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An economic capital model for APG Group?

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Management Summary

APG Group is a financial services company that offers asset management and administration services to Dutch pension funds. Additionally it provides life and disability insurance to pension holders via insurer Loyalis. The Corporate Risk Control (CRC) department of APG wanted to investigate the possibilities to implement Economic Capital (EC) as a tool for risk management and capital planning on APG Group level, also because new regulation requires APG to reassess capital adequacy. EC is a risk measure that represents an economic view on the risks an organisation is exposed to and translates risk into capital buffers needed to survive these risks materialising at a specified confidence level and time horizon. EC can enable APG CRC to translate different risk sources into one common risk currency so that risk levels and risk appetite can be compared between the activities of APG Group.

The risk profile of APG Group consists of operational risks originating from asset management and pension administration activities. Additionally insurance company Loyalis is exposed to specific market, credit and insurance risks. Because only a preliminary EC-model for Loyalis is available this research is exploratory and focuses on bringing operational risk into the EC-framework because this is the most important risk category at APG.

Methodologies developed by the banking sector are used to quantify operational risk. These methods estimate capital buffers via statistical analysis and simulation of losses. These approaches use information about historical losses as an input. Therefore data on operational losses at APG was collected from different sources, combined and analysed. This analysis showed operational losses at APG have the same characteristics as losses in banking or insurance. This result is only indicative since data on losses is scarce. Because the data driven approach did not produce robust results, structural assessment of experts, is used as input to estimate operational risk via a procedure known as expert elicitation. Using expert opinions on severity and frequency of operational losses lead to a capital estimate 5% off of the internal capital estimate.

The EC-model that was already present, but not actively used, for the financial risks of Loyalis was analysed leading to the conclusion that it contains outdated assumptions and methodology to provide useable capital estimates. If APG CRC wants to further implement EC as a risk measure to use in management information, scenario analysis and capital planning the current EC-model has to be updated. Considerable effort of management and experts is needed to bring the model up to market standards.

Considering the focus of APG risk management on risk control on process level, EC might provide another perspective on the risk profile of APG. Any new risk measurement methodology should leverage existing procedures and available information so the risk control framework and available data should be part of any new quantitative risk measure, be it EC or other. As follow up from this research the registration and collection of information on operational events is improved. The proposed expert elicitation and loss simulation methodology to quantify operational risk can be implemented in the risk control framework to become a standard part of risk management procedures. This research can serve as a starting point for capital calculation and allocation at APG since this aspect becomes more and more important due to a new regulatory regime APG is subject to.

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[NOTE]: This is a public version of this thesis, amounts deemed confidential by APG have been removed.

1. Problem identification and research approach

1.1 Introduction: Risk management and control at APG Group, a service organization for Dutch pension funds.

APG (Algemene Pensioen Groep)[1] is a financial services company that provides a range of services to Dutch pension funds (Dutch: Pensioenuitvoerder) of which ABP (Algemeen Burgerlijk Pensioenfonds) is both the biggest client and shareholder of APG. APG offers administrative services consisting of keeping records on pension holders and pension rights of the members of Dutch pension funds that are the clients of APG. Another service APG offers is the management of pension fund assets, so carrying out the investment policies the executive boards of pension funds determine. Next to administration and asset management, activities include advisory services to the boards of pension funds and offering supplementary pension and disability insurance products via the insurance company Loyalis. Loyalis offers these products to pension holders associated with the clients of APG. The product offering of APG also shows in the structure of the company, consisting of three main business lines: APG Asset Management (AM) and APG Pension Administration (RB) together making up the legal entity APG APG. Loyalis is a separate insurance company, and 100% subsidiary of APG Group, carrying out all insurance activities.

From the APG website (APG, 2013):

> *APG carries out collective pension schemes for participants in the education, government, and construction sectors, cleaning and window-cleaning companies, housing corporations and energy and utility companies as well as social or sheltered employment. We manage pension assets of in total approximately 324 billion Euros (December 2012) for these sectors. APG works for over 3.000 employers and provides for the income of around 4.5 million participants. APG administrates over 30% of all collective pension schemes in the Netherlands.*

A very important note in the light of this research on the operations of APG is that the financial or market risk of the investments APG manages on behalf of their clients is not, in any way, risk that is taken on by APG and therefore not a subject of this research. All market risks are on account of the pension funds themselves, this is due to the legal set up of APG and relevant regulations applicable for pension funds in the Netherlands, but also because the pension funds make the investment decisions themselves and these are only executed by APG. This research takes the perspective of APG rather than that of a pension fund because the CRC (Corporate Risk Control) department where this research is

[1] In the remainder of this text APG refers to APG group and APG APG refers to the organizational unit that is responsible for asset management and pension fund administration.

conducted is responsible only for the risk management of APG. The specific risks for pension funds, that of course play a major role in client reporting and asset management, are managed elsewhere in the organisation at the financial and operational risk management departments of APG AM.

The current debate about the Dutch pension system has no direct impact on APG because essentially they are just a subcontractor carrying out services on behalf of the pension funds. The pension accord (Dutch: Pensioenakkoord) of 2011 will not be further implemented. The changes in the Witteveenkader as an effect of the Dutch state budget 2013, most notably the increase in pensionable age and the decrease of the percentage of income that can be saved for pension purposes tax free, are the most recent changes in pension regulations in the Netherlands. For the activities of APG this does not matter so much, besides that ALM studies and valuation of liabilities that APG carries out for their clients need to reflect these developments. Also minor changes in the administration systems need to be made. Nonetheless any major changes in the principles of the Dutch pension system would directly affect APG especially if these changes would change the principle of collective pension schemes, meaning all Dutch employees must participate in a pension fund by law. If participants would be given the possibility to choose where they want to build up their pension this would mean a major change in the APG business model is needed. Also any changes in the regulation for pension fund asset management activities will directly affect APG AM.

Because the services that APG delivers are crucial to the pension of so many people and the amount of assets it is managing is enormous there is a very strong need, and requirement, to be in control of the business processes and to manage risk in the organization. Because of this need CRC, where this research is conducted, has a central role in the organization and keeps track of risk management policies and procedures to safeguard the process of risk management. As an addition to the procedures and methods already in place the CRC department would like to develop and implement an EC (Economic Capital) model as a means to better keep track of, and manage the risks that are present in the organization. EC is a risk measure that can be used to quantify risk into capital levels needed to sustain a certain risk materialising. Next to internal use as a tool for management information capital calculation and adequacy becomes even more important for APG in the future because of new regulatory requirements. This research will have an exploratory character as at this moment EC is not implemented by APG Group. EC is rather a topic of interest that needs further investigation. Therefore this research focuses on exploring which EC methodology fits the organisation and its purposes best and how EC could be implemented by APG risk management.

1.2 Research goal

The objective of the research project is to explore the different options to implement an EC-model that encompasses the different risk types found at APG Group, APG AM, APG RB and Loyalis and can be used in the current risk management framework. EC is defined as the potential unexpected loss over one year calculated at a pre-specified confidence level (Rao, 2004). The purpose of the EC model is to quantify risks present in the different organizational units in terms of capital figures and aggregate them on a business unit or group level to provide an overview of where in the organization what risk is taken and what capital amounts should be set apart to cover these risks. At this moment there is no EC model implemented nor is there any group wide reporting based on capital adequacy figures.

Because APG is exposed to financial risk only via Loyalis, for the remainder of the organisation operational risk is key, finding a suitable method to translate operational risk into EC figures will therefore make up a large part of this research. To develop an EC-model that is reliable and provides correct information, it should be based on scientific and professional literature on EC, current activities and information at APG. Also relevant government regulation that applies to APG and the different business line must be taken into account. The result of this research should be a description of risk types that are relevant for the APG organization and tools to quantify these risks and translate them to EC-values, both on individual risk or business unit level and group level. To arrive at the EC model this research will consist of a literature study bringing in scope all relevant and current scientific and professional debate, discussion and insights on EC and the quantification of risk. Also interviews with employees of APG, and following a more structured approach, the use of expert elicitation procedures and data on the risks from APG are part of the research. The proposed EC-model and risk measurement methodologies should be such that they can be implemented by APG CRC.

1.3 Research scope

The scope of research is broad, both in organizational and theoretical sense because at this moment only for Loyalis prior research on EC is available, which is not a working solution for the whole of APG Group. This means that for all the business line's relevant risk types have to be identified and quantified, such that they can be used in an EC-model. This also means that the research has to take place within the regulatory boundaries that hold for the different entities within APG group. For the organization structure that is the focus for this research and relevant regulation see Figure 1.

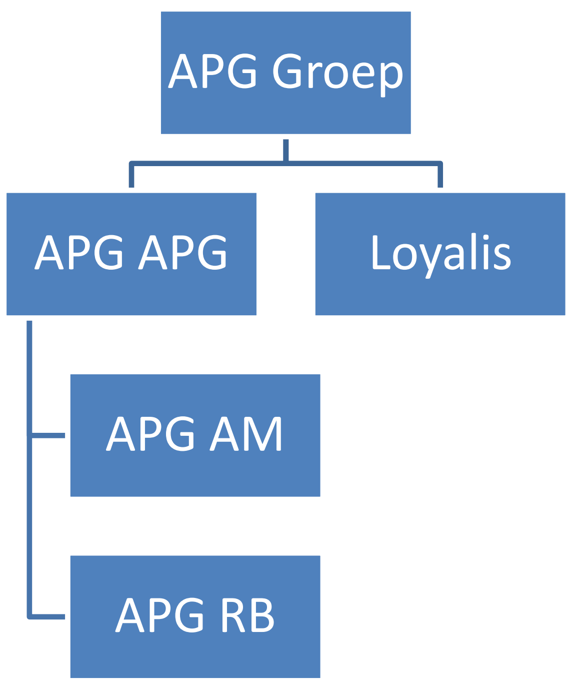

Figure 1: Overview of APG group

For each risk type in combination with its relevance for a specific part of the organization the correct model or method has to be selected to calculate risk measures and corresponding economic capital amounts, also taking into account the relevant regulation for that part of the organization. When different risk types have been identified and quantified for all business lines these have to be combined to get aggregate level results for economic capital on group level. This means that in the process of developing the EC-model a range of risk and aggregation levels have to be dealt with. On the other hand the EC-model will be specifically designed for APG group which means that risk types that are not present in the organization will not be part of the model and need not be quantified.

1.4 Problem identification

As a financial services company APG group has to be in control of their business processes and manage risk throughout the organisation, not only to operate a profitable business but also because of regulatory and contractual requirements. In order to do so a whole system of business controls is in place to organize the risk management and business control function, these controls are not necessarily quantitative however. This business control part of risk management has largely an accounting background and the process of building the control framework and testing if business control actually works is catered by one of the large accountancy firms. Also regulations for financial services companies require APG group to be in control of their processes, but more specifically require them to have enough capital in place to absorb large shocks or losses without having to file for bankruptcy, leaving their clients and owners of third pillar products at a loss. The CRC department of APG is responsible for setting up, implement and control these processes. The main risk management activities at the APG Group level consist of setting up and implementing group risk policies, collecting, aggregating and analysing risk data from business lines' and risk management reporting to the board of directors of APG. In order to do so CRC requires input from the APG business lines and receives regular updates on the current status of risks in the organisation, a.o. by collecting information on KRI's (Key Risk Indicators). At this moment however there is no general applicable "common language" to communicate about risk in the organisation leading to the question if EC might serve as a general purpose risk measure. Also there is no direct link between risk management activities and the amount of capital placed at each business line, except for Loyalis where capital requirements are managed following regulatory guidelines.

Currently risk management at APG is structured as a system of risk management policies, business controls, reporting lines and KRI's but there is no general purpose risk measure that can be compared between business lines and can help to determine risk based capital estimates.

To manage their business processes but also in order to comply with these requirements of their clients and owners as well as from the government APG implemented a risk control framework that is based on the Enterprise Risk Management model from the COSO (Committee of Sponsoring of the Treadway Commission). This framework specifies how APG organizes its risk management, control function, and processes on a structural level. The COSO framework allows for own implementations of methodology to recognize and control risks in the organization. The place of the EC-model in the risk control framework of APG is discussed in paragraph 3.3.

To get a better grip on the different risk types of APG and its entities, CRC wants to develop a model that produces capital figures and that can be used for management decision making, internal control, and communication with the regulator. The EC-model needs to quantify different risk types at different places in the organization(s) to create a common risk measure that can be compared between business lines. These measures can then be combined to establish reliable capital figures that can be used to monitor, communicate and control risks on APG Group level. At this moment there is no such generally applicable risk measure. All business lines have their own KRI's which reflect the current status of their risk profile.

At this moment at APG there is much attention for the calculation of capital requirements. Both at Loyalis and APG APG there are regulatory needs for capital adequacy reports. For Loyalis the regulatory capital framework is Solvency I, but DNB as well as Loyalis are in transition to the new Solvency II framework. The ORSA (Own Risk and Solvency Assessment), part of Pillar II of Solvency II regulation, is already a market standard and specifies that insurers have to go through their financial planning and risk management figures periodically and test whether these are adequate to survive certain pre-specified risks and periods of stress worked out in firm specific scenarios. Loyalis participated in the parallel run in 2011 of the DNB which was an preliminary implementation of Solvency II rules and tested capital adequacy and risk factors using the Solvency II model for capital calculation and risk quantification. The connection with EC is that despite there is a preliminary EC-model available for Loyalis the capital framework that is used for capital requirements and planning is Solvency I and Solvency II figure are also calculated in anticipation of new regulation.

At this moment APG APG has to make an ICAAP (Internal Capital Adequacy Assessment Process) report concerning their request for a permit as a consequence of the MiFID (Markets in Financial Instruments Directive) directive. The ICAAP follows the framework for risk and capital assessment that is specified in Basel II. Although the EC-model that is to be the result of this research will not be ready in time to provide input for these reports it could be used in the future because both procedures, ORSA and ICAAP, are to be repeated on a yearly basis. It is expected that the knowledge currently available at APG with regard to delivering these two reports can be of much value for the development of the EC-model and also can be used to validate the EC-figures that the model produces.

APG group currently already uses a whole range of techniques and methods to manage their risks throughout the organization but not all of these can be easily compared between business lines or are quantitative in nature. This is partly due to the fact that a large portion of the risk in the organisation can be specified as operational risk and the current control framework focuses on measuring how effective the controls in place to mitigate these operational risks are and less on the quantification of the risks in economic terms. To fill this gap, economic capital figures would enable CRC to produce quantitative figures that can be compared across business lines and can be used to provide an aggregated view on different risks and the consequences these risks have for the capital adequacy figures of the separate entities in APG group and for APG as a whole. The EC-model can be used to create an economic view on operational risk which is currently not related to monetary terms. Because the entities that constitute APG group are regulated separately this means that the capital adequacy calculations, which are closely related to the economic capital, are following different regulation. But because EC expresses an economic view on risks the capital amount might differ from regulatory required capital.

Because the services that APG group offers are mostly administrative in nature it has the largest exposure to operational risks, ie. risks arising from the failure of people, processes or external events. Financial risks as market and credit risk of course play an important role in the organization, but because the effects of asset management activities in terms of financial risks stay on the balance sheet of the pension funds these are not so relevant for an APG EC-model.

Because at this moment EC has no place in the risk management framework of APG, the goal of this research is an exploration of both opportunities and conditions to implement EC for APG CRC. The idea behind EC is to provide a view on capital requirements of a firm considering their own economic view on the risk profile of the organization. Financial risks are only part of the model insofar the risks are explicitly on the balance sheet of APG group, ie. only for Loyalis financial risks are relevant. The challenge in building an economic capital model for APG lies in the quantification of operational risk and the aggregation of separate economic capital figures over the different parts of APG group into group level capital. Following from the explorative character of the question the director of CRC has posed, this research will not only focus on technicalities of EC but also on more qualitative questions as added value, appropriateness and implementation.

1.5 **Problem statement**

The problem statement that is formulated using the information in the previous Section can be found below.

CRC wants to have a quantitative risk measure that can be compared between business lines, used to communicate about risks in the organisation and to determine risk based capital requirements. Investigate how EC can be implemented to answer this need taking into account financial and operational risks at the business lines , currently available risk management information and the APG risk and control framework.

1.6 **Research methodology**

The successful development and implementation of an EC-model for CRC in this context hinges on two important factors. First risk quantification methods have to be selected that fit the purpose and context at APG and secondly that the quality of inputs, specified by the design of the model, has to be guaranteed. This follows the logic that the output depends on the quality of the model and the quality of the input. Since the EC-model is to measure risk, the first part comes down to choosing methods to measure the different risk types in the organisation and also to make a choice in what method is used to aggregate the different risk measures used throughout the organisation. The data collection part of the research will be done by questioning the right people in the organisation in order to obtain data that are already available or is generated in the light of this research. Data collection will focus on finding and combining data on operational losses from different sources. The elicitation of expert opinions will also be part of the methodological toolbox in order to generate inputs for the operational risk quantification. For a more thorough description of the design methodology used in conducting this research, see Appendix B.

The selection of the correct methods to quantify and aggregate risk measures will be based on a thorough study of available scientific, and importantly, professional literature on this subject. Because EC is a concept that is developed by professional organisations and is later adopted by other institutions such as national regulators it is important to also take into account relevant information and documentation that is generated by these parties. The first step of this research will therefore be a thorough study of both scientific and professional literature on EC and operational risk quantification in order to make the right choices in the design of the EC-model and to make use of industry best practices. These choices will specify how risks present in the organisation are quantified and how these individual risk measures will be translated into EC and aggregated across risk types and business units.

The second important step in the process of developing an EC-model for APG group is finding the data that are to be used as input for the EC-model. Because the process of risk measurement is very dependent on the timely and correct use of data this step is crucial in the research process and implementation of EC. Since APG already has a risk control framework in place which also involves periodical data collection for different risks at the business units, some of the data needed for calculation of EC will be available at CRC. Next to the purposes of the internal risk framework there is also a need to collect data on the different risks in the light of regulation APG and its business lines are subject to. So both for the internal risk management function and in light of supervision from national regulators data is generated and collected throughout the organisation. Some of these data on risks in the organisation may be used as input for the EC-model, but not all data will be readily available or usable in their current form. Most notably for operational risk not all data will be available or in a format such that it can be used directly as input for the EC-model. This means that part of the research will be the collection and aggregation of data in the APG organisation. This will be done electronically by requests for data on for example operational losses, but also by interviewing employees dealing with these data in their day to day jobs or filtering available data files to collect the inputs needed for the EC-model. If the EC-model is to be implemented by CRC after this research, one important step in the implementation would be to make sure that input for the model will be generated by business lines in a structured and consistent manner to ensure data quality and output validity.

The validation of the model is an important step in the research process since in this step it will become apparent if the model produces results that are both credible and usable in the organisation. The validation process will take place with the use of existing figures on capital needs for APG and its business lines since these will provide a useful reference for the EC figures. The figures APG currently uses to determine capital adequacy are those produced for regulative purposes as in for example the ICAAP process and Solvency II.

When the EC-model is validated it can be used to produce results on the risk based capital requirements for APG. These results can then compared with the current capital figures and those required by the regulator to come to a better understanding of the (risk based) capital needs of the different business lines and APG group as a whole. This can be done on basis of the existing input, but also can be done in the process of scenario analysis or the development of new business.

2. Theoretical and professional framework

2.1 General definitions of EC

In this paragraph definitions and possible uses of EC will be discussed on basis of available scientific and professional literature, an elaborate list of definitions of both EC and the most important risk categories can be found in Appendix C. For EC also a short description of its uses is provided. When giving definitions it is already taken into account that later on in the research these definitions will be made operational in the EC-model. This means that the definitions have to be in line with the current risk control framework and practices at APG CRC. Where possible internal risk definitions will be used because they are most familiar and already used. In case no internal definitions are available regulatory documents and scientific papers will provide definitions of those concepts. In that case regulatory documents as Basel II or Solvency II have preference above scientific papers because APG has to use the same risk types when delivering required reports as ICAAP and ORSA to the regulator. Higher level definitions as for EC and risk in general tend to be more broadly and scientifically defined, gaining more specificity and context as the level of analysis approaches the granularity of the risk control framework at APG. Another note on these definitions is that they sometimes are a translation from the Dutch definitions used by APG where Dutch is the official reporting language.

2.1.1 Definition of Economic Capital

For a definition of Economic Capital there are multiple sources, of which the most informative are listed in Table 1.

Source	Definition
(BCBS, 2009)	EC can be defined as the methods or practices that allow banks to consistently assess risk and attribute capital to cover the economic effects of risk-taking activities.
(European Commission, 2009)	In order to promote good risk management and align regulatory capital requirements with industry practices, the Solvency Capital Requirement should be determined as the economic capital to be held by insurance and reinsurance undertakings in order to ensure that ruin occurs no more often than once in every 200 cases or, alternatively, that those undertakings will still be in a position, with a probability of at least 99,5%, to meet their obligations to policy holders and beneficiaries over the following 12 months. That economic capital should be calculated on the basis of the true risk profile of those undertakings, taking account of the impact of possible risk-mitigation techniques, as well as diversification effects.
(Porteous & Tapadar, 2006)	Economic capital for the business of a firm is the amount of capital, or excess assets, that this business requires to ensure that its realistic, or market value, balance sheet remains solvent, over a specified time horizon, with a prescribed probability or confidence level, following events that are unexpected, yet not so unlikely that they might never occur in practice.
(Cap Gemini, 2010)	Economic Capital is the amount of capital that banks set aside as a buffer against potential losses from their business activities. It is used to protect the bondholders and depositors.
(DNB, 2007)	The amount of capital that an institution considers it needs in order to cover its

	own economic risks in connection with a transaction or business unit.
(Hull, 2010)	The amount of capital a financial institution needs in order to absorb losses over a certain time horizon with a certain confidence level.
(Dev, 2004)	EC is a single measure of risk that captures unexpected losses or reduction in value or income from a portfolio or business in a financial institution.
(Rao, 2004)	EC is the potential unexpected loss over one year calculated at a pre-specified confidence level.

Table 1: Definitions of Economic Capital

The definitions given in the table above reflect the multiple angles at which EC can be viewed upon, for this research the definition of DNB (DNB, 2007) is used because it reflects the use of EC in businesses other than banks and the clear relation between the EC amount and (economic) risks.

> Definition 1: Economic Capital:
>
> the amount of capital that an institution considers it needs in order to cover its own economic risks in connection with a transaction or business unit.

The notion of the BCBS (Basel Committee on Banking Supervision) definition that there need also be methods and practices to produce EC figures is also important, certainly in the context of APG CRC but because the definition is not focused on EC itself but rather on the organizational context it is not a workable definition of EC.

EC is to capture all events that can cause an unexpected loss in the specified time period. This means that it is not focused on only one type of event, or risk (Porteous & Tapadar, 2006) (BCBS, 2009). This makes EC a very useable risk measure to make comparisons between different risk types, but it also makes it harder to implement an EC-model, since it has to take into account very different types of risk and quantify them into one measure. In Figure 2 below the different types of risks that may be captured by an EC-model are showed.

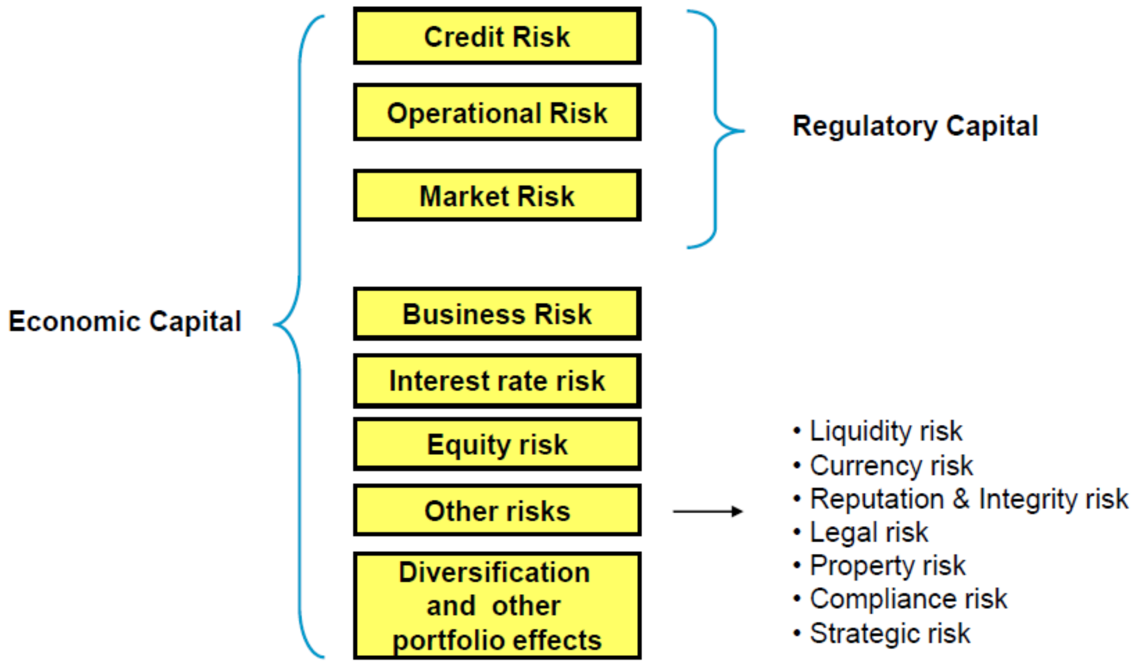

Figure 2: Risks measured by EC source: (Cap Gemini, 2010)

Another way to see what EC is about is to depict it in a graph because this shows the relationship between EC, expected losses and the losses unaccounted for by EC, see Figure 3. The graph leads also to the mathematical definition of EC given below.

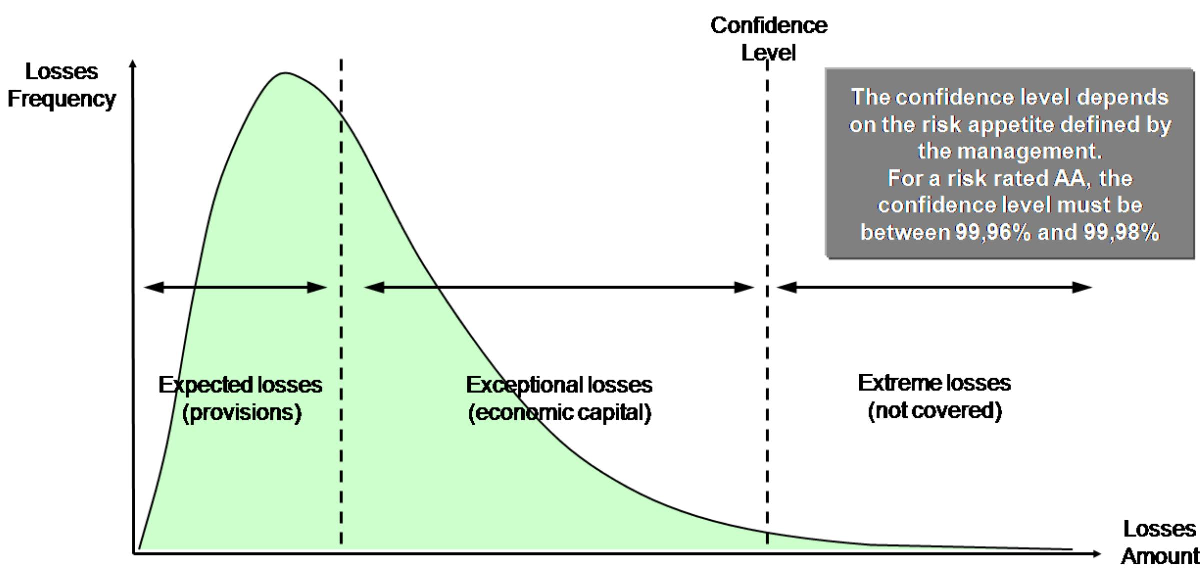

Figure 3: Economic Capital (source: (Economic Capital, 2010))

From this figure the mathematical definition of EC can be deducted, in simple form:

$$Economic\ Capital = Maximum\ loss\ (at\ given\ confidence\ level) - \ Expected\ loss$$

In mathematical terms, based on (Rao, 2004):

$$Equation\ 1: EC = EAE * F(PE, LGE, Correlation, Horizon, Confidence\ Level)$$

$$F = Complex\ function\ with\ parameters: PE, LGE, Correlation, Horizon\ and\ Confidence\ Level$$

$EAE = Exposure\ at\ Event$
$PE = Event\ probability$
$LGE = Loss\ given\ Event$

Equation 1 is a simple mathematical representation of EC, but nonetheless it is useful to see what factors determine EC amounts. Because not only losses from defaults are of interest but all events that can cause unexpected losses, whether it be credit losses, market losses or operational losses, leading to the more general formulation *events*. From Equation 1 it is clear that the amount of EC depends on a number of factors that relate to each other in a complex way which will be the subject of the main part of this research. But more importantly it gives an idea of important factors in the calculation of EC which also helps in getting a grip on the concept of EC. The function F that plays an important role in determining EC can be seen as the "risk" factor, of which a description can be found in Appendix C.

Economic capital is thus a risk measure that can be used for measuring a diverse set of risks throughout a financial institution. Furthermore it focuses on economic consequences of risks for the capital amount needed to sustain those losses and not so much on regulatory or accounting notions of capital (Embrechts, Frey, & McNeil, 2005). Because it is versatile in measuring different risks it has become best practice in risk measurement as it comes to representing risks in a way that can be compared across risk types and across organizational units (BCBS, 2009) (Porteous & Tapadar, 2006) (Dev, 2004) (Kuritzkes, Schuermann, & Weiner, 2002). These properties of the EC risk measure make it a suitable candidate for APG to measure risk at group level, because EC figures can be compared between business lines and risk types and it can serve as a common (quantitative) language to talk about risks throughout the organization.

2.1.2 Uses of economic capital

Next to a definition of EC it seems useful to also specify to which extent EC or an EC-model can be deployed, because there may be several reasons for a firm to introduce EC model in their risk control environment. EC was originally developed by banks to control and manage their return on capital, taking into account the riskiness of the activities with which those returns are generated. So EC was mainly used as a tool for capital allocation and performance measurement (BCBS, 2009). Currently there is also a lot of attention for the principles of economic capital from the side of insurers. Risk officers at insurers see the implementation of EC methodologies in their organisations as one of the biggest current challenges (Ernst & Young, 2013). In their report Range of practices and issues in economic capital frameworks (BCBS, 2009) the Basel Committee on Banking Supervision gives an overview of the uses of EC and EC-models, although somewhat biased towards the use of EC by banks, see Table 2.

Business-level use	**Credit portfolio management:** EC can be used as a measure of concentration in credit portfolios.
	Risk-based pricing: For pricing purposes the needed amount of EC and thereby the influence on performance for a given product can be used to price it.
	Customer and product profitability analysis: EC might be used to assess the risk weighted profitability of products and customers.
	Management incentives: To stimulate the use of EC in internal decision making it can be used in the remuneration of employees.
Enterprise-wide or group-level use	**Relative performance measurement:** EC can be used to assess relative performance of business units on basis of risk adjusted with measures as RAROC (risk adjusted return on capital) that are based on EC.
	Capital budgeting, strategic planning, target setting and internal reporting: When defining risk appetite and targets for profit for business units EC is used to allocate available capital to business units. EC is also used for internal reporting/control to see if business lines stay within their risk limits.
	Acquisition/divesture analysis: EC figures may be used in conducting due diligence in mergers and acquisitions.
	External communication: EC can be used in dialogues with supervisory authorities and rating agencies, but also in the disclosure in annual reports.
	Capital adequacy assessment: EC can be used in conducting the ICAAP to determine the amount of required capital.

Table 2: Uses of EC source: (BCBS, 2009)

As a reference in the book Economic Capital and Financial Risk Management (Porteous & Tapadar, 2006) the following, almost overlapping uses of EC, are given:

- Capital adequacy;
- Validation of regulatory capital;
- Risk measurement, appetite and limits;
- Business planning;
- Performance measurement.

As is stated before in the problem identification, the main intended use of the EC-model at APG is going to be the measurement and control of risks throughout the organization. As such the EC figures are going to serve as an uniform risk measure throughout the organization. Next to the use as risk measure the EC-model could be used in making the yearly ICAAP and ORSA reports, so in the dialogue with the supervisory authorities. A supplementary effect of the development of the EC-model is that it can also lead to an increase of risk awareness and familiarity with the notion that risk is more than something that is to be mitigated and controlled but also has an economic and monetary component.

2.2 Operational risk

For operational risk the story is somewhat different from the other risk categories which are quite narrowly defined, this can also be seen from the fact that operational risk is sometimes defined negatively, so as all risks that are not related to credit or market risks (Holmes, 2003). To keep the EC-model clear and understandable a choice has to be made as to which definition of operational risk, and more importantly, which types of events to be included in the measurement of operational risk. Searching for a workable definition for operational risk it becomes apparent that this is difficult, due to the many views on operational risk and also due to the different uses of data collected on operational risk. To keep the EC-model consistent with professional practice in this research the choice is made to treat operational risk in the same way as banks do to implement Basel II. This helps when defining operational risk since the documentation of the BIS can be used. Also the modeling methodologies for operational risk developed by banks are in line with these definitions so best practices developed by banks can be used in the design of the EC-model and the quantification of operational risk.

The definition of operational risk used in Basel II is (BCBS, 2006), page 158:

> *"The risk of loss resulting from inadequate or failed internal processes, people and systems or from external events. This definition includes legal risk, but excludes strategic and reputational risk."*

When collecting and filtering data in the organization this definition of operational risk is used to group events and losses that follow these events. Managers at APG are asked for information on all events that are caused by one of the causes mentioned in the definition of operational risk. The BCBS documentation also specifies eight categories and accordingly sub-categories of operational risk events see (BCBS, 2006), pages 305-307 for a precise overview. The broad categories are:

- Internal Fraud - misappropriation of assets, tax evasion, intentional mismarking of positions, bribery;
- External Fraud- theft of information, hacking damage, third-party theft and forgery
- Employment Practices and Workplace Safety - discrimination, workers compensation, employee health and safety;
- Clients, Products, & Business Practice- market manipulation, antitrust, improper trade, product defects, fiduciary breaches, account churning;
- Damage to Physical Assets - natural disasters, terrorism, vandalism;
- Business Disruption & Systems Failures - utility disruptions, software failures, hardware failures;
- Execution, Delivery, & Process Management - data entry errors, accounting errors, failed mandatory reporting, negligent loss of client assets.

As a further specification of which events to include in the analysis of operational risk the rules of the ORX (Operational Riskdata eXchange Association) are used (ORX, 2011). ORX is a not-for-profit industry association of international banks that collects data on operational events and losses in order to provide its participants with a collective database that can be used as an external data source in the modeling of operational risk.

Strategic/business risk, project risk and reputational risk are not part of operational risk. In the specific case of APG this means that the risk associated with loss of fee income due to declining AUM (Assets Under Management) because of adverse market conditions or the risk of big IT projects is not taken into account in the quantification procedure. It is not logical to hold capital for business risk because this is the risk that is caused by strategic choices for the range of products and services a firm provides. For backgrounds and arguments why these risks are not part of EC see (BCBS, 2009), (BCBS, 2003) and (ORX, 2011).

2.3 EC and risk control framework at APG group

The internal risk control framework at APG is based on the ERM (Enterprise Risk Management) model from the COSO (Committee of Sponsoring of the Treadway Commission). This framework serves as a basis for the design and organization of risk management, the process of risk management and the internal supervision on risk management (APG Group, 2012). Within the risk management framework of APG the EC model would find itself in the category risk management processes, which is specified as the periodical identification, analysis and examination of risks. Currently the main focus of CRC and risk management at APG is being in control of their business processes and provide assurance that APG can generate In Control Statements for the board of directors and clients. This is being done by a system of controls and key controls with the aim of mitigating risks throughout the processes conducted by APG APG and Loyalis. The control framework is build up by firstly recognizing the risks that the organization is exposed to, and secondly formulating risk mitigating measures to mitigate these risks followed by installing controls on these risk mitigating measures to ensure that they are working properly. These controls are regularly tested on effectiveness and this is reported by the business lines to CRC and is also part of the yearly reporting cycle resulting in the International Standards for Assurance Engagements and Internal Control Statement reports required for the board of directors and the clients of APG.

As part of their current risk management and reporting procedures APG uses the FIRM (Financial Institutions Risk Analysis Method) framework of DNB. In this framework inherent risks are put in different categories which have to be covered by risk management and need to be monitored. Inherent risks are those risks that attach inherently (apart from any controls) to operations and products of an institution or to the environment in which an institution operates. (Dutch National Bank, 2005). The FIRM manual recognizes the risk categories which are also used at APG to classify the risks in the organization, see appendix B Table 17 for a complete list of all risk types and risks in FIRM.

The EC-model is supposed to serve as a management information methodology which will be used by the CRC department to monitor risks in terms of capital figures in addition to the control framework focused on being in control. The EC-model provides periodical updates of quantitative measures that can act as a comparable indication of how much risk is taken at the different business units and relate this to the specified risk appetite. This means that the main use of the EC-model is providing management information and serve as a way to translate risks that can harm the organizations objectives in a quantitative manner into EC figures. The EC-model also can be used to test new scenarios taking into account new management decisions or more general economic scenarios to test the capital adequacy of APG. It thus will serve as the common currency of risk throughout the organisation and enable the comparison between business lines.

When quantifying risks it is important to realize that the results of quantification should be in the same unit for all risk types. Because the risk measure that is to be used is EC, which has Euro's as unit, all risks have to be measured in such a way that the result of the quantification can be expressed in Euro's. Certainly when operational type risks are concerned it is sometimes hard to see how a specific risk, such as reputational risk can materialize into an euro amount. Therefore the choice has been made to only look at risks that cause euro losses when they materialize. The distinction between risks that cost APG money and risks that don't is not that clear as it shows in the table, but in the next chapter on the quantification of risks it will become apparent that the methodology of quantification ascertains that all risks are properly dealt with in the calculation of EC.

3. Quantification of risks

In this chapter the different risks as they are found in the APG Group are further specified to the level of measurement. This means giving exact definitions of risks and the way in which they will be measured, so specifying inputs and outputs of measurement and the measurement methodology. APG already made some efforts to calculate EC for Loyalis a few years back and the model that is made back then serves as a starting point for the current modelling of EC. The available model was meant for Loyalis so it takes into account both financial and operational risks but is not complete in the treatment of operational risk and other business units at APG. Next to incompleteness the methods to quantify risks are crude and need further exploration, so there is by no means an integrated and complete EC-model but rather a basis which can be used to further build EC so it satisfies the requirements of APG CRC. This and the following chapters will explore quantification methods suitable to complete the EC-model and fit the current risk management policies, level of maturity of risk management and wishes of APG.

3.1 Which risks to measure and on what level

Before diving into the exact details of the measurement of the diverse risk types first a bit of contemplation is needed on which risks actually need to be measured by the EC-model. Because of materiality, how much impact does the realization of a risk has, some of the risks that are present in the organization might not be interesting to measure. This also has to do with the mitigating procedures and controls that are in place at APG. Also the willingness of APG to take on such risks or the risk appetite determines if risks receive attention from risk management. There also are risks that do not have a financial impact per se such as reputation risk or the risk of competitors entering the market of APG. When these risks materialize they don't need to represent a loss in euro's, however when reputation risks materialize they could have secondary monetary effects such as customers leaving or a decrease in future business but this is not something that has to be captured by the EC-model as is also not being done in other market implementations of EC (BCBS, 2009).

The level on which to measure risk has a big impact on corresponding capital levels because of diversification effects between risks (Hull, 2010) (BCBS, 2009) (Tasche, 2003) (Kuritzkes, Schuermann, & Weiner, 2002). In the case of EC this is something that should be taken into account when setting up the EC-model, because neglecting these diversification effects will result in an EC-model that not only wrongly specifies EC, but is of little practical value to APG. (Kuritzkes, Schuermann, & Weiner, 2002) provide an excellent overview of the effects of diversification on EC in financial conglomerates and provide a practical method to incorporate the effects of diversification in EC-models. One of the main findings is that diversification effects have the biggest impact on the determination of inter risk capital and less on the level of business units so this fact should be reflected in the way the EC-model works. The risks are currently captured in the broad categories: Market, Credit, Insurance and Operational which are build up from more specific risk types one level lower, see Table 3.

Risk category	Risk type
Market	Equity
Market	Interest rate assets
Market	Property
Market	Private Equity

Market	Currency
Market	Spread
Credit	Investments
Credit	Reinsurance
Credit	Derivatives
Insurance	Mortality
Insurance	Disability
Market	Interest rate liabilities
Market	Cash
Operational	Operational

Table 3: Risk types in EC-model

3.2 Financial risk

Loyalis is the only entity of APG Group where financial risk plays an important role. Because Loyalis has to comply with financial regulation for insurers, currently Solvency I and Solvency II in the future, financial risk measurement takes place at the moment following the system laid down in these regulatory frameworks. Because in the future Solvency II regulation will be introduced by DNB to supervise insurers in the Netherlands Loyalis is reporting their financial risk exposures as much as possible in line with upcoming regulation. In anticipation for the introduction of Solvency II DNB organized programs that were initiated by the European Insurance and Occupational Pensions Authority (EIOPA) to gain experience with the pillar I quantitative requirements as laid down in the Solvency II regulation. Since Loyalis participated in these studies it already has some experience with the Solvency II regulation and capital calculations following this regime. However the Solvency II methodology for calculating financial risk capital is quite simplistic in the standardized approach that is currently used by Loyalis, so the measurement of financial risk for the purpose of the EC-model will use other generally accepted methods for the measurement of financial risk.

The main difference between the Solvency II and Basel II/III methodology in relation to financial risk capital calculation is that Solvency II also devotes attention to the liability side of the balance sheet (Gatzert & Wesker, 2011). This is because the risk profile at an insurance company does not only depend on its investments but also on the valuation of its liabilities which strongly depends on market variables, most importantly interest rates. This means that any measurement of financial risk should also take into account the sensitivity of liabilities for changes in market rates. In capital adequacy tests for insurers there is paid due attention to this fact, for example by the obligatory measurement of underwriting risks in Solvency II. Of course the market risk inherent in the liability side of the balance sheet of Loyalis also needs to be captured by any EC-model.

For the calculation of financial risk there are many methods available, see (Embrechts, Frey, & McNeil, 2005), (BCBS, 2009), (Hull, 2010) or (Tasche, 2003) for an overview of quantitative risk measurement methods and risk measures. These methods range from relatively simplistic such as just recognizing the outstanding amount or the variance of a portfolio to more mathematically involved methods as Value at Risk (VaR) or Expected Shortfall which aim to say something about the possibility of extreme losses. EC is also a measure of risk itself (Porteous & Tapadar, 2006) (Dev, 2004) but in most cases it is derived from some other risk measure, most commonly from VaR (Koenig, 2004) .

Currently market risk at Loyalis is reported by calculating a Surplus at Risk (SaR) which is related to the better known Value at Risk (VaR) concept. The SaR is a measure for market risk of both assets and liabilities. In the SaR figure the market risk for all different asset classes, mainly government and corporate bonds due to the need for duration matching with liabilities, that Loyalis has invested its money in is taken into account together with the interest rate risk for the liabilities. It thus gives the value loss of the surplus of assets and liabilities that will not be surpassed with 99,5% probability, meaning once every 200 years, so generally speaking:

For a given confidence level $\alpha \in (0,1)$, the SaR of a surplus, being the difference between assets and liabilities, at the confidence level α is given by the smallest number s such that the probability that the combined value mutation of assets and liabilities S exceeds s is at most $(1-\alpha)$. Mathematically, if S is the combined value mutation of assets and liabilities, then $SaR_\alpha(S)$ is the level $\alpha - quantile$:

$$SaR_\alpha(S) = \inf\{s \in \mathbb{R} : P(S > s) \leq 1 - \alpha\}$$

Other financial risks at Loyalis are the insurance risks that also need to be reported under Solvency II regulation. While Loyalis currently works on implementing Solvency II in both its data collection and risk measurement it still has to report to DNB the Solvency I capital ratios based on the simpler Solvency I methodology. Loyalis has a separate project in place to prepare the organisation for all the requirements in Solvency II regulation. Loyalis also works on calculating VaR like measures for insurance risk, this will be measuring the risk that the liabilities of Loyalis will be larger than expected due to actuarial errors or just unexpected changes in for example the mortality rates in a life insurance portfolio.

The SaR works well to display financial risks in a single figure, but in order to express financial risk in terms of EC it is defined on a too high level and does not take into account diversification effects in risk categories or between risk categories as explained in (Kuritzkes, Schuermann, & Weiner, 2002). To capture these effects in terms of capital adequacy the EC-model will have to recognize risks on category level and risk type level, meaning that the risk types from Table 3 will be recognised by the model, see for the implementation of financial risk measurement in the EC-model paragraph 5.2.

3.3 Operational risk

Operational or non-financial risk forms the major part of the risk landscape at APG because financial risk is only relevant for Loyalis. At RB and AM all risks consist of the risk of loss as a result of failing systems, processes, people or external events. This follows from the fact that the (financial) risk associated to the investments APG is managing in name of their clients only has impact on the bottom line of the pension funds. This is governed via liability agreements between APG and the pension funds that are their clients. In these agreements it is laid down that APG is only liable for losses on investment portfolios when they are caused by gross negligence or intentional act, leaving all other financial losses on account of the pension funds. On top of these contractual agreements APG buys insurance, covering possible claims of their clients in case of financial losses. Therefore APG is exposed only to unexpected events causing a loss in their operations, which are mainly asset management and administration services. The other side of the story is that APG is regulated by DNB and AFM via the same regulation that holds for banks and insurers, or financial services firms in general as laid down in the WFT (financial supervision bill). This means that these operational risks need to be quantified to assess capital adequacy issues, of course the EC-model also needs quantified operational risk as a basis for capital calculations.

The quantification of operational risk is notoriously difficult and slippery (BCBS, 2003), because other than with market and credit risk there is no clear view on the exact way in which operational risk expresses itself and which modelling techniques are most appropriate to model operational risk. Aside from mapping the manifestations of operational risk there is the problem that the source of the risk is not as easily counted as for market or credit risk where portfolios of credits or investments can be observed on a regular basis, thus providing input for risk management calculations.

The value and function for operational risk measurement and management does not lie in simply calculating risk measures, but in knowing what the tolerances for operational risk are. The measurement of operational risk enables management to really manage operational risk either by increasing risk by removing costly controls or decrease risk by adding controls or capital (Peccia A. , 2003). An important aspect of a good measure of operational risk should be that the amount of capital required by the risk measure should be an accurate reflection of the potential for loss of the business process and implemented controls (Peccia A. , 2003).

3.1 Data

Depending on the method that is chosen to quantify a certain risk type data needs to be collected, filtered, analysed and used as an input in a quantification procedure. All risk quantification methods have some form of backward looking procedure to determine risk levels on basis of the behaviour of one or more underlying risk factors. For instance market risk can be computed using observed volatilities. For operational risk the input data is harder to come by because currently at APG the systems and management of operational risk differs per business line. Most advanced AMA (Advanced Measurement Approach) methods for measuring operational risk capital use data on loss frequency and severity as an input for the model to determine operational risk capital. These data on operational events and losses are not always recorded at APG. This means that in the selection of methods to measure operational risk this is a factor to be taken into account.

An overview of the different sources of data as specified by BCBS as input data for the AMA available at APG can be found in table 4 below. Note that for external data there are two main sources that can be used by banks and insurers to obtain external data on operational losses, the ORX database for banks and the ORIC database for insurers. Banks and insurers upload their operational losses combined with information about the event type, gross loss, recovery rates and other relevant information to the corresponding database so that the members of the consortium can use these data as input for and calibration of their models. For non-members it is only possible to obtain high level data on gross losses and event numbers. For APG it is thus not very interesting to make use of these external data sources since it is not possible to have access to the complete data sets which would be needed to scale the data to the situation at APG. Secondly the operations at banks and insurers are different from the operations at APG so using these external data sources would result in biased estimates of operational risk capital for the situation at APG.

	APG Group	Loyalis	Asset Management	Pension Administration
Internal data	Only big losses	Information about events and loss amounts	Only information about settlements with clients	Only information about losses on projects
External data	Not available	Not available because Loyalis is not a member of ORIC	Not available because AM is not a member of ORX	Not available since no comparable businesses disclose information on operational risk
Expert opinion	Possible	Possible	Possible	Possible
Control framework	Yes	Yes	Yes	Yes

Table 4: Data sources operational risk

Table 4 shows that some data sources are not available for this research. Internal data is registered at every business line in own systems and following own procedures, this means that all internal data has to be collected and combined with care because different data collection methodologies are used. When EC is to be implemented structurally at APG CRC the regular and structural collection of input data is an important step in the implementation. External loss databases are not accessible so no external loss data can be used in the determination of operational loss capital at APG. Expert opinions can be collected and structured in such a way that they can serve as input for different risk quantification methods as is explained in Section 4.6. The control framework of the different business lines could be used as input data, but since the controls are defined on process level this is not a part of this research.

Next to the difference in data collection for operational events between the business lines there is also the lack of data, meaning the data driven approaches such as the advanced LDA (Loss Distribution Approach) approaches in the Basel II AMA category cannot be applied because not enough data is avaialble. To arrive at EC-quantities for operational risk the most fruitful method seems to be some adaptation of the LDA with parameters estimated from other sources than available data which then can be used to conduct a Monte Carlo simulation using the estimated frequency and severity distributions (Alderweireld, Garcia, & Leonard, 2006) (Shevchenko & Wüthrich, 2006). The result from these simulations can then be used as an input for the EC-model as described in Chapter 6. The use of expert opinions as a basis to estimate frequency and severity distributions is worked out in Section 4.6.

3.2 Conclusion

This chapter provides an overview of the different methodologies for the measurement of risk in financial services organisations. The presented methodologies are based on and formed by applicable regulation for banks and insurance firms as specified in the Basel II and Solvency II directives. However because APG is neither a bank nor an insurance company, these methods for calculation of risks can't be applied unaltered to the situation at APG to provide inputs for the EC-model. Also the old EC-model that is build for Loyalis cannot be used unaltered since this model does not take into account operational risk and the existence of business units other than Loyalis, but also because it relies on outdated information and assumptions.

For APG APG and group functions, the only and most important risk category is operational risk. Where for the financial risks a firm hold could be provided by regulation, for operational risk this is a somewhat different because also regulatory methodology is not very specific, see for instance (BCBS, 2006). Next to the freedom regulation provides there is also the fact that APG is neither an insurance company nor a bank, making application of regulatory methodology for calculation of operational risk based capital more difficult. This means specifically that the methods that are developed mainly by banks to apply the AMA for operational risk are interesting for the calculation of operational risk at APG. AMA methods are the only method that focuses on specific risks in the organization as opposed to taking in some way a percentage of income, premiums or provisions such as the current Solvency II standard methodology. In the next chapter the quantification of operational risk will be subject of investigation in order to capture the measurement of operational capital as an input for the EC-model.

4. Quantification of operational risk

In this chapter the quantification of operational risk will be treated in depth. As is concluded in the last paragraph of chapter five, the regulatory treatment of operational risk will provide some guidance when setting up operational risk calculations for APG with the cautionary note that neither Solvency II nor Basel II is directly applicable to APG because of the specific set of services APG is providing. This means that only the AMA from Basel II can provide some guidelines for quantification of operational risk since this is the only methodology that focuses on the specific operational risks present in an organisation. Availability, quality and data type play an important role in the selection of an operational risk quantification method and will therefore be discussed.

4.1 Operational risk at APG

Since APG is neither a bank nor an insurer the choice for the right quantification method for operational risk as an input for the EC-model will not be determined by regulation. This means that there is more freedom in the choice of a quantification methodology than would be the case if there would be a strict regulatory framework. But it also means that none of the methods developed by banks or insurers is directly applicable to the situation at APG. Adding to the complexity is the fact that APG group consists of business lines that perform very different activities. Therefore the operational risks that these activities expose APG to are also different. These different business lines all work with own definitions of, and methods to manage, control and document operational risk and operational risk events. This means that data collected at the business lines is not always comparable and therefore the usage of data collected about operational risk events requires attention to avoid working with flawed or incomplete data.

Next to the fact that operational risk is defined and recorded differently throughout APG also the fact that a whole riskcontrol-framework in place to manage and control operational risk cannot be neglected. Ideally a new operational risk measure or tool such as the EC-model should leverage or improve the existing operational risk management process (Peccia A. , 2003). In order to do so procedures currently in place and data already captured in operational risk management should be used as much as possible. Also the APG control framework and the risk mitigating effects this framework achieves should be reflected by the EC-model and as a consequence in the capital figures for the business lines.

As is discussed above, and apparent from Table 4, the differences in the recording of operational event and loss data between the business lines result in differences in availability of data. Only for Loyalis the dataset is complete in the sense that the scope is broad enough to be reasonably sure that the data give an overview of the operational events and losses. This means that the data can be used in the estimation of operational risk capital for Loyalis following the methods developed in the light of Basel II. The scope of the EC-model needs a first estimation of operational risk capital using available but proven methodologies.

4.2 Operational risk LDA

The purpose of the LDA is to arrive at an aggregate loss distribution by combining information about both frequency and severity of operational events and losses. As an implementation of the AMA the LDA has become the industry standard among banks causing a lot of scientific and professional interest for the different techniques that can be used to apply the LDA (Frachot & Roncalli, 2004) (Chapelle, Crama, Hübner, & Peters, 2008). The most common way to apply this method is by using internal data on operational events and losses to estimate distributions for both severity and frequency of operational losses which are then combined into an aggregate loss distribution which can be used to arrive at capital figures for operational risk. Because there are many methodologies available for applying the LDA making the right choice depends on a lot of factors. For APG the choice for the most suitable LDA will be determined by the availability of data and the expertise and time needed to apply a certain approach which will result in a trade-off between complexity of the model and ease of implementation.

The general set up for the LDA is formed by the periodical aggregated loss Z for a given risk type is a compound process (Shevchenko & Wüthrich, 2006) (Dutta & Perry, 2007) (Shevchenko, 2010):

$Z = \sum_{i=1}^{N} L_i$

The periodical loss Z is determined by a random variable N that represents the frequency of losses in that period and the loss events L_i which are the loss events in which the company makes a loss that can be measured and falls into the risk category. The L_i's are assumed to be identically distributed and each L_i to be independent from N (Shevchenko, 2010). To arrive at input for the EC-model the value of the aggregated loss Z has to be estimated for all relevant business lines. This can be done by separately modeling the frequency distribution of N and the severity distribution of the L_i's, resulting in an aggregate loss distribution for Z. From this aggregate distribution the high quantiles can be determined to estimate capital levels for operational risk, 99.9% or 99.97% quantiles for determining operational risk EC are industry practice (Dutta & Babbel, 2010).

4.2.1 Data analysis

The selection of a probability distribution to model the severity of operational events starts with a visual inspection of the characteristics of the data such as a histogram, q-q plots (quantile-quantile plots of data vs. theoretical distribution) for various distributions, tail plots and mean excess plots, those last two plots focusing on the tail of the data because that is the part of the empirical data that is interesting for modelling of operational risk events. A complication in the analysis of empirical loss data is when data are truncated or in other words if losses are only recorded if they are higher than some threshold this, asks for correction procedures when data are analysed. At APG non such threshold for the recording of loss data is used so these data can be analysed without correcting for truncation, see (Shevchenko, 2010) for more information on working with truncated data. For the generation of graphical figures and the implementation of data analysis and estimation procedures the open source statistical software R is used. Following visual inspection of the data the shape of the empirical distribution gives a hint as to what distribution type can best be used. After selecting candidate distributions based on the shape of the empirical distribution the parameters for the theoretical distributions can be estimated from the data using one or different procedures. In this case MLE (Maximum Likelihood Estimation) will be used to perform this task, this is common in many of the applications found in scientific and professional literature (Fontnouvelle de, Jordan, & Rosengren, 2005) (Shevchenko, 2010). After fitting the distributions different goodness of fit statistics can be calculated to assess the way the data conform with the fitted distribution. For this purpose the Anderson Darling (Anderson & Darling, 1954) and chisquare statistics are common choices. The value of these statistics gives can be compared between fits of the data with different distribution functions, on basis of which a choice for the distribution that best fits the empirical data can be made. Next to fitting these ordinary distributions with the procedures described above EVT (Extreme Value Theory) can be used to describe the tails of the distribution and the techniques accompanying EVT to estimate OpVaR and EC figures for operational risk.

4.2.2 Severity modeling

Choosing and implementing a distribution function for the severity of losses is a complex task. Not only choosing the distribution with the right fit with loss data is important, but due to truncation or limited availability of data the estimation of distribution parameters is a procedure with many pitfalls, see for an overview (Dutta & Perry, 2007), (Shevchenko, 2010) or (Embrechts, Frey, & McNeil, 2005). Because in the light of capital adequacy and risk management the most interesting part of the probability distribution is the tail, while the rare but large losses (Aue & Kalkbrener, 2007), while these determine the level of capital to be held.

Previous research on the topic suggests a number of probability distributions that may be used to model the severity of loss events (Dutta & Perry, 2007) (Fontnouvelle de, Jordan, & Rosengren, 2005). The distributions most commonly used to model severity of losses exhibit a characteristic that is called heavy tailedness, meaning that there is more probability mass in the tail of the distribution as compared with the exponential distribution. This follows from the fact that most operational loss datasets consist of a large number of high frequency, low severity losses and very few low frequency, high severity losses which dominate the tail of the distribution. Distributions found to fit operational loss data are listed below (Dutta & Perry, 2007) (Fontnouvelle de, Jordan, & Rosengren, 2005), of which the lognormal and weibull distributions are used most often for severity modelling in industry practice (BCBS, 2009) and therefore also will be used to model severity in the remainder of this research.

- Burr
- G-and-H
- LogGamma
- LogLogistic
- LogNormal
- Weibull (is also one of EVT distributions, but mentioned here as “stand-alone” distribution)
- *GPD (Generalized Pareto Distribution)*

Out of this list with probability distributions that may be used to model severity of operational losses the G-and-H distribution seems to be a good candidate to not only model either the body or the tail of the dataset conveniently but can be used to model the whole severity distribution (Dutta & Perry, 2007), (Jiménez & Arunachalam, 2011). Although the G-and-H distribution can be used to model the whole severity distribution it is hard to estimate parameters for this specific distribution because it is specified by a set of four parameters. Because the conventional methods as MLE cannot be used to estimate the G-and-H distribution it will not be part of the exploratory data analysis in 4.3 because the limited time available for this analysis.

Note that the GPD is a special case because this distribution is used in the application of EVT (Extreme Value Theory), see 4.2.3.

4.2.3 EVT

Next to the more classical approaches for working with loss data and distribution fitting described in the previous setting another frequently used approach is the application of EVT to the loss data. EVT focuses the analysis on the tail of the distribution in order to capture the properties of the behaviour of a distribution at high quantiles, see for an introduction and detailed overview of EVT in insurance and finance (Embrechts, Klüppelberg, & Mikosch, 1997). Many professional and academic articles cite the use of EVT in the modelling of operational risk, see for an overview (Singh, Allen, & Powell, 2011) or (Embrechts, Frey, & McNeil, 2005). There are two distinct models in use in the application of EVT to loss data, GEV (Generalized Extreme Value) distribution and a method based on threshold excedances of which only the latter is part of this research because it is perceived to be more powerful and more efficient with limited data (Embrechts, Frey, & McNeil, 2005). The main theory behind "Peaks Over Threshold" is that above some high threshold u distributions converge to a GPD, which can then be used to estimate specific quantiles in the tail of the distribution. The df (distribution function) of the GPD is defined as follows;

$$G_{\xi,\beta}\,(x) = \begin{cases} 1-(1+\xi x/\beta)^{-1/\xi}, \xi \neq 0, \\ 1-\exp\left(-\frac{x}{\beta}\right), \xi = 0, \end{cases}$$

where $\beta > 0$, and $x \geq 0$ when $\xi \geq 0$ and $0 \leq x \leq -\beta\ /\ \xi$ when $\xi < 0$. The parameters ξ and β are referred to, respectively, as the *shape* and *scale* parameters of the GPD (Embrechts, Frey, & McNeil, 2005). Estimation of the tail parameters of the GPD differs from the techniques described in the section above because the location of the threshold plays a large role in the estimation of GPD parameters, this means an extra step has to be carried out to determine the correct threshold value before parameters for the GPD can be estimated using the MLE procedure. The role of the GPD in EVT is that it serves as a natural excess distribution after a certain high threshold is exceeded. To test this a mean excess plot can be used, see also the next Section for an example.

A critical note on EVT is that although it is, at least theoretically, an appealing way to model the tails of probability distributions and calculate high quantiles of severity distributions, capital estimates can be very misleading due to overestimation by the use of EVT. This overestimation is thought to be the result of data paucity and the fact that most internal data don't contain low frequency high severity losses meaning there is no information available for the estimation of the shape of the tail of the distribution which is precisely the matter with which EVT is concerned. For a correct specification of the GPD distribution parameters (Dutta & Perry, 2007) mention that experiments point out that at least 2000 data points have to be available to arrive at an acceptable estimation error and capital estimates. These critiques in addition to the fact that at APG very little data on operational losses is available make that EVT is not a very suitable candidate to model operational risk at APG at this moment.

4.3 **APG Loss data**

Data on operational losses at APG is scarce since the implementation of a database where all operational issues are recorded systematically, B-Wise software, is currently in process. Therefore all business lines have their own issue administration and work with different criteria as to when to record something as an operational event. Finding and combining data on operational events and issues at APG was a complicated task because all separate information sets and their owners had to be found and combined. This poses some practical and methodological issues when using the data on operational losses to estimate parameters to use in the LDA. There was not enough data available to conduct a data analysis of separate business lines.

To give a general idea of the analysis needed to use loss data in the context of LDA procedures for data analysis are used on the APG Group total loss data. So the dataset used is a combination of data from the different business lines because otherwise there would not be enough information available to analyze. Therefore data are not necessarily recorded using the same definitions of operational events or using the same procedures. When the loss event registration is further developed and the loss database contains more data points for each business line this analysis could be repeated on a business line level. The analysis in this chapter is therefore not used to determine operational risk capital for the separate business lines but only tells something about undiversified operational risk on the group level.

Due to confidentiality the data and data analysis are not displayed in this public report. The outcome of this preliminary data analysis was that information collected at APG showed great similarities with loss data found at banks and insurers including many high frequency low impact and few low frequency high impact losses. Also data was fitted to theoretical probability distribution to see if there was a good fit graphically with the help of q-q plots. The log-normal and weibull distributions are used because they are mentioned as most used in the AMA for operational loss modeling so can be seen as industry practice, see (BCBS, 2009). The fitting of distributions is done via MLE (Maximum Likelihood Estimation) in R. The most probable cause of the observed poor fit of the data is that the sample size of operational losses is not large enough to support the methodologies for fitting theoretical distributions. It is therefore important that any results based on such a low number of observations should be considered with caution, because limited data can easily lead to wrongly specified model parameters and therefore untrustworthy capital estimates.

EVT

Although not a lot of data are available meaning EVT is probably not a suitable option, to get an idea if EVT can be used to model the tail of the distribution some first graphical procedures to get a grip on the data are performed (Dutta & Perry, 2007). First of all a q-q plot is suggested with theoretical quantiles from the exponential distribution so as to see if the data exhibits sub or supra exponential properties, from the q-q plot can be seen if the data lie on a straight line following the data points in the graph. Data lying more or less on a straight line can point to the data behaving like coming from an exponential distribution, the position under or above the line through the origin determining if the behavior is sub or supra exponential. Another way to see if data can be modeled using EVT is looking at a mean excess plot, this figure shows the mean excess over a certain threshold, again the check is whether the data points lie on a straight line (Embrechts, Frey, & McNeil, 2005). The mean excess over a threshold u is defined as:

$e(u) = E(X - u|X > u)$

4.4 Frequency modelling

For sake of simplicity and to follow industry standards the most straightforward choice for the frequency distribution of operational losses would be to assume the number of losses is Poisson distributed. This is the most commonly used frequency distribution by banks in models used in the AMA because the underlying assumptions and estimation of the distribution parameters are straightforward (BCBS, 2009) (Frachot & Roncalli, 2004) (Dutta & Babbel, 2010), and the high quantile results are not found to be materially different than those obtained when other distributions are used (Fontnouvelle de, Jordan, & Rosengren, 2005). Adding strength to the argument for the use of the Poisson distribution to model frequency of operational losses is the fact that the effect of the frequency model on the aggregate distribution is limited (Aue & Kalkbrener, 2007). Other sources mention the use of the negative binomial distribution to model loss frequencies, but since this would mean increasing the complexity of the model this distribution is not taken into account in this research, interested readers are referred to (Dutta & Perry, 2007) or (Shevchenko, 2010) for implementations of the binomial distribution for frequency modelling.

Estimation of frequency parameters:

Whereas the estimation of parameters for the severity distribution is much more involved, estimation of the frequency parameter from observed data is relatively simple after the choice has been made to use the Poisson distribution to model frequency. When the frequency of loss events is modelled by a Poisson distribution only one parameter λ has to be estimated. The maximum likelihood estimator of the parameter $\hat{\lambda}$ is defined as the average number of losses during a given period:

$$\hat{\lambda} = \frac{1}{n}\,, n = number\ of\ events\ during\ a\ period$$

For the probability mass Poisson function:

$$f(k;\lambda) = \Pr(\mathrm{X} = \mathrm{k}) = \frac{\lambda^k e^{-\lambda}}{k!}$$

4.5 Aggregate loss distribution

After modelling separately the frequency and severity distributions of operational losses these need to be combined to arrive at the aggregate loss distribution which is to be used to calculate capital levels for operational risk. There are several methods available to perform this task described in literature, the most important being: Monte Carlo simulation, single point estimation, Panjer’s algorithm and fast Fourier transformation. Monte Carlo simulation seems to be the most often used technique to combine severity and frequency distribution into an aggregated loss distribution because of its relative simplicity (Fontnouvelle de, Jordan, & Rosengren, 2005) (BCBS, 2009) and will therefore also be used in this research, for an overview of the other aggregation e.g. (Dutta & Perry, 2007) (Embrechts, Frey, & McNeil, 2005). The general framework for the Monte Carlo method works as follows (Hull, 2010), also see Figure 4:

1. Sample from the frequency distribution to determine the number of loss events (=n)
2. Sample n times from the loss severity distribution to determine the loss experienced for each loss event $(L_1, L_2, \dots, L_n)$
3. Determine the total loss experienced $(= L_1 + L_2 + \cdots + L_n)$

This procedure is repeated 10.000-1.000.000 times, the results are ranked and depending on the number of simulation runs the desired quantile can be computed by selecting the (1-quantile) largest loss from the ordered total losses obtained in the Monte Carlo simulation.

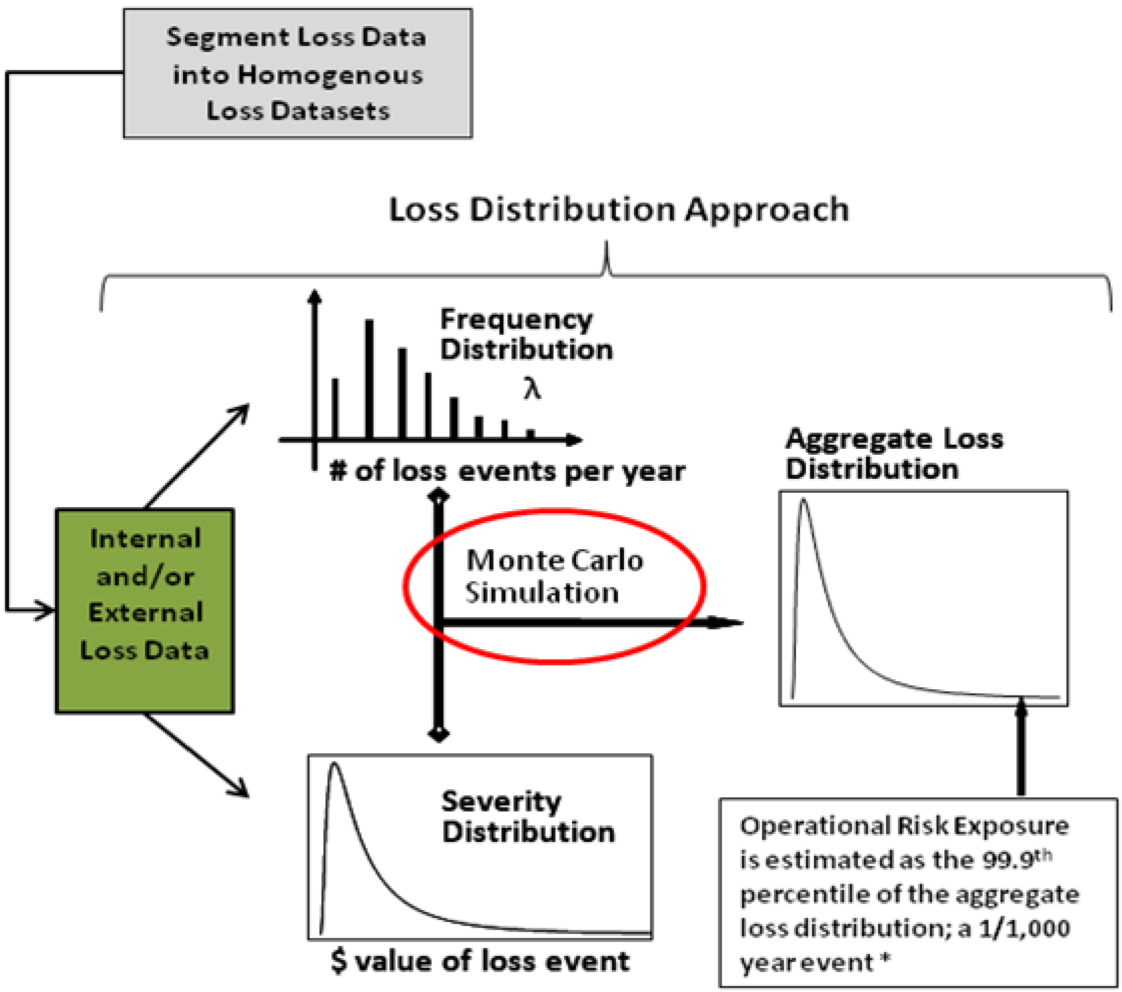

Figure 4: Aggregate distribution

4.6 Expert elicitation

Because the lack of data on operational events and losses at APG the methods described in the previous paragraphs cannot be applied to all business lines. Therefore another method to obtain the parameters for the severity and frequency distributions is needed if the LDA approach is to be used. Because the EC-model needs input on the amount of operational risk capital for the different business lines in order to arrive at risk based capital figures for APG expert elicitation methods are introduced as a way to extract information out of the organisation in order to set up the operational risk LDA model. In the context of operational risk obtaining and using the expert opinion to enhance the risk models is customary and of course obligatory when using the AMA approach for banks (BCBS, 2006). The way in which this is implemented in the actual risk management framework and operational risk calculations differs greatly in design, frequency of meetings and results (BCBS, 2009). Although an obligatory aspect of any AMA implementation, there is not a great body of professional or academic literature on the topic of the elicitation of expert opinions in the context of operational risk modelling as compared to the volume of literature on other aspects of the AMA. Ways to combine expert opinions with loss data are described more elaborately by literature and it seems that the use of Bayesian statistics is the focus of research and is currently implemented by the banking industry (Agostini, Talamo, & Vecchione, 2010) (Shevchenko & Wüthrich, 2006). However the practical question of how to obtain usable information through experts in the organisation does not receive much attention. There are however some practical papers describing methods to elicit experts on the frequency and severity of losses in other fields than operational risk modelling that can serve as inspiration for correct methodology when trying to obtain information from experts.

There are some aspects of expert elicitation that need to be kept in mind when gathering information from experts which are mainly researched by psychologists, (Kadane & Wolfson, 1998) provide an overview of findings related to the elicitation of expert opinions in order to obtain statistical quantities. They state that (Kadane & Wolfson, 1998, p. 3):

“to make it as easy as possible for subject-matter experts to tell us what they believe, in probabilistic terms, while reducing how much they need to know about probability theory to do so.”

An important factor to take into account when conducting expert elicitation is the existence of heuristics and biases that people use when asked to specify quantities. The design of the elicitation method has to try to counter the effects of these known shortcuts in human estimation behaviour. From the oversight articles of (Garthwaite, Kadane, & O'Hagan, 2005) , (Kadane & Wolfson, 1998) and (O'Hagan, 2006) the most important biases to deal with in the light of expert elicitation with the goal of eliciting operational risk distributions are:

- Judgment by availability: When people assess probabilities they do so by estimating frequencies of events that fall in the event class which is to be assessed. In case of operational risk losses this means that people estimate the magnitude of those losses by recalling examples of losses, meaning that if no large losses ever occurred it is likely that people underestimate the magnitude of loss.
- Anchoring: People tend to assess quantities by starting from some initial, known, value and then adjusting it to obtain a final estimate. For operational loss this means that they start by some loss value they can remember and then adjust their estimate somewhat upward or downward to estimate the loss amount.
- “law of small numbers”, also remarked by (Peccia A. , 2003): People expect a sample from a population to represent all the essential characteristics of that population, even if the sample is small. This means that when assessing loss amounts risk managers will tend to base their estimates on basis on the little information they have on losses that actually occurred. Certainly

when loss registration is nonexistent or very recent this poses a problem because people estimate loss amounts only based on a few known operational losses which might not at all represent the low frequency high severity losses known to be present in loss data of firms that record their losses over a longer period.

- Overconfidence: Difficulty in the assessing the tails of a distribution. The biases and heuristics described above lead to the problem that people are generally bad in estimating the tail of a distribution where the low frequency events are positioned. For operational losses this an extra problem because the LDA in which the elicited distribution is to be used will be focused on this tail of the distribution.

Other results (Garthwaite, Kadane, & O'Hagan, 2005) are that people are generally capable of estimating proportions, modes and medians, are doing less well at estimating means from skewed distributions and often have misconceptions of variance. Furthermore practice with and feedback on elicitations will enhance results by reducing biases, but still assessing high quantiles of distributions is generally not done properly. The quantile method to estimate distributions is found to be slightly preferable (Garthwaite, Kadane, & O'Hagan, 2005) to other methods because it provides the least tight distribution estimates. Certainly for operational risk this is an important point since unnatural low variance influences the tail estimates.

One approach tailored specifically to operational risk is proposed by (Alderweireld, Garcia, & Leonard, 2006) and partly inspired by (Frachot & Roncalli, 2004) and is designed to elicit expert opinions on frequency and severity distributions without the need for the experts to have a thorough understanding of statistics. The simple method developed by (Frachot & Roncalli, 2004) consists of asking experts for three sets of estimated (x, d) meaning: "A loss of x or higher happens once every d years." In this way the question and meaning of the question is kept simple and having three pairs of points for the frequency and amount of perceived losses it is possible to find distribution parameters for loss severity and frequency. (Alderweireld, Garcia, & Leonard, 2006) enhanced this method by introducing other questions in order to make it more robust for methodological changes. Also (Dutta & Babbel, 2010) preliminary claim that formatting questions in terms of duration and ranges of loss amounts reduces bias and subjectivity in talking with experts about probabilities.

A more elaborate approach to estimating distribution parameters with the use of expert opinion is SHELF (Sheffield elicitation framework), which is a freely distributed open source tool for expert solicitation[2]. A method developed and maintained by Tony O'Hagan from Sheffield university aimed at eliciting expert opinions in order to obtain a probability distribution and avoiding bias or other forms of distortion during the process. The method is not designed for the use in the risk management field per se but is general in set up and application. The SHELF methodology accommodates different methodologies to elicit expert opinions on probabilities all based on giving specific quantiles of the distribution or describing the shape of a distribution by putting weights on a specific interval to form an indicative histogram. The results can be obtained by combining the opinions of one or a group of experts. To process the results from these

[2] More information on the SHELF project can be found on http://www.tonyohagan.co.uk/shelf/

elicitation rounds the statistical programming language R is used to deliver parameters estimates and graphical feedback when performing the elicitation procedures.

Yet another method to elicit expert opinions on statistical quantities is described in (Hübner & Peters, 2009) and specifically aimed at using the expertise of (risk)-managers in the organisation to assess parameters for frequency and severity distributions that can be used in the general LDA framework. This method makes use of a supra Bayesian approach to arrive at a posterior distribution that can be used to model the severity of operational losses, and tries to counter the effects of the biases mentioned above. The method is partly inspired by (Baule & Steinhoff, 2006) who describe the difficulties in soliciting operational risk severity distributions from experts. They conclude that it is better to ask for durations between events of a certain magnitude instead of asking experts to define the parameters of a severity distribution directly. Since the method described in (Hübner & Peters, 2009) is both recent and specifically aimed at examination of operational risk it is preferred over both the SHELF method which is very thorough but is general in nature and requires significant commitment from management and experts. The method developed by (Alderweireld, Garcia, & Leonard, 2006) is a bit too simple and rough cut for the current setting at APG, the next Section will describe the specific method for expert elicitation used at APG.

4.7 Expert elicitation at APG

To obtain probability distributions for both the frequency and severity of operational losses at APG an adaptation of both the SHELF method and the methods of (Alderweireld, Garcia, & Leonard, 2006) and the one described by (Hübner & Peters, 2009) is used. The SHELF method for eliciting groups of experts is found to be too intensive and demanding on the staff of APG because it requires the experts to come together for at least two two-hour meetings which is not feasible at the moment of writing. A good compromise is the elicitation method from (Hübner & Peters, 2009) which is both specifically designed for the use in an operational risk setting and doesn't involve lengthy sessions requiring all experts to come together. The elicitation procedure at APG will consist of an e-mail with an explanation of the purpose and goal of the elicitation procedure and a meeting with responsible managers where more information is given and the actual expert elicitation takes place. Whereas in SHELF there is real time feedback during the sessions the results of the interviews at APG will be processed afterwards. The e-mail with introduction and elicitation questions can be found in Appendix D .

The method described by (Hübner & Peters, 2009) is based on asking experts for durations for events with certain financial impacts which can then be used to compute probabilities for the disjoint ranges that are based on the duration estimates, which corresponds to the variable interval method described in (Garthwaite, Kadane, & O'Hagan, 2005). The duration approach is based on the paper of (Baule & Steinhoff, 2006) and uses the fact that durations for events are described in terms that are familiar to experts so that they feel more comfortable with giving their opinions on these quantities. Biases are countered as good as possible by using familiar quantities, providing an explanation of known biases and what their effects are and structuring the questions in such a way that anchoring is countered as much as possible. The durations that are questioned are used to produce quantiles of the supposed distribution function so the method corresponds to what (Gatzert & Wesker, 2011) call the quantile method which has the desirable property that it produces the least tight interval estimates as compared with other elicitation procedures.

Because in the light of EC the most interesting part of the severity distribution that is to be elicited is the tail, the focus of the questions in the elicitation procedure will be the higher quantiles or the less frequent events. This is tricky because the risk managers that will take part in the procedure will in general not have seen such low frequency high impact events. To counter the tendency of people to anchor their answers on known quantities beforehand the loss amounts that will be used in the questionnaire will be discussed with the head of the risk department of the business line. He or she is thought to have better oversight over the processes and is generally a more senior employee who has more experience with operational risk. The amounts he/she provides corresponds to a pre specified duration corresponding more or less to a quantile on the distribution, despite the fact that this is different from the method described by (Hübner & Peters, 2009). It is thought best to determine the loss amounts that will be used in the questionnaire in an preliminary interview with the head of the risk department of the business line based on some roughly indicated quantiles. The questions to the head of department will take the form: what is the loss amount x that will on average take place every d years. This also means that the first step in the method is already filled in by the business line heads in the preliminary interview as they directly specify their amounts given the durations. In this way a list of loss amounts is created that correspond to the beliefs of the risk department head about the given durations which can then be used to question the other risk managers. The amounts that are going to be asked for reflect the fact that eliciting information about the shape of the tail of the distribution is most important, therefore the loss amounts and also durations to be used in the questionnaire are on the higher end of the spectrum.

To validate elicited distributions the best fit can be checked with other distributions that fit the elicited values to check whether there is much difference between the values obtained by the two distributions. (Garthwaite, Kadane, & O'Hagan, 2005).

4.7.1 Technical specification and results expert elicitation AM

To show the working of the expert elicitation method in this section the method is applied to the AM business line and all numbers used are obtained from the operational risk management department from AM, the same exact same method should be applied to the other business lines to guarantee methodological soundness and robustness in the process of EC determination. In the expert elicitation process used at APG to elicit severity distributions for operational losses follows the set up created by (Hübner & Peters, 2009) using a supra Bayesian methodology to combine expert opinions. First experts are asked to give their opinions on frequencies of operational loss events, durations before losses of certain magnitude will happen and the median value of losses during a certain year, see Appendix D. This information is displayed inTable 5, note that MvS who is the head of the operational risk department of AM specified his durations in advance during the pre-elicitation interview. In Table 6 the answers the head of risk management expects the other risk managers to give are shown. Loss amounts are not displayed in the public version of this paper.

Expert opinion	Median

€M Loss	-	-	-	#	
MvS	5	10	40	3	0,5
JS	5	10	15	10	0,1
AA	5	10	25	4	8

Table 5: Expert opinion

	Expected opinions				Median
€M Loss	-	-	-	#	
JS	4	8	32	3	0,5
AA	6	12	48	3	0,5

Table 6: Expected answers experts

Using the following formula the duration estimates, both for the expert opinions and the expected opinions, are transformed to probabilities that an operational loss will fall into a certain interval. The assumption is that experts will give their opinion on θ, specified on the domain $\Theta \in R$ with which is an unspecified parametric probability distribution of the severity of losses, for the distribution common choices are LogNormal and Weibull (BCBS, 2009).

$$d(x) = \frac{1}{\lambda\big(F(y;\Theta) - F(x;\Theta)\big)}$$

$$\xrightarrow{yields}$$

$$\frac{1}{d(x)} = \lambda F(y;\Theta) - \lambda F(x;\Theta)$$

$$\xrightarrow{yields}$$

$$\frac{1}{d(x)} - \lambda F(y;\Theta) = -\lambda F(x;\Theta)$$

$$\xrightarrow{yields}$$

$$\frac{(\frac{1}{d(x)} - \lambda F(y;\Theta))}{-\lambda} = F(x;\Theta) \; (4.1)$$

Where:

$d(x)$ = duration until loss of magnitude x is observed

λ= parameter of poisson distribution for number of losses

$F(y;\Theta)$= any parametric distribution function

The domain Θ is an interval in R with lower bound $a_0 = \inf(\theta \in \Theta)$ and upper bound $a_k = \sup(\theta \in \Theta)$, furthermore Θ is divided in *n* intervals determined by points $a_0 < a_1 < \cdots < a_k$, so interval $I_j = (a_{j-1}, a_j)$. $p_i^T = (p_{i1}, p_{i2}, \dots, p_{ik})$ with $p_{ij}$is the opinion of the i^{th} expert of the probability that $\theta \in I_j$. Both the experts and the supra Bayesian, ie. the head of the risk department, provide a vector of probabilities for a given set of intervals. For a complete explanation of the underlying Bayesian statistics see (Hübner & Peters, 2009), for now it is sufficient to remark that the head of the department only needs to specify the first moment, or expected values, of the vector of experts' probabilities for the occurrence $\theta \in I_j$, which is shown in Table 6. The results of transforming the duration estimates from the experts and head of department to probability measures following equation 4.1 is shown in Table 7, and the probability measures according to expected answers by the head of the department in Table 8.

Interval I	-	-	-	-
MvS	0,9333	0,0333	0,0250	0,0083
JS	0,9800	0,0100	0,0033	0,0067
AA	0,9500	0,0250	0,0150	0,0100

Table 7: Probability measures

Interval I	-	-	-	-
JS	0,917	0,042	0,031	0,010
AA	0,944	0,028	0,021	0,007

Table 8: Probability measures expected answers

To combine these probability measures into figures that can be used in the application of the LDA they are combined using the following formula for the posterior probability P_j^*.

$$P_j^* = \rho_j + \sum_{i=1}^{k} \lambda_{ij}(p_{ij} - \mu_{ij}) \quad (4.2)$$

Where:

ρ_j=opionion of head of department probability of interval *j*

λ_{ij}= weight for opinion of expert *i* for probability of interval *j*

p_{ij}= opinion of expert *i* for probability of interval *j*

μ_{ij}= expected opinion of expert *i* for probability of interval *j*

The λ_{ij}'s have to satisfy equalities of the form:

$$max\left\{\sum_{i=1}^{k} \frac{\lambda_{ij}\mu_{ij}}{\rho_j}; \sum_{i=1}^{k} \frac{\lambda_{ij}(1-\mu_{ij})}{(1-\rho_j)}\right\} \leq 1, \forall j = 1, \dots, n \ (4.3)$$

Using equation 4.2 to combine expert opinions and expected answers into probability measures results in with the probability measures that a loss will lie in a specified interval and the cumulative probabilities for the intervals. The same weighting scheme is used to produce an estimate for the yearly number of operational loss events.

Interval I	-	-	-	-	# losses

FINAL	**0,966**	**0,017**	**0,009**	**0,008**	**6,840**
P(x<X)	**0,966**	**0,983**	**0,992**	**1,000**	

Table 9: Resulting probability measures

These results can then be used to fit a parametric distribution to the given values, using the R statistical software package to do so for the lognormal and Weibull distribution results in the parameter estimates in Table 10. The procedure used fits the quantiles, ie. the loss amounts, and the probabilities, ie. the P(x<X), generated in the expert opinion to fit a specified probability distribution.

Distribution/Parameter	Parameter 1	Parameter 2
Lognormal	Meanlog = 1.36	Sdlog = .55
Weibull	Shape = .7	Scale = 6.61
Poisson	λ = 6.840	

Table 10: Parameter estimates

4.8 LDA at APG

With the parameter estimates found using expert elicitation as described in 4.7 the loss distribution approach as in Section 4.2 can be used to arrive at EC figures for operational risk. Using the @Risk package to implement the Monte Carlo simulation from Section 4.5 needed to arrive at an aggregate loss distribution which can be used to estimate the EC amount needed. Monte Carlo results are based on 100 simulations of 10000 iterations each, corresponding to 100 simulations of a 10000 year period. This procedure is done twice, one time using the lognormal severity distribution and once using the Weibull distribution both with the parameters from the expert elicitation procedure. The results of the Monte Carlo simulation are not displayed in this version of the paper.

As can be seen from the results from the simulation runs the outcome heavily depends on the choice for the severity distribution. Using the Weibull distribution results in significantly higher capital estimates, than using the lognormal distribution. However there is no statistical method available to select the correct severity distribution since both results are based on the parameters specified by the user. This is one of the mayor drawbacks of using this method to estimate operational risk capital figures. Comparing the outcomes obtained with Monte Carlo simulation shows that the difference with the Weibull outcome for the 99% quantile is 5% considering the two methods to arrive at the capital figure differ entirely the model outcome is at least of the same magnitude and could be seen as a proof of principle.

4.9 Scenario analysis

Yet another method can be used to get a grip on operational risk is scenario analysis. This is a tool that is mostly used concurrently with other methods because where other methods such as modelling losses on basis of historical data are backward looking, scenario analysis is forward looking (Rippel & Teplý, 2011). Scenario analysis is an assessment of possible losses an institution may experience in the future (Dutta & Babbel, 2010). Regulators also recognize the need for forward looking procedures in the determination of capital adequacy as scenario analysis is an obligatory part of Basel II as well as Solvency II regulation. Furthermore letting experts draw out scenarios provides an opportunity to account for low frequency high severity operational losses that are likely not captured by historical loss data (Ergashev, 2012). To construct scenarios employees with a thorough understanding of the business are asked to participate in sessions where operational loss scenarios are created. Scenario analysis and expert elicitation are closely related and the former can be seen as an expansion on the latter. Where expert elicitation deals specifically with getting to know expert views on specific probabilities, scenario analysis also deals with getting experts to reveal information about possible scenarios in which the firm suffers large but not unlikely losses. Expert elicitation can be one of the steps in the process of scenario analysis when probabilities have to be attached to specific scenarios. Scenario analysis consists at least of the following main steps (Dutta & Babbel, 2010):

- *Evaluation of future possibilities (future states) with respect to a certain characteristic.*
- *What we know now (current states) with regard to that characteristic for an entity.*

When incorporating information from scenario analysis by experts into the operational risk capital calculations one of the challenges is to combine two noisy and imperfect data sources, historical data and expert opinions. One method to incorporate scenarios in determining operational risk capital is pooling, incorporating estimated scenario losses in the pool of historical loss data. The danger of this method is that it does not take into account the frequency of scenario's because they are entered as if they have already happened, leading to a possible overstatement of scenarios because frequencies are not taken into account when merging historical data and scenarios. (Dutta & Babbel, 2010) propose a change of measure approach to overcome this problem en scale the historical losses so as to also incorporate frequencies of scenarios created in scenario analysis. This method seems promising, also due to it combining scenarios and historical loss data in a meaningful way.

4.9.1 Scenario analysis at APG

Because scenario analysis takes a lot time when done properly it is not deemed feasible to conduct a whole scenario analysis process during this research at APG CRC. However further implementation of the methods described in the previous literature reflecting industry best practice could very well be used in future plans of CRC. Currently CRC is investigating how yearly RSA's (Risk Self Assessment) at the business lines could be constructed to update the risk profile of the organization each year. When conducting the RSA's at the different business lines of APG the use of techniques described in literature could be helpful. Since Loyalis has to conduct a ORSA each year they are already familiar with the scenario analysis process.

5. EC-model

In this chapter aspects of the EC-model that is developed to calculate capital figures for Loyalis are discussed together with the different risk types and technical implementation of quantification techniques for the different risk types.

5.1 Background of Loyalis EC-model

In the course of this research it became clear that APG already did some effort to develop an EC-model for internal use. The model was developed by APG AM Financial Risk Management department and focused only on the insurance subsidiary of APG, Loyalis. Since the goal of this research was to develop an EC-model for APG CRC the existence of a current model was very useful. This next chapter therefore has a more descriptive character and describes the set up and working of the current EC-model used for Loyalis. Also results obtained with this EC-model, with updated inputs, are presented. The last sections focus on validation and possible implementation at CRC of the model. It is noted that at this stage the other business lines of APG are not part of the model nor are the methods to measure operational risk described in the previous chapters. Discussion of the model and more notably the design choices and assumptions made in setting up the EC-model can be found in Chapter 6, future research on EC and implementation issues can be found in Chapter 7.

5.2 Financial risk

The basic quantification method for financial risk in the EC-model is using the VaR methodology to calculate stand alone capital amounts for the different risk types, which are then aggregated following the methodology described in (Kuritzkes, Schuermann, & Weiner, 2002). A formal definition of VaR follows the same line as the SaR definition in section 3.2, the practical application looks like:

$$VaR_{\alpha}(Risk\ type) = Position\ in\ € * Inverse\ Standard\ Normal(Confidence\ level) * \ Volatility * Sensitivity$$

- **Position**: The IFRS balance sheet amount in Euros per category.
- **Confidence level**: The confidence level is given by a quantile number, in the current model 99,5%. For the sake of simplicity the current EC-model assumes risks to be normally distributed so the confidence interval factor in the formula can be calculated using the inverse standard normal distribution. This assumption greatly increases the ease of modelling at the cost of loosing grip on reality where returns, including losses, are not normally distributed but exhibit fatter tails, meaning greater possibility of large losses as compared to the normal distribution. See the discussion section for more information on the normality assumption. There is a direct link between the confidence level used in capital calculations and the credit rating of a firm (Hull, 2010).
- **Volatility**: One year volatilities for risk types on basis of AM figures, expert judgement or the annual report of Loyalis.
- **Sensitivity**: Sensitivity of a certain position for volatility, for market category this is either 1 for assets or the duration in years for interest rate related risk types. For insurance categories the sensitivity is the change in liabilities as result of a 1% change in actuarial mortality or disability rates.

In Table 11 all risk types are described and relevant information data sources are given.

Risk	Risk type	Description (Risk of loss due	Position	Volatility

category		to…)		
Market	Equity	Adverse market movements in equity prices	IFRS balance sheet	MSCI World / 3Y
Market	Interest rate assets	Changes in interest rates adjusted for duration of assets	IFRS balance sheet	Relative volatility German government bonds
Market	Property	Adverse market movements in property prices	IFRS balance sheet	Weighted average volatility APG AM property pools
Market	Private Equity	Adverse market movements in property prices	IFRS balance sheet	Volatility APG AM PE pool
Market	Currency	Adverse market movements in FX rates, almost zero because of currency hedges	IFRS balance sheet	EURUSD 5Y
Market	Spread	Adverse market movements in property prices	IFRS balance sheet	Loyalis investment control
Credit	Investments	Counterparties not meeting their contractual agreements	IFRS balance sheet	Loyalis Investment control
Credit	Reinsurance	Counterparties not meeting their contractual agreements	IFRS balance sheet	Loyalis Investment control
Credit	Derivatives	Counterparties not meeting contractual agreements	IFRS balance sheet	Loyalis Investment control
Insurance	Mortality	Averse changes in mortality rates	IFRS balance sheet	Derived from Solvency II Mortality risk module
Insurance	Disability	Averse changes in disability rates	IFRS balance sheet	Derived from Solvency II Disability risk module
Market	Interest rate Liabilities	Changes in interest rates adjusted for duration of liabilities	IFRS balance sheet	Loyalis Investment control
Market	Cash	Adverse market movements in interest rates on deposits	IFRS balance sheet	Loyalis Investment control
Operational	Operational	Failing systems, processes, human errors or external events	SII	Derived from Solvency II Operational risk module

Table 11: Risk types

5.3 Operational risk

Operational risk is currently implemented in the Loyalis EC-model by simply applying the Solvency II formula for operational risk and use this result in the calculation of EC. In the future operational risk could be implemented by using the methods described in Chapter 4 to calculate operational risk capital estimates for the business lines and use these in the EC-model.

5.4 Main model assumptions:

- EC is modelled by using the inverse normal distribution to compute confidence levels, ie. $N^{-1}(Confidence\ level) = \ multiplication\ factor$ in the current implementation a confidence level of 99.5% is used so the multiplication factor is $N^{-1}(0.95) = \ 2.58$
- Correlations between risk types are modelled by a correlation matrix, meaning linear dependencies are assumed.
- Duration of assets is assumed to be exactly the same as duration of liabilities due to duration matching in the light of ALM.
- Proxies are used for volatilities of asset classes, for example the volatility of the MSCI world index is used as a proxy for the volatility of all assets in the portfolio.

5.5 Aggregation

Correlations between risk types and business lines are used to calculate diversification benefits across risk types. The use of correlations implies linear dependent risk categories of which the correlation determines the combined behaviour of risk types, categories and risk within business lines. Correlation between risk types is the source of the diversification benefit. This means that stand alone EC is diminished when it is combined with another risk type because diversification benefits between risk types.

Distributing the diversification benefit of EC over the different business lines is implemented by using both component and marginal EC's when calculating total EC figures for both business lines and on group level as is worked out in detail in (Kuritzkes, Schuermann, & Weiner, 2002). This is done by using the correlations estimated between risk types and between business lines. The EC-model uses a variance-covariance table to compute aggregate values. Component VaR and Marginal VaR are then used to distribute the diversification benefits back to the different risk types and business lines, both VaR types are described below.

Marginal VaR:

The marginal VaR is the sensitivity of VaR to the size of the ith subportfolio x_i, so in the EC-model the ith risk type. In symbols:

$$Marginal\ VaR\ (MVaR) = \frac{\partial VaR}{\partial x_i}$$

Component VaR, :

$$Component\ VaR\ (CVaR) = \frac{\partial VaR}{\partial x_i} x_i = MVaR * \ x_i$$

These VaR based figures are used to determine which VaR amounts correspond to what business unit and how to determine which business line gets what part of the diversification benefit. As is described in (Kuritzkes, Schuermann, & Weiner, 2002) the major diversification benefits are found to be in the aggregation between risk types, leading to a reduction of EC in the current model of roughly 40%,. The subsequent reduction because of aggregation between business lines amount to only 2%. This is also due to the way in which the model copes with correlations because these are only specified for inter risk relationships. The diversification between Loyalis business lines is not recorded because the assets are pooled on entity level meaning the risks between asset pools for the separate business lines are perfectly correlated leading to no further reduction in EC.

The only difficulty remaining is the aggregation of operational risk EC over the different APG business lines. This can be done on basis of estimated correlations by the head of APG CRC, see . The arguments behind the values is the degree to which operational risk in for example AM is linked to the operational risk at Loyalis. Arguably these are linked together because both business lines make use of the same IT-systems and locations, but there also is a idiosyncratic risk only connected to a specific business line.

5.6 Results

The results obtained with the Loyalis EC-model are not available in the public version of this report.

5.7 Validation

Validation of the expert elicitation method is possible through comparison with other capital figures for operational risk available at the business lines. For Loyalis this means comparing the results of the elicitation exercise with the capital requirements obtained by the Solvency II methodology that is described in appendix C.2.1. For APG AM there is the possibility to compare the obtained operational risk capital figures with the figures calculated in the ICAAP. This comparison tells whether the figures obtained with the expert elicitation procedure compare reasonably with the methods used by Solvency II and the ICAAP. The comparison between the model outcome and ICAAP procedure shows a difference of 5%, with the ICAAP outcome being higher. Considering the methods to calculate both figures are totally different, the limited time available for expert elicitation and the fact that only two probability distributions are used in the Monte Carlo simulation, the difference of 5% shows that the proposed method for expert elicitation, parameter estimation and loss simulation is at least indicative as a measure of operational risk capital.

Comparing the outcomes of the EC model to the outcomes of Solvency II capital requirements is not feasible at the moment because the input for the EC-model is incomplete and not entirely up to date. However from the different modelling assumptions between the EC-model and the risk modules described in the QIS 5 project in the light of Solvency II the capital estimates of both models will most likely not align. This poses further questions if the EC-model is going to be developed further since both methods, EC and Solvency II or QIS, aim to deliver risk based capital figures. Since Loyalis is regulated under Solvency I/II regulation it seems logical to use that methodology as a basis for capital estimates. EC could be used as an internal model to enumerate the effects of different business scenarios or as an indication of the view of Loyalis on their risk profile using own parameters and models instead of that of the regulator. However this would mean that significant effort and time is dedicated to bringing the EC-model in line with current risk quantification standards.

5.8 Implementation

EC is more of use in other environments such as large financial conglomerates where the need exists for a risk measure that can be used across business lines and risk types to compare both riskiness of specific portfolios, operations but also to measure risk based performance and economic profit. (Mikes, 2011). Also the state of group risk management being currently in the process of rewriting risk management policies and focusing on implementing structured reporting of business lines to group level makes that implementing an integrated EC-model approach is a bridge too far at the moment. Considering the fact that EC is heavily reliant on the timely and high quality inputs there is a strong need to have a high quality reporting structure and culture if EC is going to be used as a structural part of the risk management framework. Also the fact that the APG organization is focused on risk management based on business control testing and to a far lesser extent on quantitative risk measurement, the implementation of EC is not a logical step per se because it is not focused on business controls and the control environment but approaching risk management from a quantitative perspective. The gap between control focused and risk focused risk management may be too broad currently for a successful structural implementation of EC throughout the organisation, also because risk management departments at the business lines may not understand its specifics and use. This last point is certainly true when considering that setting up a successful implementation of EC requires management commitment and investing time of senior employees to set up data collection procedures, which is not guaranteed at this moment considering all organisational changes occurring at APG.

This also translates in the fact that in S&P's ERM rating the implementation of completely integrated quantitative models for risk measurement and aggregation is placed in the highest attainable classifications of the ERM system for insurers (Standard & Poor's, 2013). Again APG is not an insurer so not all qualifications in the S&P evaluation scheme can be directly applied to APG but internally the ERM scheme of S&P is used as a way to guide the development of ERM so the EC-model can also be viewed upon in this light. If the current implementation of the EC-model were scrutinized against the S&P subfactors it would score somewhere between negative and neutral due to the limited scope and validation, data quality and assumptions that underpin the model. Given the fact that CRC set their priorities on updating the risk management policies and risk control procedures and that the EC model at this stage is not going to be used in capital planning but as an alternative risk measure this poses no serious issues for risk management quality. However when CRC decides to implement EC as an additional method in the risk management toolbox these are all issues to take into account.

6. Discussion

6.1 General discussion

Currently the risk management function at APG group level but also at the business lines is very much focussed on being in control of business processes using a control framework to couple specific, process level, risks to control measures. This means that the attention of risk management and reporting focus lies on generating information on testing the control framework, both internally and by an external accountant. In this light the further development of a fully functional, validated EC-model might be not appropriate given the current focus of APG risk management. A further development of specific tools to quantify operational risk at the different business lines, in terms of EC or otherwise, seems more functional. When developing these tools it is important to keep in mind that the business lines and their risk management and reporting approaches differ substantially from each other.

6.2 Operational risk

A high level problem with measuring operational risk with the use of sophisticated probabilistic models is that while for market or credit risk inferences about the level of riskiness can be made directly from the structure and contents of a portfolio this is not true for operational risk. This also can be seen from the balance sheet where financial risk can directly be linked to either asset or liability items, operational risk is contained in more or less every item on the balance sheet making it a lot harder to model. This means that operational risk can only be estimated by looking at historical observations which all have their very own specific background and causes which are not likely to replicate themselves in the future, making them not very reliable for estimating capital. This does not mean that it is useless to make use of historical observations as a basis for operational risk capital estimation, but rather is a method that gives an incomplete view of the risk profile and should be augmented with .

Due to the limited available data on operational losses at specific business lines, as shows from the disputable results in the data analysis chapter, it is troublesome to give robust capital estimates based on limited information. To further develop operational risk quantification APG CRC stimulates the use of the central loss database and increases awareness of the importance of a comprehensive and precise loss administration in order to use these data as input for risk quantification procedures. Next to the historical loss based, LDA, approach it would be valuable for APG to also continue developing forward looking approaches to determine operational risk capital such as the expert elicitation method and scenario analysis based methods described in this research. The fact that the capital estimate obtained using expert elicitation and Monte Carlo simulation only differs 5% with internally used capital estimates is an indication that this method might proof useful. However also the internal capital estimate is not robust so it is only an indicative step in the right direction that both differ not too much from each other. Next to that the estimate is also very dependent on the probability distribution to model severity of operational losses. However these methods broaden the view of operational risk capital estimation and guarantee that not only historical data are used but also a view on the future risk profile of the organisation is used in operational risk capital estimates.

Operational risk doesn't fit well in EC framework (van den Tillaart, 2003). The risk of using advanced statistical models to estimate operational risk capital requirements is that they provide a false feeling of precision. Because the models used in the LDA are often, and certainly in the case of APG, based on limited loss databases and data sources that are subjective or known to be flawed or biased it is legitimate to question the usefulness of very high percentile estimates of operational risk losses (Alexander, 2003). This means that although the models might help to get a grip on what sort of numbers fit the operational risk exposure of an organisation such as APG they can by no means taken for very precise estimates of operational risk capital. However for the aim of this research and as management information to have at least some figures to use in the discussion about capital adequacy the methods described can serve as a first indication of operational risk capital.

Expert elicitation based on little experience with low frequency losses is a very crude process (Peccia A. , 2003). This also derives from the fact that it is hard for operational risk managers to think of losses that have never occurred. Next to this operational risk not result of risk taking, but rather indigenous to running a business. (Kuritzkes, Schuermann, & Weiner, 2002) This means that operational risk capital figures need to be interpreted differently, in a more indicative high level way, than capital figures resulting from credit or market risk quantification methods.

6.3 **EC-model**

For the EC-model that was already build for Loyalis there are also some methodological and practical remarks that should be taken into account when APG chooses to further develop the EC-model for use as management information or even capital planning.

For the Loyalis EC-model the normality assumption in calculation of all risk type EC values is in modern financial modelling seen as being a too simplifying assumption resulting in untrustworthy capital estimates, see (Hull, 2010), (Embrechts, Frey, & McNeil, 2005) or (Taleb, 2007) for a discussion of why the return distribution of financial instruments cannot be assumed normal and methods to account for this. This means that the EC-model that was already built for the Loyalis business line and used subsequently in this research can only be seen as a coarse estimate of capital requirements. The normal, Gaussian or bell-curve distribution is probably giving too low EC estimates considering that returns of financial products exhibit "fat tails" meaning that if fat tailed distributions, which place more probability on large deviations of portfolio value meaning large losses, are used to model EC estimates these will probably be higher than the current figures. When the EC-model will be developed further this is an important point of attention because the assumption that losses are distributed normally leads to unreliable capital estimates potentially underestimating risks and subsequently capital figures. Only for the sake of simplicity it is convenient to build up the model using the normality assumption, but the uncertainty of estimates is a high price to pay for such modelling ease. This is the background of the setup of the current Loyalis EC-model, if this model is to be used further as management information or capital planning tool this should be one of the first aspects of the model to be reviewed.

Also the assumption in the EC-model that risks are interrelated linearly using a variance-covariance matrix to compute aggregation benefits makes modelling easier but results in more unreliably capital estimates and possibly underestimated capital figures. Using linear correlation to model risk dependencies is currently replaced by using copula approaches to model risk interrelationships in EC-models (BCBS, 2009) (Embrechts, Frey, & McNeil, 2005). The implementation of copula structures would make the EC-model more state of the art but also poses data problems because setting up the model and estimating parameters for the copula approach requires more data and a more complete view on risk relatedness. The upside is that dependencies that manifest themselves in the tails of distributions are much better modelled with copulas than with correlations. Also the tendency of losses occurring simultaneously during times of crisis or stressed situations (Hull, 2010) can be brought into the EC-model using copulas.

7. Conclusion and further research

7.1 Conclusion

The result of this research is not so much a complete working EC-model that can be used by APG Group to use in their capital management process because it was not feasible to design such a model given the limited time and resources available. Looking at the research question:

> *CRC wants to have a quantitative risk measure that can be compared between business lines and used to communicate about risks in the organisation. Investigate how EC can be implemented to answer this need taking into account different risk types, structure of APG Group, currently available information and data and the APG risk and control framework.*

The main topic of attention in this research was the quantification of operational risk since this risk type formed both the common denominator between the different business lines and the big unknown because no method for quantifying operational risk was available yet. Although there was almost no data available to analyse and use in statistical quantification the data analysis showed that information on operational losses at APG shows the same patterns as that at banks and insurers. This can serve as an indication that also the same methods might be used to quantify operational risk. The lack of data on operational events or losses is a major problem when wishing to produce EC-figures for operational risk. This research has led to more attention from risk management for the structural collection of information on operational issues and losses.

Because not enough data was available for robust capital estimated based on data driven methods. The proposed solution consists of using expert knowledge present at the operational risk management divisions of the business lines to estimate worst case loss amounts and use these to model operational risk EC. The procedure used at APG AM lead to an capital estimate 5% different of internally used capital estimates. This was done following methods developed by banks and insurers in their efforts to comply with regulations for financial institutions. Models developed by banks and insurers are a good source of inspiration and information for the further development of EC because these parties are generally much further with these models also because they are required to be so by regulators.

This research into the different aspects of EC for APG has lead to other results. An overview of all operational losses and information about these losses is collected and put together into one data file. These data were analysed and if possible conclusions about the nature of losses at APG are made and communicated within CRC and business lines. The search for relevant data also lead to the fact that at this moment CRC is putting more effort in synchronizing data recording and collection at the different business lines. In the end the main topic of interest was the quantification of operational risk which lead to the set up and actual implementation of expert elicitation to collect expert opinions on operational loss frequency and severity from one of the APG business lines. The methodology used to do so could easily be further developed by CRC into a standard procedure to gain insight into expert opinions on operational risk losses. Also the use and critical evaluation of the EC-model that already existed for

Loyalis is of value to the organisation because it puts the results of this model into perspective and provides guidelines for how to further develop the model.

The conclusion has to be that at this moment there is still a lot of work to be done before APG Group can make use of one comprehensive EC-model that can be used to compare risk between risk types and business lines and use such a model in the process of capital planning and management. However at this moment the implementation of EC at APG Group might be one bridge too far considering the most important factors as available information, reporting standards and risk management style and culture. This research might prove valuable as background information and an attempt to arrive at an holistic approach to capital planning at APG, a topic that will get more attention now that APG is regulated under a different supervisory regime. In the next Section further research and possibilities to develop the EC-model are worked out in more detail.

7.2 Further research

Considering the current focus and goals of CRC EC might not be the best candidate to fulfill the need for comparable risk figures and comprehensive risk reporting. Risk management at APG is focused on testing the working of process controls and the control framework in place to guarantee control over the business processes rather than on a quantitative style of risk management. A method taking into account both risk and control environment would suit the risk management organization better and has the advantage that results could be better communicated to local risk managers because the language would be more familiar than the quantitative language of EC is. A framework as described by (Peccia A. , 2003) which is more focused on the business and control environments, aligns better with reporting practices and control centered culture at APG. This methodology could be used in periodical risk self-assessments at the different business lines and will also enable CRC to have a comprehensive overview of the situation.

Given the fact that operational risk forms the major part of the risk profile of APG and that currently no methods are available to quantify operational risk in monetary or economic terms, further development of the methods proposed in this research would be a logical step. Somewhere in the future when the Bayesian approach using both historical data and expert opinion is worked out further and successfully implemented by industry leaders in the banking or insurance this could be a very interesting solution to the problem of loss data paucity at APG.

If APG wants to further develop the EC-model as a source of management information and as a basis for capital allocation between business lines there are a number of critical points the model has to improve upon. The most important of which is the model wide use of the normal distribution to calculate EC-figures for the different risk categories. If EC really is to be implemented by CRC as the group wide risk currency and common language to discuss current state of risk exposure the current model will not suffice, since the model assumptions result in too rough cut capital estimates. Results from the current EC-model could serve as indicative quantitative information in management discussion or decision making but are not precise enough to provide trustworthy and reliable management decision input. Further development of the EC-model could lead to a model that could serve this purpose but considerable effort is needed to reach that level of reliability. If CRC wants to develop the model further it is advisable to commit resources from the AM or Loyalis financial risk management team to the development of the EC-model. There is a lot of knowledge on financial risk present in the organisation considering AM is one of the largest asset managers active in the Netherlands and has a large financial risk team, although they are managing the financial risk of pension fund assets. The first steps in fine-tuning the model would be the development of specific risk quantification methods for each of the risk types specifically tailored to the composition of the exposure to the risk types of which interest rates assets and liabilities would be the first main classes to investigate.

Appendix A: Bibliography

Agostini, A., Talamo, P., & Vecchione, V. (2010). Combining operational loss data with expert opinions through advanced credibility theory. *The Journal of Operational Risk* , 3-28.

Alderweireld, Garcia, & Leonard. (2006). A practical operational risk scenario analysis quantification. *Operational Risk* , 93-95.

Alexander. (2003). *Operational Risk Regulation, Analysis and Management.* Edingburgh: Pearson Education.

Anderson, T., & Darling, D. (1954). Asymptotic theory of certain "goodness-of-fit" criteria bbased on stochastic processes". *Annals of Mathematical Statistics* , 193-212.

APG. (2013). *About APG*. Retrieved 2 28, 2013, from APG: http://www.apg.nl/apgsite/pages/english/about-apg/

APG Group. (2012). *APG Groep NV Jaarverslag.* Heerlen: APG Corporate Communicatie en Branding.

Aue, F., & Kalkbrener, M. (2007). LDA at Work. *The Journal of Operational Risk* , Vol. 1, No. 4.

Baule, & Steinhoff. (2006). How to validate op risk distributions. *Operational Risk & Regulation* , 1-6.

BCBS. (2006). *International Convergence of Capital Measurement and Capital Standards.* Basel: Bank for International Settlements.

BCBS. (2009). *Observed range of practice in key elements of Advanced Measurement Approaches.* Basel: Bank for International Settlements.

BCBS. (2009). *Range of practices and issues in economic capital frameworks.* Basel: Bank for International Settlements.

BCBS. (2010). *Recognising the risk mitigating impact of insurance in operational risk modelling.* Basel: Bank for International Settlements.

BCBS. (2003). *Sound Practices for the Management and Supervision of Operational Risk.* Basel: Bank for International Settlements.

BCBS. (2001). *Working Paper on the Regulatory Treatment of Operational Risk.* Basel: Bank for International Settlement.

Bielecki, T. R., & Rutkowski, M. (2001). *Credit Risk: Modeling, Valuation, and Hedging.* Berlin: Springer-Verlag.

Cap Gemini. (2010). Principles of Economic Capital .

CEBS. (2010). *Guidelines for the joint assessment of the elements covered by the supervisory review and evaluation process (SREP) and the joint decision regarding the capital adequay of cross border groups (GL39).* Committee of European Banking Supervisors.

Chapelle, A., Crama, Y., Hübner, G., & Peters, J. (2008). Practical methods for measuring and managing operational risk in the financial sector: A clinical study. *Journal of Banking and Finance* , 1049-1061.

Committee of European Banking Supervisors. (2006). *Paper on the Internal Capital Adequacy Assessment Process (ICAAP) for Smaller Institutions.* Committee of European Banking Supervisors.

COSO. (2004). *Enterprise Risk Management - Integrated Framework.* Jersey City: Committee of Sponsoring Organizations of the Treadway Commission.

CRO Forum. (2009). *Internal Model Admmissibility.* Amstelveen: CRO Forum.

Delft University of Technology. (2010). *Approaches to Product Design in Delft.* Retrieved 2 21, 2013, from Product Design: http://ocw.tudelft.nl/courses/product-design/delft-design-guide/part-1-approaches-to-product-design-in-delft/?jumpurl=uploads%2Fmedia%2FPart_1_-_Approaches_to_Product_Design_in_Delft_01.pdf&juSecure=1&mimeType=application%2Fpdf&locationData=6820%3Att_cont

Dev, A. (2004). *Economic Capital: A Practitioner Guide.* London: Incisive Financial Publishing .

DNB. (2007, 1 1). *Economic Capital*. Retrieved 5 17, 2013, from dnb.nl: http://www.toezicht.dnb.nl/en/2/51-202232.jsp

Dutch National Bank. (2005). *FIRM Manual.* Amsterdam: De Nederlandsche Bank.

Dutch National bank. (2012, September 3). *Solvency II general*. Retrieved 3 27, 2013, from Dutch National Bank: http://www.toezicht.dnb.nl/en/2/51-202376.jsp

Dutta, & Babbel. (2010, 9 24). Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach. *Working Paper* , pp. 1-27.

Dutta, & Perry. (2007). *A Tale of Tails: An Empirical Analysis of Loss Distribution Models for Estimating Operational Risk Capital.* Boston: Federal Reserve Bank of Boston.

EC. (2010). *QIS5 Technical Specifications.* Brussels: EC Internal Market and Services DG.

Economic Capital. (2010, 9 26). Retrieved 2 28, 2013, from Economic Capital Insurance Blogspot: http://economiccapitalinsurance.blogspot.nl/2010/09/editorials-interviews-news-analysis.html

Embrechts, P., Frey, R., & McNeil, A. (2005). *Quantitative Risk Measurement.* Princeton: Princeton University Press.

Embrechts, P., Klüppelberg, C., & Mikosch, T. (1997). *Modelling Extremal Events for Insurance and Finance.* Berlin: Springer Verlag.

Ergashev. (2012, 6 1). A theoretical framework for incoporating scenarios into operational risk modeling. *Journal of Financial Services Research* , pp. 145-161.

Ernst & Young. (2013). *Insurance CRO Survey 2013.* Ernst & Young.

European Commission. (2009). DIRECTIVE 2009/138/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. *Official Journal of the European Union* , 335/1-335/155.

Fontnouvelle de, P., Jordan, J., & Rosengren, E. (2005). *Working Paper 11103: Implication of alternative operational risk modeling techniques.* Cambridge: National bureau of economic research.

Frachot, O., & Roncalli, T. (2004). The basel handbook. In Ong, *The Basel Handbook: A Guide for Practitioners .* Risk Books.

Garthwaite, P., Kadane, J., & O'Hagan, A. (2005). *Statistical Methods for Eliciting Probablity Distributions.* Department of Statistics.

Gatzert, N., & Wesker, H. (2011). A comparative assessment of Basel II/III and Solvency II. *The Geneva Papers on Risk and Insurance, Forthcoming* .

Global Association of Risk Professionals Risk-Glossary. (2013, February 15). Retrieved February 15, 2013, from Global Association of Risk Professionals: http://www.garp.org/risk-news-and-resources/risk-glossary/risk-glossary.aspx?p=3

Holmes, M. (2003, 9 1). Measuring operational risk: a reality check. *Risk Magazine* .

Holton, G. A. (2006). Defining Risk. *Financial Analyst Journal* , 19-24.

Hübner, G., & Peters, J. (2009). Modeling Operational Risk Based on Multiple Experts' Opinions. In G. Gregoriou, *Operational Risk Toward Basel III* (pp. 3-21). Hoboken: John Wiley & Sons.

Hull. (2010). *Risk Management and Financial Institutions.* Boston: Pearson.

ISO. (2009). *ISO 31000:2009 Risk management - Principles and guidelines.* Geneva: International Standardization Organization.

Jiménez, J., & Arunachalam, V. (2011). Using Tukey's g and h family of distributions to calcualte value-at-risk and conditional value-at-risk. *The Journal of Risk* , 95-116.

Kadane, J., & Wolfson, L. (1998). Experiences in elicitation. *The Statitician* , 3-19.

Kaplan, S., & Garrick, B. J. (1981). On the quantitative definition of risk. *Risk Analysis* , 11-27.

Knight, F. D. (1912). *Risk, Uncertainty and Profit.* Cambridge: The Riverside Press.

Koenig, D. (2004). Economic Capital for Market Risk. In A. Dev, *Economic Capital: A Practitioners Guide* (pp. 167-183). London: Incisive Financial Publishing.

Kuritzkes, Schuermann, & Weiner. (2002). Risk Measurement, Risk Management and Capital Adequacy in Financial Conglomerats. *Wharton Working Paper Series* , 1-52.

Merriam-Webster Dictionary Risk. (n.d.). Retrieved 6 21, 2013, from Merriam-Webster: http://www.merriam-webster.com/dictionary/risk

Messem, V. (2002). *Fair Value van Verzekeringen en Economisch Kapitaal.*

Mikes, A. (2011). From coutning risk to making risk coutn: Boundary-work in risk management. *Journal of Accounting, Organizations and Society* , 226-245.

O'Hagan, A. (2006). Research in elicitation. *Bayesian Statistics and its Applications* , 375-382.

ORX. (2011). *Operational risk reporting standards .* Zürich: Operational Riskdata eXchange Association (ORX).

Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. (2007). *Engineering Design: A Systematic Approach.* London: Springer.

Peccia. (2003). Using operational risk models to manage operational risk . In C. Alexander, *Operational risk: Regulation, Analysis and Management* (pp. 262-284). Edinburgh: Pearson.

Peccia, A. (2003). Measuring and Calculating Economic Operational Risk Capital . In A. Dev, *Economic Capital: A Practitioners Guide* (pp. 183-207). London: Incisive Financial Publishers.

Porteous. (2004). Economic capital for life insurance with-profit long-term business funds. *Journal of Risk* , 1-26.

Porteous, B. T., & Tapadar, P. (2006). *Economic Capital and Financial Risk Management for Financial Services Firms and Conglomerats.* New York: Palgrave MacMillan.

Rao, V. (2004). The Significance of Economic Capital to Financial Institutions. In A. Dev, *Economic Capital: A Practitioners Guide* (pp. 69-89). London: Incisive Financial Publishing.

Rippel, & Teplý. (2011). Operational Risk - Scenario Analysis. *Prague Economic Papers* , 23-39.

Romme, A. G. (2003). Making a Difference: Organization as Design. *Organization Science* , 558-573.

Romme, A. G., & Endenburg, G. (2006). Construction Principles and Design Rules in the Case of Circular Design. *Organziation Science* , 287-297.

Saunders, A., & Millon Cornett, M. (2008). *Financial institutions management, a risk management approach.* New York: McGraw-Hill/Irwin.

Shevchenko. (2010). Implementing Loss Distribution Approach for Operational Risk. *Applied Stochastic Models in Business and Industry* , 277-307.

Shevchenko, P., & Wüthrich, M. (2006). The Structural Modelling of Operational Risk via Bayesian inference: Combining Loss Data with Exper Opinions. *The Journal of Operational Risk* , 3-26.

Singh, A., Allen, D., & Powell, R. (2011). Value at Risk Estimation Using Extreme Value Theory. *19th International Congress on Modelling and Simulation*, (pp. 1478-1484). Perth.

Standard & Poor's. (2013). *Enterprise Risk Management .* New York: Standard & Poor's .

Taleb. (2007). *The Black Swan.* London: Allen Lane.

Tasche, D. (2003). Allocating Portfolio Economic Capital to Sub-Portfolios. In A. Dev, *Economic Capital: A Practitioners Guide* (pp. 275-302). London: Incisive Financial Publishers.

Teker, D. (2005). Comparative Analysis of Operational Risk Measurement Techniques. *Paper 39 International Trade and Finance Organization 15th International Conference* (pp. -). Istanbul: The Berkeley Electronic Press.

TSM business school. (2005). *Algemene bedrijfskundige probleemaanpak.* TSM business school.

van Aken, J. A. (2005b). Valid knowledge for the professional design of large and complex design processes. *Design Studies* , 379-404.

van den Tillaart, A. (2003). *Controlling Operational Risk.* 's-Hertogenbosch: AlfaBase Publicatie Processors.

Verein Deutscher Ingenieure. (1987). *Systematic Approach to the Design of Technical Systems and Products.* Berlin: VDI Verlag.

Walter, J. S. (2003). Background on Economic Capital. In A. Dev, *Economic Capital: A Practitioners Guide* (pp. 3-14). London: Incisive Financial Publishing.

Appendix B: Research methodology

B.1 Type of research: Goal of research aligns best with design type research.

This paper adopts a design type research because this is most in line with the objectives and properties of this research project, namely the development and in the end the implementation of an economic capital model for APG. Because the end product of the research is known upfront, an EC-model for APG group CRC, it is possible to concentrate on the precise characteristics that this model has to satisfy instead of first searching for the correct model to use in a situation. The design type research is characterized on five dimensions as opposed by science and humanities types of research: Purpose, role model, view of knowledge, nature of objects and focus of theory development which are presented in Table 12 below (Romme, 2003).

Dimension	Design type research
Purpose	Produce systems that do not yet exist—that is, change existing organizational systems and situations into desired ones.
Role model	Design and engineering (e.g., architecture, aeronautical engineering, computer science).
View of knowledge	*Pragmatic:* Knowledge in the service of action; nature of thinking is normative and synthetic.
Nature of objects	Organizational issues and systems as *artificial objects* with descriptive as well as imperative (ill-defined) properties, requiring non routine action by agents in insider positions. Imperative properties also draw on broader purposes and ideal target systems.
Focus on theory development	Does an integrated set of design propositions work in a certain ill-defined (problem) situation? The design and development of new (states of existing) artefacts tends to move outside boundaries of initial definition of the situation.

Table 12: Characteristics of design type research. Source: (Romme, Making a Difference: Organization as Design, 2003)

On all five dimension the description of the design type research aligns with the purpose and characteristics of this thesis research. The purpose is to come up with a new model for economic capital in a specific organizational context, with sometimes ill-defined properties and procedures, where knowledge will be used in a pragmatic way to construct this model. Currently there is no EC-model at APG, meaning that this research will start with enquiring into the precise role the EC-model has to fulfill and what the ideal implementation of the model should look like. Furthermore the situation at APG group is unique which means that no standard solution for the problem is available or can be readily implemented. In the end the successfulness of this whole research project will hinge on the question of whether the proposed solution works in this specific setting. Designing in this context is defined as: designing is the process of determining the required function of an object to be designed, combined with making a model of it (van Aken, 2005b). This sets out the context in which this research is performed and provides the direction in which the research methodology is to be developed.

Large organizations perceive difficulties in constructing, implementing and creating commitment to strategies, next to these problems there are often difficulties relating to generating and communicating vital information throughout the organization. (Romme & Endenburg, 2006). More specific for financial institutions there is also great pressure on their organization to produce the required information for regulatory purposes (Saunders & Millon Cornett, 2008). These observations are useful to keep in mind when further developing the research design and defining the objectives and limitations of this research project. To help structure this research a solution concept for the design process, defined as when you want Y in situation X do Z (or something alike Z) (van Aken, 2005b), that fits this model design process is adopted. This solution concept will provide a process structure and a role structure for the design process from which the process structure will be the most important since this will help specifying the various steps or sub-processes of the design process and their sequence and timing (van Aken, 2005b).

B.2 Research methodology

Following the hybrid methodology developed in paragraph 0 the different stages of this research can be specified. This paragraph describes the stages and their research content. These can also be seen as the different research questions following from the problem statement in the Section 1.5 and provide an overview of what this thesis project will consist off and how the different parts of the research link together. The stages in Figure 2 can be seen as stages 3-8 of the research methodology of paragraph 1.5, where chapter 1 fulfils the role of stage 1 and this chapter 2 being the content of stage 2. The stages will also help with formulating a planning and the different feedback points with the internal and external supervisors of this project. For this specification of research stages and their content the same as for the general methodology holds; some of the stages, 2-4 must be seen more iteratively than that they will be followed in strict sequential order. This is either because it may prove that it works better to implement a specific partial solution directly or because of the specific questions of APG CRC to start working with parts of the model before the model is finished in its entirety. Because this implementation of the research stages is made in an early stage of the research they may not reflect the path the research takes correctly, but of course this can only be known after the research project is finished. Because of that the earlier stages of the model are more narrowly defined than the stages later on.

Regarding the modules that combine different functions the final product has to perform, stages 3 and 4, quantifying risks and aggregation of EC, can be seen as essential functions of the EC-model and therefore as the most important functional modules. Of course these stages will be performed for each of the risks identified in the first stage and EC models found in the second stage resulting in functional modules per risk type and for each aggregation level of EC. The order and contents of the research stages are listed in

Figure 5 For a detailed description of the research stages see Appendix A.

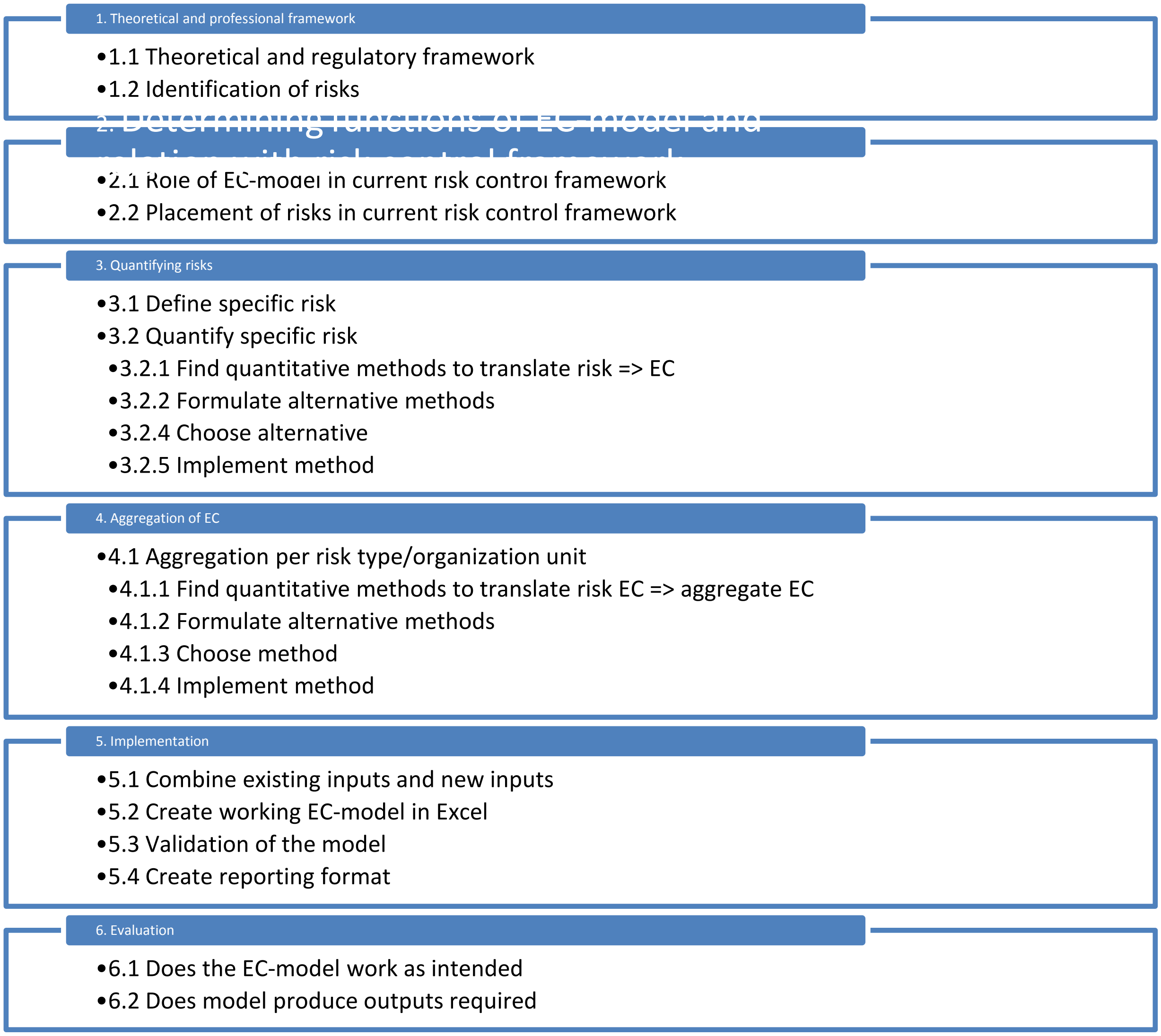

Figure 5: Research stages and their content

The research methodology of this paper is based on practical problem solving and design approaches. As is argued in the last section the fact that it is known upfront what the result of the research should be makes that an approach aimed at the design of a system or product suits this research best. See Appendix B for a detailed explanation of how the research design was set up for this paper. In table 2 below the different research stages and their contents are explained.

Stage	Activity	Result
1	**Preliminary research** Dependent on what kind of assignment or problem needs to be solved preliminary research will consist of getting acquainted with the problem and its characteristics and the	Goal and scope of the research. Consistent ideas of what the problem is about and the general direction in which the solution is

	organizational context in which the problem is situated. Furthermore the method for finding the solution may be investigated and some rules and guidelines for the problem solving can be set up. In the case that is known that the outcome has to be some kind of model, model types and contents can be investigated but only on a general level, avoiding really detailed descriptions or analysis of specific models.	to be found. Idea about what problem solving method, guidelines and boundary conditions for solving the problem are applicable.
2	**Problem identification** After the preliminary research the problem/situation is more rigorously investigated with the goal of producing a precise and concise problem definition. Finding out which requirements the solution has to satisfy is very important in this stage because the requirements will be used throughout the research to keep going in the right direction.	A precise problem description involving current and desired situation, together with a problem statement and main research question(s). Next to that a detailed (functional) requirement list of what exactly the solution/model should satisfy.
3	**Determine theoretical and professional framework** In order go from the general problem statement and requirements list in the last stage tot the functions and structure of the solution in stage 4 a theoretical framework is to be developed. In this framework information about the concepts that are to be used during the design process are defined based on scientific as well as professional literature, but also taking into account the organizational context for which the solution is to be developed.	Theoretical and professional framework including definitions of key concepts.
4	**Determine functions and structure** Based on the requirement list and problem statement an investigation into the precise functions of the solution/model should be conducted. Also the structure of these functions in the solution should be clear. When possible the functions may be combined into modules, which act as the unit of analysis in the design of the final solution.	General outline of the solution in terms of function and the structure of those functions. When possible division of the functions into modules.
5	**Alternatives per module or partial solutions for the different functions** Using the modules as the unit of analysis, solutions for the modules can be developed by investigating different possibilities, all the time keeping the list of requirements in mind. Important is to also look at the aggregation or combination of the different modules, this aggregation of modules may be seen as just another module that needs a partial solution. Depending on the number of modules and the complexity of the solution possibilities one or more alternative solutions per module may be developed.	Solution alternatives(s) per module or per function.
6	**Develop general solution** Again using the list of requirements made in step 2 develop a general solution/final model for the problem consisting of the solutions for the different modules found in the last	General solution/final model. Answers to research questions and problem statement.

	step. This general solution has to be the answer to the research questions posed in stage 2 and a solution to the problem statement.	
7	**Implementation and testing** Implementing of the general solution developed in stage 5, however the testing and implementing can be done concurrently with the development of the final solution. This means that the module solution can be tested separately before being combined in the general solution. Implementation will follow when the modules are tested, and the general solution is found. This stage also includes the validation of the solution, when applicable. The execution of the implementation stage also depends on the amount of time available and outline of the project.	Tested and implemented solution to the initial problem. Validated model.
8	**Evaluation** Evaluate the final result, again using the list of requirements, but part of the test also can be the evaluation of the list of requirements itself because after implementation it may become clear that the original (functional) requirements for a solution where not correct. Next to the requirements testing also the questions can be asked to people working with the model/solution.	Evaluation results which can be used for possible next projects or improvements to the current solution.

Table 13: Hybrid approach

The idea behind the hybrid design/problem solving approach is that it provides a path which can be used to systematically identify, decompose and find solutions for a problem where it is known upfront that the result will be a model that can be used in business practice, which does not need to be an economic capital model per se but can also be for instance some software or organizational model. The fact that it is known upfront that the result of the research will be a model is the premises of this method and makes it possible to change general problem solving approach in the knowledge that it is more focused on the development of a specific product and not on the more general concept of a solution. It thus helps to guide the process from the abstract to the concrete, also a starting point from the VDI 2221 (Verein Deutscher Ingenieure, 1987). Because it provides a guideline for the design process and sub-processes together with a clear start and end-point specifying what to do in a situation where a specific organizational solution is desired it can be seen as the solution concept from (van Aken, 2005b).

Stages 4-7 can be seen as iterative and not defined by clear boundaries because it seems logical that in the actual process of researching and designing the model, these stages will not be followed in strict sequential order but more in concurrence. This could mean that first an initial idea of the solution or solutions may arise and then, after some further research and maybe some testing, these ideas may be discarded or worked out further into a solution. Also in the step of fitting the module solutions in the general solution it may become apparent that a certain partial solution may not fit very well in the proposed general solution leading to a new partial solution or a adaptation of the previous one.

Theoretical and regulatory framework

To get a better grip on the contents of this research in this stage, definitions of the key concepts are given, EC and risk. Furthermore the regulatory framework and the definitions it uses to define the requirements on capital adequacy and the different reports APG has to deliver is investigated. The definition process will be based on higher levels on general definitions or definition from regulatory frameworks as Solvency II or Basel II when applicable. These last definitions have the advantage that these are widely used and studied risk definitions, which are also used as reference in scientific literature. Of course these definitions may have a too general character for the specific organizational context at APG group, in that case clear definitions are needed which consider the need to further operationalise the definition into workable input for the quantification of these risks. A source for these more context dependent definitions may be the current risk control framework at APG group or more specific papers on specialized risk measurement.

Identification of risks

In the current risk control framework of APG group, risks specified and measured by testing various controls in place to mitigate these risks. To get a comprehensive overview of these risks the current risk control framework together with information from members of the CRC team will be used to generate an overview of the risks that are present in the various organizational units and should be measured in the EC model. This overview of the different risk types that are present in the organization is used as an input for the next stage where for each risk type a method to quantify this risk is formulated.

B.3 Determining functions of EC-model and relation with risk control framework

Role of EC-model in the current risk control framework

The role and functions of the EC-model in relation to the current risk control framework of APG is researched to make sure that the results of the following stages will fit the current risk control framework and the processes it describes.

Placing risks in risk control framework

To get an, initial, understanding of the different risks and their nature and place in the organization the current risk control framework is used as a source of information to identify risks. The current risk control framework encompasses all the risks in the organization but does not necessarily quantify them, which is the goal of this research thesis.

B.4 Quantifying risks

After the initial identification of risks in the previous stage the individual risks need to be quantified with a risk measure that captures their nature and importance, for each of the specific risks this stage is repeated.

Define specific risk

Risk is further identified and a precise identification of its nature, causes and effects takes place. This definition per risk will be used in subsequent research to determine the best method of quantification and further use in the EC-model. Before quantifying specific risks a precise definition of each risk is needed. When no definition is available as identified in previous stages these definitions are decided upon together with members of the CRC team.

Quantify specific risk

After a concise definition of a specific risk in the organization is given the next step is to quantify this specific risk by means of a quantitative risk measure, preferably in terms of EC. This step is needed to in the end convert individual risks into comprehensive economic capital figures. For some risks this step will be relatively easy because APG group records already some quantitative risk measures which can be converted into EC figures. For other risks only qualitative data will be available and for some risks there may be even no available data or information.

Find quantitative methods to translate risk => EC

To give each of the specific risks found at APG a place in the EC-model that is to be developed, these risks need to be quantified into EC figures. For the risks that are not measured by APG group in such a way that they can be readily converted into EC figures, scientific work on EC will serve as a basis for finding these quantitative methods. Next to articles published in scientific journals there is also the regulatory aspect of economic capital which serves as a large body of information that be input for determining methods to calculate economic capital.

Formulate alternative methods

After finding and listing different methods to quantify risks into EC figures these need to be formalized into one or more alternative methods. For each method the inputs need to be specified together with how it exactly works and how the implementation for APG group will look like in mathematical terms. This means that for all presented alternatives it has to be clear if and how they can be implemented at APG so an informed decision based on the characteristics of the method and how well it fits the current systems and procedures at APG can follow.

Choose alternative

After listing and describing the working and implementation of the different methods a choice has to be made. The different options will be compared on issues such as reliability, complexity and computational efforts but also on how well they are in line with the current risk control framework at APG to minimize the organizational effort to produce the EC figures. This information will be presented to APG CRC so they can make informed decisions as to what method to use.

Implement method

For some or all of the methods at this stage an implementation of the specific calculations can be made to test the method and already produce some figures on EC for that specific risk in that context. This may be done because APG group already wants some preliminary results on individual risks or to test if a method really works, in which case the results can be used in the previous stage of comparing and choosing alternatives.

B.5 Aggregation of EC

Aggregation per risk type/organization unit

Because individual EC figures may be aggregated on a risk type or organizational unit basis depending on the preferences of APG these options have to be researched. The aggregation of risk figures is a relatively new and complex subject in the scientific and professional debate because it involves many factors and can be done in a number of ways. This makes that there are a lot of options for treatment of the aggregation of economic capital depending on the preferences of APG for which aggregated figures they want to use. For all these option different aggregation techniques can be looked at which again will be found in scientific literature and in the regulatory documents on capital adequacy that are also use to quantify the different risks.

Find quantitative methods to translate risk EC => aggregate EC

Because at this moment APG does not have economic capital models there is limited in house knowledge on the aggregation of risk figures. Scientific literature and regulatory documents will serve as a knowledge base for different aggregation techniques.

Formulate alternative methods

From these theoretical or regulatory methods a selection is made which is worked out further. Also here inputs and the exact working of the method is specified. Because the aggregation method tend to be mathematically more involved not all alternative methods will be worked out in detail but the general line of mathematical reasoning is made clear, where most attention is given to the practical implications for APG group of each method.

Choose method

After listing and describing the working and implementation of the different methods a choice has to be made. The different options will be compared on issues such as reliability, complexity and computational efforts but also on how well they are in line with current procedures at APG group to minimize the organizational effort to produce the aggregated EC figures. This information will be presented to APG CRC so they can make informed decisions as to what method to use.

Implement method

Because the implementation of aggregation methods to create aggregated EC figures is rather involved, mathematically and practically, the implementation of these methods will depend on the situation at that point in the research and the type of aggregation method that is chosen in the last stage. If there is time enough and APG group wants the figures it can be done directly after the formulation of the methods and otherwise it can wait until the implementation stage.

B.6 Implementation

Combine existing inputs and new inputs

Before the actual calculation of EC figures can commence the input has to be ready, therefore the first step should be to find all the necessary inputs for the model and make sure that reliable data is available for the calculations.

Create working EC-model in Excel

To come up with final EC-figures the individual EC calculations from the last stage need to be combined. Not only theoretically using aggregation methods but also on a practical level because APG group wants to have a look at the EC-figures. Therefore a working model should be made, the most logical way to do so is using Excel, probably with some extension to facilitate the use of simulation methods like Monte Carlo simulation.

Validation of the model

After a working version of the model is created it needs to be validated. That is, there has to be determined if the model produces reliable figures. This can be done by a number of techniques that will be discussed and compared at this stage.

Create reporting format

To communicate the results of the EC-model in a clear way that can be used for decision making throughout the organization the results need to be presented in a clear way. To do so a reporting format that is both informative and simple is to be developed.

B.7 Evaluation

Does the EC-model work as intended

For the evaluation of the model it is crucial that is looked at if the EC-model does as promised and therefore the model has to be used for some time. This means that the evaluation can only take place after the model is implemented by APG Group and is used for some time.

Does model produce outputs required

Also this can only be looked when the model is used in practice.

Appendix C: Risk definitions

C.1 Definition of risk

As is clear from the definitions of economic capital there is a direct relation to risk, and different risk categories, which seems only logical because EC is in essence a measure of risk. Before further exploring the different risk types present at APG a more general enquiry into the precise definition of risk and its place in the risk control framework at APG is made. Since APG uses the Enterprise Risk Management model from the Committee of Sponsoring of the Treadway Commission (COSO ERM), this is a good starting point for a definition of risk. But just as for the definition of EC, a number of definitions can be found within the organization and in other sources as regulation and in scientific debate, it seems however that organizations and scientists are weary to give a definition of risk, since nowhere in documents from for example the Bank for International Settlements or European Commission is a simple definition of the word risk to be found. Even in books that have the word risk in their titles not a single definition of risk is to be found, which indicates that giving a definition of risk is neither a simple nor a desirable task.

Despite this apparent hesitance of the scientific and professional community, risk is a very, if not the most, important concept in the light of this research. This because the end product, ie. The EC model, will derive from the different risks present in the organization and therefore the reliability of this model is heavily influenced by the reliability of the measurement of risk. But on the other hand, also here it is not the goal to give a complete ontological definition of the concept risk, but a definition on a more practical or pragmatic level because the goal of this research is to produce a workable EC model for use at APG rather than a more theoretical essay on EC and risk. So it is good to establish a good notion of what risk is about, but in the end definitions are used that are also capable of capturing the organizational context at APG. In Table 14 an overview of risk definition is provided.

Source	Definition
(COSO, 2004)	Risk is the possibility that an event will occur and adversely affect the achievement of objectives.
(Knight, 1912)	Measurable uncertainty
(Knight, 1912)	A proposition for which the distribution of the outcome in a group of instances is known (either through calculation a priori or from statistics of past experience)
(Holton, 2006)	Risk is exposure to a proposition of which one is uncertain.
(ISO, 2009)	Effect of uncertainty on objectives NOTE 1 An effect is a deviation from the expected — positive and/or negative. NOTE 2 Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process). NOTE 3 Risk is often characterized by reference to potential **events** (2.17) and **consequences** (2.18), or a combination of these.

	NOTE 4 Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated **likelihood** (2.19) of occurrence. NOTE 5 Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood.
(Kaplan & Garrick, 1981)	Risk analysis consists of an answer to the following three questions: (i) What can happen? (i.e., What can go wrong?) (ii) How likely is it that that will happen? (iii) If it does happen, what are the consequences?
Bank of America (Walter, 2003)	Volatility in the firms market value
Loyalis (2011) Translated from Dutch	The probability that, on the long or short term, financial damage occurs causing threats to the continuity or solvability of Loyalis or to short term objectives.
Webster Dictionary	The possibility of loss

Table 14: Definitions of risk

As can be seen from the different definitions of risk found in scientific and professional sources, it is hard to arrive at a single all encompassing definition of risk. For this research the most important feature of a definition would be that it is useable in the process of arriving at an EC-model for APG. Of course the most important task will be arriving at operational definitions and measurement for the specific risk types later in this chapter, but an overall definition of risk would reflect the level on which the aggregated EC value will has to be interpreted. The definition that feels most comfortable in the context of the risk control framework at APG and the task of designing an EC model, because it incorporates both the fact that risk is about exposures and uncertainties, is the definition of Holton (2006). This aspect will be covered extensively in the remainder of this research because the risk measures for individual risks are all about bringing together frequencies and severity of events, thus constituting a more technical or mathematical definition of risk.

Definition 2: *Risk is exposure to a proposition of which one is uncertain.* (Holton, 2006)

Also here it may help to define risk in a more mathematical manner to get a bather grasp of what the concept risk signifies, using as a basis (Kaplan & Garrick, 1981) who define risk as consisting of a triplet answering the questions:

i. What can happen? (i.e., What can go wrong?)
ii. How likely is it that that will happen?
iii. If it does happen, what are the consequences?

Leading to the following definition of risk, *R,* is the set of triplets (Kaplan & Garrick, 1981):

$$R = \{< s_i, p_i, x_i >\}, \qquad i = 1, \dots, N$$

Where s_i is the definition or description of a scenario;

p_i is the probability of that scenario; and
x_i is the consequence or evaluation measure of that scenario.

The authors further acknowledge that risk is more than just the simple multiplication of probability and severity, it is the whole curve linking probability to severity. This is a meaningful addition to the standard mathematical definition of risk because it provides more insight into the nature of risk and the way in which it should be perceived, not just as the expected value of damage but rather as the whole range of severities and probabilities describing the relationship between these values. It is important that any risk measurement method should acknowledge this relationship between probability and severity rather than focus on either one of them.

When connecting this definition to the mathematical definition of EC given in equation 2 we can see a loose correspondence between the scenarios and the events in the EC definition, probabilities and the probability of an event and consequences can be seen as a mix of the exposure at an event and the loss given an event, thus clearly showing the relationship between EC and risk. In the end EC is also a risk measure and what it does is exactly identifying possible scenarios where something can go wrong, leading to a unexpected loss of which the amount is to be determined. On the basis of these characteristics the amount of EC is to be calculated which acts as a buffer against these risks ensuring that the organization can survive encountering the materialization of these risks.

C.2 Regulatory definitions of risk

In the light of the different regulations that APG has to deal with, BASEL II and Solvency II on a general level and in the light of capital adequacy the parallel run based on Solvency II of DNB for Loyalis and ICAAP for APG APG, the definitions of the different risk types specified in those documents are given in this paragraph. Because financial risks are only relevant and reported at Loyalis the definitions of financial risk, and insurance risks, for these risk categories it is only logical to use the definitions of the Solvency II framework. Because in the other parts of APG the most important risk factor is operational risk it is important to have a good idea of what operational risk is about. Since the concept of operational risk is not as clearly defined as for example market and credit risk it is necessary to be clear about what falls under the definition of operational risk. For example business risks or reputation risk may or may not form part of operational risk. Because APG uses the Financial Institutions Risk Management Method (FIRM) framework of DNB internally, although it is slightly adjusted in some parts of the organization, for categorizing and managing risks, the FIRM classification of risks in general and operational risk in particular is used throughout this thesis, see for a definitions and categorization of FIRM risks Table 17 in Appendix B.

C.2.1 Solvency II definitions of financial and insurance risks

The Solvency Capital Requirement shall cover at least the following risks (European Commission, 2009) (page 52-54):

Non-life underwriting risk	the risk of loss, or of adverse change in the value of insurance liabilities, resulting from fluctuations in the timing, frequency and severity of insured events, and in

	the timing and amount of claim settlements (non-life premium and reserve risk) the risk of loss, or of adverse change in the value of insurance liabilities, resulting from significant uncertainty of pricing and provisioning assumptions related to extreme or exceptional events (non-life catastrophe risk).
Life underwriting risk	the risk of loss, or of adverse change in the value of insurance liabilities, resulting from changes in the level, trend, or volatility of mortality rates, where an increase in the mortality rate leads to an increase in the value of insurance liabilities (mortality risk) the risk of loss, or of adverse change in the value of insurance liabilities, resulting from changes in the level, trend, or volatility of mortality rates, where a decrease in the mortality rate leads to an increase in the value of insurance liabilities (longevity risk) the risk of loss, or of adverse change in the value of insurance liabilities, resulting from changes in the level, trend or volatility of disability, sickness and morbidity rates (disability – morbidity risk) the risk of loss, or of adverse change in the value of insurance liabilities, resulting from changes in the level, trend, or volatility of the expenses incurred in servicing insurance or reinsurance contracts (life-expense risk) the risk of loss, or of adverse change in the value of insurance liabilities, resulting from fluctuations in the level, trend, or volatility of the revision rates applied to annuities, due to changes in the legal environment or in the state of health of the person insured (revision risk) the risk of loss, or of adverse change in the value of insurance liabilities, resulting from changes in the level or volatility of the rates of policy lapses, terminations, renewals and surrenders (lapse risk) the risk of loss, or of adverse change in the value of insurance liabilities, resulting from the significant uncertainty of pricing and provisioning assumptions related to extreme or irregular events (life-catastrophe risk)
Market risk	the sensitivity of the values of assets, liabilities and financial instruments to changes in the term structure of interest rates, or in the volatility of interest rates (interest rate risk) the sensitivity of the values of assets, liabilities and financial instruments to changes in the level or in the volatility of market prices of equities (equity risk) the sensitivity of the values of assets, liabilities and financial instruments to changes in the level or in the volatility of market prices of real estate (property risk) the sensitivity of the values of assets, liabilities and financial instruments to changes in the level or in the volatility of credit spreads over the risk-free interest rate term structure (spread risk) the sensitivity of the values of assets, liabilities and financial instruments to changes in the level or in the volatility of currency exchange rates (currency risk) additional risks to an insurance or reinsurance undertaking stemming either from lack of diversification in the asset portfolio or from large exposure to default risk by a single issuer of securities or a group of related issuers (market risk concentrations)
Counterparty default risk	The counterparty default risk module shall reflect possible losses due to unexpected default, or deterioration in the credit standing, of the counterparties and debtors of insurance and reinsurance undertakings over the following 12

	months. The counterparty default risk module shall cover risk-mitigating contracts, such as reinsurance arrangements, securitizations and derivatives, and receivables from intermediaries, as well as any other credit exposures which are not covered in the spread risk sub-module. It shall take appropriate account of collateral or other security held by or for the account of the insurance or reinsurance undertaking and the risks associated therewith.

Table 15: Definitions of risks from Solvency II directive (European Commission, 2009)

The capital adequacy calculation with ICAAP is divided between Pillar I and Pillar II risks, Pillar I risks being the most important and also part of the Basel II framework: Credit, Market and Operational risk. Pillar II encompasses all other risks. Definitions of the Pillar I risks (BCBS, 2009) (page 24-25) :

> Market risk: Refers to portfolio value changes due to changes in rates and prices that are perceived as exogenous from the viewpoint of the bank. These comprise exposures to asset classes such as equities, commodities, foreign exchange and fixed-income, as well as to changes in discount factors such as the risk-free yield curve and risk premiums. A specific type of market risk is IRRBB, which stems from repricing risk (arising from differences in the maturity and repricing terms of customer loans and liabilities), yield curve risk (stemming from asymmetric movements in rates along the yield curve), and basis risk (arising from imperfect correlation in the adjustment of the rates earned and paid on different financial instruments with otherwise similar repricing characteristics). IRRBB also arises from the embedded option features of many financial instruments on banks' balance sheets.
>
> *Credit risk*: Refers to portfolio value changes due to shifts in the likelihood that an obligor (or counterparty) may fail to deliver cash flows (principal and interest) as previously contracted. The distinction between market and credit risk, while fairly clear on the surface, is less so in practice since individual exposures typically contain elements of both risks. For example, prices of corporate bonds can vary because of changes in the perceived likelihood of issuer default but also because shifts in the risk-free yield curve. In addition, credit and market risk factors can interact in ways that complicate the distinction between the two (see the next section).

Operational risk: Refers to the risk of loss associated with human or system failures, as well as fraud, natural disaster and litigation. While not a pure economic risk it does represent losses (either outright outlays or foregone earnings) from all types of activity where banks engage, and it is indirectly linked to the level, intensity and complexity of these activities.

Business risk: Captures the risk to the firm's future earnings, dividend distributions and equity price. In leading practice banks, business risk is more clearly defined as the risk that volumes may decline or margins may shrink, with no opportunity to offset the revenue declines with a reduction in costs. For example, business risk measures the risk that a business may lose value because its customers sharply curtail their activities during a market down-turn or because a new entrant takes market share away from the bank. Moreover, this risk increasingly extends beyond balance-sheet items to fee-generating services, such as origination, cash management, asset management, securities underwriting and client advisory services.

Pillar II risks are harder to define because these are by definition all risks that aren't specified by the pillar I risks, but in (Porteous & Tapadar, 2006) a list of Pillar II risks is given including definitions:

Risk	Definition
Credit concentration risk	If a bank has, for example, a large exposure to one corporate counterparty, or to one segment of the retail market, this risk may not be captured by a bank's Pillar 1 regulatory capital requirement and banks are required to self assess the additional capital that should be held to cover this risk.
Business cycle risk	If the bank feels that the business, or economic, cycle may turn down and that it may need additional capital to maintain its position through the cycle, it is required to self assess the amount of capital that it needs to cover this risk.
Liquidity risk	the risk that a firm, although solvent, either does not have available sufficient financial resources to enable it to meet its obligations as they fall due, or can secure such resources only at excessive cost.
Persistency risk	When financial services firms price their retail products, mortgages or credit cards, for example, they will make certain assumptions about the persistency experience of their customers. If customers are less persistent than has been priced for, then firms may lose money on these customers
Expense risk	If the firm's actual unit costs are in excess of those priced for and cannot be managed down to the priced level, then the firm will make expense losses as a consequence.

Margin risk	When banks, or firms, price their products, they will price using an assumed interest rate margin for the product. This is the interest rate they expect to earn on the invested assets less the associated costs of funding, or financing, the product. If the bank does not earn the interest rate margin assumed in its pricing, perhaps because its cost of funding has increased as a result of a ratings downgrade, the bank will make a margin loss. It may therefore be appropriate for banks to self assess the amount of capital that is required to back interest rate margin risk for those product segments where this is a genuine risk. These risk examples illustrate that, sometimes, material risks run by a bank may not always be straightforward to identify. Moreover, such risks will be highly bank specific and will require banks to invest time and effort in identifying and understanding the risks that they are running.

Table 16: Definitions of Pillar II risks source: (Porteous & Tapadar, 2006)

Matching/interest rate risk	· interest rate · currency · liquidity · inflation
Market risk	· price volatility · market liquidity · concentration and correlation
Credit risk	· default probability · concentration and correlation · loss given default · exposure at default
Insurance technical risk	· mortality · disability · loss · concentration and correlation
Environmental risk	· competition · dependence · reputation · business climate
Operational risk	· (pre)acceptance/transaction · processing · payment/clearing/settlement · information · product development · cost · staff · sensitivity to fraud
Outsourcing risk	· business continuity · integrity · quality of services
IT risk	· strategy and policies · security · controllability · continuity

Integrity risk	· prejudice to third parties · insider trading · money laundering · financing of terrorism · improper conduct
Legal risk	· legislation and regulation · compliance · liability · enforceability of contracts

Table 17: FIRM risk categories (Dutch National Bank, 2005)

Basel II specifies 7 types of operational risk categories together with 8 standard business lines present in a bank. In Table 18 a specification of the risk types and business lines is given, together with the matrix that banks should use when applying the AMA. In this approach for each of the cells in Table 18 a bank should develop a frequency and severity distribution.

Risk Factor (i) / Business Lines (j)	Internal Fraud	External Fraud	Employment Practices and Workplace Safety	Clients, Products & Business Practices	Damage to Physical Assets	Business Disruption and System Failures	Execution Delivery & Process Management
Corporate Finance							
Trading and Sales							
Retail Banking							
Comm. Banking							
Payments and Settl.							
Agency Services							
Asset Mngmt.							
Retail Brkrg.							

Table 18: Operational risk categories and business lines

C.3 Overview of operational risk measurement methods in Basel II and Solvency II

In paragraph 2.2 and Appendix C: Risk definitions definitions of operational risk following FIRM are given and they are mapped on the organization. The next step is to determine which method to use to quantify operational risk at APG. Again regulation for financial services gives some ideas on how to measure operational risk. Both Solvency II and Basel II specify methods that describe which data to collect and how to calculate operational risk in terms of capital allocation. These regulatory methods can be simple, just taking a fixed percentage of gross income or very complex, estimating complicated probability distributions. The choice of the correct method depends on data availability and the objectives and size of the organization, but it is the intention of both Basel II and Solvency II to let organizations move from the simple models when regulations are effectuated to the complex approaches in the future (Gatzert &

Wesker, 2011). In the next paragraphs the different possibilities for quantifying operational risk are described together with the pro's and con's for each of the method, for an overview see also (BCBS, 2003), (Teker, 2005) or (European Commission, 2009).

C.3.1 Solvency II Operational Risk Module

The operational risk module in Solvency II is still part of discussion after testing a specification in the Quantitative Impact Study 4 . The current level II advice from the Committee of European Insurance and Occupational Pensions Supervisors (CEIOPS) is a calculation for the operational risk capital charge which is the higher of a fixed percentage, 30% in QIS 5, of the Basic Solvency Capital Charge (BSCR) or a formula based on the earned insurance premium and technical provisions. For a breakdown of the exact calculations of the operational risk module in Solvency II see the QIS 5 consultative document chapter SCR 3 operational risk, page 102 (EC, 2010).

Although the capital calculations as laid down in QIS5 are somewhat more precise than the BIA and SA from the Basel II operational risk section the capital charges are still based on percentages of premiums and technical provisions. This means that the capital charges are not linked in any way to the specific risks that an organization is taking on in its operations. For this current research into an EC-model for APG this means that the Solvency II methodology is not of much use since it focuses on insurance activities and these are only found at Loyalis, although for this part of the organization the module may be used as a way to validate the operational risk methodology used in the EC-model. Also the operational risk module still doesn't focus itself on the risks present in the organisation but is merely a somewhat more elaborate version of the BIA of Basel II. This means that also here a pro of the module is that it is relatively easy to calculate the capital charges but that they don't in any way reflect the risks the organisation is exposed to. In the context of the EC-model at APG the operational risk module can't be used because it uses technical provisions and premiums as inputs and those figures are specific to insurance operations.

C.3.2 Basel II Basic Indicator Approach (BIA)

The basis indicator approach in Basel II bases the capital charge for operational risk on a fixed percentage of an exposure indicator. This exposure indicator is the gross income of a company over the last three years. Gross income is calculated as the sum of net interest income and net non interest income and should be gross of any provisions, operating expenses and any extraordinary or irregular items (Teker, 2005). This results in the following formula to calculate the capital charge for operational risk (BCBS, 2006):

$$K_{BIA} = [\sum (GI_{1..N} \times \alpha)] / N$$

$where$:
$K_{BIA} = The\ capital\ charge\ under\ Basic\ Indicator\ Approach$
$GI = annual\ gross\ income, where\ positive, over\ the\ previous\ three\ years$
$N = number\ of\ the\ previous\ three\ years\ for\ which\ gross\ income\ is\ positive$
$\alpha = 15\%, which\ is\ set\ by\ the\ Committee, relating\ the\ industry\ wide\ level\ of\ required\ capital$

$to\ the\ industry\ wide\ level\ of\ the\ indicator$

The 15 % of gross income is based on the operational loss experience of 89 banks and is the result of the loss collection exercise of the Bank for International Settlements (BIS) that was held in 2002. This number is calibrated for an average bank and reflects the 99.9% confidence level highest loss that a bank can suffer during a year due to an operational risk (Peccia A. , 2003).

The BIA is certainly interesting because of its simplicity, but of course it doesn't provide any insights into the risk drivers of an organisation. It just calculates a very rough estimate of the capital that needs to be set aside to cover operational risks. The BIA can be seen as a regulatory tool to force banks to set aside capital for operational events, but it doesn't take into account the particularities of a specific organisation. Although its main parameter alpha is based on the loss data of 89 large international banks these data are from 2002 so any recent trends in the frequency or severity of operational losses are not taken into account. For APG means that this method is practically out of the question because it doesn't in any way take into account the fact that APG is not a bank and that because of that fact APG is exposed to different risks. Therefore the alpha that is estimated from the 2002 loss collection exercise that the BIS conducted isn't in any way related to the risks that APG is running.

C.3.3 Basel II Standardised Approach

The standardized approach from Basel II regulation encompasses calculating capital charges for operational risk based on individual capital charges for the eight standard business lines in a bank. For each business line BIS has calculated a standard loss distributions for all the business lines that are common in banks again based on the loss collection exercise of 2002. Based on these results a separate capital charge for each business line is proposed, but these capital charges per business line are still based on a percentage of the gross income of that business line.

$$K_{TSA} = \{\sum\nolimits_{years\ 1-3} \max\left[\sum(GI_{1-8} \times \beta_{1-8}), 0\right]\}/3$$

$where$:
$K_{TSA} = The\ capital\ charge\ under\ the\ StandardisedApproach$
$GI_{1-8} = annual\ gross\ income, as\ defined\ for\ BIA, for\ each\ of\ the\ eight\ business\ lines$
β_{1-8}
$= a\ fixed\ percentage, set\ by\ the\ Committee, relating\ the\ level\ of\ required\ capital\ tot\ the\ level$

$of\ the\ gross\ icome\ for\ each\ of\ the\ eight\ business\ lines.\ to\ the\ industry\ wide\ level\ of\ the\ indicator$

Table 19 below gives the values for $\beta's$ for each of the eight business lines as proposed by the BCBS.

Business Lines	Beta Factors
Corporate finance (β_1)	18%
Trading and sales (β_2)	18%
Retail banking (β_3)	12%
Commercial banking (β_4)	15%
Payment and settlement (β_5)	18%
Agency services (β_6)	15%
Asset management (β_7)	12%
Retail brokerage (β_8)	12%

Table 19: Betas for the different business lines, source: (BCBS, 2006)

Of course these betas can't be used exactly for APG because these are specified for a banks and not for the type of company that APG is. Nevertheless can be used to give an idea of how much capital the different business lines would need if this methodology would be followed to calculate capital charges for operational risk. For instance asset management is both a BIS category and a business line at APG, indicating that this method could give an idea of the capital charge needed. However also in this case the remarks holds that asset management in a bank is not completely comparable to the service APG provides for their clients. The capital charges following the Standardised Approach could be used to validate the more complex models that are the subject of the next paragraph.

The SA provides a refinement to the BIA, but still suffers from most of the shortcomings of that approach. It doesn't take into account particular risk drivers nor mitigating controls in place to reduce operational risk. The fact that it provides a further division of capital to the different business units of a bank is helpful for management.

C.3.4 Basel II Advanced Measurement Approach (AMA)

The LDA is a parametric technique that consists of estimating separate probability distributions for both the frequency and severity in terms of economic impact of operational losses, these two distributions are then combined, via for example Monte Carlo simulation, to create a aggregate loss distribution (Shevchenko & Wüthrich, 2006). For each of the cells corresponding to a combination of a specific risk and one of the business lines an aggregate loss distribution is needed, meaning that banks have to estimate a total of 7 (risk categories) x 8 (business lines) = 56 loss distributions.

The main question when applying the LDA is which probability distribution to use to model the severities and frequencies of operational losses in the different business lines (Chapelle, Crama, Hübner, & Peters, 2008). For both the frequency and the severity distribution there are multiple possibilities, but mainly modelling the severity distribution correctly poses some real difficulties because of the fact that the model has to predict low frequency high impact events that may have never occurred in practice so are not present in internal data (Dutta & Perry, 2007). An overview of the possible distributions for modelling frequency and severity is given below.

The advanced measurement approach lets a bank come up with capital amounts for operational risk following internal models. The design of these models is free to the individual institutions but must be approved by their national supervisor. The qualitative and quantitative requirements for using the AMA for calculating operational risk capital are first laid down in the working paper on regulatory treatment of operational risk (BCBS, 2001), but include at least the use of internal and external data on operational losses together, scenario analysis and internal control factors (Chapelle, Crama, Hübner, & Peters, 2008) (Shevchenko & Wüthrich, 2006) (Agostini, Talamo, & Vecchione, 2010). To incorporate all these factors into one model for the calculation of operational risk capital requirement the best practice among banks is the Loss Distribution Approach (LDA) that has its roots in the insurance industry (Chapelle, Crama, Hübner, & Peters, 2008).

To arrive at this aggregate distribution there are different options that are developed by different banks, see (Shevchenko, 2010) for an overview. Both for the form and the method of estimating the frequency and severity distribution there are numerous methods described in academic and professional literature. Choosing the right model isn't simple and depends on factors as the availability of data, expertise and management focus. For the estimation of the parameters for these distributions there are different methods such as MLE or EM (Expectation Maximization), see (Dutta & Perry, A Tale of Tails: An Empirical Analysis of Loss Distribution Models for Estimating Operational Risk Capital, 2007) for an excellent overview.

Appendix D: Vragenlijst inschatting operationeel risico juni 2013

Deze vragenlijst is opgesteld met als doel een inschatting te maken van het operationeel risico uitgedrukt in economisch kapitaal. Deze inschatting moet worden gezien als toevoeging aan de huidige methoden voor het inschatten van operationeel risico en wordt uitgevoerd in het kader van een afstudeeronderzoek naar economisch kapitaal voor APG Groep bij de afdeling CRC. U ontvangt deze vragenlijst omdat u als risk manager in de positie bent het operationele risico te overzien en ervaring hebt met het in kaart brengen en beoordelen van risico's. Het beantwoorden van de vragen kost ongeveer 15 minuten, retourneren van de vragenlijst kan naar Hidde.terpoorten@apg.nl. Bij voorbaat dank voor uw medewerking, voor vragen of verdere uitleg kunt u altijd contact opnemen met Hidde Terpoorten op 06-19065661 of via bovenstaand e-mailadres.

Operationeel risico is gedefinieerd als:
Operationeel risico is het risico op verliezen door tekortschietende of falende interne procedures, door personeel of systemen of door externe gebeurtenissen. Het risico omvat tevens het integriteitrisico, IT risico, uitbestedingrisico en het juridisch risico.

Voorbeelden van operationeel risico zijn:

- Fouten in processen en controles
- Interne en externe fraude
- Fouten in systemen
- Juridische claims
- Boetes door het niet voldoen aan wetten, regels en ethische normen

Toelichting op de vragen:
Alle vragen gaan over (financiële) verliezen ten gevolge van operationele events zoals hierboven beschreven. Het gaat om realistische worst case verliezen ten gevolge van een enkel event, dus niet om gemiddelde of totale verliezen. Inschattingen dienen te worden gebaseerd op huidige risico's en status van beheersmaatregelen, dus bij vragen naar verliezen in de toekomst hoeft geen rekening gehouden te worden met eventuele veranderingen in het risicoprofiel of kwaliteit van de beheersing van de organisatie. Verder gaat het nadrukkelijk om verliezen geleden door APG Groep, dus events die alleen een impact hebben op client money worden niet meegenomen. Hoewel de meeste vragen gaan over verliezen met hoge bedragen moet bij het beantwoorden van de eerste en laatste vraag wel rekening worden gehouden met kleine verliezen zoals bijvoorbeeld een uur productieverlies door uitvallende IT-systemen of de vergoeding van schade aan privé-eigendommen.

Uit onderzoek blijkt dat bij het beantwoorden van onderstaande vragen, men over het algemeen te lage inschattingen maakt van bedragen en te hoge inschattingen van de periodes. Dit komt doordat het eigen referentiekader gebruikt wordt waarin mogelijk nog geen verliezen van dergelijke omvang zijn opgenomen. Voor een betere inschatting helpt het om van deze afwijking op de hoogte te zijn en hier rekening mee te houden. Probeer bij het beantwoorden van de vragen eerst een situatie voor te stellen waarin een verlies van genoemde grootte wordt geleden en daarna de vraag te beantwoorden.

De vragenlijst bestaat uit vijf vragen:

Vraag 1:

Hoeveel operationele verliezen doen zich gemiddeld in een jaar voor (tip: zie de brede risicodefinitie en verschijningsvormen hierboven)

Vraag 2:

Hoeveel jaar duurt het voordat zich, in een realistisch worst case scenario, een verlies van € mln voordoet ten gevolge van een operationeel risico?

Vraag 3:

Hoeveel jaar duurt het voordat zich, in een realistisch worst case scenario, een verlies van € mln voordoet ten gevolge van een operationeel risico?

Vraag 4:

Hoeveel jaar duurt het voordat zich, in een realistisch worst case scenario, een verlies van € mln voordoet ten gevolge van een operationeel risico?

Vraag 5:

Wat is volgens u het bedrag waarvoor de helft van de verliezen in een jaar hoger is en de helft van de verliezen in een jaar kleiner? (vergelijk met modaal inkomen, ene helft inkomens hoger andere helft inkomens lager)

Dit was de laatste vraag, bedankt voor uw medewerking! De resultaten van dit onderzoek worden verwerkt en in een later stadium bekend gemaakt.