optics/UV: the forwards "NDF DEAL CONFIRMATION" (21) which are related to the option contracts

This documentation should be added monthly:
- "Report F2: Exposures and Related Hedges Funloc Level Specification" from Deal Station (18)
- The Fair Value and Settlement overviews from Deal Station (22)
- All sheets from the file "Hedging overview" (23)

This documentation should be added quarterly:
- The quarterly sales/purchases forecast (1), "Exposures to be approved" (2), "FX Option Request" (3), 'return receipt' confirmation (4)

October 2003, John van der Linden

Appendix 11 First model

1. Defining the model

Actually the cost of a specific hedging policy, expressed in $, generally consists of two parts, namely:
- The absolute value of the following aspects:
  + The risk in $ if the exposure is left un-hedged
  – The risk reduction in $ if the exposure is hedged with x% forwards
  – The risk reduction in $ if the exposure is hedged with y% options
- + The option premium in $

In formula (2):

$$Cost_{hedgingstrategy} = \left| Risk_{unhedged} - Riskreduction_{forwards} - Riskreduction_{options} \right| + optionpremium_{\$}$$

The cost of a particular hedging policy in € can easily be calculated by multiplying the cost in $ by the €/$ rate.

Now the different parts of the model will be explained.

- The risk in $ if the exposure is left un-hedged

First of all, the forecasted exposure has to be defined. It is the forecasted $ sales multiplied by the volatility of the €/$ currency pair. In formula (3):

$$Exposure_{forecasted} = sales_{forecasted} * Currencyratefluctuation$$

The calculation of the currency rate fluctuation will be illustrated using table 2 further on.

The risk in $ if the exposure is left un-hedged is calculated by multiplying the sales forecast accuracy by the forecasted exposure.

In formula (4):

$$Risk_{unhedged} = salesfc.ab. * Exposure_{forecasted}$$

- The risk reduction in $ if the exposure is hedged with x% forwards

Forwards contracts imply an obligation to buy or deliver a specific amount of a foreign currency in the future. Therefore the risk reduction of forward contracts can be more than the forecasted exposure, leading to a 'negative risk'. The absolute value of this 'negative risk' results in a risk again. This means that over-hedging with forwards leads to a risk.
The risk reduction in $ if the exposure is hedged with x% forwards is defined by the percentage of the forecasted exposure being hedged with forwards multiplied by the forecasted exposure. In formula (5):

$$Riskreduction_{forwards} = x\%forwards * Exposure_{forecasted}$$

- The risk reduction in $ if the exposure is hedged with y% options

Due to a sales forecast accuracy which usually does not equal 100%, there is a chance that the exposure is being over- / under-hedged, which results in different possibilities to exercise the option. Namely, options give you the right (and not the obligation) to buy or sell a specific amount of a foreign currency in the future. The different situations are:

- If the percentage of the forecasted exposure being hedged with forwards exceeds or equals the sales forecast accuracy, the option will not be exercised (because risk reduction is the goal!) and then the risk reduction of the option is 0.

- If the percentage of the forecasted exposure being hedged with forwards is less then the forecast accuracy, the option will reduce some risk and the following possibilities exist:
  - If the sum of the percentage of the forecasted exposure being hedged with forwards and the percentage of the forecasted exposure being hedged with options exceeds the forecast accuracy, the risk reduction of the option is (the sales forecast accuracy – the percentage of the forecasted exposure being hedged with forwards) multiplied by the forecasted exposure. This is because it is possible to only exercise a part of the option.
  - If the sum of the percentage of the forecasted exposure being hedged with forwards and the percentage of the forecasted exposure being hedged with options is less then the forecast accuracy, the forecasted exposure is under-hedged. This means that the option will be fully exercised (in reality the option will not be exercised if this incurs a loss, but remember that the goal is to reduce risk!). Now the risk reduction of the option is the percentage of the forecasted exposure being hedged with options multiplied by the forecasted exposure.

In formula (6):

$$Riskreduction_{options} = IF\left\langle \begin{array}{l} x\%forwards \geq salesfc.ab.;THEN(0);ELSE \\ \left\{ \begin{array}{l} IF \\ \left[\begin{array}{l} x\%forwards + y\%options > salesfc.ab.;THEN(salesfc.ab. - x\%forwards) * Exposure_{forecasted}; \\ ELSE(y\%options * Exposure_{forecasted}) \end{array} \right] \end{array} \right\} \end{array} \right\rangle$$

Like explained in formula (2), in order to determine the cost of a specific hedging policy, the absolute value of formulas [(4)–(5)–(6)] should be calculated, together with the option premium which will be explained now.

- The option premium in $

This equals the percentage of the forecasted exposure being hedged with options multiplied by the option premium percentage multiplied by the forecasted exposure. In formula:

$$Optionpremium_{\$} = y\%options * optionpremium\% * Exposure_{forecasted}$$

Issues about this model, which should still be considered, are:
- Is it true that forwards and options can lead to full risk reduction? Namely, the hedge contracts are not concluded against the budgeted currency rate.
- Should the standard deviation of the average absolute deviation of the realized sales from the forecasted sales (based on a 15-months horizon) over the last two years forecast accuracy be included in the model?
- Is it valid to add the risks and risk reductions expressed in $ and the option premium?

2. Results

To show and explain the results of the model the following set of variables is defined (table 1):

Table 1 Set of variables

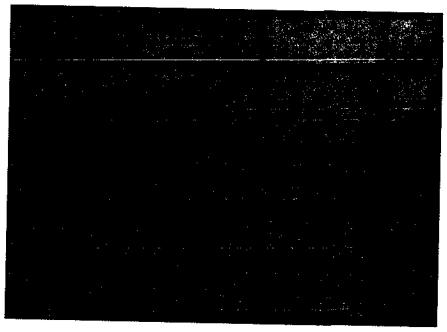


Table 2 on the next page illustrates the forecasted exposure based on the distribution of the currency rate fluctuation specified in table 1.

The first column in table 2 shows different currency rate fluctuations. The second columns shows the chances that these fluctuations are smaller or equal to x%, under the normal distribution specified by the variables in table 1. The third column rearranges the first column; this is just an operation in order to be able to create the results in the fourth column. This column shows the chances that the currency rate fluctuations in the fourth column are equal to or in between x-1% and x%, also under the normal distribution specified by the variables in table 1. From this column a graph can be created showing the normal distribution curve for this set of variables (see figure 1).

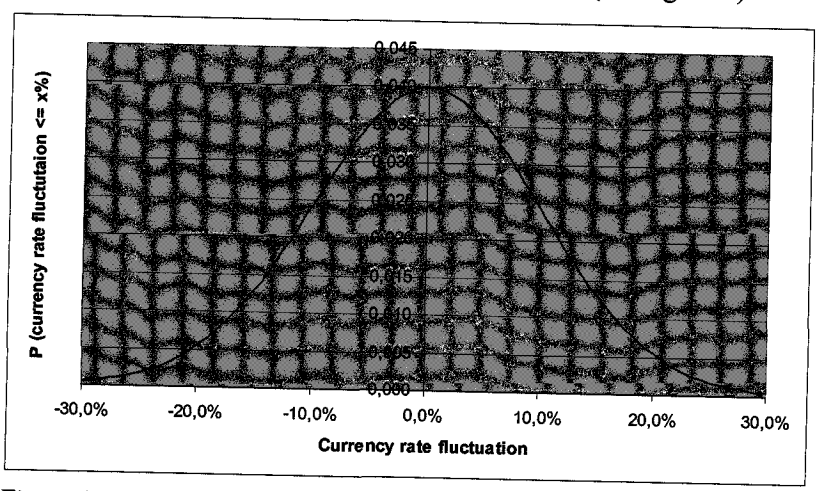


Figure 1 Normal distribution of the currency rate fluctuation

The fifth column shows the exposure if the p-value of each currency rate fluctuation is 1. Finally, the sixth column presents the exposure, assuming the specified normal distribution. Each cell is calculated by multiplying the value in the same row from the fourth column by the value in the fifth column.

Table 2 Currency rate fluctuation distribution

Currency rate fluctuaton	P (currency rate fluctuation <= x%)	Currency rate fluctuation	P (x-1,0% <= currency rate fluctuation <= x%)	Forecasted exposure	Forecasted exposure normal distr
[illegible]	0,001	-30,0%	0,000	-300.000	-133
[illegible]	0,002	-29,0%	0,001	-290.000	-173
[illegible]	0,002	-28,0%	0,001	-280 000	-222
[illegible]	0,003	-27,0%	0,001	-270.000	-282
[illegible]	0,004	-26,0%	0,001	-260.000	-354
[illegible]	0,005	-25,0%	0,002	-250.000	-439
[illegible]	0,007	-24,0%	0,002	-240.000	-539
[illegible]	0,009	-23,0%	0,003	-230.000	-653
[illegible]	0,012	-22,0%	0,004	-220.000	-782
[illegible]	0,016	-21,0%	0,004	-210.000	-925
[illegible]	0,020	-20,0%	0,005	-200.000	-1.081
[illegible]	0,026	-19,0%	0,007	-190.000	-1.248
[illegible]	0,032	-18,0%	0,006	-180.000	-1.422
[illegible]	0,040	-17,0%	0,009	-170.000	-1.600
[illegible]	0,049	-16,0%	0,011	-160.000	-1.776
[illegible]	0,061	-15,0%	0,013	-150.000	-1.944
[illegible]	0,074	-14,0%	0,015	-140.000	-2.097
[illegible]	0,089	-13,0%	0,017	-130.000	-2.228
[illegible]	0,106	-12,0%	0,019	-120.000	-2.331
[illegible]	0,125	-11,0%	0,022	-110.000	-2.397
[illegible]	0,147	-10,0%	0,024	-100.000	-2.420
[illegible]	0,171	-9,0%	0,027	-90.000	-2.395
[illegible]	0,198	-8,0%	0,029	-80.000	-2.317
[illegible]	0,227	-7,0%	0,031	-70.000	-2.185
[illegible]	0,258	-6,0%	0,033	-60.000	-1.999
[illegible]	0,291	-5,0%	0,035	-50.000	-1.760
[illegible]	0,326	-4,0%	0,037	-40.000	-1.473
[illegible]	0,363	-3,0%	0,038	-30.000	-1 144
[illegible]	0,401	-2,0%	0,039	-20.000	-782
[illegible]	0,440	-1,0%	0,040	-10.000	-397
[illegible]	0,480	0,0%	0,040	0	0
[illegible]	0,520	1,0%	0,040	10.000	397
[illegible]	0,560	2,0%	0,039	20.000	782
[illegible]	0,599	3,0%	0,038	30.000	1.144
[illegible]	0,637	4,0%	0,037	40.000	1.473
[illegible]	0,674	5,0%	0,035	50.000	1.760
[illegible]	0,709	6,0%	0,033	60.000	1.999
[illegible]	0,742	7,0%	0,031	70.000	2.185
[illegible]	0,773	8,0%	0,029	80.000	2.317
[illegible]	0,802	9,0%	0,027	90.000	2.395
[illegible]	0,829	10,0%	0,024	100.000	2.420
[illegible]	0,853	11,0%	0,022	110.000	2 397
[illegible]	0,875	12,0%	0,019	120.000	2.331
[illegible]	0,894	13,0%	0,017	130.000	2.228
[illegible]	0,911	14,0%	0,015	140.000	2.097
[illegible]	0,926	15,0%	0,013	150.000	1.944
[illegible]	0,939	16,0%	0,011	160.000	1.776
[illegible]	0,951	17,0%	0,009	170.000	1.600
[illegible]	0,960	18,0%	0,008	180.000	1.422
[illegible]	0,968	19,0%	0,007	190.000	1.248
[illegible]	0,974	20,0%	0,005	200.000	1.081
[illegible]	0,980	21,0%	0,004	210.000	925
[illegible]	0,984	22,0%	0,004	220.000	782
[illegible]	0,988	23,0%	0,003	230.000	653
[illegible]	0,991	24,0%	0,002	240.000	539
[illegible]	0,993	25,0%	0,002	250.000	439
[illegible]	0,995	26,0%	0,001	260.000	354
[illegible]	0,996	27,0%	0,001	270.000	282
[illegible]	0,997	28,0%	0,001	280.000	222
[illegible]	0,998	29,0%	0,001	290.000	173
[illegible]	0,998	30,0%	0,000	300.000	133
[illegible]	0,999				
[illegible]			[illegible]		[illegible]

Using tables 1 and 2, the model creates a set of results summarized in table 3. This table displays the risk in $ for each hedging policy.

Table 3 Grid with outcomes

	% Options						
	0%	10%	20%	30%	40%	[illegible]	[illegible]
[illegible]	39 496	39 552	39.614	39.691	39.803	39.988	40.3[illegible]
[illegible]	35.555	35.617	35.694	35.806	35.991	36.307	36.8[illegible]
[illegible]	31.626	31.703	31 815	32.000	32.317	32.850	33.7[illegible]
[illegible]	27.728	27.840	28.025	28.341	28.874	29.726	30.9[illegible]
[illegible]	23 900	24.084	24.401	24.934	25.786	27.057	28.8[illegible]
[illegible]	20.216	20.533	21.066	21.918	23.189	24.955	[illegible]
[illegible]	16 797	17 330	18.182	19.453	21.219	[illegible]	[illegible]
[illegible]	13 810	14 662	15.934	17 700	[illegible]	[illegible]	[illegible]
[illegible]	11.461	12.733	14.499	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	9.951	11.717	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The gray area in this grid would show outcomes if more than 100% of the forecasted exposure is hedged. This is left out of the scope and construction of the model.

The red cells show the risk for the optimal hedging policy. Under the specified set of variables it is optimal to hedge 100% of the forecasted exposure using forwards and 0% using options.

It might be useful to explain some values out of this grid. Table 4 below does this for the forward / option combinations of 100/0, 50/50 and 0/100.

Table 4 Construction of specific cells out of table 3

Realized sales / forecasted sales	P (realized sales / forecasted sales <= x%)	Realized sales / forecasted sales	P (x% <= sales forecast ability <= x%)	Risk in $ 100% Forw / 0% Opt	Risk in $ 50% Forw / 50% Opt	Risk in $ 0% Forw / 100% Opt	Risk in $ 100% Forw / 0% Opt normal distr.	Risk in $ 50% Forw / 50% Opt normal distr.	Risk in $ 0% Forw / 100% Opt normal distr.
[redacted]									

Note:

- Negative sales are excluded from the model. This is realized by calculating the chance P (realized sales / forecasted sales <= 10%) in the first cell of column 4 in order to include the total left tail of the normal distribution in the model. The sum of column 4 should be as close as possible to 1. Otherwise, if the standard deviation of the sales forecast accuracy is extremely big, a relatively big part of the risk would not be taken into account and the model would be less valid.

The first column shows different (realized sales / forecasted sales) ratios. The second column shows the chances that these ratios are smaller or equal to x%, under the normal distribution specified by the variables in table 1. The third column rearranges the first column; this is just an operation in order to be able to create the results in the fourth column. This column shows the chances that the (realized sales / forecasted sales) ratios in the third column are equal to or in between x-10% and x%, also under the normal distribution specified by the variables in table 1. From this column a graph can be created showing the normal distribution curve for this set of variables (see figure 2).

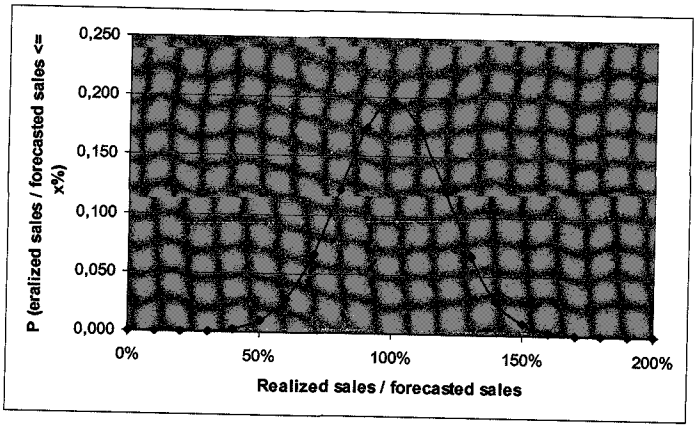


Figure 2 Normal distribution of the (realized sales / forecasted sales)

The fifth to seventh column from table 4 show the risk in $ for three different forward / option combinations, namely 100/0, 50/50 and 0/100. Please pay attention to the fact that these numbers assume that the p-value of each (realized sales / forecasted sales) ratio is 1. The normal distribution is not taken into account here.

The eighth to tenth column show the risk in $ for the same forward / option combinations, assuming the specified normal distribution. For example, each cell in column 8 is calculated by multiplying the value in the same row from the fourth column by the value in the fifth column.

Finally, adding the cells in columns 8, 9 or 10 displays the total risk in $ for that specific hedging policy (forward / option combination) under the assumptions of a normal distribution specified by the variables in table 1.

Appendix 12 Second model

Appendices 13 and 14 contain the total dataset for $ and €, including formulas, all hedging policies and all statistic analysis numbers. Tables 5 and 6 show snapshots of these datasets, namely the analysis of different hedging policies.

Table 5 Hedging alternatives $

Month	Unhedged USD	100%Fwd Amt[t] USD	100%Fwd Amt[t-1] USD	75%F/25%O Amt[t-1] USD	50%F/50%O Amt[t-1] USD	25%F/75%O Amt[t-1] USD	100%Opt Amt[t-1] USD
feb-03	1,28%	0,30%	0,28%	-0,13%	-0,54%	-0,95%	-1,37%
mrt-03	2,02%	0,36%	0,73%	0,33%	-0,06%	-0,45%	-0,84%
apr-03	-13,89%	0,32%	-0,26%	-1,12%	-1,97%	-2,83%	-3,69%
Average	-2,07%	0,18%	0,22%	-0,07%	-0,36%	-0,65%	-0,94%
SD	4,25%	0,10%	0,75%	0,77%	0,89%	1,07%	1,28%
AR (1)	0,24	0,86	-0,01	-0,02	0,07	0,17	0,24
Var (95%)	-8,89%	0,04%	-0,88%	-1,36%	-1,97%	-2,81%	-3,53%
Var / SD	-3,68	0,02	-0,36	-0,56	-0,82	-1,16	-1,46

Table 6 Hedging alternatives ¥

Month	Unhedged JPY	Always 1_Fwd only JPY	Fwd_Amt[t-1] JPY	75F/50O_ Amt[t-1] JPY	50/50_Amt[t-1] JPY	25F/75O_ Amt[t-1] JPY	Opt_Amt [t-1] JPY
feb-03	1,42%	0,19%	-0,25%	-0,13%	0,00%	0,12%	0,25%
mrt-03	-1,19%	0,15%	0,53%	0,32%	0,11%	-0,10%	-0,31%
apr-03	-3,76%	0,24%	-1,45%	-1,60%	-1,76%	-1,91%	-2,06%
Average	-1,11%	0,26%	0,02%	-0,16%	-0,35%	-0,53%	-0,72%
SD	2,06%	0,08%	0,63%	0,63%	0,65%	0,70%	0,76%
AR (1)	-0,16	0,48	-0,24	-0,24	-0,21	-0,18	-0,14
Var (95%)	-4,60%	0,15%	-1,30%	-1,57%	-1,74%	-1,90%	-2,05%
Var / SD	-2,17	0,07	-0,61	-0,74	-0,82	-0,90	-0,97

Column 2 indicates what happened if the cash flow had been left un-hedged each month. This is given as an implied benchmark, the goal being to reduce the Value At Risk (VaR). Value At Risk (VaR) is the criterion to determine the effectiveness of different hedging scenarios. It is a statistical technique that combines sensitivity and probability analysis. By examining the left tail of the distribution of outcomes for a certain hedging policy one can get an estimation of the downside risk associated with that particular policy. In simple words VaR is the risk of losing money in that policy. Throughout the analysis we are focusing on 95% level of confidence.

Column 3 illustrates the effects of having hedged every month one hundred percent of one unit via forwards. This would be a reasonable policy if one expects the sales figures to be independent from each other and identically distributed with a mean equal to one unit. However, the key assumption of independence does not hold when looking at the strong auto-correlation in the sales time series, exhibiting in turn the fundamental flaw in this strategy. As a consequence a more rational strategy consists in using as a predictor of next period sales, the present value of this period export sales. As column 4 shows, a notable risk reduction can be achieved by doing so.

So far, only hedging via forwards has been considered and a potential improvement may result by including options. Columns 5, 6 and 7 consider |VaR| minimizing combinations of forwards and options and column 8 when only using options.

The VaR coefficient is calculated as follows:

$$X_{O,F} = VAR(95\%)_{O,F} / SD_E$$

In which:

$X_{O,F}$ =	95% VaR coefficient for the specific Option/Forward combination
O =	option % used to hedge
F =	forward % used to hedge
$VaR(95\%)_{O,F}$ =	95% VaR for the specific Option/Forward combination
SD_E =	standard deviation of all monthly spot returns

$VaR(95\%)_{O,F}$ is calculated by taking the 5th% percentile of all monthly risk factors for the specific Option/Forward combination.

The monthly risk factor can be expressed as:

$$RF_n = IS_n * SR_n + \{[MAX(IRD_n - SR_n, 0) - OP_n] * O + I_n * F\} * M_{n-1}$$
$$SR_n = \ln(SR_{n-1} / SR_n)$$
$$IRD_n = \ln(SR_n / FR_n)$$
$$FR_n = SR_n * [(1 + IRF_n / 12)/(1 + IRE_n / 12)]$$
$$FL_n = \ln(SR_n / FR_{n-1})$$

In which:

RF_n = risk factor in month *n*
IS_n = indexed sales in month *n*
SR_n = spot return in month *n*
IRD_n = interest rate difference in month *n*
OP_n = option premium in month *n*
SR_n = balance sheet rate in month *n*
FR_n = forward rate in month *n*
IRF_n = interest rate foreign currency in month *n*
IRE_n = interest rate € in month *n*

Remarks:

- The indexed sales are the standardized sales figures, where the starting value of sales as of June 2001 has been rescaled to one unit.
- The option premium is calculated using an option price calculator, as shown in appendix 9.
- The interest rates are provided by the Bank of America
- The monthly risk factor is composed of three components, namely:
  - $M_n * E_n$ expresses the risk factor if the sales would be left un-hedged
  - $\{IF[E_n > J_n, 0, ELSE\text{-}(E_n\text{-}J_n)]\text{-}C_n\} * O$ expresses the risk factor caused by hedging O% using options, which should be multiplied by the standardized sales. If the spot return in month *n* is bigger than the interest rate difference in month *n*, then the option risk factor is $-C_n * O$, otherwise [-(En-Jn)-Cn]*O.
  - $I_n * F$ expresses the forward risk factor, which should be multiplied by the standardized sales.

- The results are based on a hedging horizon of 15 months, while currently PLT uses a horizon of 15 months. This should be applied into the model, but the short history on which the model is based might have a negative influence on the validity.

This model is applicable for $ as well as ¥.

At the money forward put options are back tested. The a grid of hedging outcomes via a combination of options and forwards where the proportion of each instrument varies from zero to 170 percent of the amount to be hedged as given by the last sales figures. The criterion has been to minimize the value at risk measure. The VaR is commonly defined as the worst expected loss over a given time interval under normal market conditions at a given confidence level. The level of confidence used in this case is 95%. This means an exposure is expected to lose less than the VaR percentage 95 times out of 100. VaR can always be formulated as a coefficient of proportionality to the underlying currency's market volatility, which is the convention adopted in this thesis. Looking at a € against $ exchange rate exposure and the underlying currency market's monthly volatility is 2,45%, a VaR of –2,35 means that there is only a 5% chance that the portfolio will fall by more than 2,0% (-0,82 x 2,45%).
A pure back testing exercise provides simple grids (tables 7 and 8). It is worthwhile remembering that these percentages firstly refer to the amount to be hedged as given by the last sales figures and secondly that the total hedge ratio can and actually does exceed one hundred percent.

Table 7 VaR coefficients for all option and forward combinations $

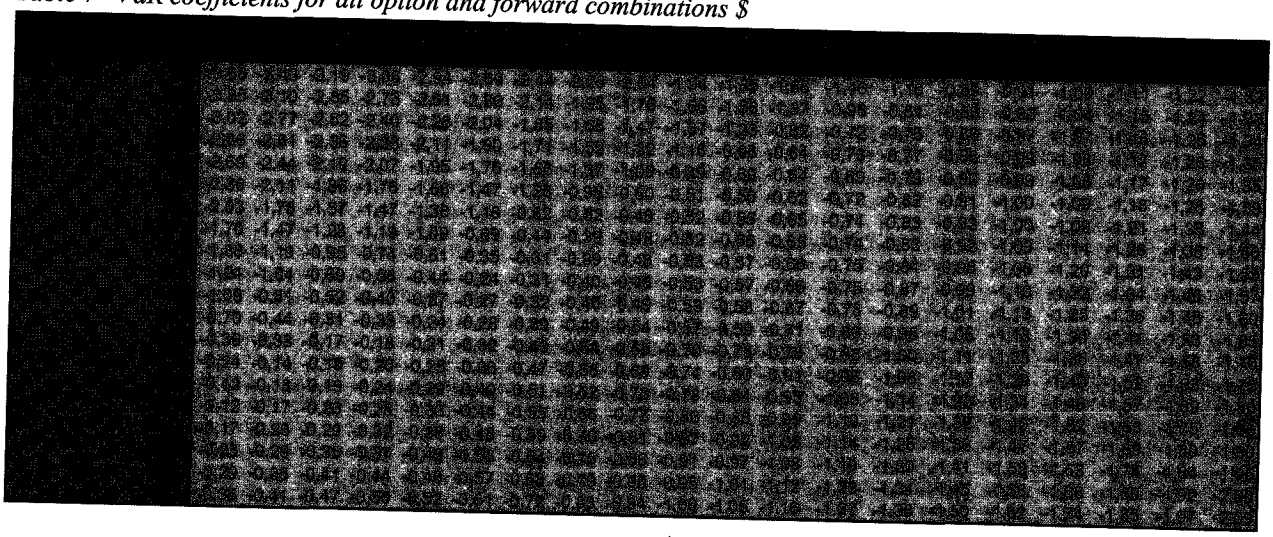
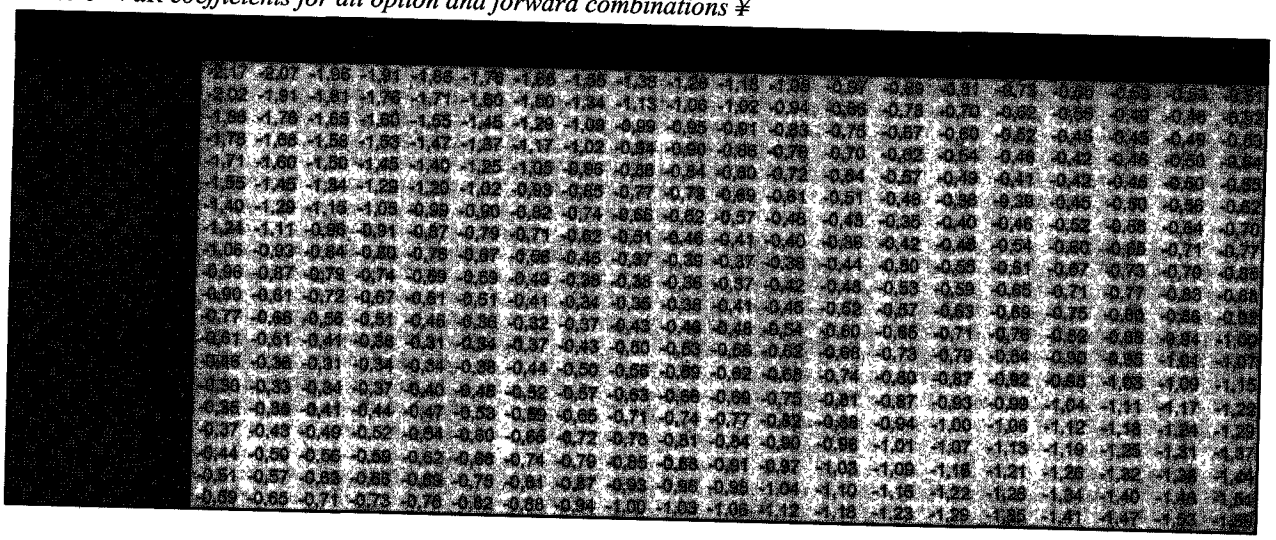


Table 8 VaR coefficients for all option and forward combinations ¥



One way of testing the validity of this model is assuming standardized sales of 1 for each month. This means that every month the sales figures are fixed and 100% predictable. In this way you would say that hedging 100% of the sales using forward options minimizes the risk. This proves to be true, as shown for the $ in appendix 15. In the grid you can see that the highest VaR coefficient is reached with hedging using 100% with forwards and 0% with options. For the ¥ this proves to be true as well.

Note again that the current hedging policy within PLT is based on a hedging horizon of 15 months with forecasted sales based on the strategic plan, while the analysis in this section is based on a horizon of 1 month with the current period sales as a predictor of next period sales. So this model cannot be used in the current situation and a lot of efforts should still be paid to fit this model to PLT's situation.

Actually the strong point of the model should be the flexibility to use the hedging horizon as a variable. However, because of the short history of the dataset the validity will become less with an enlarged horizon. The available dataset is easier manageable when considering a short hedging horizon.

So a major issue is how to incorporate the variable sales horizon into the model. In fact the sales forecast accuracy should be built in, which might imply the correlation between the sales in month *n* and the in month *n-15* forecasted sales. In the current model the correlation between the sales in month *n* and month *n-1* is built in. This is an important difference/issue with regard to this model.

An important remark is the clear trend in the $ and ¥ currency rate in the dataset.

An extreme situation analysis will show the influences of different datasets to the results of the model.

Appendix 13 Dataset $ second model

A	C	D	E	F	G	H	I	J	K	L	M	N	Q	S	T	U	V	W	X
		USD/EUR BS rate	(USD/EUR) Spot return	Interest EUR	Interest USD	Forward rate	Forward leg	Interest rate difference	Sales USD	D (Sales USD)	Indexed Sales USD	D (Indexed Sales USD)	Unhedged USD	100%For w Amt[t] USD	100%Fwd Amt[t-1] USD	75%F/25% O Amt[t-1] USD	50%F/50% O Amt[t-1] USD	25%F/75% O Amt[t-1] USD	100%Opt Amt[t-1] USD
		0,8597		4,55%	3,92%	0,8592		0,05%	1909541		1,00								
		0,8813	-2,48%	4,54%	3,81%	0,8808	2,53%	0,06%	1470698	-438842	0,77	-0,23	-1,91%	0,04%	0,62%	0,30%	-0,03%	-0,35%	-0,67%
		0,9144	-3,69%	4,32%	3,64%	0,9139	3,75%	0,06%	952073	-518626	0,50	-0,27	-1,84%	0,03%	1,05%	0,81%	0,57%	0,33%	0,09%
		0,9231	-0,95%	3,79%	3,06%	0,9225	1,00%	0,06%	1794654	842581	0,94	0,44	-0,89%	0,05%	-0,39%	-0,55%	-0,72%	-0,88%	-1,04%
		0,8905	3,60%	3,78%	2,50%	0,8895	-3,54%	0,11%	1308036	-486618	0,69	-0,25	2,47%	0,04%	-0,86%	-0,31%	0,24%	0,79%	1,34%
		0,8786	1,34%	3,36%	2,13%	0,8777	-1,24%	0,10%	1653240	345204	0,87	0,18	1,16%	0,09%	0,32%	0,32%	0,32%	0,32%	0,32%
		0,8829	-0,49%	3,34%	1,94%	0,8819	0,60%	0,12%	1559516	-93724	0,82	-0,05	-0,40%	0,08%	0,11%	-0,12%	-0,35%	-0,58%	-0,81%
		0,8785	0,50%	3,35%	1,80%	0,8774	-0,39%	0,13%	1997149	437634	1,05	0,23	0,53%	0,12%	0,21%	0,07%	-0,07%	-0,21%	-0,36%
		0,8698	1,00%	3,34%	1,86%	0,8687	-0,87%	0,12%	2734412	737262	1,43	0,39	1,43%	0,18%	0,52%	0,50%	0,48%	0,47%	0,45%
		0,8725	-0,31%	3,34%	1,88%	0,8715	0,44%	0,12%	3569668	835257	1,87	0,44	-0,59%	0,23%	0,04%	-0,27%	-0,57%	-0,88%	-1,19%
		0,8927	-2,29%	3,33%	1,86%	0,8916	2,41%	0,12%	2412736	-1156932	1,26	-0,61	-2,89%	0,15%	1,61%	1,16%	0,72%	0,27%	-0,18%
		0,9260	-3,66%	3,37%	1,85%	0,9248	3,79%	0,13%	2199620	-213116	1,15	-0,11	-4,22%	0,14%	0,56%	0,23%	-0,11%	-0,45%	-0,79%
		0,9826	-5,93%	3,37%	1,84%	0,9814	6,06%	0,13%	2469906	270286	1,29	0,14	-7,67%	0,16%	-0,69%	-1,11%	-1,53%	-1,95%	-2,37%
		0,9957	-1,33%	3,34%	1,84%	0,9945	1,45%	0,12%	2094748	-375158	1,10	-0,20	-1,45%	0,14%	0,42%	0,02%	-0,39%	-0,79%	-1,20%
		0,9810	1,49%	3,32%	1,82%	0,9797	-1,37%	0,12%	2134301	39553	1,12	0,02	1,67%	0,14%	0,17%	0,22%	0,27%	0,33%	0,38%
		0,9770	0,40%	3,32%	1,83%	0,9758	-0,28%	0,12%	4318476	2184175	2,26	1,14	0,91%	0,28%	0,60%	0,36%	0,12%	-0,12%	-0,35%
		0,9753	0,18%	3,31%	1,82%	0,9741	-0,05%	0,12%	4300651	-17825	2,25	-0,01	0,40%	0,28%	0,28%	-0,22%	-0,73%	-1,23%	-1,73%
		1,0013	-2,63%	3,41%	1,44%	0,9997	2,75%	0,16%	3263058	-1037593	1,71	-0,54	-4,49%	0,21%	1,71%	1,24%	0,76%	0,29%	-0,18%
		1,0479	-4,55%	2,92%	1,41%	1,0466	4,71%	0,13%	3750095	487037	1,96	0,26	-8,93%	0,32%	-0,88%	-1,37%	-1,87%	-2,36%	-2,86%
		1,0838	-3,37%	2,83%	1,32%	1,0824	3,49%	0,13%	4612103	862008	2,42	0,45	-8,13%	0,30%	-1,27%	-1,85%	-2,42%	-3,00%	-3,57%
		1,0779	0,54%	2,79%	1,35%	1,0766	-0,41%	0,12%	4524889	-87214	2,37	-0,05	1,28%	0,30%	0,28%	-0,13%	-0,54%	-0,95%	-1,37%
		1,0708	0,67%	2,58%	1,36%	1,0697	-0,55%	0,10%	5796564	1271675	3,04	0,67	2,02%	0,36%	0,73%	0,33%	-0,06%	-0,45%	-0,84%
		1,1188	-4,39%	2,56%	1,32%	1,1177	4,49%	0,10%	6044175	247611	3,17	0,13	-13,89%	0,32%	-0,26%	-1,12%	-1,97%	-2,63%	-3,69%
									4736375										
Average		0,9557	-1,20%						2907405	187938	1,52	0,10	-2,07%	0,18%	0,22%	-0,07%	-0,36%	-0,65%	-0,94%
SD		0,0808	2,41%						1446611	765477	0,76	0,40	4,25%	0,10%	0,75%	0,77%	0,89%	1,07%	1,28%
Skew		0,5939	-0,16						1	1	0,77	0,56	-1,37	0,17	-0,02	-0,57	-0,98	-0,94	-0,71
Kurtosis		-0,9223	-0,63						0	1	-0,38	0,99	149%	-125%	15%	31%	24%	15%	29%
AR (1)		0,9562	0,42						1	0	0,85	-0,13	0,24	0,86	-0,01	-0,02	0,07	0,17	0,24
Var (95%)													-8,89%	0,04%	-0,88%	-1,36%	-1,97%	-2,81%	-3,53%
Var / SD													-3,68	0,02	-0,36	-0,56	-0,82	-1,16	-1,46

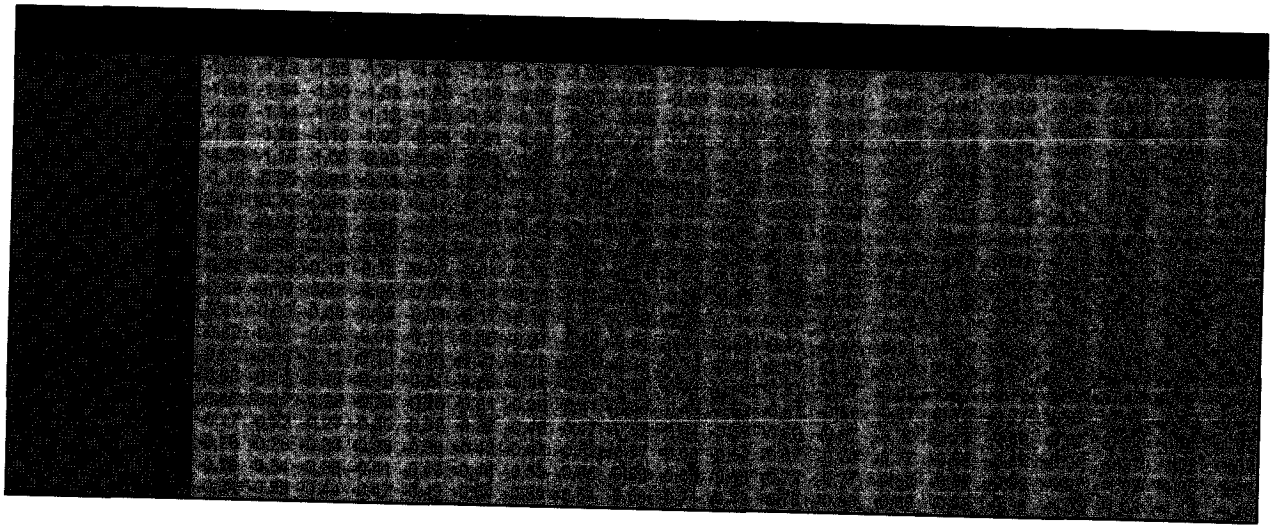
Hedge ratio							
Forward	0%	100%	100%	75%	50%	25%	0%
Option	0%	0%	0%	25%	50%	75%	100%

Appendix 14 Dataset ¥ second model

Y	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AO	AQ	AR	AS	AT	AU	AV
		JPY/EUR BS rate	D (JPY/EUR) Spot return	Interest EUR	Interest JPY	Forward rate	Forward leg	Interest rate differenc e	Sales JPY	D (Sales JPY)	Indexed Sales JPY	D (Indexed Sales JPY)	Unhedge d JPY	Always 1_Fwd only JPY	Fwd_Amt[t-1] JPY	75F/50O_ Amt[t-1] JPY	50/50_A mt[t-1] JPY	25F/75O_ Amt[t-1] JPY	Opt_Amt[t-1] JPY
		106,89		4,55%	0,10%	106,4998		0,37%	461976100		1,00								
		108,86	-1,82%	4,54%	0,10%	108,4600	2,19%	0,37%	476723800	14747700	1,03	0,03	-1,88%	0,38%	0,31%	-0,03%	-0,36%	-0,70%	-1,04%
		110,08	-1,12%	4,32%	0,10%	109,6979	1,49%	0,35%	478688727	1964927	1,04	0,00	-1,16%	0,38%	0,38%	0,06%	-0,26%	-0,57%	-0,89%
		108,67	1,29%	3,79%	0,10%	108,3389	-0,94%	0,31%	313565740	-165122987	0,68	-0,36	0,88%	0,24%	-0,10%	-0,20%	-0,30%	-0,40%	-0,49%
		109,15	-0,44%	3,78%	0,10%	108,8128	0,74%	0,31%	342828700	29262960	0,74	0,06	-0,32%	0,23%	0,18%	-0,01%	-0,20%	-0,39%	-0,59%
		108,26	0,82%	3,36%	0,10%	107,9670	-0,51%	0,27%	335220800	-7607900	0,73	-0,02	0,59%	0,22%	0,21%	0,11%	0,01%	-0,09%	-0,19%
		116,36	-7,22%	3,34%	0,10%	116,0470	7,49%	0,27%	388210700	52989900	0,84	0,11	-6,06%	0,23%	-0,63%	-0,88%	-1,12%	-1,36%	-1,61%
		118,26	-1,62%	3,35%	0,10%	117,9398	1,89%	0,27%	202419550	-185791150	0,44	-0,40	-0,71%	0,12%	0,88%	0,62%	0,37%	0,11%	-0,15%
		116,32	1,65%	3,34%	0,10%	116,0065	-1,38%	0,27%	362850350	160430800	0,79	0,35	1,30%	0,21%	0,69%	0,71%	0,74%	0,76%	0,78%
		115,73	0,51%	3,34%	0,09%	115,4148	-0,24%	0,27%	335454950	-27395400	0,73	-0,06	0,37%	0,20%	0,18%	0,01%	-0,15%	-0,32%	-0,49%
		115,70	0,02%	3,33%	0,09%	115,3890	0,25%	0,27%	435881400	100426450	0,94	0,22	0,02%	0,26%	0,20%	0,04%	-0,12%	-0,28%	-0,44%
		115,00	0,61%	3,37%	0,09%	114,6820	-0,34%	0,27%	342577750	-93303650	0,74	-0,20	0,45%	0,20%	0,13%	-0,01%	-0,15%	-0,29%	-0,43%
		117,97	-2,55%	3,37%	0,09%	117,6447	2,82%	0,27%	563914941	221337191	1,22	0,48	-3,11%	0,33%	-1,02%	-1,23%	-1,45%	-1,66%	-1,87%
		116,13	1,57%	3,34%	0,09%	115,8169	-1,30%	0,27%	417942500	-145972441	0,90	-0,32	1,42%	0,25%	-0,16%	-0,08%	0,01%	0,09%	0,18%
		116,25	-0,10%	3,32%	0,08%	115,9390	0,38%	0,27%	451168350	33225850	0,98	0,07	-0,10%	0,26%	0,24%	0,02%	-0,19%	-0,40%	-0,61%
		119,96	-3,14%	3,32%	0,08%	119,6386	3,41%	0,27%	682794700	231626350	1,48	0,50	-4,64%	0,40%	-1,31%	-1,59%	-1,87%	-2,15%	-2,43%
		121,52	-1,29%	3,31%	0,08%	121,1953	1,56%	0,27%	561689021	-121105679	1,22	-0,26	-1,57%	0,33%	0,74%	0,37%	0,00%	-0,36%	-0,73%
		122,90	-1,12%	3,41%	0,08%	122,5553	1,39%	0,28%	597399305	35710284	1,29	0,08	-1,45%	0,35%	0,24%	-0,03%	-0,31%	-0,58%	-0,86%
		124,19	-1,05%	2,92%	0,07%	123,8985	1,33%	0,24%	482630969	-114768336	1,04	-0,25	-1,10%	0,29%	0,62%	0,28%	-0,05%	-0,39%	-0,72%
		128,27	-3,23%	2,83%	0,06%	127,9755	3,47%	0,23%	530299930	47668961	1,15	0,10	-3,71%	0,27%	-0,09%	-0,35%	-0,61%	-0,88%	-1,14%
		126,12	1,69%	2,79%	0,06%	125,8331	-1,46%	0,23%	388966141	-141333789	0,84	-0,31	1,42%	0,19%	-0,25%	-0,13%	0,00%	0,12%	0,25%
		128,44	-1,82%	2,58%	0,06%	128,1665	2,05%	0,21%	303268200	-85697941	0,66	-0,19	-1,19%	0,15%	0,53%	0,32%	0,11%	-0,10%	-0,31%
		132,75	-3,30%	2,56%	0,03%	132,4700	3,51%	0,21%	525180840	221912640	1,14	0,48	-3,76%	0,24%	-1,45%	-1,60%	-1,76%	-1,91%	-2,06%
									347840357										
Average		117,56	-0,98%						433984933	2872943	0,94	0,01	-1,11%	0,26%	0,02%	-0,16%	-0,35%	-0,53%	-0,72%
SD		7,18	2,12%						112299254	127956239	0,24	0,28	2,06%	0,08%	0,63%	0,63%	0,65%	0,70%	0,76%
Skew		0,37	-1,10						0	0	0,20	0,38	-0,86	0,30	-1,11	-1,27	-1,18	-0,88	-0,50
Kurtosis		-0,54	2,14						0	-1	-0,07	-0,74	15%	-45%	74%	114%	112%	80%	44%
AR (1)		0,93	-0,13						0	-1	0,37	-0,53	-0,16	0,48	-0,24	-0,24	-0,21	-0,18	-0,14
Var (95%)													-4,60%	0,15%	-1,30%	-1,57%	-1,74%	-1,90%	-2,05%
Var / SD													-2,17	0,07	-0,61	-0,74	-0,82	-0,90	-0,97

Hedge rat							
Forward	0%	100%	100%	75%	50%	25%	0%
Option	0%	0%	0%	25%	50%	75%	100%

Appendix 15 Optimal $ hedging policy assuming constant sales



Appendix 16 The effect of price fluctuations on economic and transaction exposures

The influence of data about UHP's competitors and its sales on the data in table 3.3 is:

- Stable €/¥ rate versus €/¥ rate rise of 10% (difference between column F and I)

  - If the €/¥ rate rises 10%, the price erosion of Infocus is smaller because of:
  - The cost price of UHP's competitors rises.
  - Their margins (towards $ customers) become smaller.
  - The pressure from Infocus towards UHP to let its prices fall strongly becomes less, because Infocus will not go to competitors for price reasons that easy anymore.

  - If the €/¥ rate rises 10%, the price erosion of CDS remains the same because for UHP this is local production for a local customer, while UHP has local competitors (OSRAM).

  - If the €/¥ rate rises 10%, the price erosion of Sanyo and Sony is bigger because the price setting towards customers in Japan will have a strong trend to compensate a currency rise of the ¥ as much as possible in the price, because UHP's customers' sales in Japan are mainly € and $ related.

- Stable €/¥ rate versus €/¥ rate fall of 10% (difference between column F and J)

  - If the €/¥ rate falls 10%, the price erosion of Infocus is bigger because of:
  - The cost price of UHP's competitors falls.
  - Their margins (towards $ customers) become bigger.
  - The pressure from Infocus towards UHP to let its prices fall strongly becomes more, because Infocus will go to competitors for price reasons easier.

  - If the €/¥ rate falls 10%, the price erosion of CDS remains the same because for UHP this is local production for a local customer, while UHP has local competitors (OSRAM).

  - If the €/¥ rate falls 10%, the price erosion of Sanyo and Sony is smaller because the price setting with UHP's customers in Japan will have less reasons to compensate a currency fall of the ¥ in the price, since UHP's customers' sales in Japan are € and $ related. It should be noted that the difference between a falling ¥ and a stable ¥ is less than in case of a rising ¥. This is due to the presence of UHP's competitors in Japan. If UHP does not let its sales prices fall quite strongly, its customers might be inclined to go to its competitors.

The reasoning for a stable €/$ rate versus a €/$ rate rise of 10% (difference between column F and G) and a stable €/$ rate versus a €/$ rate fall of 10% (difference between column F and H) are similar. I will provide them in the final version of this thesis.

Modeling the effect of price fluctuations

Using table 3.3 the following set of equations can be set up, showing yearly price erosions in € in case of €/$ and €/¥ rate decreases of 10%. Note that this model is just another way of representing the data from table 3.3.

$PE_{€,Inf} = A + \alpha_{Inf}*\Delta_{€/\$} + \beta_{Inf}*\Delta_{€/¥}$

$-26,3 = -14,2 + \alpha_{Inf}*-10,0 + \beta_{Inf}*-10,0$

$PE_{€,CDS} = A + \alpha_{CDS}*\Delta_{€/\$} + \beta_{CDS}*\Delta_{€/¥}$

$-14,2 = -14,2 + \alpha_{CDS}*-10,0 + \beta_{CDS}*-10,0$

$PE_{€,Sanyo/Sony} = A + \alpha_{Sanyo/Sony}*\Delta_{€/\$} + \beta_{Sanyo/Sony}*\Delta_{€/¥}$
$-25,6 = -14,2 + \alpha_{Sanyo/Sony}*-10,0 + \beta_{Sanyo/Sony}*-10,0$

In which:

- $PE_{€,Inf}$ = yearly price erosion in € for Infocus
- $PE_{€,CDS}$ = yearly price erosion in € for Philips CDS
- $PE_{€,Sanyo/Sony}$ = average yearly price erosion in € for Sanyo and Sony
- A = average price erosion in ¥
- α_{Inf} = € price erosion factor for Infocus caused by a €/$ currency rate fluctuation
- α_{CDS} = € price erosion factor for Philips CDS caused by a €/$ currency rate fluctuation
- $\alpha_{Sanyo/Sony}$ = average € price erosion factor for Sanyo and Sony caused by a €/$ currency rate fluctuation
- β_{Inf} = € price erosion factor for Infocus caused by a €/¥ currency rate fluctuation
- β_{CDS} = € price erosion factor for Philips CDS caused by a €/¥ currency rate fluctuation
- $\beta_{Sanyo/Sony}$ = average € price erosion factor for Sanyo and Sony caused by a €/¥ currency rate fluctuation
- $\Delta_{€/\$}$ = €/$ currency rate fluctuation
- $\Delta_{€/¥}$ = €/¥ currency rate fluctuation

The solutions, together with its meanings, are the following:

$\alpha_{Inf} =$ 0,86: $ falls → quite strong PE in € for Infocus
$\beta_{Inf} =$ 0,35: ¥ falls → moderate PE in € for Infocus
$\alpha_{CDS} =$ 0: $ falls → no PE in € for CDS
$\beta_{CDS} =$ 0: ¥ falls → no PE in € for CDS
$\alpha_{Sanyo/Sony} =$ 0,61: $ falls → quite strong PE in € for Sanyo and Sony
$\beta_{Sanyo/Sony} =$ 0,53: ¥ falls → quite strong PE in € for Sanyo and Sony

For explanation: if α_{Inf} = 1 a $ fall of 10% will result in a price erosion for Infocus in € of 10%.

On the other side the following set of equations can be set up, showing yearly price erosions in € in case of €/$ and €/¥ rate rises of 10%:

$PE_{€,Inf} = A + \alpha_{Inf}*\Delta_{€/\$} + \beta_{Inf}*\Delta_{€/¥}$
$2,0 = -14,2 + \alpha_{Inf}*10,0 + \beta_{Inf}*10,0$

$PE_{€,CDS} = A + \alpha_{CDS}*\Delta_{€/\$} + \beta_{CDS}*\Delta_{€/¥}$
$-14,2 = -14,2 + \alpha_{CDS}*10,0 + \beta_{CDS}*10,0$

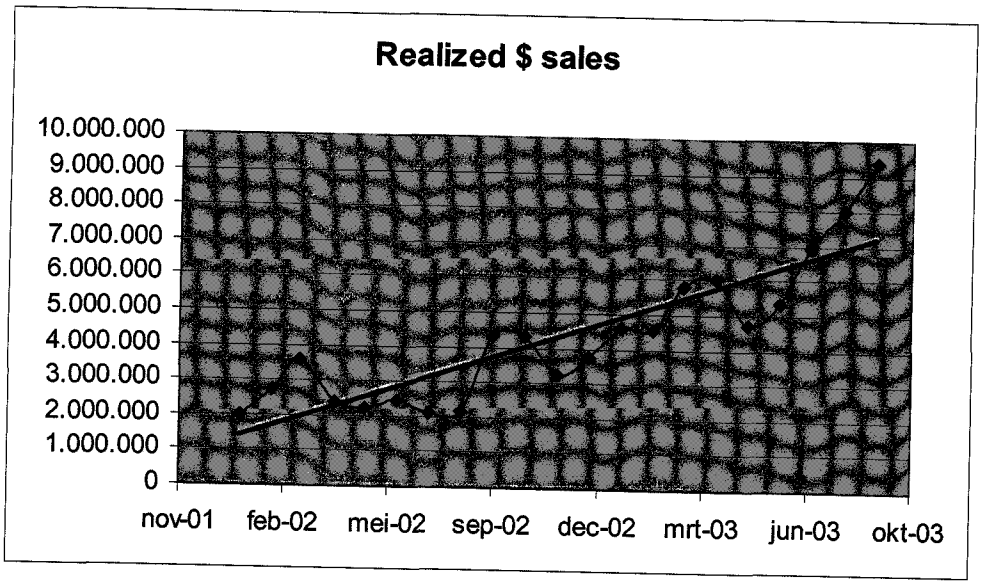
$PE_{€,Sanyo/Sony} = A + \alpha_{Sanyo/Sony}*\Delta_{€/\$} + \beta_{Sanyo/Sony}*\Delta_{€/¥}$
$-12,3 = -14,2 + \alpha_{Sanyo/Sony}*10,0 + \beta_{Sanyo/Sony}*10,0$

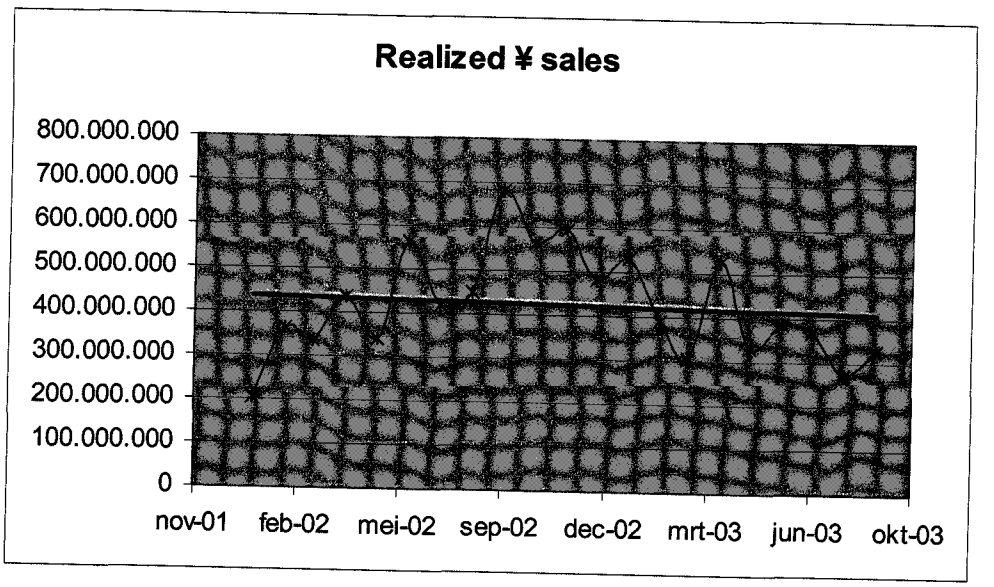
The solutions, together with its meanings, are the following:

$\alpha_{Inf} =$ 1,58: $ rises → very strong price rise in € for Infocus
$\beta_{Inf} =$ 0,36: ¥ rises → moderate price rise in € for Infocus
$\alpha_{CDS} =$ 0: $ rises → no PE in € for CDS
$\beta_{CDS} =$ 0: ¥ rises → no PE in € for CDS
$\alpha_{Sanyo/Sony} =$ 0,36: $ rises → moderate price rise in € for Sanyo and Sony
$\beta_{Sanyo/Sony} =$ -0,17: ¥ rises → moderate PE in € for Sanyo and Sony

It is notable that the α and β factors are not exactly the same for rising and falling €/$ and €/¥ rates. However, some conclusions can be drawn (see subsection 3.6.3).

Appendix 17 $ and ¥ sales trends





Graphically looking at the sales figures, one can see there has been a clear trend in $ sales over the last two years, as the trend line shows. On the other hand the ¥ sales have slightly fallen.

Appendix 18 Monthly hedging effectiveness

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	JPY Philips Balance sheet Rate	77,96	79,29	77,86	75,33	72,16	73,46	73,42	78,35	77,87			
	Exposure No.	21269	21270	21271	21281	21282	21283	22385	22386	22387	23070	23073	23074
Total Hedged Amount (Based on SALES)		**550.000.000**	**504.137.009**	**353.000.000**	**564.794.000**	**360.786.219**	**431.950.917**	**292.518.651**	**262.500.000**	**372.000.000**			
Total Sales		530.299.930	388.966.141	303.268.200	525.180.840	331.840.357	384.868.989	369.900.744	274.053.731	327.005.521			
Effectiveness Check		**96%**	**77%**	**86%**	**93%**	**92%**	**89%**	**100%**	**100%**	**88%**			

	USD 2003												
	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	USD Philips Balance sheet Rate	92,27	92,77	93,39	89,38	84,51	86,91	88,19	92,1	87,18			
	Exposure No.	21266	21267	21268	21275	21276	21277	22388	22389	22390	23075	23218	23222
Total Hedged Amount (Based on SALES)		**3.900.000**	**4.291.256**	**5.600.000**	**6.521.000**	**5.058.200**	**5.163.800**	**6.175.270**	**7.384.650**	**9.709.000**			
Total Sales		4.612.102,56	4.524.888,67	5.796.564,14	6.044.175,20	4.736.375,04	5.366.676,06	6.928.116,07	8.006.182,00	9.350.352,26			
Effectiveness Check		**100%**	**100%**	**100%**	**93%**	**94%**	**100%**	**100%**	**100%**	**96%**			

Appendix 19 Quarterly hedging effectiveness

Business: UHP Turnhout
Reporting funloc: 1720549013

This format is used to execute a quarterly effectiveness check on all outstanding anticipated exposures, according to FAS 133.
Until 2004, exposures are 100% sales hedges, consisting of 50% forwards and 50% options.
From 2004 onwards, exposures are 90% sales hedges, consisting of 50% forwards and 40% options.
If the last exposure has not been changed at the moment of the effectiveness check, a V is written down.

Date of effectiveness check:

Check executed by:

Month	Currency	Exposure number	Original exposure	Update	Date	Total exposure	Q3 2003
Oct '03	JPY	23070	627.045.000	-227.045.000	22-aug-03	400.000.000	
	USD	23075	5.586.000	1.414.000	22-aug-03	7.000.000	
Nov '03	JPY	23073	502.466.000	-102.466.000	22-aug-03	400.000.000	
	USD	23222	4.476.000	2.524.000	22-aug-03	7.000.000	
Dec '03	JPY	23074	519.077.000	-119.077.000	22-aug-03	400.000.000	
	USD	23218	4.624.000	2.376.000	22-aug-03	7.000.000	
Jan '04	JPY	30985	720.000.000			720.000.000	
	USD	30980	6.000.000			6.000.000	
Feb '04	JPY	30989	550.000.000			550.000.000	
	USD	30981	4.650.000			4.650.000	
Mar '04	JPY	30987	550.000.000			550.000.000	
	USD	30988	4.650.000			4.650.000	
Apr '04	JPY	34078	818.000.000			818.000.000	
	USD	34072	7.481.000			7.481.000	
May '04	JPY	34080	654.000.000			654.000.000	
	USD	34087	5.985.000			5.985.000	
Jun '04	JPY	34081	654.000.000			654.000.000	
	USD	34088	5.985.000			5.985.000	
Jul '04	JPY	40847	749.382.000			749.382.000	
	USD	40844	7.254.000			7.254.000	
Aug '04	JPY	80848	600.467.000			600.467.000	
	USD	40845	5.813.000			5.813.000	
Sep '04	JPY	40849	600.467.000			600.467.000	
	USD	40846	5.813.000			5.813.000	
Oct '04	JPY	47232	749.382.000			749.382.000	
	USD	47230	7.254.000			7.254.000	
Nov '04	JPY	47233	600.467.000			600.467.000	
	USD	47231	5.813.000			5.813.000	

Appendix 20 Forward valuation calculator

Example valuation forward contracts

Current date
Date that contract matures

Current balance sheet rate:
Currency 1
Currency 2
Foreign currency
Interest rate USD
Interest rate EUR
Day count
Current two month forward rate:

Please use market convention (I.e. the inverse of the balance sheet rate published by Corp.Control every month
(As it is quoted in financial markets)

(fixed for both currencies for simplification)

Rate at which original forward was concluded

This is the rate that is written in the conformation you get from Corporate Treasury, at the moment the contract was concluded

Contract

	Buy (+/+) or Sell (-/-)		Forward rate	EUR value	
Forward contract		USD			(this amount is the amount in EUR that you will receive)
What if sold at time of balance sheet rate calculation:		USD			(this is the amount that you would receive if you would have sold at current forward ra
					Future value of your outstanding contract
					Discount rate (for you need to calculate the present value of this future value)
					Present value of forward contract
					in fair value report

For questions on this example, please contact Corporate Treasury, Risk Consulting; Tel.nr. +31.20.59.77.359 or +31.20.59.77.362

Appendix 21 Formula to calculate the percentage of the currency result compensated by hedging

$$y = \{-[(b+c)/1000]\} / \left\langle u - x + v - \left\{ \sum_{i=1}^{5} (k_i / d_i - k_i / e_i) + \sum_{i=1}^{5} [(l_i + m_i)/e_i - (l_i + m_i)/d_i] \right\} - t/1000 \right\rangle$$

s.t.

$$i = 1....5(1 = eur, 2 = jpy, 3 = usd, 4 = gbp, 5 = chf)$$

In which:

y	percentage of currency result compensated by hedging
x	result on hedging contracts
z	EBIT gain/loss due to currency effects
a	total hedge result
b	sales hedges (841009)
c	cash flow hedges (841000)
v	EBIT excluding hedging result
w	EBIT excluding hedging result if currency at AOP (Annual Operations Plan) rate
u	EBIT actual
s	total netted currency result on result flows
t	total balance sheet revaluation
q	delta currency results for total outgoing result flows (in €)
r	delta currency results for total incoming result flows (in €)
k_i	delta currency results for outgoing flows for currency i (in €)
i	currency
p_i	delta currency results for incoming flows for currency i (in €)
f_i	outgoing result flow at activity rate for currency i (in €)
g_i	outgoing result flow at AOP rate for currency i (in €)
h_i	incoming result flow at AOP rate for currency i (in €)
j_i	incoming result flow at activity rate for currency i (in €)
o_i	total outgoing flows (sales and supplies) in currency i
d_i	activity rate currency i
e_i	AOP rate currency i
l_i	incoming flows (material costs) in currency i
m_i	incoming flows (OCOO) in currency i

Appendix 22 Percentage of currency result compensated by hedging

Currency flows

	Jan 2003	Feb 2003	Mrt 2003	Apr 2003	May 2003	June 2003	July 2003	Aug 2003	Sep 2003	Okt 2003	Nov 2003	Dec 2003	Ytd
Total outgoing result flows in foreign currency													
EUR	1 725.381	1.542 103	1 091 482	1 058 499	3 240 035	822.752	1 114 595	1 795 875	1 688 459				14 079 181
JPY	530 299 930	388 966.141	303.268.200	525 180 840	331 840 357	384 868 989	369 900 744	274 053 731	327.005 521				3 435 384 453
USD	4 612 103	4 524 889	5 776.308	6 044 175	4 736.375	5 366 676	6 928 116	8.006 182	9.350.352				55.345 176
GBP	0	0	0	0	0	0	0	0	0				0
CHF	0	0	0	0	0	0	0	0	0				0
Materiaal													
EUR	2.874 637	2 106 276	2 454 413	2 025.527	1.641 467	2773237,79	2013126,55	2056105,36	2601696,41				0
JPY	104 057 655	95 585 821	94.255 299	181 488 143	91 168 774	211 810 866	226 805 534	205 817 785	162.508 554				20 546 486
USD	109 420	80 802	323.286	108 499	70 945	4 419	15 359	20.409	27.963				1 373.498 431
GBP	0	0	0	0	0	0	0	0	0				761.104
CHF	0	0	0	0	0	0	0	0	0				0
OCOO													0
EUR	1 303 244	2 475 221	1 280 492	125 953	1.481 174	1.226.699	1 823 186	688 394	1 445 405				0
JPY	6 621 582	2 826 791	7 893.627	13 157 555	3 407 519	3 985 791	12 899 483	2 559.996	7.427.409				11 849 768
USD	3 424	38 652	45.790	516	11 415	12 723	36 520	16 822	70 547				60 779.753
GBP	440	7 200	1 151	345	90	7 533	0	3 004	0				236.409
CHF	1 717	13 141	0	0	0	0	0	0	0				19 763
Total incoming result flows in foreign currency													14 858
EUR	4 177.881	4 581 497	3.734.905	2 151.480	3 122 641	3 999 937	3 836 313	2.744 500	4.047.101	0	0	0	0
JPY	110 679.237	98 412 612	102 148 926	194 645 698	94 576 293	215 796 657	239 705 017	208 377.781	169 935 963	0	0	0	32 396 254
USD	112 845	119 455	369 077	109.015	82.359	17 142	51 879	37 231	98 510	0	0	0	1 434 278 184
GBP	440	7.200	1 151	345	90	7 533	0	3 004	0	0	0	0	997 512
CHF	1 717	13.141	0	0	0	0	0	0	0	0	0	0	19 763
													14.858

Activity rate	Jan 2003	Feb 2003	Mrt 2003	Apr 2003	May 2003	June 2003	July 2003	Aug 2003	Sep 2003	Okt 2003	Nov 2003	Dec 2003	Avg rate
EUR	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00			
JPY	124,19	128,27	126,12	128,44	132,75	138,58	136,13	136,20	127,63	128,42			
USD	1,05	1,08	1,08	1,07	1,12	1,18	1,15	1,13	1,09	1,15			
GBP	0,65	0,66	0,68	0,68	0,70	0,72	0,69	0,70	0,69	0,69			
CHF	1,45	1,47	1,46	1,48	1,52	1,52	1,54	1,55	1,54	1,55			
Aop exchange rate													
EUR	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,0
JPY	114,39	114,39	114,39	114,39	114,39	114,39	114,39	114,39	114,39	114,39	114,39	114,39	114,4
USD	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	1,0
GBP	0,64	0,64	0,64	0,64	0,64	0,64	0,64	0,64	0,64	0,64	0,64	0,64	0,6
CHF	1,45	1,45	1,45	1,45	1,45	1,45	1,45	1,45	1,45	1,45	1,45	1,45	1,5

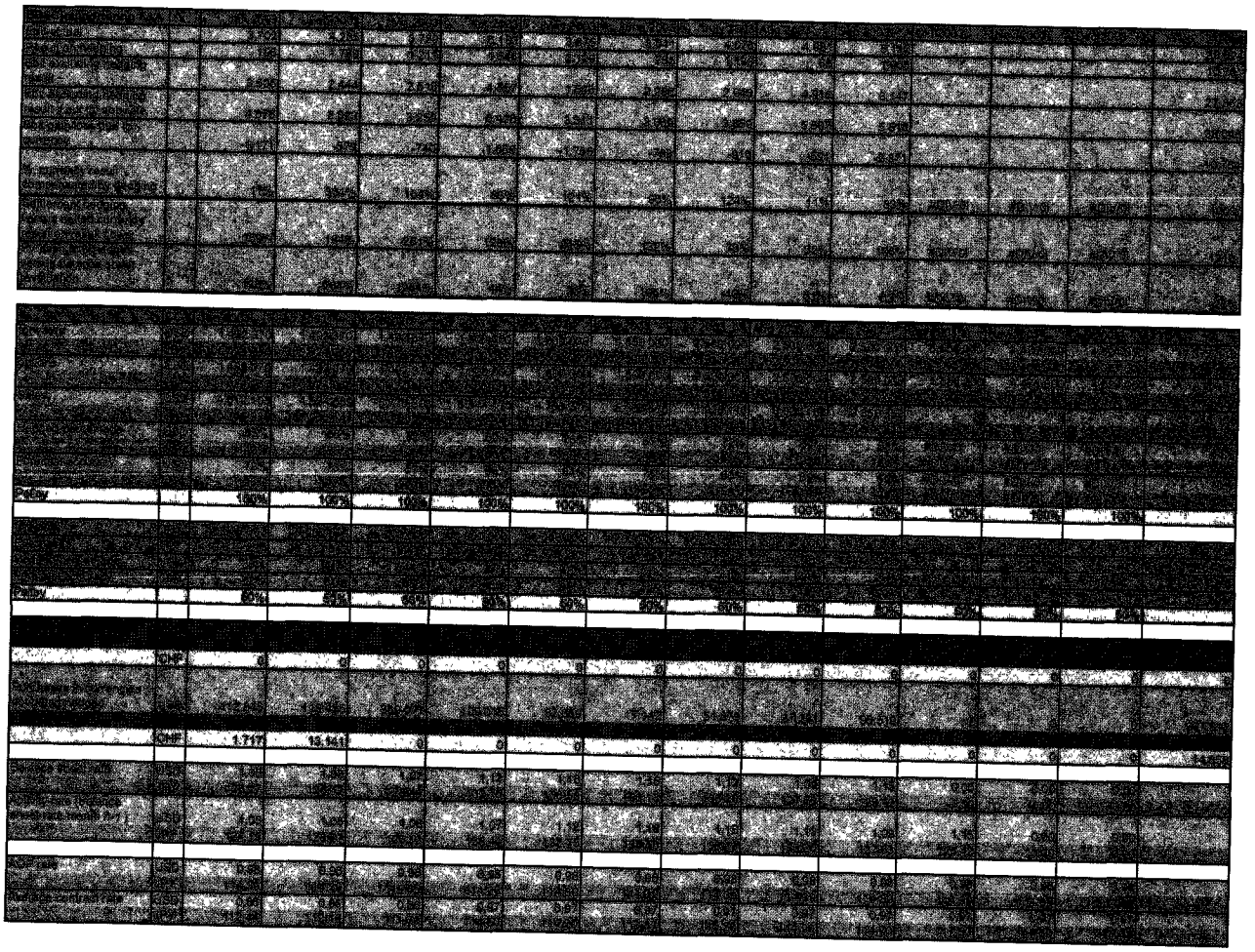
	Jan 2003	Feb 2003	Mrt 2003	Apr 2003	May 2003	June 2003	July 2003	Aug 2003	Sep 2003	Okt 2003	Nov 2003	Dec 2003	Total
Total outgoing result flows (in euro)													
EUR	1 725 381	1 542.103	1 091 482	1 058 499	3 240 035	822 752	1.114 595	1.795 875	1 688 459				14 079 181
JPY	4 269 975	3 032 380	2 404 614	4.089.058	2.499 753	2 777 215	2 717 291	2 012 102	2 562 088				26 364 476
USD	4 401 329	4 175 115	5.358.681	5.644 655	4 233 372	4 535 378	6 021 226	7.060.652	8.611.674				50.042.082
GBP	0	0	0	0	0	0	0	0	0				
CHF	0	0	0	0	0	0	0	0	0				
Total	**10.396.686**	**8.749.598**	**8.854.777**	**10.792.213**	**9.973.160**	**8.135.345**	**9.853.112**	**10.868.629**	**12.862.222**				90 485 740
Total incoming result flows (in euro)													0
EUR	4 177.881	4 581 497	3 734.905	2.151 480	3 122 641	3 999 937	3 836 313	2.744 500	4.047.101				0
JPY	891 189	767.225	809 939	1 515 511	712 443	1 557 189	1 760.873	1 529 910	1 331 448				32 396.254
USD	107 688	110 221	342 392	101 809	73.613	14 487	45.088	32 834	90 728				10 875 727
GBP	673	10 944	1 692	508	129	10.471	0	4 265	0				918.859
CHF	1 181	8.945	0	0	0	0	0	0	0				28 682
Total	**5.178.613**	**5.478.832**	**4.888.928**	**3.769.308**	**3.908.826**	**5.582.083**	**5.642.274**	**4.311.508**	**5.469.277**				10 126
													44 229 649

see next page

Total outgoing result flows (in euro)	Jan 2003	Feb 2003	Mrt 2003	Apr 2003	May 2003	June 2003	July 2003	Aug 2003	Sep 2003	Okt 2003	Nov 2003	Dec 2003	Total
EUR	1 725 381	1 542 103	1 091 482	1.058 499	3 240 035	822 752	1 114 595	1 795 875	1 688 459				14.079 181
JPY	4 635 894	3 400 351	2 651 178	4.591 143	2 900 956	3 364 534	3 233 681	2 395.784	2 858.690				30.032 210
USD	4 730 362	4 640 911	5 924 418	6 199 154	4 857 821	5 504 283	7 105 760	8 211 469	9 590 105				56 764 283
GBP	0	0	0	0	0	0	0	0	0				
CHF	0	0	0	0	0	0	0	0	0				
Total	**11.091.637**	**9.583.365**	**9.667.078**	**11.848.796**	**10.998.811**	**9.691.569**	**11.454.036**	**12.403.127**	**14.137.254**				100 875 673
Total incoming result flows (in euro)													0
EUR	4 177.881	4 581 497	3 734 905	2 151 480	3 122 641	3 999 937	3 836 313	2 744 500	4.047 101				0
JPY	967.560	860 325	892.988	1 701 597	826 788	1 886 499	2 095.507	1 821 643	1 485 584				32.396 254
USD	115.738	122 518	378.540	111 810	84.471	17 582	53.209	38 185	101 036				12.538 493
GBP	691	11 304	1 807	542	142	11 827	0	4 716	0				1.023 089
CHF	1 182	9 046	0	0	0	0	0	0	0				31 028
Total	**5.263.053**	**5.584.691**	**5.008.240**	**3.965.430**	**4.034.042**	**5.915.844**	**5.985.029**	**4.609.044**	**5.633.721**				10.228
													45 999 093

Total outgoing result flows (in euro)	Jan 2003	Feb 2003	Mrt 2003	Apr 2003	May 2003	June 2003	July 2003	Aug 2003	Sep 2003	Okt 2003	Nov 2003	Dec 2003	Total
EUR	0	0	0	0	0	0	0	0	0				0
JPY	-365 919	-367 971	-246 564	-502 085	-401 203	-587 319	-516.390	-383 682	-296.601				-3 667 733
USD	-329 032	-465.797	-565 738	-554 499	-624 449	-968 905	-1.084.534	-1 150.817	-978.430				-6 722 201
GBP	0	0	0	0	0	0	0	0	0				
CHF	0	0	0	0	0	0	0	0	0				
Total	**-694.951**	**-833.768**	**-812.302**	**-1.056.584**	**-1.025.651**	**-1.556.224**	**-1.600.924**	**-1.534.498**	**-1.275.032**				-10 389.934
Total incoming result flows (in euro)													0
EUR	0	0	0	0	0	0	0	0	0				0
JPY	76 371	93.101	83 049	186.086	114.345	329.311	334 634	291.734	154 136				0
USD	8.050	12.297	36 148	10 001	10 858	3.095	8 121	5.352	10 308				1 662 766
GBP	18	360	115	35	13	1 356	0	451	0				104 230
CHF	1	101	0	0	0	0	0	0	0				2 346
Total	**84.440**	**105.859**	**119.312**	**196.121**	**125.216**	**333.761**	**342.755**	**297.536**	**164.444**				102
													1 769 444
Netted currency result on result flows													
EUR	0	0	0	0	0	0	0	0	0	0	0	0	0
JPY	-289 548	-274.870	-163 515	-315 999	-286 858	-258 008	-181 756	-91 948	-142 466	0	0	0	-2 004.968
USD	-320 982	-453 500	-529.590	-544 498	-613.590	-965.810	-1 076.413	-1 145 465	-968 122	0	0	0	-6 617 970
GBP	18	360	115	35	13	1 356	0	451	0	0	0	0	2 346
CHF	1	101	0	0	0	0	0	0	0	0	0	0	102
Total	**-610.511**	**-727.909**	**-692.989**	**-860.462**	**-900.435**	**-1.222.463**	**-1.258.169**	**-1.236.963**	**-1.110.588**	**0**	**0**	**0**	**-8.620.490**
Hedge results P&L													
FV cash flow hedges (841009)	-771 782	422 170	-594 575	442 406	194 830	-855 447	137 096	-331 514	788 532				-568 285
Settlement hedging (841000)	968 197	1 338.127	1 805.329	1 103 689	1 934.254	1.610 670	996.184	396.318	1 176 434				11 329.202
Total hedge result	**196.415**	**1.760.297**	**1.210.754**	**1.546.095**	**2.129.084**	**755.223**	**1.133.280**	**64.804**	**1.964.966**				10 760 918
Balance revaluation													
Total balance sheet revaluation	**-560.247**	**148.880**	**-47.432**	**-1.007.334**	**-864.839**	**439.368**	**342.651**	**645.664**	**-1.260.489**				-2 163 778
Total currency result P&L	**-363.832**	**1.909.177**	**1.163.322**	**538.761**	**1.264.245**	**1.194.591**	**1.475.931**	**710.468**	**704.477**				0
													8.597.140

see next page



Appendix 23 Hedging result forecast

[redacted]

	Turnhout UHP										Fair Value				
	Inflow (local) 01/01/04 - 30/11/04	In EUR Forwards	Hedged Forwards (local)	In EUR Options	Hedged Options (local)	At risk (in local)		Aver rate forwards	Aver rate Options	Aver rate Total	Fair Value Forwards	Fair Value Options	Fair Value Total	Option Premium	Total
EUR															
USD															
jan	5 400.000	2.827.388	3.000.000	2 262.657	2.400.000			94,25	94,28	94,26	83.288	67.377	150.665	88.130	62 534
feb	4.185.000	2.192.569	2 325.000	1.754 551	1.860.000			94,30	94,33	94,32	65.891	53.209	119.101	71.147	47.954
mar	4.185.000	2.193.086	2.325.000	1.755 545	1.860.000			94,33	94,38	94,35	66.408	54.203	120.611	73.777	46.835
apr	6.740 500	3.537 952	3.740 500	2 839.296	3.000.000			94,59	94,64	94,61	116.517	95.196	211.713	122.161	89.552
may	5.382.500	2.876.479	2 992.500	2.253.472	2.390.000			96,12	94,29	95,31	139.240	67.339	206.578	100.838	105.741
jun	5.382.500	2.878.009	2 992.500	2.264 759	2.390.000			96,17	94,76	95,55	140 769	78.626	219.395	104.179	115.216
jul	6.529.000	3.132 327	3.627 000	2 518.004	2.902 000			86,36	86,77	86,54	-185.290	-136.455	-321.745	102.546	-424.290
aug	5 231.500	2.511.601	2.906.500	2.018.404	2.325.000			86,41	86,81	86,59	-146.975	-108.273	-255.248	84.924	-340 172
sep	5.231.500	2.548.622	2.906.500	2.019 456	2.325.000			87,69	86,86	87,32	-109 953	-107.221	-217.174	87.543	-304.718
okt	6.529.000	3.293.680	3.627.000	2.640.102	2.902.000			90,81	90,98	90,88	-23.937	-14.358	-38.295	110.620	-148.915
nov	5 231.500	2.671.956	2 906.500	2 116.330	2.325.000			91,93	91,02	91,53	13.380	-10.348	3.033	91.373	-88.340
dec	10.800.000	5.226.708	6 000.000	4.162 331	4.800.000			87,11	86,72	86,94	-261.492	-228.229	-489.721	188 345	-678.066
total	**70.828.000**	**35.890.378**	**39.349.000**	**28.604.908**	**31.479.000**	-		**91,21**	**90,87**	**91,06**	**(102.153)**	**(188.934)**	**(291.087)**	**1.225.583**	**-1.516.670**
JPY															
jan	570.500.000	2.288.796	282.500.000	2.309.173	288.000.000			81,02	80,18	80,60	61 566	38.581	100.147	84.747	15.400
feb	432.500.000	1.726.050	212.500.000	1.767 210	220.000.000			81,23	80,33	80,77	50.700	32 730	83.430	67.552	15.879
mar	432 500 000	1.729.339	212.500 000	1.770.481	220.000.000			81,38	80,48	80,92	53.989	36.001	89.990	70.200	19 790
apr	651.000.000	2.617.007	324.000.000	2.621.242	327.000.000			80,77	80,16	80,46	62.591	43.174	105.765	102.884	2 881
may	521.500.000	2.100.461	259.500.000	2.104.080	262.000.000			80,94	80,31	80,62	54.563	38.472	93.035	85.636	7.399
jun	521.500.000	2 105 040	259.500.000	2 108.313	262.000 000			81,12	80,47	80,79	59.142	42 705	101.847	88.813	13.034
jul	582 191.000	2.044.464	282.191.000	2.226.510	300.000.000			72,45	74,22	73,36	(180.330)	(138.690)	(319.020)	82.437	-401.456
aug	447.733.500	1.455.875	207.733.500	1.783 724	240.000.000			70,08	74,32	72,36	(181.896)	(108.436)	(290.332)	68 317	-358.649
sep	447.733.500	1.495.190	207.733.500	1.786.645	240.000.000			71,98	74,44	73,30	(142.581)	(105.515)	(248.096)	70.617	-318.713
okt	569.691 000	2.107 285	269.691 000	2 347.418	300.000.000			78,14	78,25	78,20	(18.959)	(17.782)	(36.741)	93.660	-130.401
nov	455.233.500	1.746.041	215.233.500	1.881.468	240 000.000			81,12	78,39	79,68	49.140	(10.692)	38.448	77 425	-38.977
dec	255.000.000	763.484	95.000.000	1.283.388	160.000.000			80,37	80,21	80,27	14.504	21.948	36.452	53.709	-17.257
total	**5.887.082.500**	**22.179.031**	**2.828.082.500**	**23.989.652**	**3.059.000.000**	-		**78,42**	**78,42**	**78,42**	**(117.571)**	**(127.504)**	**(245.076)**	**945.995**	**-1.191.071**
											(219.724)	**(316.438)**	**(536.162)**	**2.171.579**	***(2.707.741)***