

Analyzing operational risks of the Source-to-Pay process at Nedap N.V.



University of Twente

P.B. van Goor

September 2023

The following report is intended for Nedap N.V. and the examiners from the University of Twente.

University of Twente
Industrial Engineering and Management
Postbus 217
7500 AE Enschede
Tel. +31 (0) 53 489 9111

Nedap N.V.
Parallelweg 2
7141 DC Groenlo
Tel. +31 (0)54 447 1111

Analyzing operational risks of the Source-to-Pay process at Nedap N.V.

Student

P.B. van Goor
s2299127
Bachelor Industrial Engineering and
Management
University of Twente

Supervisors

University of Twente
First supervisor:
dr. R.A.M.G. Joosten
Assistant professor
*Faculty of Behavioral Management
and Social Sciences (BMS)*

Nedap N.V.
K. van de Groep
Program Manager Accelerate

Second supervisor:
dr. B. Roorda
Associate professor
*Faculty of Behavioral Management
and Social Sciences (BMS)*

Publication date: September 29, 2023

This report was written as part of the bachelor assignment of the Industrial Engineering and Management educational program at the University of Twente.

Preface

Dear reader,

It is with great pride that I hereby present my bachelor thesis ‘Analyzing operational risks of the Source-to-Pay process at Nedap N.V.’. This report was written as my graduation assignment for the bachelor Industrial Engineering and Management at the University of Twente. I conducted this research at Nedap N.V. from March 2023 until July 2023. During these months, I gained many insights into the application of my study in practice. Prior to reading my thesis, allow me to express my gratitude to certain people who were crucial during this research.

First or all, I would like to thank Nedap N.V. for giving me this opportunity. During this research I was given all the support and guidance needed, and had the freedom to explore thoughts and initiatives. In particular, I would like to express my sincere gratitude to Kevin van de Groep for the great encouragement and guidance within the company. I was always able to ask you anything and discuss new ideas. Moreover, I want to thank the financial control team and purchase departments for always helping and for providing me with the necessary information while answering all my questions.

Additionally, I would like to thank my supervisors of the University of Twente, Reinoud Joosten and Berend Roorda, for the guidance during this research and for providing critical and useful feedback. Due to this, I was able to bring my research to a higher level.

Finally, I would like to thank my family and friends for their support during this period.

Pien van Goor

Enschede, September 2023

Executive summary

Nedap is an exchange-listed company that develops products to help people become more productive, successful, and meaningful in their professional lives. Its product portfolio consists of both hardware and software. The company faces the difficulty that little documentation exists on the end-to-end processes and wishes to improve its insights into risks. Therefore, we create several process models of the Source-to-Pay process and identify unaddressed operational risks.

The Source-to-Pay process includes the procurement of products and services, from the first step of finding suppliers to the final step of payment. Nedap has four different main categories of invoices, which all have different processes. Purchase orders are used for ordering Nedap's own products that are outsourced, while purchase cost orders are used for expenses that are needed for business. Furthermore, spend plans are used to process invoices of expenses that are expected periodically, and the company receives invoices for expenses without an order number.

We analyze four widely used risk management frameworks and conclude that all include four main steps: identify, analyze, respond, and monitor. We therefore use these four elements for the risk management of additional operational risk within the Source-to-Pay process. We identify 25 unaddressed operational risks and interviewed 19 risk owners to select the risks that would be most severe for the company. The interviewees identify three risks that are most important for Nedap.

The first risk that the risk owners identify as severe for the company, is that spend plans stay open after a contractor has stopped earlier than contractually agreed. The risk is that invoices are sent and processed matched on that spend plan even though a contractor is no longer providing their services to Nedap. Depending on the parameters of the spend plan, the invoice gets approved or removed. Based on a Monte Carlo simulation performed using excel-VBA programming language, the probability of this risk is minimal. Depending on different variables, we done severe sensitivity tests resulting in a 94% to 60% of no losses. In the other cases Nedap would lose money due to this risk, yet the impact does not have a clear distribution. We recommend sending a message to the financial controllers when a contractor stops working at Nedap.

The second risk that interviewees select, is the correctness of semi-annual price increases sourcing partners are allowed to make. The price increases are sent to Nedap through an open price calculation including all the components of the bill of material. However, the sourcing partners have no incentive to keep the costs low because they receive a percentage of the total assembly costs for overhead costs and profit. The purchase departments of the business units check the price calculation yet cannot go over all components which can cause prices to be higher than needed. Based on the price negotiations of eleven products, and the revenues of Nedap N.V., the company risks a loss of €63,7467 in 2023. The implementation of a standardized procedure can lower this loss by helping the purchase department.

The last risk that would be severe for Nedap according to 19 interviewees, is the fact that the company is financially liable for components that sourcing partners buy according to the forecast of products Nedap sends. When components become obsolete due to the end of life of products or the replacement of a specific component, Nedap needs to buy all the components that the partner has bought according to forecasts. In 2022 approximately €100,000 was spent on excess stock, and in the first half of 2023 approximately €40,000. In 2022 this total was not even 0.05% of Nedap's revenue. The company can accept this risk because it is relatively not high or can try to reduce both its impact and probability by having a standardized procedure.

Table of Contents

Acronyms.....	8
1. Introduction.....	9
1.1 Company introduction.....	9
1.2 Research motivation.....	10
1.3 Problem identification.....	10
1.4 Research design.....	11
1.4.1 Research questions.....	11
1.4.2 Limitations.....	12
1.4.3 Reliability and validity.....	12
1.5 Research scope.....	13
2. Analysis of the Current Situation.....	14
2.1 Source to pay process.....	14
2.1.1 Purchase documents.....	14
2.1.2 Lanes in business process model.....	16
2.1.3 Business process model.....	16
2.1.4 Differences within business units.....	21
2.2 Operational risks.....	24
2.3 Risk mitigation strategy.....	25
3. Literature Review.....	29
3.1 Existing risk management framework.....	29
3.2 Risk identification.....	30
3.2.1 Operational risk categories.....	31
3.2.2 Identifying risks according to a process model.....	31
3.3 Risk analysis.....	31
3.3.1 Qualitative.....	31
3.3.2 Quantitative.....	32
3.4 Risk response.....	33
3.5 Risk monitor.....	33
3.5.1 Key risk indicators.....	33
4. Additional Operational Risks.....	36
4.1 Operational risk identification.....	36
4.1.1 Most severe operational risks.....	36
4.1.2 Extra operational risks mentioned.....	41
4.1.3 Extra information gathered.....	42

4.2 Active spend plans.....	43
4.2.1 Analysis.....	44
4.2.2 Response	49
4.3 Semi-annual price increases.....	52
4.3.1 Analysis.....	52
4.3.2 Response	53
4.4 Liability of components	54
4.4.1 Analysis.....	54
4.4.2 Response	55
4.5 KRI dashboard.....	56
5. Conclusion and Recommendations	57
5.1 Conclusion	57
5.2 Recommendations.....	58
5.3 Discussion	58
References.....	60
Appendices	63
Appendix A. Current business process model.....	63
Appendix B. Level of detail process model	67
Appendix C. Classification loss events.....	68
Appendix D. Supplier duplicates	68
Appendix E. Interviews.....	70
Appendix F. Code Monte Carlo simulation.....	72
Appendix G. Results Monte Carlo simulation.....	76
Appendix H. Semi-annual price increase.....	79

Acronyms

BOM	Bill Of Materials
BPMBRA	Business-Process Model-Based Risk Analysis
BPMN	Business Process Model and Notation
CRM	Continuous Risk Management
EDI	Electronic Data Interchange
EMS	Electronics Manufacturing Services
EOL	End Of Life
ERM	Enterprise Risk Management
ERP	Enterprise Resource Planning
HR	Human Resources
KPI	Key Performance Indicator
KRI	Key Risk Indicator
LOD	Level of Detail
MPSM	Managerial Problem Solving Method
NCR	Non Conformity Report
PCO	Purchase Cost Order
PLM	Product Lifecycle Management
PO	Purchase Order
R&D	Research and Development
S2P	Source to Pay
SLA	Service Level Agreement
VaR	Value-at-Risk
WRNV	Warehouse Receipt Nedap NV

1. Introduction

This chapter introduces the research and provides a description of the company Nedap N.V. Moreover, we present the problem that motivates this research. Moreover, we explain the design and scope of the research. We use the Managerial Problem Solving Method (MPSM) by Heerkens and Van Winden (2017) to structure the approach.

1.1 Company introduction

Nedap is a Dutch high-tech company that started in 1929 named the Nederlandsche Apparatenfabriek (Nedap, n.d.). The company first started producing a wide variety of products at the request of others, but later shifted from manufacturing electromechanics to specializing in the production of electronics, and subsequently started developing RFID (Radio Frequency Identification) technology as one of the global pioneers. The company switched from being a hardware-oriented company to a software focused firm. RFID is still a big component of their market portfolio. The name got changed in 1933 to the present name, Nedap, and the firm became exchange-listed in 1947. The company has a headquarter based in Groenlo and multiple subsidiaries worldwide that operate under the same name. Nedap currently has outsourced almost all their products to third parties, except for a small proportion of its product portfolio that is produced at Nedap SMART, a production facility next to the main office in Groenlo and legally part of Nedap N.V. The reason for Nedap to keep this facility operating, is that Nedap wants to keep certain production closer to home in case issues arise. Moreover, some operations, such as startups, are too small to be interesting for its EMS partners. The company has seven different business units, with diverse product portfolio focused on different markets. It is in Nedap's belief that, in order to add true value, detailed knowledge is needed of these markets. The different business units are:

- Healthcare.
- Identification Systems.
- Light Controls.
- Livestock Management.
- Retail.
- Security Management.
- Staffing Solutions.

The company has five end-to-end processes, of which three can be seen in Figure 1. The other two are the Concept2PhaseOut process and the Record2Report process. Some of the subprocesses are done by each business unit itself, but other subprocesses are handled by the general department. The business units were initially created in 1993 for more freedom of decisions and responsibility for employees (Nedap, n.d.). This freedom and responsibility still exist in the business. Nedap has over 900 employees, eleven offices around the world and a consolidated revenue of over 230 million euros in 2022 (Nedap, 2023). It focuses on creating innovative solutions for professional life, also what is called "Technology for life" (Nedap, 2023, p. 13). The company develops innovative products that support customers in developing a more sustainable business model. The Research and Development (R&D) department of each business unit develops new products both by listening to the needs of customers and by constantly keeping an eye on new technology that might be relevant for (potential) customers.

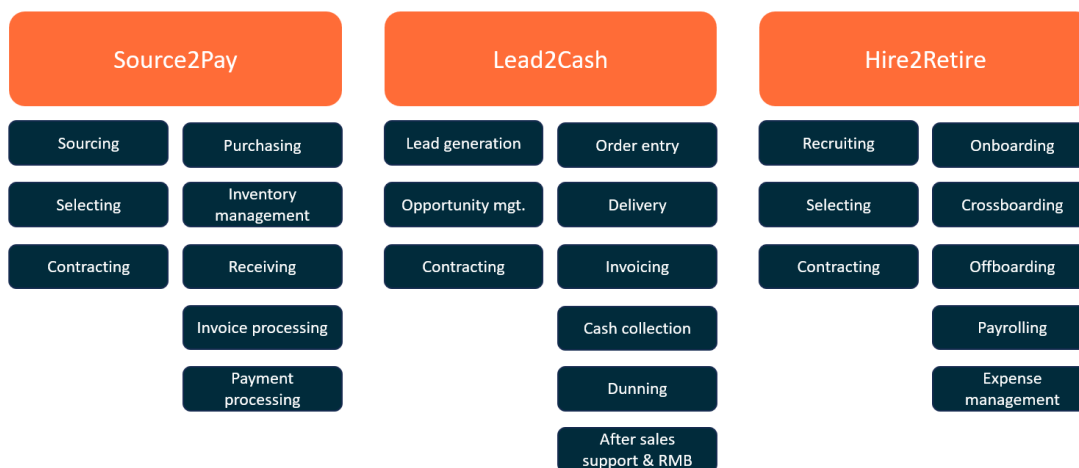


Figure 1. Nedap's end-to-end processes.

1.2 Research motivation

The culture of the organization is informal with a minimal hierarchic structure; Nedap believes that when it gives space and responsibilities to people, sensible decisions and good results will follow (Nedap, 2022). This culture is something Nedap values highly, because the company puts its employees first (Nedap, 2023). The culture also implies that the employees have access to many applications within the ERP system, creating a high degree of freedom. The current concern is that if something goes wrong, this freedom is cut down which affects the culture within the organization. Currently, Nedap does not have adequate insights into some of the operational risks of the different business processes and therefore its mitigation strategy could be improved. The firm is aware of some operational risks. The knowledge of the operational risks is not complete since there is a lack of insight into the business processes. As seen in Figure 1, the end-to-end processes are documented in a general overview with their subprocesses. Therefore, each business unit has its own manner of doing the same processes without documenting this. By not knowing what the differences are, risks cannot be identified. A more comprehensive mitigation strategy is needed, in order to keep the business culture informal and avoid failures. In order to create a realizable analysis, the scope of this research is narrowed down to the 'source to pay' (S2P) end-to-end process within the company. See Figure 1 for an overview of the S2P process, depending on the subprocess it is either done by the general departments or by the business units themselves.

1.3 Problem identification

Nedap is a company with minimal hierarchy and an informal work culture, where a lot of freedom is available for the employees. This freedom is partly possible since little steps and procedures within the company are documented. Another consequence of the limited documentation is that the seven business units work differently while still operating under the same 'Nedap' name.

The company believes that there is a lack of documented knowledge and wishes to improve this by having a clear business process model of the end-to-end processes. By generating this process model, more knowledge can be gathered. Moreover, accountants are requesting process descriptions during the audits for better insights and a clear overview, yet these descriptions are currently missing. Therefore, a business process model is wanted even more.

When the process is modeled, and more insights are gathered, the process can be improved by eliminating potential risks. Nedap already has many mitigations in place for certain risks, yet believes that due to a lack of process models the mitigation strategy is not complete.

1.4 Research design

In order for the problem to be solved using a structured approach, we determine a research methodology and research design. The research methodology is the method used to determine how the research is being conducted. Having this determined, we can determine different research questions.

The research methodology used for this analysis is the Managerial Problem-Solving Method (MPSM). This methodology solves action problems by handling them in their organizational context (Heerkens & Van Winden, 2017). The MPSM is categorized in the following seven phases:

1. Problem identification.
2. Solution planning.
3. Problem analysis.
4. Solution generation.
5. Solution choice.
6. Solution implementation.
7. Solution evaluation.

The first phase of the MPSM is performed in Section 1.3, where the problem was identified. This section, containing the research design and thus problem-solving approach, is linked to Phase 2 of the MPSM. Phases 3 to 5 are included in this research, while Phases 6 and 7 cannot be performed due to time limitations.

1.4.1 Research questions

We formulate different sub research questions in order to answer the main research question. The research is divided into different phases corresponding to the different chapters with each different sub research questions, starting at Chapter 2.

Chapter 2. Current situation

In this chapter, we analyze the current S2P process and determine the operational risks which are already known and the accompanying mitigation strategy. The knowledge and understanding of the process is needed to determine additional operational risks.

Research Question 1: What does the S2P process look like at Nedap?

Research Question 2: Which operational risks are known within the S2P process?

Research Question 3: What is the current mitigation strategy for operational risks within the S2P process?

Chapter 3. Literature review

When the current situation is analyzed, knowledge of risk management frameworks is needed. Theory provided by scientific articles and other literature sources provide this knowledge.

Research Question 4: What are known risk management frameworks?

Research Question 5: What steps need to be taken for the risk management of operational risks within Nedap's S2P process?

Chapter 4. Additional operational risks

After the knowledge about risk management is obtained, we can use it to apply it for Nedap. In this chapter, we identify additional operational risks and analyze them in order to create a mitigation strategy.

Research Question 6: What are operational risks within the S2P process which are not yet addressed?

Research Question 7: What is the impact of the identified operational risks?

Research Question 8: What are mitigation options for the identified operational risks?

Research Question 9: Which mitigation options are suitable for Nedap?

Chapter 5. Conclusion and recommendations

Finally, conclusions are drawn by evaluating our findings. We give recommendations to Nedap N.V., and discuss the limitations and practical contribution of this research.

1.4.2 Limitations

Potential limitations put restrictions on our research, caused by shortcoming conditions. Therefore, the scope of the research is also adjusted on these limitations. First of all, there is a constraint on the timespan of the research; the research needs to be conducted within 10 weeks. 10 weeks is a relatively short period of time for research. Therefore, the implementation and evaluation of my recommendations are not possible within this timespan.

Another limitation can occur during the gathering of data. There is a possibility that some data might not exist, yet the chances of this are small since the method used for data gathering is mostly qualitative and Nedap gathers a substantial amount of data. Moreover, retrieving contradicting information can occur. When this happens, the outcome and credibility of the research will be affected significantly.

1.4.3 Reliability and validity

We are going to gather most of the data by a qualitative data gathering method. According to Kirk and Miller (1986) qualitative research depends mainly on observing an individual or group of individuals in their own territory and communication in their own language on their own terms. Qualitative research is often criticized for being “merely a collection of personal opinions subject to researcher bias” (Noble & Smith, 2015).

Since the data gathered for this research are mostly qualitative, reliability and validity issues can arise. Reliability according to Noble and Smith (2015) is the consistency of procedures including accounting for possible biases that influence how the data are gathered and interpreted. In order to minimize reliability risks, I try to account for possible personal bias which may influence the qualitative data by keeping an extensive record of decisions with clear explanation about decisions taken. Moreover, I combine the findings of the qualitative data with existing data in order to get more comprehensive findings.

Research validity is the extent to which the findings represent the data (Noble & Smith, 2015). Validity can both be internal and external. This research is internally valid since we assume that the data presented by Nedap and by the employees are correct since the interests are in line. External validity refers to how the findings can be generalized to other situations. The research is externally valid in the sense of us applying the results to the same business process as the data are gathered from; the S2P process of Nedap. It can be generalized to other companies to some extent.

1.5 Research scope

The scope of this research is limited to the S2P process within Nedap as mentioned, meaning that the other end-to-end processes are out of scope. The reason for this is the research time span of 10 weeks. This implies that elements such as sales forecast and R&D are not addressed. These elements do affect the S2P process but are not included in the S2P process and thus out of the scope. Moreover, Nedap Smart is left out of the scope. The reason for this is that the purchase process of Smart differs highly from the seven business units, since this department buys components to assemble themselves instead of buying finished products. Nedap SMART works in a separate ERP environment from the rest of Nedap and is administratively considered as an external supplier. This is due to difficulties and administrative inconveniences when both organizations would work in the same environment. When employees of Nedap speak about Nedap N.V., they usually refer to the seven business units plus the general departments. We consider Nedap N.V. as the company excluding Nedap SMART, unless stated otherwise. The S2P process of Nedap SMART is thus out of scope.

Furthermore, we analyze the S2P process of Nedap N.V., which exclude its subsidiaries abroad. The S2P process of these subsidiaries differ hugely, since they buy the products from Nedap N.V. instead of from sourcing partners.

Operational risks are analyzed in this research. Operational risks are categorized by the Basel Committee on Banking Supervision as the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events (2011). This category of risk includes legal risk. However, we lack legal knowledge, and thus the legal risks are left out of the scope.

Lastly, we analyze the S2P process of Nedap yet focus on the Purchase-to-Pay process. This part of the entire end-to-end process is the cycle of procuring goods and services needed and processing the invoices and payments. The purchase-to-pay process excludes the sourcing, selecting and contracting of suppliers. We include these steps of the S2P process in this research, yet focus on the purchase-to-pay part of the end-to-end process.

2. Analysis of the Current Situation

In this chapter we focus on analyzing the current situation of Nedap N.V., by mapping the S2P process and looking at known operational risks. We can identify additional operational risks more easily by having a business process model and analyzing the current situation. We conduct interviews and analyze existing data in order to collect this information and knowledge. This chapter answers both research questions “*What does the S2P process look like at Nedap*” and “*Which operational risks are known within the S2P process?*” as well as “*What is the current mitigation strategy for operational risks within the S2P process?*”.

2.1 Source to pay process

The S2P process within Nedap is the complete procedure to purchase products or services. This can be both products of their own product portfolio which are outsourced to be manufactured, as well as goods or services that are used in order to maintain business. Almost all of Nedap’s products are outsourced. Most of these products are outsourced to Electronics Manufacturing Services (EMS) companies that produce and test the electrical products of Nedap. Three EMS partners are located in the Netherlands, one in the Philippines and four in the East of Europe. As mentioned in Section 1.5, the production facility Nedap SMART is seen as an external supplier.

Nedap mainly uses third party warehouses to store its finished products. The two exceptions are products stored in a small warehouse in the main office in Groenlo, and products produced at Nedap SMART. Depending on the business unit, products produced at Nedap SMART either are transported to an external warehouse or stay at the warehouse of Nedap SMART. In both cases, the products are booked as inventory of Nedap N.V.

Within the S2P process, two software programs are used extensively: Navision and Basware. Navision is an Enterprise Resource Planning (ERP) system, while Basware is a system for purchase invoice processing and for creating cost orders. These systems are connected through an interface. Nedap N.V. has been working in the same software environment since the end of 2020, yet the business units used to all have their own ERP environment. A third system used less extensively in the S2P process but is still of importance, is Aton. Aton is Nedap’s Product Lifecycle Management (PLM) system.

Currently, the performance within the purchase process is not measured by means of key performance indicators (KPIs), nor key risk indicators (KRIs). However, predetermined, mutually agreed-upon KPIs exist with the EMS parties regarding their performance.

2.1.1 Purchase documents

Different purchase documents are handled during the S2P process of Nedap.

The first type of purchase documents are the contracts that Nedap has with its suppliers. EMS partners producing the outsourced goods always have a purchase agreement with the Nedap N.V., including general purchase conditions, a Service Level Agreement (SLA) and a logistic agreement. In this SLA, product related and additional requirements are agreed, including an agreement regarding the quality of produced products. The logistic agreement defines the logistic manner the EMS party supplies products to Nedap, for example agreements regarding forecasting, stock levels and financial liability regarding this forecast.

Suppliers providing products or services for business operations do not always have contracts with Nedap N.V. Depending on the products or services, employees of Nedap decide whether purchase agreements or other legal documents are needed. Nedap's general conditions of purchase are sent with every purchase the company makes, yet this is not guaranteed when employees order a product or service by themselves without using the Nedap channels.

Another document is the purchase order, which is a document asking "a company to supply goods or services, and that gives details such as the price to be paid and the method and date of payment" (Cambridge Dictionary, n.d.). Nedap uses two types of orders. The first is the regular Purchase Order (PO). POs are ordered within the ERP system for the outsourced products, which have a sales purpose. This includes items produced at Nedap SMART. Each PO consists of predetermined products listed in the ERP system, which is sourced from a list within Aton. Changes into Aton can only be made by certain departments and individuals. The ordering of POs is done by the operational purchase departments of the business units. The second type are orders with operational purposes, called Purchase Cost Orders (PCO). These orders concern products and services needed for the business operations. Examples of PCOs are office supplies, marketing costs and travel expenses. Every employee at Nedap is allowed to make a work-related expense and create a PCO, which is done in Basware. The PCO needs approval beforehand above €10,000, while below this threshold the approval is done afterwards. Each PO of Nedap N.V. receives a PO-NV number, while each PCO gets a PCO-NV number.

The last type of document used in the S2P process is an invoice. An invoice is a document including products or services provided with their costs, intended for payment in the future. The invoice processing system Basware tries to match invoices to open POs or PCOs according to PO-NV and PCO-NV numbers. However, it is also possible to match invoices using spend plans. Spend plans are made for costs that are expected periodically. Nedap uses them for externally hired personnel mostly. Parameters of such a spend plan are determined while creating it. Parameters are the number of invoices a supplier is allowed to send in a specific time period, the maximum amount stated per invoice, and the maximum total amount invoiced per time period. The spend plans always need approval after creation, but the invoices only need approval when such a parameter is exceeded. Financial controllers use these parameters to create a difference between hourly paid expenses, and periodically paid expenses. When it is desired to always put a control on an invoice of a spend plan, because the work log needs to be checked, the maximum amount per invoice is put at €1. By doing this, every invoice of this spend plan above €1 needs to be checked, which is every invoice. Each spend plan gets a SP number with which Basware tries to match an invoice including the same number. Additionally, Nedap receives invoices that cannot be matched. These invoices are for orders made for which no number can be generated since the expenses or costs are not known prior to ordering, or because a supplier is logistically not able to include a reference number to each invoice.

The number of invoices in 2022 are seen Table 1 categorized according to the type of match. Some invoices are sent for multiple orders. In addition to this, in 2022 some spend plans were used for POs due to increases in prices that were not included in the PO. A fast and easy solution was to create a spend plan for the monetary difference, whereafter the supplier could send invoices under this spend plan number. These invoices are therefore matched as spend plans and are included in this category in Table 1.

Table 1. Processed invoices per order type in 2022.

Match type	Number invoices	% number of invoices	Net total of invoices (€ x 1,000)	% net total of invoices
PO	10,068	48.06%	70,314	49.07%
PCO	4,426	11.95%	16,346	11.41%
Spend plan	2,830	16.55%	22,653	15.81%
Unmatched	7,612	23.44%	33,978	23.71%
Total	24,936	100%	143,291	100%

Moreover, payments are made by direct debit, credit cards or declarations. No invoices are received for these payments. Declarations are done quite often, yet credit card and direct debit payments are relatively rare.

2.1.2 Lanes in business process model

The different lanes in the process model indicate who is responsible for each step in the process (Weske, 2007). The current S2P process consist of 13 lanes, as seen in Figure 16 to 19 in Appendix A. These lanes consist of both internal and external parties. External parties are the suppliers of Nedap, external warehouses and transportation carriers. For the suppliers of Nedap, both suppliers of products as well as of services are meant. Moreover, some steps within the process are done automatically.

The lanes that represent internal parties are the financial controllers, the operational purchase department, employees of Nedap, the front desk, certain specific individuals, the legal department, the HR department, and employees with approval rights. The financial controllers hold operational responsibility for financing and each business unit has at least one financial controller responsible for it. The operational purchase department refers to the people ordering POs. Employees of Nedap refer to an individual working at Nedap, since everyone is allowed to create a PCO. The front desk refers to the people working at the front desk of the office in Groenlo. Moreover, specific individuals do specific tasks in the S2P process. To create a clear overview, also to represent the segregation of tasks, we choose to create three different lanes for these specific individuals. Both the legal department and HR are Nedap-wide department of Nedap have roles in this process. Lastly, a lane is created for the employees of Nedap that have rights in Basware to approve invoices: approvers. These individuals are determined according to a matrix, depending on the total amount of the invoice and the corresponding cost center.

2.1.3 Business process model

There are several graphical notations for business process modeling (Weske, 2007). We decided to create the process flow diagram by means of Business Process Model and Notation (BPMN). BPMN uses rounded rectangles to represent activities, marked with the name of the activity. Start and end events are marked as rounds, and the ordering of activities within a process is expressed by directed arrows. Moreover, diamonds marked with different symbols represent gateways. Gateways are the branching and joining of nodes, meaning that these symbols are used when a single activity has multiple outgoing arcs or when multiple arcs are merged into a singular activity. The different symbols in the diamonds represent different gateways, as can be seen in Figure 2.



Figure 2. Gateway types in the BPMN (Weske, 2007).

This method can be carried out at different levels of detail (LOD); a characteristic of business process modeling referring to the extent and therefore granularity of the modeling (Nissen et al., 2014). In order to determine the LOD, certain professional characteristics and external conditions of the process that have impact on the LOD need to be estimated. The LOD varies from Level 1 to Level 5, from main process to activities respectively. The calculated LOD of the S2P process is 3, as depicted in Figure 20 of Appendix B. A LOD of Three is a process model on process step level, and includes approximately 80% of the cases within the process. However, for the purpose of this process model, the choice was made to go one level further, Level 4 the operational level, in order to include all relevant details to identify operation risks.

See Appendix A for the business process model of Nedap’s S2P process. In order to create a clear and readable overview, we choose to split the model into the four different types of orders. As can be seen in Figure 16 to 19, the models have the exact same steps after the invoice is transferred from Basware to Navision. These steps represent the payment process which is done weekly for Nedap-wide. Moreover, the invoice processing is done on the same manner but varies slightly for the different type of invoices

2.1.3.1 Purchase orders

The purchase department receives purchase recommendations from the ERP system depending on the inventory, safety stock, sales forecast, upcoming sales and upcoming POs. The employees need to assess if this recommendation is valid and if a PO should be placed. If this is the case, this employee approves the recommendation and Navision will send the PO to the supplier. The supplier needs to confirm the PO and communicates whether it is able to deliver on the requested date. The purchase department, and possible sales department, acts according to this confirmation.

Next the supplier then produces the products as agreed², however deviations might occur in terms of delivery date and quantity of finished products to deliver. This is communicated with Nedap. When products get transported, a message is sent to the operational purchase department. Depending on the business unit, the data concerning the expected date of arrival get adjusted in Navision. Moreover, the Warehouse Receipt Nedap NV (WRNV) number is generated and sent to the external warehouse. A WRNV number is the warehouse number from Nedap N.V. for external warehouses, which are needed to book the order.

The warehouse inspects the order and books it as received. Depending on whether the warehouse is internal or external, this is done in Navision or the ERP system of the external warehouse. When the orders display deviations, the warehouse communicates with the operational purchasers. The operational purchasers decide on further actions.

After the order is received and booked, the supplier sends an invoice, which Nedap processes as described in Section 2.1.3.6.

Nedap is currently looking to implement Electronic Data Interchange (EDI) with its suppliers. EDI is a system for exchanging business documents or other information between computer systems. This is done in a manner that replaces emails. The company is currently testing the software with a couple of its EMS partners to see whether this software is successful. EDI will change the S2P process of POs by

replacing confirmation emails with electronic automatic messages and the communication regarding expected date of arrival might change.

2.1.3.2 Purchase cost orders

Every employee of Nedap has the freedom to order products or services needed for business. The process of ordering a PCO starts when an employee wishes to do so, which is displayed in Figure 17 in Appendix A. This employee is able to create a PCO in Basware by choosing a category of expense, and by filling in certain fields that can be seen in Figure 3. When the total amount of this PCO is €10,000 or more, approval prior to the order is needed. This approval goes according to the approval matrix. If the supplier already exists and is not a web shop, the order is automatically emailed to the supplier. If the supplier is a web shop or new, the ordering needs to be done by the Nedap employees themselves. Moreover, when a supplier is new it cannot be chosen in the list suppliers, and the dummy supplier 999999 needs to be filled in this field. During the invoice processing stage, financial controllers change this dummy supplier to the actual supplier.

Add item(s) to your 'Shopping Cart' and your confirmed Purchase Order (self approval up to € 10,000,-) will be emailed to the supplier automatically.

-- Only exception is for PO's created for supplier '999999' - To be specified'. These PO's are not sent out automatically -- Please fill the 'new supplier' details in the Remarks field for a smooth supplier validation and invoicing process --

Purchasing category *	Order description (purpose) *
<input type="text"/>	<input type="text"/>
Supplier *	Product description (line) *
<input type="text"/>	<input type="text"/>
Quantity *	Unit price *
<input type="text"/>	<input type="text"/>
Desired delivery date *	Currency code *
<input type="text"/>	<input type="text"/>
Cost center *	Project
<input type="text"/>	<input type="text"/>
Delivery address *	Project Task Code
<input type="text"/>	<input type="text"/>
Remarks	
<input type="text"/>	

Figure 3. Creation PCO.

When the package is received by Nedap at its warehouse in Groenlo, the individual who ordered the package collects it and records the order as received in Basware. When an employee created the PCO for a service, the order needs to be marked as received as well. The reason for this is that only the invoices get paid when the order is actually received. When the invoice is received, the invoice is processed as explained in Section 2.1.3.5.

Several employees of Nedap have stated undergoing difficulties while creating PCOs in Basware. Main reasons are not knowing which category of expense it entails, not knowing the correct cost center, and not understanding what to do when a supplier is not stated in the supplier list. Moreover, Basware only includes values having two decimal places while prices of components can be calculated with more than that.

2.1.3.3 Spend plans

The S2P process regarding spend plans can be seen in Figure 18 of Appendix A. Spend plans are usually used for external hires, whom Nedap calls contractors. These contractors usually are employed, provide their service and send an invoice. Most of the time, only after receiving the first invoice, a spend plan is created. The financial controllers have adequate knowledge to recognize such an invoice, and know that if no spend plan exists yet, one should be made. The financial controller communicates with the business unit what kind of spend plan is needed and its parameters. This spend plan needs approval, and the contractor is categorized as a new supplier. From here on, having a spend plan, the

invoices are processed with the same SP number and uses the regular invoice processing procedure as described in Section 2.1.3.5.

Sometimes a financial controller discovers the existence of a new contractor, who needs a spend plan, by looking at Nedap's TalentSoft; an HR platform containing information of employees, including contractors. When this happens, the spend plan gets created prior to receiving the first invoice.

Spend plans can also be used when a certain expense occurs periodically. In this case, the spend plan is created prior to receiving the order and thus prior to receiving the invoice. This has approximately the same steps. First the spend plan is made by a financial controller, after which this needs to get approved by an individual with the appropriate rights. Afterwards, the service or product is received and when the invoice is sent by the supplier, the invoice can be processed as explained in Section 2.1.3.5.

2.1.3.4 Invoices without reference number

It can also happen that a product is ordered, or a service is performed, without it being part of a PCO, PO or spend plan. If this happens the process in Figure 19 in Appendix A starts. The product or service is received by someone from Nedap, and the supplier sends an invoice. This invoice is received and can be processed as described in Section 2.1.3.5.

2.1.3.5 Invoice processing

All invoices sent by suppliers are sent to the same email address, which is connected to the invoice processing software called Basware. All invoices received are uploaded to Basware, which automatically reads the variables and tries to match the invoice with a spend plan, PO, or PCO number. However, sometimes duplicates are received, based on invoice number, or Basware is not able to read all the variables. In other cases, there is no reference number tied to this invoice, or the supplier is new. Moreover, the invoice might match with an order, yet it is possible that there are deviations between the two. When this happens, financial controllers need to code the invoice themselves or add missing data, yet sometimes contact with the supplier is needed. When a supplier is new, the financial controller additionally needs to create this new supplier in Navision.

When the invoice is successfully matched or coded, an approval is needed depending on the match type and certain characteristics. An approval is needed for PO invoices that are manually coded, all PCO invoices, invoices connected to spend plans that exceed its parameters, and all invoices without a reference number. The approval goes according to the approval matrix.

The average cycle time of an invoice within Basware in 2022 was 6.2 days. Different tasks are executed to process invoices, both manually and automatically. The average number of tasks per invoice was 13.1 in 2022. See Table 2 for the task counts and average duration of the manual activities. A main task is the approval of an invoice, both on row and header level. The difference is that row level indicates that a financial controller manually coded deviations on row level, while header level indicates the entire invoice. Another task that needs to be done manually is the matching of an invoice when such an invoice does not match exactly with a spend plan, PCO or PO, or because there is no reference number on the invoice. When this is done for a spend plan, this is indicated as the task of manual spend plan matching. The sending of an invoice refers to pushing the invoice into process, which needs to be done after a financial controller manually matches it or manually codes the invoice. Lastly, the invoices need to be transferred from Basware to Navision, which is one click in the system. The reason that the number of transfers is higher than the total number of invoices, 25,630 and 24,935 respectively, is that a transfer can fail. A transfer can fail when Navision is blocked for receiving new invoices, for example at the end of a period, or when Navision is not able to match certain elements of the invoice on row level, for example product numbers.

Table 2. Manual activities invoice processing in 2022.

Task	Task count	Average duration task, in days
Row approval	14,114	3.0
Header approval	2,570	2.9
Manual matching	17,580	1.7
Manual spend plan matching	2,401	2.2
Sending	11,183	3.4
Transfer	25,630	0.4

The individuals with approval rights vary in the average duration of approval. This can be seen in Figure 4 which contains the count of both row and header approval. On average, the individuals that have a longer average duration of approving an invoice have a lower task count, while the individuals with a higher task count, on average, have a lower task duration. This indicates that the risk for a long task duration lies at the people that must approve invoices on a less frequent basis. However, some individuals have a high task count and need to approve many invoices each year, with a maximum of 1,603 tasks in 2022. The sum of the approval counts in Figure 4 is 2.42% lower than the sum of the header and approval count in Table 2. The reason might lie in the manner Basware counts the approvals and is caused by adjustments that are made to an invoice after it is approved, and new approval is needed.

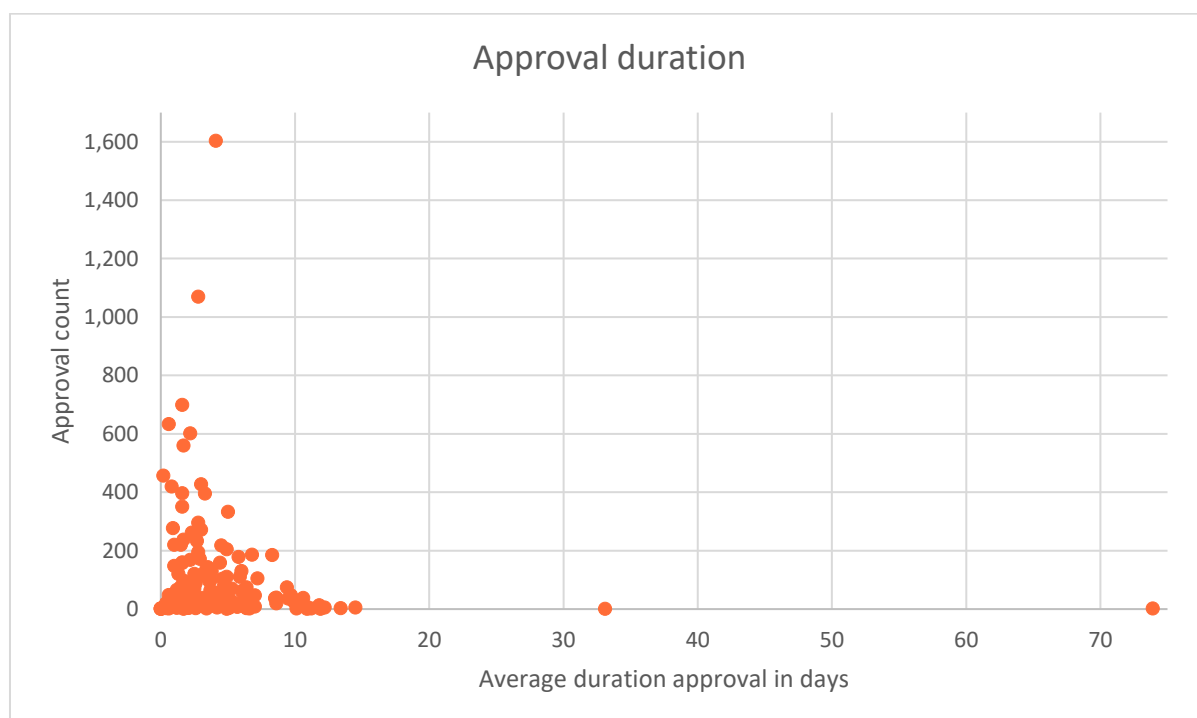


Figure 4. Average duration approval per individual in 2022.

2.1.3.6 Payment processing

The payment process is done by the general department for all the business units, and can be seen in Figure 5. Figure 5 is part of all four business process models in Appendix A. When the invoice is uploaded from Basware to Navision, the ERP system automatically looks whether the supplier is new. The reason for this has been elaborated in Section 2.3. If the supplier is new, a process starts to verify the bank account on the invoice. The supplier is included in an excel file. The front desk calls the supplier according to this excel file to verify the bank account. The telephone number the front desk

uses is obtained from the supplier’s website, and not from the invoice. On Wednesdays, one day prior to the actual payments, a designated individual approves the suppliers in Navision from whom the bank accounts have been successfully verified according to the excel file. If the front desk was not able to verify the bank account before this Wednesday, due to difficulties reaching the supplier or because the invoice was recently uploaded to Navision, the supplier does not get paid that week. When the supplier is not new, or the bank account of the new supplier is verified, the payments are made on Thursdays. An individual creates the payment file in Navision including all invoices that are due up to and including the upcoming Sunday, and uploads this file to the online environment of Nedap’s bank. After this, another individual receives an email including a hash code to check the payments. This person checks the file by randomly selecting several payments. When this person is satisfied, they approve the payments, and the money is wired to the suppliers.

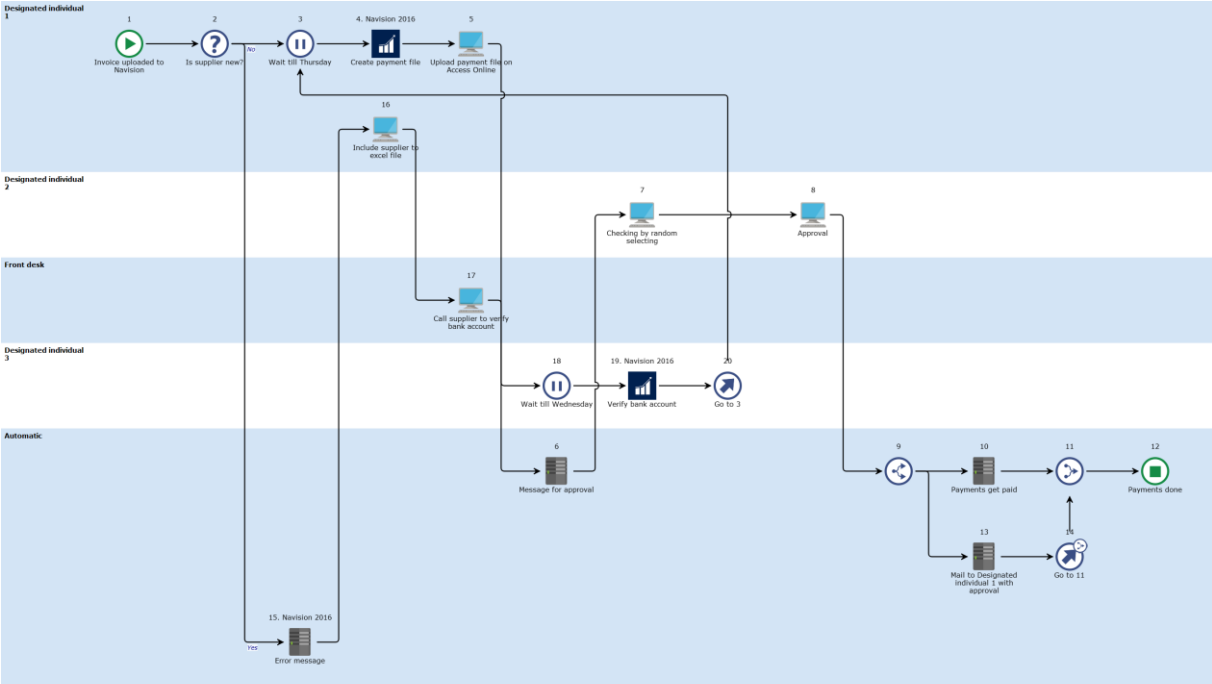


Figure 5. Payment process.

By choosing to pay Thursdays the invoices that are due up until Sundays, some invoices are paid too early while other invoices, for example those that are due on Mondays, are paid too late. This creates that on average invoices are paid on time. The reason for this is cash flow related. Moreover, doing this process weekly saves time compared to doing this daily.

2.1.4 Differences within business units

There are seven business units as mentioned in Section 1.1 that operate under Nedap N.V., and use the same ERP system. There is an overlap of EMS parties that they use. However, all business units have their own product portfolio and operate independently. Some departments operate Nedap-wide, yet other processes are done independently at each business unit. The general departments that operate Nedap-wide are for example Human Resources (HR), recruitment and IT. The inventory management and placing orders is done by each business unit separately. This consequently means that each business unit has independent contact with suppliers, including the EMS parties. The approval matrix is arranged according to each business unit, and renewed in January 2022. The business units are also separated physically by having different spaces in the main office in Groenlo, and mostly different employees. By operating independently, there are differences between them in

the S2P process. The main procedure is the same, which is reasonable because the systems are the same, yet there are minor variations between the seven business units.

Firstly, there is a difference in the organization of the purchase departments of the business units. For the four business units affiliated to the IDEAS group within Nedap (Healthcare, Staffing Solutions, Security Management and Identification Systems), one person is responsible for the operational purchases. This is also due to the fact that these business units have relatively less hardware that needs to be bought and this group originates from the past when these business units used to work in the same ERP environment while all the other business units had their own ERP environment. Livestock Management has a team of six people to order the POs. The individuals in this team have a bundle of suppliers they are responsible for. Only two out of those six individuals do not handle the operational purchases, but are busy with strategic supplier operations within Livestock Management, for example looking at the long term picture. At the business unit Light Control, one person is responsible for both the operational purchases and for the strategic elements. The business unit Light Control gets support when needed from the two operational purchasers from Retail. Yet, Retail also has a technical purchaser.

Another deviation regarding POs is the fact that Nedap N.V. and Nedap SMART have intercompany communication. This causes the confirmation of a PO from Nedap SMART differs from other external suppliers. Nedap does not have to send a PDF file of the PO, and wait to receive a confirmation through e-mail. Yet, this step is done through an EDI connection between both ERP environments. This creates a small difference for business units working with Nedap SMART. When Nedap SMART confirms all requested data without deviations, the purchase department does not get informed. However, when SMART indicates not being able to deliver the products as requested, the operational purchase department needs to approve the proposal of SMART within Navision. Therefore, it is a bit different, yet not substantially.

Another difference is an administrative discrepancy at the moment a supplier indicates that an order has been sent, and that Nedap can expect the products of a PO at a certain date. Some purchase departments revise this expected arrival date in Navision while others do not. Causing that this step in the process differs per business unit. Consequently, how neat data from the POs are arranged within Navision differ according to this. For some business units the expected date of arrival is reliable yet for another business unit this is not the case. Moreover, a WRNV number is made a number of days prior to the expected date of arrival. The number of days between the generation of a WRNV number and the expected date of arrival can be altered per warehouse by the IT department. When this expected date deviates from reality, or when this expected date is not changed according to the supplier's information, this WRNV number can be generated too early or too late. When it is made too late and not sent to the external warehouse prior to the arrival of the order, this warehouse is not able to book the products. However, when the WRNV number is generated too early and the reality deviates from expected, for example when it turns out the supplier was only able to send half of the quantity, the WRNV number needs to get manually deleted and a new one has to be made. Each business unit makes its own tradeoff between the extra work to adjust entries when receiving more information from the supplier, and the work that can arise when the WRNV number is wrong. In addition to this difference, some purchase departments mail the warehouses the WRNV number after generation while others trust that the ERP system does this automatically accordingly. It is extra work, yet some find it more reliable to do this step themselves than to trust Navision.

How individuals approve invoices differs even per person within the same business unit. One individual, who approves invoices regarding spend plans of contractors, approves an invoice by comparing the hours that they approved earlier. Contractors, both self-employed hirers as well as

hirers that Nedap seconds, usually always need to have their hours signed for approval. This individual, who approves both the invoices as well as signing the logged hours, assesses the work logs by looking whether people have written hours while having days off. Yet, according to this individual it is impossible and not desired to check every hour. Two other individuals, that both need to approve invoices, have stated to approve invoices if they seem legit and make sense. The difference between these two individuals regarding regular invoices without a reference number, is that one person indicated to reject an invoice if there is no clear reference of a party within Nedap on an invoice. This reference could be a person who ordered a product or service, or a license plate for a car owned by the company. The other person approved an invoice without such a reference, yet the invoice was for an expense that was logical and could have been made. It is common knowledge within the company that there is a difference in how precise individuals are regarding approval invoices.

According to the contract with the EMS partners of Nedap, the EMS companies are allowed to increase their prices twice a year, yet need to communicate this three weeks prior. These prices are completely transparent, consisting of the cost of the Bill Of Material (BOM) which are listed in Aton, and predetermined markup percentages. Three weeks prior to the implementation of these price increases, the EMS company sends the entire calculation to Nedap for approval. For an EMS party, there is no motivation to keep the costs as low as possible, because it receives a markup percentage of the Bill Of Material (BOM) costs. For the purchase departments, it is difficult to determine whether these price increases are justifiable. It is nearly impossible to check a realistic price for all the components of the BOM for a certain product. This is therefore also not done. Yet, there is a difference in how the operational purchase departments check whether the price increases are supported. Some purchasers only check the components that are increased the most percentual, others look at the price increase and quantity of those components to see which price increase has the biggest monetary impact.

Moreover, the manner that the spend plans are used differ at each business unit. Healthcare indicates to use them not only for contractors, but also for other periodic expenses. This is for example not done at Identification Systems nor at Livestock Management. The benefit of such a spend plan is that the supplier has to indicate the same number, the SP number, on all invoices instead of sending regular invoices without a number that the controllers need to code entirely by themselves. Moreover, when an invoice with SP number does not exceed the parameters of its spend plan, the invoice is processed automatically without manual steps or approval, which is faster and requires less manual labor.

Lastly, the usage of cost centers varies per business unit. Cost centers are used internally to allocate costs to a specific business unit and expense category. All business units have different cost centers each starting with an exclusive number. Cost centers starting with a 1 are for general costs Nedap-wide, while cost centers starting with a 2 are for costs of the business unit Security Management, and so on. However, Security Management only uses two cost centers while Livestock Management works with 28 active cost centers. Retail has 15 working cost centers, yet only uses 2 for the cost orders. The others are used for example for employee expenses. The upside of using many cost centers is to gain more insight to the allocation of costs, yet it is more work when having to choose from more cost centers.

2.2 Operational risks

Nedap tries to balance between acceptable risks on the one side, and entrepreneurship and long-term value creation on the other (Nedap, 2023). Risk management is an essential part of its business strategy. Its categorized risk appetite ranges from low to high. When it comes to compliance with legislation or financial risks, the risk appetite of the company is low, while it has a high risk appetite for strategic risks. The willingness of the company for operational risks is moderate.

Both the Board of Directors and the Supervisory Board have adopted the Nedap Risk Management Framework, which contains formal and informal procedures and controls as part of the risk management process (Nedap, 2023). Moreover, there is an annual risk update session with all business units and corporate teams present in order to increase awareness and to identify risks Nedap-wide. During this update session, the different business units indicate their perceived risks and by doing so the Nedap-wide risks can be identified. These risks are tackled and are included in Nedap's annual report. This session creates an opportunity for Nedap to identify various risks which are unknown or to expand or highlight already known risks. Therefore, the company already has a good insight into risks, including operation risks within the S2P process.

Three main operational risks which are perceived Nedap-wide are identified according to Nedap (2023). The first operational risk identified is the dependency on the supply chain. This risk can impact the business of Nedap by not having a sufficient amount of product available on time, which happened when COVID-19 broke out and the component shortages led to longer lead times. The second operation risk identified is the internationalization and can cause insufficient access to international customers, or insufficient implementation capacity abroad. Lastly, Nedap sees IT as an operational risk. The potential impact when IT is not functioning or malfunctioning, is the loss of its customers or partners. Relevant and reliable information is more important than ever, and IT is an integrated part of many of Nedap's propositions. Both the impact and probability trend of all three mentioned risks are categorized as stable.

This last risk, malfunctioning of IT, came to realization during a data breach late 2022. Private documents were downloaded from one of the products of the business unit Healthcare, where people can control their own health care environment. The person responsible for this breach was reported and it is believed that those documents were not distributed. Nedap learned to optimize crisis management and this situation increased the urgency of continued investment in cybersecurity (Nedap, 2023). This shows that risk management, and continuously improving it, is of high importance.

In addition to the three Nedap-wide operation risks mentioned, other operational risks within the S2P process are known. The company is already aware of the possibility of internal and external fraud, dependency on a single production location, and quality issues regarding the outsourced production. This dependency on a single production location can also form an issue concerning production capacity of the supplier which is too low for demand, resulting in a loss of potential sales. Moreover, the POs that are ordered, are based on estimated forecasted sales. This forecast is difficult since the demand is unpredictable, yet due to the long lead times for components (sometimes even 90 weeks) the sales need to be forecasted months if not years prior. An operational risk regarding the sales forecast is that it deviates substantially from reality, causing too much inventory and being liable for the components bought by the suppliers, or having too little products available and potentially losing sales due to this.

2.3 Risk mitigation strategy

Nedap's risk management is incorporated into its daily operations as well as in its strategic planning process (Nedap, 2023). It is in the company's belief that employees' personal responsibility and ownership lead to optimal risk management. Nedap has a vision to create a culture of ethical behavior where people are committed to being honest and respect each other. In order to create and maintain this culture, Nedap has created the Nedap Code of Conduct including principles and values that the company lives by. By having this code of conduct, and a mandatory e-learning course that all employees need to pass, the measure is taken to create awareness among people.

An important department for financial management is the controlling group, who also play a large role in risk mitigation strategy and are responsible for the risk management process globally (Nedap, 2023). This department implemented a reporting system to inform the Board of Directors. By means of an extensive financial report, the actual financial state is compared to the budget and the previous year. According to this financial report and a regular exchange of information by the business units, the Board of Directors reports to the supervisory board.

Moreover, the firm has created the Nedap Risk Management Framework as a guideline to manage risks, roles and responsibilities. This framework is a Nedap-wide used principle and identifies correlations between internal control and enterprise risk. By having this framework, the firm has standard and known processes for risk management. According to the Nedap Risk Management Framework (Nedap, 2022), three levels of control exist based on the impact of a risk. The first level of control, the normal operation, contains risks of which the impact is not critical for the company of one of its business units. Those who are involved and observe the risk, need to deal with it. The second level of control, the critical operation, relates to risks that cause substantial damage to a business unit or reasonable damage to Nedap. In a situation where such a risk is realized, the Nedap Risk Management process needs to be used and the Board of Directors decides on a possible follow-up. The last level of control, the vital operation, concerns risks that have catastrophic damage to a business unit or substantial damage to Nedap. When such a risk is encountered, a comprehensive report on this risk should be brought to the Board of Directors, who subsequently need to decide on a possible follow-up.

Nedap has taken measures to mitigate the three main operational risks mentioned in Section 2.2 (Nedap, 2023). The main measure for the first risk, the dependency on the supply chain, is to hold partners to the highest standards and conduct frequent audits. Moreover, Nedap holds more inventory that can work as a buffer for when a shortage of components arises. The inventory of Nedap N.V., including Nedap SMART, was raised in 2022 to €21,727,000 compared to €17,372,000 in 2021 (Nedap, 2023); an increase from 9.1% to 10.2% of its revenue. During the component shortage, the R&D teams became more flexible to offer alternatives and redesign products to use alternative components that were better available. Close collaboration between business units, suppliers, and customers helped during this time and is still done in present time. Yet, this frequently demands time from people. In order to become less dependent on a single party, a dual sourcing is introduced. For the second risk, the internationalization that can cause insufficient access to customers, Nedap has introduced an ecosystem with business partners, implementation partners and technology partners. In order to mitigate the last risk of malfunctioning IT, Nedap appointed security officers and an Information Security Committee. These employees drew up a security policy and continually improve general security standards. In addition to this, various business units have obtained several international standards that specify how an organization should protect data and to maintain a quality management system, for example ISO14001 and SOC2.

The company has many more risk mitigation strategies for operational risks that can occur in the S2P process. A main mitigation strategy in the control system is the segregation of duties. By breaking down tasks, Nedap prevents that one person is in sole control. At Nedap, this segregation is seen both in responsibilities and rights within several systems. As can be seen in Appendix A, tasks are done by specific roles, yet some tasks are only possible to be done with certain rights. Within the ERP system and Basware, different roles have different rights. Within Basware, the only people who are able to manually match or force match invoices are the financial controllers. They are responsible for the invoice processing. Moreover, only specific individuals have the rights to approve the invoices, if needed, according to the matrix. Also, when payments are made, the tasks and therefore the rights within the system are segregated. One person, a financial controller, is responsible for preparing the payments and uploading these to the cash management system of Nedap's bank account. These payments need official approval from a different employee. A hash code is included, to make sure that no other changes are made in the meantime without knowledge. If changes are made, the hash code does not correspond, creating another control during this subprocess. Only when this designated employee approves the payments, the bank can transfer money.

Another essential element in the control system is the approval control within Basware. Invoices need to be approved according a matrix depending on the cost center and cost. By having this approval step, the invoices are controlled whether or not the expenditures are justifiable. As mentioned in Section 2.1.4, this approval is different per business unit. This is partly due to the different structures of business units. Basware in itself is an control step and mitigation strategy against fraud and human error. By matching the invoices with the orders, a control is included that all the parameters on the invoice are correct and that invoices are based on orders.

By having more automatic steps within the S2P process done by Basware and Navision, the risk of human error is mitigated. However, the operational risk of being more dependent on such systems increases substantially.

In order for the sales forecast to be made more accurate, Nedap tested a platform that is able to enhance the demand forecast incorporating data from a wide range of sources. Yet, this platform was not as successful as hoped, thus Nedap stopped using it and the partnership end this year. This option could have helped to mitigate the risk of placing POs according to a not accurate forecast.

Another mitigation strategy to reduce the probability of both internal and external fraud is an extra control on the bank details of a supplier. This extra control happens in three cases: when a supplier is new, is not wired money to it in the past 1.5 years, or when the supplier indicates to have altered its bank details. This control exists to prevent wiring money to a bank account which is not correct. When a supplier is new, the payment is marked and put on an excel file the moment the invoice is uploaded to Nedap's ERP system Navision. After this, the front desk calls the supplier according to a telephone number stated on the supplier's website, and verifies the bank account number. The front desk registers all contact details, and marks the supplier as verified in this excel file. Once a week, on Wednesdays, a designated individual authorizes these bank accounts as verified in Navision. This procedure again uses the segregation of tasks. When an invoice is sent from a supplier where Nedap has not wired money to in the past 1.5 years, it can happen that the bank account is not correct anymore. This can cause the payment to bounce, yet it can also happen that the payment goes to a party different from the supplier, when the bank has reused the bank account number. Little information is available on this, yet it is understood that the reusing of bank accounts is typically not done within 3 years of when the owner closes this bank account (Jones, 2016). Clydesdale, a Scottish bank, has confirmed that such an account will be given to a new customer when it has been closed for four years. The Dutch bank Rabobank claims that a bank account can be reused after approximately

two years (personal communication, May 22, 2023). Two other banks, the British HSBC and Santander, do not recycle bank accounts at all (Jones, 2016). Nedap decided to control the bank account again after 1.5 years. When an invoice is received from a supplier where no money was transferred to in the past 1.5 years, Basware will give an error message. After this, a financial controller needs to compare the bank detail on the invoice with the one registered in Navision. If this is still the same, the financial controller needs to release this supplier in Navision. When a supplier indicates to alter its bank account, the process in Figure 6 is used. During this process, the front desk calls the supplier, using the telephone number shown on its website and not in Nedap’s ERP system, to verify the bank details. If all is correct, a designated employee of Nedap needs to approve this within Navision, on when money can be transferred. The verification and approval are tried to be done prior to the weekly payment moment. Yet, the verification of the bank details can take a few days, especially if it concerns a foreign supplier in a different time zone. The task within this process is also segregated, creating an extra form of control and mitigation.

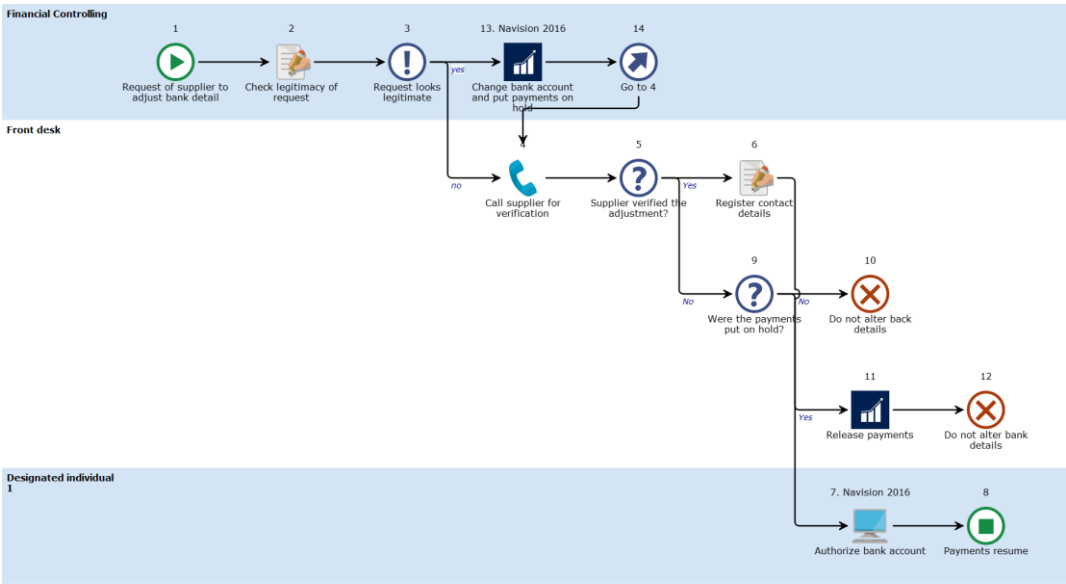


Figure 6. Adjusting bank account supplier.

Furthermore, Nedap is aware of the operational risk regarding quality issues concerning the outsourced products at EMS parties. In order to ensure the desired quality, a SLA between Nedap and EMS is made. Moreover, Nedap supplies EMS parties with production- and test- equipment and is able to see the test results. This equipment is property of Nedap but the supplier needs to maintain it. The test and measure department of Nedap is able to read these test results online. Nedap ensures the product quality by measuring the quality performance of a supplier by two KPIs calculated on a quarterly basis, see Equations 1 and 2. Non-Conformity Reports (NCR) are sent at the moment that non-conformities are noticed. The customer is the one who notices this and contacts Nedap to report this issue. The quality manager per business unit is responsible to send a NCR to the EMS company if this issue is, or potentially is, the result of poor production. These NCRs are not gathered or communicated between the different business units. Therefore, the KPI in Equation 1 is not tracked and thus not accurate.

$$\frac{\textit{number of NCRs}}{\textit{number of deliveries}}$$

(1)

$$\frac{\text{number of failed product}}{\text{total number of delivered product}}$$

(2)

In order to also ensure the logistic performance of EMS parties, the logistic agreement includes two KPIs, see Equations 3 and 4. In the past, extra measures were taken to ensure an easy data generation for these KPIs. Within Navision, extra entries were included in order for these KPIs to be calculated. The operational purchase departments needed to enter the first confirmed date of delivery by themselves. This would create an objective and quantitative manner of evaluating the performance of the EMS companies. This has been done regularly, but the discipline from people to enter this field faded away. The KPIs displayed in Equations 3 and 4 are still displayed within PowerBI and discussed quarterly during meetings with these suppliers, yet when the purchase department does not enter in this extra entry, the KPI is not reliable.

$$\text{Confirmed line item performance} = \frac{\text{orders delivered in full on confirmed date}}{\text{total number of orders in that period}} * 100\%$$

(2)

$$\text{Requested line item performance} = \frac{\text{orders delivered in full on requested date}}{\text{total number of orders in that period}} * 100\%$$

(3)

Another way to mitigate a risk, is to transfer the risk to a third party and protect the company from specific risks. This transfer of risks can be done by means of insurance. Nedap has several insurances: fire, liability, transportation issues and the continuity of the company, for example when an EMS goes out of business.

3. Literature Review

In his chapter, we focus on relevant literature to this research. By looking at existing risk management frameworks, we can determine the phases needed to complete for the risk management of operational risks within the S2P process of Nedap. The knowledge obtained in this chapter can be used during the remainder of this research. Section 3.1 answers the research question “*What are known risk management frameworks?*”. Sections 3.2 to 3.5 answer the research question “*What steps need to be taken for the risk management of operational risks within Nedap’s S2P process?*”.

3.1 Existing risk management framework

The past twenty years, risk management has significantly developed and multiple frameworks have been formed (Zur Muehlen & Ho, 2006). The purpose of risk management is to reduce or neutralize potential risks, to ensure that threats to the business are identified and controlled. The literature suggests various risk management frameworks (Jallow et al., 2007). A general risk management framework consists of three main phases: identification, analysis and response (Zur Muehlen & Ho, 2006). A selection of four existing frameworks is explained below, with their phases displayed in Table 3.

The Committee of Sponsoring Organizations of the Treadway Commission (COSO) created the COSO Enterprise Risk Management (ERM) Framework in 2004 when COSO noticed that many organizations were struggling with ERM (Jayantha, 2018). The framework was renewed in 2017, creating a new, more detailed and complex version focused on the integration between strategy and performance (Prewett & Terry, 2018). The framework focuses on the link between five interrelated components and the established mission, vision and performance of a company. These components are: governance & culture, strategy & objective setting, performance, review & revision, and information, communication & reporting. They are supported by a set of 20 principles that are more manageable in size. An important element stated by the COSO ERM framework is that the primary responsibility of risk management lies with management (Jayantha, 2018). This framework is one of the most widely recognized frameworks worldwide.

Another ERM framework is the Casualty Actuarial Society (CAS) Enterprise Risk Management framework. This framework considers a useful way to conceptualize ERM by focusing on two dimensions: the type of risk and the process steps (CAS Enterprise Risk Management Committee, 2003). The CAS has divided the types of or risk into four different categories: hazard, financial, operational, and strategic. The process steps of this framework are displayed in Table 3.

The next risk management framework selected, is the Continuous Risk Management (CRM) Framework. CRM is a practice that focuses on software development, and a tool to manage risk in mainly projects (Dorofee et al., 1996). Both the NASA and the Software Engineer Institute adopted this framework and have included it in their literature (NASA, 2011; Dorofee et al., 1996). The CRM process consists of five cyclical phases while continuously communicating and documenting. Communication and documentation are key elements for a successful CMR framework, because well-defined protocols assure that the risks are identified in a manner that supports the evaluation of their impacts. Moreover, when an individual risk impacts multiple organizational units, risk management efforts can be coordinated.

The last framework selected is the risk management framework adopted by the Project Management Institute (PMI). This risk framework focuses on risks that can occur during projects (PMI, 1996). Its definition of project is “a temporary endeavor undertaken to create a [sic] unique product or

service”(PMI, 1996, p. 7). This framework concerns four phases, as described in Table 3, that interact with each other.

Table 3. Phases of a selection of existing risk management frameworks

Framework	Phases
COSO Enterprise Risk Management Framework (Prewett & Terry, 2018)	<ol style="list-style-type: none"> 1. Internal environment. 2. Objective setting. 3. Event identification. 4. Risk assessment. 5. Risk response. 6. Control activities. 7. Information and communication. 8. Monitoring.
CAS Enterprise Risk Management framework (The CAS Enterprise Risk Management Committee, 2003)	<ol style="list-style-type: none"> 1. Establish context. 2. Identify risks. 3. Analyze/ quantify risks. 4. Integrate risks. 5. Assess/ prioritize risks. 6. Treat/ exploit risks. 7. Monitor and review.
Continuous Risk Management framework (NASA, 2011; Dorofee et al., 1996)	<ol style="list-style-type: none"> 1. Identification. 2. Analysis. 3. Response planning. 4. Tracking. 5. Control.
PMI body of knowledge (PMI, 1996)	<ol style="list-style-type: none"> 1. Risk identification. 2. Risk quantification. 3. Risk response development. 4. Risk response control.

Since some of the selected frameworks are for projects or are software focused, not all of these frameworks fit risk management of operational risks at Nedap. Despite their different steps, these frameworks all aim at the three main phases of a general management framework mentioned above (Zur Muehlen & Ho, 2006), and include a fourth step of monitoring. Due to this, we use these four phases of risk management in upcoming research: identification, analysis, control and monitor.

3.2 Risk identification

The first phase is the identification of operational risks. This phase involves identifying risk factors, both internally driven as well as externally driven (Jallow et al., 2007). According to the COSO framework, risk identification should occur at all levels: entity, division, operating unit, function, and process (Jayantha, 2018). The objective of risk identification is to locate risks prior to them becoming problems, with undesired consequences (Dorofee et al., 1996). Risk identification can be done through several techniques. A business can choose to undertake simple questionnaires, yet can also choose for elaborate workshops. Moreover, a company can use techniques enabled by technology, such as data tracking or complex analytics, to identify risks.

3.2.1 Operational risk categories

According to the Basel Committee of Banking Supervision (BCBS, 2011, p. 3), operational risks are defined as “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”. This same committee has generated loss event types of operational risks, see Appendix C. According to these risk categories, operational risks can be identified.

3.2.2 Identifying risks according to a process model

A less common approach to identify operational risks is by analyzing the business process model, using a process-oriented risk management (Strzelczak, 2008). In this method, business diagrams are used to create a list of control points and related risks in the process. This can provide the company an overview and design for organizational procedures. The downside of this approach is that a detailed description is needed of a process. This level of detail creates a high workload, especially for larger organizations, and is difficult to maintain.

Business-process model-based risk analysis (BPMBRA) is the utilization of business process models as a source of information for risk identification and analysis (Mordecai & Dori, 2015). This can concern both specific processes in the organization, as well as the organization in its entirety. BPMBRA has mostly evolved in IT and systems engineering.

3.3 Risk analysis

Risk analysis is the phase of analyzing the likelihood of the identified risks and the magnitude of the consequences (NASA, 2011). When analyzing risks, challenges arise regarding the uncertainty associated with risks (Jallow et al., 2007). In order to avoid an unrealistic analysis, assumptions should be defined. Moreover, it is possible to work with a three-point estimate to estimate these uncertainties: a low, most likely and maximum situation. When these assumptions are estimated and defined, the risk output is calculated. There are two main risk analysis methods: qualitative and quantitative.

3.3.1 Qualitative

Qualitative risk analysis is a method used to quantify risks. The qualitative risk analysis method determines loss based on the judgment of a risk analyst, rather than a precious monetary value (Jallow et al., 2007). Most frequently, the analysis of probability and impact is done by the risk owner. This method tends to be more subjective. The most common qualitative risk analysis is the risk matrix (Cox, 2008), yet there are variations of this method.

3.3.1.1 Risk matrix

A risk matrix is a table with several categories of probability and impact, used for assessing risk and setting priorities (Cox, 2008). These categories can go from rare to likely, when looking at the probability of a risk, yet the category can also be numerical from 1-5. By putting individual risks in the table, at the proper probability and proper impact, the risk is categorized by where it is positioned in the risk matrix. This method is widely praised and seen as simple yet effective. The usage of risk matrices does not require special expertise in risk assessment methods or data analysis.

3.3.1.2 Delphi method

The Delphi method is a method used to arrive at a decision based on expert consultation (Shi et al., 2020). This approach follows a structured and anonymous process, where experts give their opinions in a written form, done mostly in multiple rounds. By doing it in this manner, the downsides of traditional group discussions are eliminated. Markmann et al. (2013) examined the option to use the

Delphi method for risk analysis, and to quantify uncertainty. Experts should estimate the probability and impact of certain risks, which then can be entered in the risk matrix. In most cases, this method compensates for subjectivity and biases. According to Kuusi (1999), these experts should see the risk from different perspectives, to develop relevant arguments.

3.3.2 Quantitative

The quantitative risk assessment, on the other hand, measures the risk based on a monetary or discrete value (Jallow et al., 2007). This method strives to a greater precision compared to the qualitative method. Moreover, many software models exist to support the method of quantifying risk with the help of statistical methods. Most of these software models support Monte Carlo simulation.

3.3.2.1 Expected monetary value

Expected monetary value is a method that incorporates the probability and impact of a risk, by multiplying those values to create a number that is used in risk decision making (Pritchard, 2015). This concept is similar to the risk matrix, that puts a risk in the risk matrix according to its probability and impact. Yet differs in that this concept gives a monetary value. The sum of the expected monetary values of all risks is also used for estimating the contingency reserve.

3.3.2.2 Monte Carlo simulation

A Monte Carlo simulation is a method used to model complex systems for analysis (Zio, 2013). It can be used to determine the impact of a risk, and to understand the uncertainty. The simulation repeatedly samples random numbers to generate numerical results. The random numbers are obtained through “a roulette-like machine” based on a distribution (Zio, 2013, p.1). By generating a large number of possible scenarios, it is possible to estimate the probability and impact of a risk.

Greselin et al. (2019) state that Monte Carlo simulations are widely used to quantify operational risks.

3.3.2.3 Value-at-Risk

It is possible to quantify the impact of the risk by means of a Value-at-Risk (VaR) measure. VaR describes the largest percentage loss that can occur due to a risk at a given probability, a confidence level (Amédée-Manesme & Barthélémy, 2018). Meaning that the VaR is the maximum amount of money lost over a time frame with a probability of $\alpha\%$, thus working with the worst-case loss at a given confidence level (Adrian & Shin, 2014). A large VaR indicates a large value of lost money, indicating a higher risk. The downside of this method is that there is still a $(100 - \alpha)\%$ probability that the loss is higher than the VaR (Amédée-Manesme & Barthélémy, 2018).

The three main concepts to compute the VaR are: the variance-covariance method, the historical simulation, and the Monte Carlo simulation (Best, 1999; Linsmeier & Pearson, 1996). The first way to calculate VaR is a popular and widely used calculation, yet assumes normal distribution of logarithmic returns. Once the distribution of possible profits and losses of a risk is determined, mathematical properties of the normal distribution are used to determine the loss equal to the given confidence level. See Equation 5(4 for the equation, where α is the z-score of the confidence level and σ is the standard deviation of change.

$$VaR = \alpha \cdot \sigma \tag{4}$$

The second method to compute the VaR is historical simulation (Linsmeier & Pearson, 1996). Historical simulation uses historical data to predict the future and assumes that history will repeats itself. See Equation 6 for the calculation of this method, where R_i is the return over period $[i - 1, i]$, and v_i is the number of variables at time i . The distribution of the historical returns gets sorted in ascending

order, and the VAR is determined by this distribution and the confidence level α . Meaning that with a confidence level of 95%, the loss is not greater than the top 5% of the distribution.

$$R_i = \frac{v_i - v_{i-1}}{v_{i-1}}$$

(5)

The third method, the Monte Carlo simulation, uses simulation models to generate possible outcomes with the input of random numbers, see Section 3.3.2.2 (Linsmeier & Pearson, 1996). The VaR is calculated by looking at the sum of the first $\alpha\%$ of the losses to say that with a confidence of $\alpha\%$, the losses are not big than this sum. This method assumes normal distribution of logarithmic returns as well.

3.4 Risk response

Four risk response strategies are suggested (Zur Muehlen & Ho, 2006; Baijal, 2021). These are avoidance, transfer, acceptance and mitigation. Avoidance refers to the elimination of the probability that a certain risk occurs. This avoidance can be realized by deciding not to proceed with an activity (Baijal, 2021), or by trading the risk with other risks that are less threatening or easier to handle (Zur Muehlen & Ho, 2006). Risk avoidance can be done by process redesign. The strategy to transfer a risk concerns to shift the risk and/or the consequences to a third party. The most common method of this strategy is insurance, but this strategy can also be applied through outsourcing the risky process parts (Zur Muehlen & Ho, 2006; Baijal, 2021). The third strategy, acceptance, is accepting a risk because the consequences are within an acceptable limit. Accepting a risk can also be chosen because the costs to change the risk are disproportionate compared to the reduction in risk. Most common thing to do when this strategy is chosen, is to adapt to the risk. Lastly, a business can choose to mitigate the risk. Risk mitigation is the activity to reduce the probability and/or impact of a risk.

3.5 Risk monitor

The last step is to continuously monitor the risk by tracking the company's risk exposure (Baijal, 2021) and to track the progress of implementing the risk response strategy (NASA, 2011). This can be done through audit data provided by an internal or external auditor with an independent view on the control weaknesses or potential process failures. Moreover, a risk can be monitored with usage of risk event data. By using internal risk event data, risks can be reassessed. Yet, events happening at an external organization can also be used to compare or to analyze industrial trends. Another good monitoring measurements are Key Risk Indicators (KRI) (Peček & Kovačič, 2019).

3.5.1 Key risk indicators

A manner to monitor risk is the proactively monitoring of risks in order to provide an early signal of increasing risk exposure by means of KRIs (Baijal, 2021).

KRIs are similar to KPIs, yet are often mistaken for these (Peček & Kovačič, 2019). While KPIs are “a summarized set of the most important measures that inform managers how well an operation is achieving organizational goals” (Boddy, 2014, p.619), KRIs focuses on future threats. They are useful to keep track of certain statistics and measurements in order to provide information on the risk position of a company (Coleman, 2009). KRIs can help in two ways: either minimizing the probability of the risk occurring, or minimizing the accompanying consequences (Peček & Kovačič, 2019).

Quantitative indicators with data obtained from operational information systems are easier to measure, do not rely on subjective assessment and are less intrusive (Coderre, 2015).

A good KRI should have eight attributes according to Baijal (2021):

1. The KRI should be quantitative and easily measurable. Moreover, the source of the data should be clearly defined.
2. The KRI should be leading instead of lagging, meaning that the focus is on forward-looking in order to provide signals of potential losses in advance.
3. The KRI should have a clear link with the associated risk. It is essential that the KRI that is measured has an explicit link to the risk wanted to be monitored.
4. The KRI should assist in driving specific actions when it indicates a worsening risk profile.
5. The thresholds of the KRI should be clearly defined to ensure that management observes the worsening of a risk.
6. The KRI should assist in providing appropriate trend analysis key messages to the management.
7. The input for the KRI should be easily auditable to ensure its effectiveness and quality.
8. The number of KRIs should be appropriate, in order to focus the management's attention on the most important risks.

According to Peček and Kovačič (2019), a KRI should be measurable, relevant, auditable, non-redundant, and easy to monitor. The first three attributes correspond to Attributes 1, 3 and 7 respectively as stated by Baijal (2021). However, Peček and Kovačič (2019) state that the KRI should also be non-redundant, referring to when two indicators are strongly corresponding only one should be monitored. In addition, the KRI should have the attribute of easily monitorable; monitoring should not be too expensive nor too inconvenient.

According to Horwitz (2004), a key component of understanding risk is visualization. Risk visualization entails using images to communicate risks, that helps experts and decision makers to better handle risks (Eppler & Aeschmann, 2008). KRIs are usually shown in a dashboard. According to Eppler and Aeschmann (2008), the following guidelines should be used for proper risk visualization:

- Do not use risk visualizations sooner than expected. Once an individual has seen an image, it is difficult to view it another way. Therefore, it is important to carefully time the use of visualization.
- Consider the application context and possible constraints. Some elements are not possible due to constraints, or are not fit for the context. For example, a risk report for shareholders should try to avoid ambiguity and therefore text could be the best means of communication.
- Risk visualization should respect the basic rules of visualization:
 - Items that are shown bigger should be more important or more significant.
 - Items that are positioned more centrally, are perceived more important than those closer to the periphery of the diagram.
 - Items placed close to each other are perceived to be similar or part of the same group.
 - Represent the same items in the same style, and different items in a different style.
 - Do not overload the diagram and eliminate unnecessary items.
 - Time is usually mapped from left to right.
 - Provide clear titles for each element to indicate the key message.
- Avoid decorative visualization without added benefit. Risk visualization should always add value, making the risk exposure easier to understand or faster to read. Unessential elements, such as shading, borders or too many colors could make it more difficult to read.

- See the risk visualization as a work in progress that still can be changed. In this way, the visualization is changed according to the knowledge and feedback of the users.
- Test the risk visualization with someone who was not involved in the creation of the visualization, and use their feedback. Moreover, discuss possible areas of misunderstanding of the graphic.

4. Additional Operational Risks

In this chapter, we identify additional operational risks that are unknown or underexposed and try to analyze them. Section 4.1 answers the research question *“What are operational risks within the S2P process which are not yet addressed?”* and select the most severe risks for Nedap according to the risk owners. Sections 4.2 up to and including Section 4.4 answer the following research questions for the most severe risks: *“What is the impact of the identified operational risks?”*, *“What are mitigation options for the identified operational risks?”* and *“Which mitigation options are suitable for Nedap?”*.

4.1 Operational risk identification

As mentioned in Section 3.2, the first step in risk management is the identification of risks. We create a list with identified operational risks through interviews, data analysis and observations. In order to select the most severe risks out of this list, we do additional interviews with parties involved in the process, the risk owners.

4.1.1 Most severe operational risks

The additional operational risks we discovered in the S2P process are the following:

1. Spend plans are not stopped when a contractor stops earlier than anticipated or agreed. Currently spend plans are still active of contractors that have stopped prematurely, both spend plans where invoices need to be approved above €1 and where invoices only need to be approved above a fixed (high) monetary value. The risk of this is that a contractor, accidentally or knowingly, sends an additional invoice. Depending on the parameters of the spend plans, the invoice gets processed and paid.
2. Verifying bank accounts of new suppliers starts when an invoice is transferred into Navision, meaning after the invoice has been completely processed in Basware. This can generate delays in the payment process, and might cause the first invoice of a new supplier to be not paid on time. This risk would occur more often for new contractors, since their invoices have a shorter payment term of 14 days.
3. Business units are making purchases without knowing that the product or service has already been bought by Nedap. An individual explained during an interview that they had experienced twice while purchasing a software license, that Nedap already purchased it by another business unit. This causes the risk of unnecessary double costs.
4. The risk exists of a human typing error of adding an extra zero at the quantity while placing or adjusting a PO, creating an order increased by a factor of ten compared to desired. Most of the time, POs are ordered according to a proposal of Navision; the quantity does not need to be inserted. Yet, this is needed when creating a new order without it being proposed. Moreover, when a PO is divided into multiple rows due to multiple shipments, the quantity per row needs to be entered again.
5. Nedap risks paying double when suppliers send duplicates of invoices. Basware checks whether invoices are duplicates based on the invoice number, yet does not recognize duplicates when this number differs and the invoice is not matched to a PO or PCO. The individual approving the invoice should recognize this duplicate based on their memory. However, an individual already indicated that this duplicate might not be recognized. They experience that if an invoice needs to be approved again after minor changes, individuals that give this approval rarely ask why they need to approve the invoice again.
6. The VAT is not deductible for expenses that employees themselves incur for the company, even though they are able to present receipts. This means that Nedap risks missing out VAT when

employees send claims for expenses they paid, which could also be done by means of invoices directly to Nedap.

7. The financial team has access to bank account numbers of all Nedap's employees in the ERP system. Nedap risks that this is at the displeasure of its employees due to privacy reasons.
8. Nedap employees themselves need to decide whether a contract or NDA is needed at the moment they order a product or service. There are currently no clear guidelines for this.
9. The pre-agreed KPIs of EMS partners are currently not tracked Nedap-wide. Moreover, other KPIs that indicate the performance or liability in an objective manner of the EMS parties are not used.
10. Spend plans of contractors are usually created after an invoice has been received, instead of during the onboarding. This might cause delay during the first payment.
11. Due to the choice to include invoices that are due up until Sunday in the payments on Thursday, approximately half the payments are paid several days too late (if not more due to delay in other steps of the process). On average Nedap N.V. is on time.
12. There are 29 duplicates in the supplier list of Navision according to exact name match, and 22 duplicates according to the same VAT number. In many of these duplicate cases one supplier is blocked and therefore cannot be used. There are also suppliers that have duplicates in the supplier list for specific reasons, such as a difference in production location or different bank details. See Table 10 and Table 9 in Appendix D for the lists of duplicates with explanation. This situation is accompanied with the risk that the wrong supplier is selected with different VAT numbers or bank accounts, creating a lot of internal labor to correct this. Moreover, duplicates in the supplier list can cause a blurred representation when analyzing the data.
13. Anyone with access to Navision is able to create a new supplier in Navision, risking duplicates in the supplier list. Only the financial team is able to release a new supplier after creation and to include bank account numbers.
14. The semi-annual price increases of EMS partners are difficult to check whether these are correct and justifiable. Every business unit has a different manner of controlling the price increases of components, and indicates that extra help or guidance is welcome. The risk is that Nedap is paying more than needed, both on the components and the markup for the EMS party which is a percentage of the cost price.
15. There are no adequate backup plans if individuals with certain rights are absent, for example individuals that verify bank accounts, do the payments, check the payments, or approve invoices in Basware. When the individual who is the only person in the company capable of verifying new suppliers was on vacation, the verification paused for a week. Moreover, the individual who checks the payments did this while abroad on vacation. It is possible in Basware to indicate your absence and transfer your tasks including approval to someone else, yet this is not common knowledge and not done extensively. This situation creates the risk that certain tasks are not done during absence and the process pauses.
16. Nedap does not always use the advantages of its size regarding bulk purchasing, especially with the seven business units buying certain products and services for themselves. The company risks that it is paying too much for orders, and missing out on leverage on its suppliers.
17. There is not always a four-eyes principle during invoice processing. For example, the financial controller who orders the charging stations for electrical cars of Nedap is also the one creating a PCO for this, and approves them. Since the four-eyes principle is used as an internal control mechanism, the risk of internal fraud remains.
18. A manner for employees to commit internal fraud is to create a PCO for their own company, mark this order as received and send the invoice. As a new supplier, the bank account number is checked, which will be correct, and if the invoice is approved the money is paid. The only mitigation

against the risk of this happening is the approval, yet employees know which expenses are logical and can vouch for the expense.

19. Individuals with approval rights do not always approve invoices with the accuracy as desired. Nedap risks that invoices are approved, and thus paid, while these are incorrect or while the expenses are not justifiable.
20. The real control regarding unmatched invoices and invoices with spend plans is the approval according to the matrix. This person needs to check that the service or product is actually ordered and received, all for the same price.
21. The risk exists that invoices are paid late due to approvals in Basware that have a long duration, see Figure 4.
22. The percentage of invoices unmatched in 2022 was 23.71%. Unmatched invoices cause the risk of unmanaged expense and more manual labor. Moreover, expenses not connected to orders or spend plans cannot be reserved at the end of a period, because they are simply not known yet.
23. The screen of the ERP system is synced when multiple purchasers place orders according to the order proposals and no filters are applied. This implies that if two individuals are putting orders in at the same time and one prints the order to the suppliers, all orders of both persons are included. Filters need to be applied every time the screen is opened again. Nedap risks that orders are placed without knowing or that are not correct.
24. The purchasing department focuses on prices of components that increase during the semi-annual price changes of EMS parties, but not on the prices that stay the same. The risk Nedap is facing when doing this, is that some components might have become cheaper and not adjusted in the price change.
25. Nedap is financially liable for the components that EMS parties buy according to the send forecast. However, when an EMS partner buys a component that has a minimum order quantity, Nedap becomes liable for the entire batch that is bought even though this quantity is more than the send forecast. The risk is that Nedap needs to pay for unused components when components get replaced or when an entire product is stopped.

In order to decide which of these risks are most severe for Nedap and need to be managed, we conducted interviews with the financial controllers and purchasers of each business unit. We asked these individuals to indicate their most important risks, yet did not give a limit for the number of risks. Therefore, some individuals indicated ten important risks while others only indicated two risks that they perceived as crucial. We did this on purpose in order to get an answer containing important risks without limiting the interviewees.

In total 19 people were asked to identify the risks, see Table 11 of Appendix D. Three financial controllers preferred to receive the list over e-mail instead of an interview, and did not receive explanation of the risks. Moreover, some individuals that were interviewed indicated to prefer to receive the list afterwards to determine their top risks, but did receive explanation and context of the risks. The 19 individuals belong either to the financial controller department or purchasing department, both operational purchases and technical purchasers are included. As can be seen in Table 12 of Appendix D, nine interviews were done with financial controllers and ten with purchasers. As mentioned, the number of risks identified per individual differed, creating a differences between the departments of total risks identified. 59.21% of the identified risks originates from financial controllers while only 40.79% comes from the perspectives purchasing department, see Table 12 of Appendix D. An explanation of this can be that more identified operational risks belong to the steps in the process that are done by financial controllers. Moreover, these steps are also included in the processes of ordering a PCO, processing invoices regarding spend plans and unmatched invoices, while the purchase department focuses on ordering POs.

Table 4 indicates the most important risks according to each interview. Moreover, we calculated the total number a risk is mentioned as severe per department, and the absolute total. However, in order to create an equal distribution between the total mentioned risks of the two departments, the total is calculated with a ratio per department creating that the risks mentioned by both departments are equal to each other. Moreover, the total is calculated when each interviewee had the same voting weight for the sum of their chosen risks, to eliminate the difference between someone who only identified two important risks while another person had ten.

Table 4. Identified risks according to interviewees.

Interview Risk	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total Financial Controller team	Total Purchasing team	Absolute total	Total according to department ratio	Total according to individual ratio
1	X		X		X	X	X	X	X	X										8	0	8	5.5	1.9
2										X										1	0	1	0.7	0.2
3			X						X	X										3	0	3	2.1	0.6
4						X			X									X		2	1	3	2.4	0.6
5	X		X	X									X	X						3	2	5	4.1	1.5
6																				0	0	0	0	0
7																				0	0	0	0	0
8						X									X			X	X	1	3	4	3.7	1.0
9		X							X			X							X	2	2	4	3.4	0.9
10							X													1	0	1	0.7	0.3
11																				0	0	0	0	0
12	X					X			X											3	0	3	2.1	0.5
13																				0	0	0	0	0
14											X		X	X	X	X			X	0	6	6	6.0	1.8
15		X			X				X	X		X						X		4	2	6	4.8	1.5
16											X						X		X	0	3	3	3.0	0.9
17					X	X		X	X				X	X						4	2	6	4.8	1.5
18																				0	0	0	0	0
19				X	X			X	X							X				4	1	5	3.8	1.4
20						X			X											2	0	2	1.4	0.3
21												X								0	1	1	1.0	0.3
22							X			X					X					2	1	3	2.4	0.9
23											X					X				0	2	2	2.0	0.6
24	X	X																X		2	2	4	3.4	1.2
25	X			X					X		X	X							X	3	3	6	5.1	1.3
Total	5	3	3	3	4	6	3	3	10	5	4	4	3	3	3	3	2	3	6	45	31	76	62	19

The financial control department perceives Risk 1 as the most severe, with eight out of ten financial controllers selecting this risk. Risk 1 is regarding the spend plans that are not stopped or deleted when a contractor stops early. Striking is that none of the purchasers perceived this as important. Moreover, four controllers marked Risks 15, 17 and 19 as important, causing these risks to come second place for this department. The purchasing department perceives Risk 14 as significant, yet their opinions regarding other risks are more divided. This risk concerns the semi-annual price increases EMS partners are allowed to do with an open calculation, and the difficulty to check these. Moreover, this risk is not seen as severe by any of the financial controllers. This is again striking and indicates that both departments do not recognize each other's risks. There are more differences between the two answers of both departments, which show that their perspectives and understanding differ.

In order to select the most severe risks for Nedap in the S2P process, we focused on the absolute total of mentioned risks. Due to the time constraint of this research we decide to only choose three risks to analyze further. As mentioned, the list contained more risks regarding financial steps than regarding the placing POs that can explain the difference between the difference of total risks identified by both departments and the difference selected by everyone. Risks 1 has the highest absolute total with 8 interviewees selecting this risk, while Risks 14, 15, 17 and 25 come second place with a total of 6. In order to choose among these four risks, the total with department ratio and individual ratio is taken into consideration. Risk 14 scores high in all the totals, and thus we can say that the interviewees categories this risk as important. In addition to this, Risk 25 is recognized by both departments indicating that there is common knowledge that this risk has a high impact. Therefore, the risks selected to analyze are Risks 1, 14 and 25.

4.1.2 Extra operational risks mentioned

Some interviewees mentioned additional operational risks that they thought to be important for Nedap. It was not possible to add these to the list of identified risks, yet they are important to mention for the company to become aware of them. These risks were not mentioned in previous conversations and the general interviews. We believe that after interviewees were presented the list with additional operational risks, they understood the type of risks better and got inspired. The extra risks that were mentioned during the interviews are the following:

- The four-eyes principle is not applied when placing POs at all business units except Retail, creating a bigger risk of human error.
- The risk of receiving a PO too late. When the order is adjusted to be sent to a different warehouse, the requested date is changed automatically. This can cause inconvenience.
- Price quotes connected to invoices are not visible in Basware, risking that a supplier introduces a higher price than previously agreed on and someone approves this. The probability of this risk is higher at unmatched invoices because there is no order.
- PCOs that are not deleted while the order is canceled, or the invoice has been paid yet not matched to a PCO. This causes manual work of checking up. Moreover, costs are reserved.
- When Nedap employees buy software licenses with their personal Nedap email address and stop working at Nedap, the access to licenses may disappear.
- The agreements with EMS partners are not known by the purchasing departments, risking that they do not know what Nedap's rights are and missing out on certain rights.
- The (EMS) sourcing partners selected in 2016 are not updated or adjusted, while the business of Nedap changed. The risk of a possible outdated sourcing strategy can cause missing out on opportunities at other production facilities.

- It is possible for the purchase department to commit fraud by adjusting the prices of POs in Navision, which might be profitable if these people make a deal with suppliers yet Nedap risks paying too much for products.
- The risk of paying to the wrong supplier is present, and has gone wrong in the past. The cause of this risk is that Basware can read the wrong supplier of the invoice while the bank account numbers of the invoice would still be different from the detected supplier. A financial controller can tick a box to ignore this difference, which can happen in a hurry due to human error.
- Basware does not always capture the correct variables of an invoice.
- The risk can occur of ordering PCOs multiple times because an employee does not understand how Basware works, and might order it again.
- Many employees do not understand that the costs entered while placing a PCO in Basware exclude VAT. This causes that invoices do not match with PCO and thus manual work, yet is also accompanied with the risk that the VAT is calculated over the cost price inclusive VAT by the supplier.
- It is unknown how business units accept price increases regarding the prior placed POs when the date of arrival gets changed. Navision automatically calculates the cost price according to the calculated order date. The calculated order date is automatically calculated by the ERP system that subtracts the lead time of a product to the expected date of arrival. The cost price is determined for certain periods of time. If the expected date of arrival is changed, the order might fall in a different time period regarding the cost price which results in a higher price.
- The price of a PO is adjusted automatically when an order line gets adjusted, causing the risk of working with different prices then initially communicated with the supplier, which leads to a mismatch of the invoice and the PO.

4.1.3 Extra information gathered

During the interviews shown in Table 11 of Appendix E, we gathered more information about the S2P process. This extra information does not necessarily contain risks, yet also portrays the opinions of interviewees and adds to Section 4.1.2 of extra mentioned risks.

During Interview 11 we became aware that there are dummy products in the item list of the ERP system, meaning dummy products are created in Aton. The purchase department uses these products to buy components that Nedap sells to their EMS partners. Usually, the production partners are responsible for the purchase of all components, yet in some cases it is beneficial when Nedap does this itself. For example, when components are not available due to shortage, Nedap has the incentive to search better and is willing to invest time in this search. Moreover, it can save money when searching for a lower price for components. The benefit of buying these components under a dummy product in Navision over buying them using a PCO in Basware, is that the inventory and sales of the bought components can be tracked. However, this causes that there is a loophole in the S2P process; it is possible to order products that should be ordered with a PCO in Navision as a PO. The downside of this loophole is that invoices that match perfectly with a PO do not need approval and are processed automatically.

The costs of POs are not reserved at the end of a period nor are these costs transparent. Some business units already stopped using these dummy products in Navision and created a new product in Aton for every component that has the purpose of selling to the EMS parties. After this interview we reviewed the POs of 2022 and discovered one PO for the spray painting of 13 products. This PO was striking and stood out due to the supplier being a vehicle repair shop, which is not a logical supplier for POs. The invoice of this PO was automatically processed in Basware due to a perfect match, and thus no

approval or manual coding was needed. During a conversation about this case with the financial controller responsible, it became clear that this indeed is an expense that needs to be ordered using a PCO in Basware. The costs of these dummy products are booked under the price difference of inventory; a cost center that each financial controller checks periodically. Therefore, this loophole should be noticed eventually when misused. This case shows that it is possible to order products this manner and that the invoice gets paid, and that it has been done in the past. A reason why this is done can be the antagonism of employees towards Basware, which is a known issue. However, this can also be a one time mistake by an employee. It can also have been a human error because the individual ordering this PO places a lot of orders in Navision as purchaser.

Other information we received during an interview regarding the dislike of Basware, is that there are employees who knowingly send claims instead of creating PCOs to avoid the software program. This is connected to Risk 6, concerning the risk of missing out VAT when employees send claims for expenses they paid. This indicates that the risk of missing out VAT is not only caused due to employees not knowing that invoices are preferred, yet also because people are stubborn.

After the discovery of Risk 1, a financial controller checked the open spend plans for their correctness. They discovered that two spend plans were created for the same contractor, yet the first was not visible because it was still pending approval.

Multiple interviewees have indicated that the purchase departments currently have too much freedom, which is not needed. There are EMS partners with whom different business units do business with, yet each business unit has the freedom to handle situations differently and to their own liking. The business units operate under the same Nedap name, but this is not always shown to their suppliers. Business units with the same EMS partner differ in the degree of negotiation they do in the semi-annual price increases, but also if more price increases were allowed during the component crisis. Moreover, one business unit is currently looking to change an EMS partner, but decided this for themselves. This sense of freedom is in line with the feeling from interviewees that they are missing clear guidance from management.

Interviewee 19 indicated to believe that many of the identified operational risks were caused by the fact that the focus in the company lies at the sales department. They believe that the culture in the company should be more directed to the operational purchasing.

Interviewees 15 and 19 believe that certain agreed KPIs are not nuanced enough. The two KPIs according to the logistic agreement, see Equations 3 and 4, measure the percentage of orders where the order is delivered on time compared to the requested date and the first confirmed date. However, it also happens that the purchase department of Nedap asks to postpone the order several days or weeks after the order has already been placed and confirmed. Moreover, it is possible that Nedap requests the order on a date that is not reasonable. The interviewees believe that these KPIs could therefore portray a blurred reality.

4.2 Active spend plans

Spend plans are not stopped at the moment a contractor stops earlier than anticipated or agreed. Currently spend plans are still active of contractors that have stopped prematurely, both spend plans where invoices need to be approved above €1 and where invoices only need to be approved above a fixed (high) monetary value. The risk of this is that a contractor, accidentally or knowingly, sends an additional invoice while already stopped working for Nedap. Depending on the parameters of the spend plans, the invoice gets processed and paid.

It does not often happen that a contractor stops earlier than priorly agreed, yet it does happen. These individuals get offboarded, but there is no procedure that the financial controller gets updated about this development. Financial controllers sporadically discover that someone has stopped, yet this is by accident. As can be seen in Table 11, eighty percent of the financial controllers viewed this risk as severe for Nedap, while no individuals working at the purchase department identified it. This shows that this risk is present for people working with spend plans, yet people without knowledge of the invoice processing process are unaware of it.

4.2.1 Analysis

The risk of processing invoices of contractors that already stopped has many uncertainties. In order to estimate the impact of this risk, we use Monte Carlo simulation by repeatedly sampling random numbers to generate numerical results. By generating a large number of possible scenarios, it is possible to estimate the impact. Several pieces of data are needed for this method.

Not all invoices that are linked to spend plans originate from contractors. Nedap also uses spend plans for costs that are expected periodically from businesses. The risk we have identified is specifically for contractors. In order to estimate how many invoices were sent by contractors and how many were sent for other expenses, a financial controller selected the suppliers with expenses that are connected to contractors. They did this to the best of their ability, yet it is not guaranteed that all the contractors were selected. Of the 216 suppliers that have sent an invoice in 2022 that were based on a spend plan, 46 were identified as contractors. See Table 5 for the number of invoices and the net total for the contractors.

Table 5. Processed invoices matched to spend plans regarding their expenses in 2022.

Invoice expense	Number invoices	% number of invoices	Net total of invoices (€ x 1,000)	% net total of invoices
Contractors	787	27.81%	5,194	22.93%
Other	2,043	72.19%	17,459	77.07%
Total	2,830	100%	22,653	100%

See Figure 7 for the probability density of the total received invoices of contractors matched to spend plans. Figure 8 shows the difference in probability density between invoices of contractors that needed approval, and those that did not need approval because the parameters of the invoices did not exceed the parameters of the spend plan. There is a difference between these probability density functions, yet we believe that they are similar enough for comparison. Invoices with a negative total are received, these represent credit notes and are credited to the outstanding balance of a supplier. Since the credit notes are not important for this risk, because “receiving” extra money without knowing it after a contractor has stopped does not cause the potential loss.

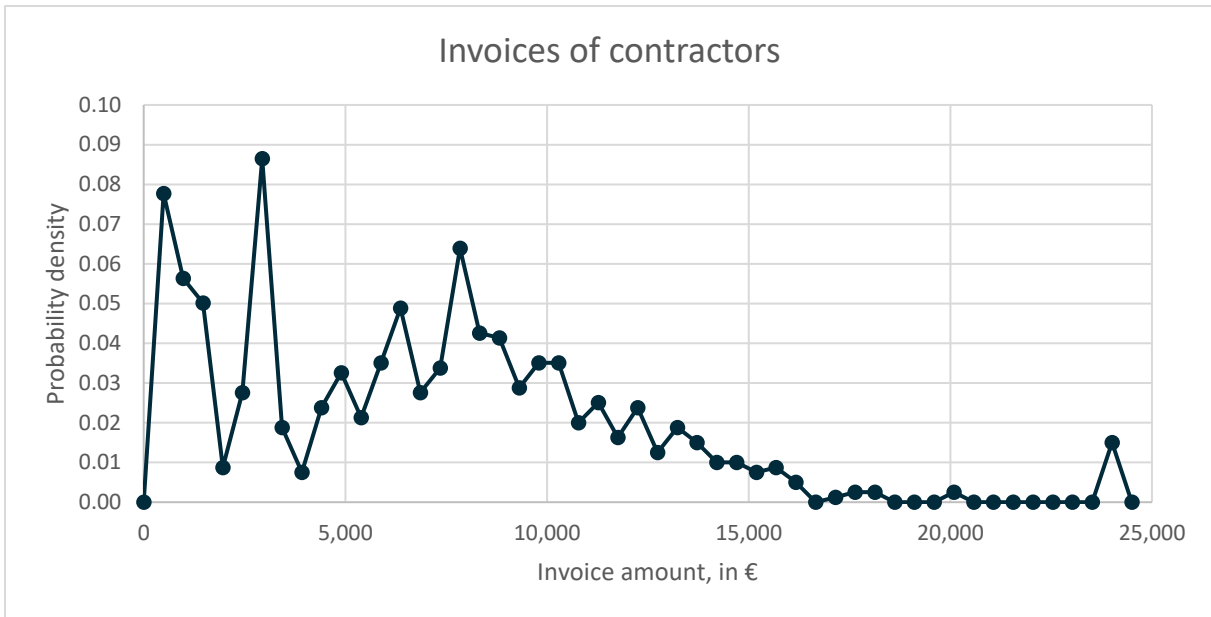


Figure 7. Probability density of invoices received of contractors in 2022, both removed and processed

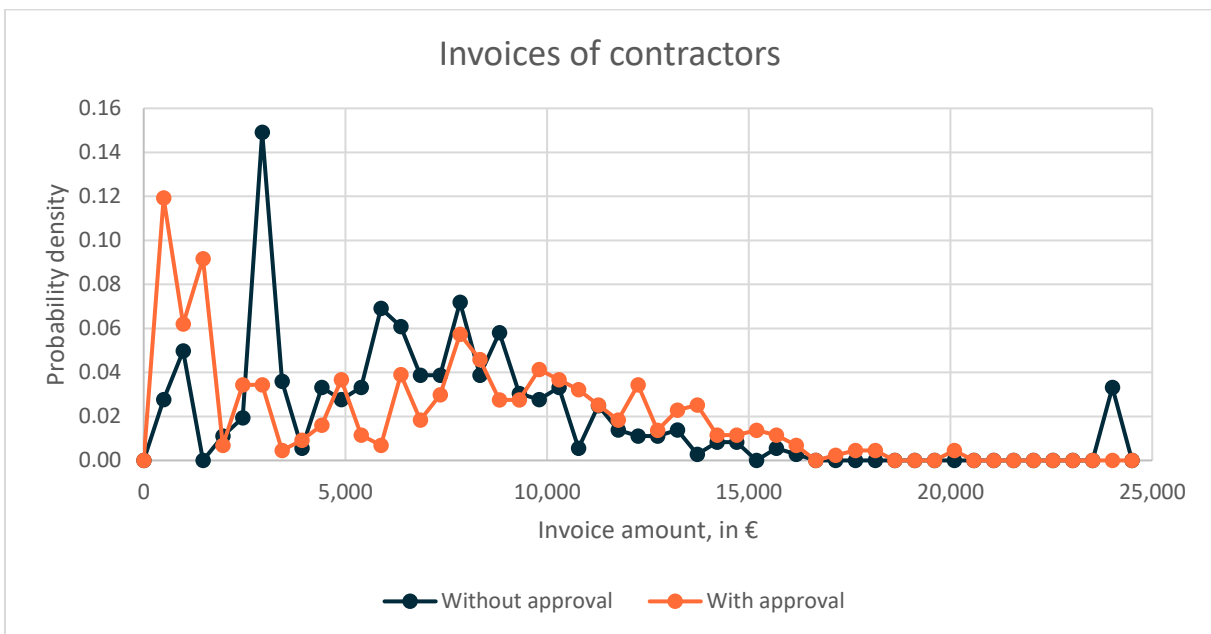


Figure 8. Probability density of invoices received of contractors in 2022, both removed and processed.

It is not clear how many contractors stop prior to the agreed date, because the contract end date is overwritten when it is adjusted. Therefore, we cannot determine the correct percentage of contractors that stop early according to this data, and how much earlier. However, the HR department does record the reason for the end of the contract. Of the 50 contractors that stopped in 2021, 30 of them had a different reason for end of contract than “pre-agreed term” or “contract extension”. In the first half of 2023, up and until June 30, 9 of the 24 contractors that stopped had a different reason. In 2022 the reason of the end of contract has not been recorded. On average of 2021 and 2023, assuming that the second half of 2023 has the same distribution as the first half, 48.75% of the contractors had a different reason for end of contract. Individuals within Nedap have indicated that this percentage is too high. If we would only exclude “other” as reason for end of contract, the average of 2021 and 2023 of

contractors stopping early, also assuming that the second half of 2023 has the same distribution as the first half, is 20.17%. The reasons included in the 20.17% are the following:

- Early retirement.
- Retirement.
- Conflict situation.
- Started an own company.
- Career move.
- No cultural fit.
- Insufficient performance.
- Job content.
- Employment conditions.
- Initiative Nedap.
- Initiative employee.

The contract duration of contractors differs, yet we need the distribution to analyze this risk. The impact of this risk varies to the contract duration since the spend plan is valid for those months that are prior agreed. See Figure 9 for the probability density of the duration of contractors. However, the end date of the contract gets rewritten in the data we collected when a contractor stops early. Therefore, the contract duration depicted in Figure 9 is the actual time contractors have worked at Nedap and not the original contract duration that was agreed prior to hiring. This causes the data to be slightly incorrect, yet due to a lack of better data we have decided to use it.

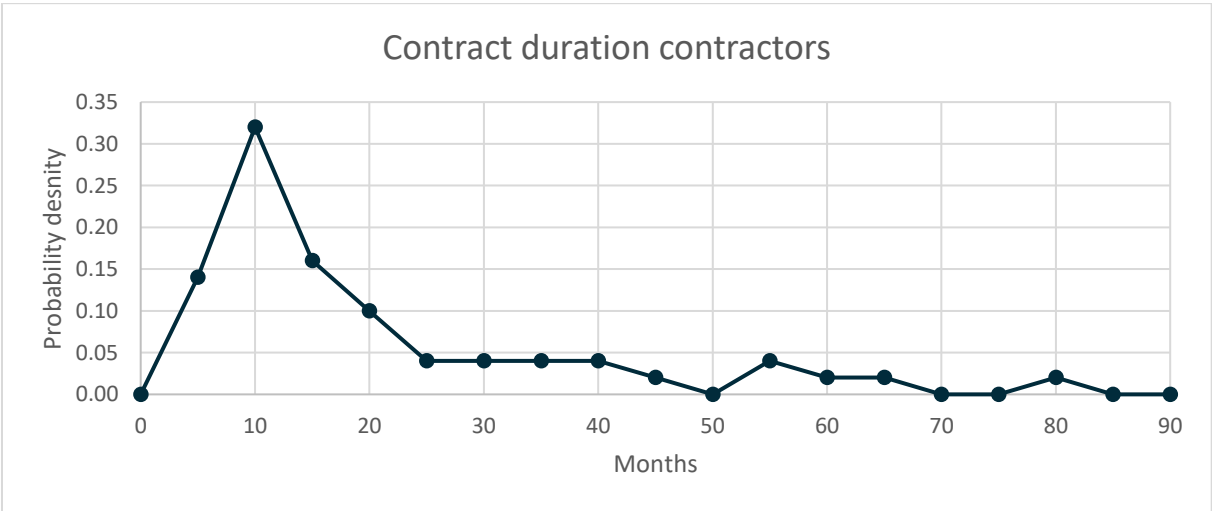


Figure 9. Probability density of the contract duration of contractors that have left in 2022.

As mentioned in Section 2.1.3.3, invoices connected to a spend plan need approval depending on the parameters of the matched spend plan. These parameters are the invoice period, the total budget, the maximum number of invoices in the invoice period and the maximum invoice total. When one of these parameters gets exceeded, an individual that is selected based on the cost center and invoice total needs to approve the invoice. See Table 6 for the ratio of invoices of contractors with approval and without.

Table 6. Processed invoices of contractors matched to spend plans regarding approval in 2022.

Approval	Number invoices	% number of invoices	Net total of invoices (€ x 1,000)	% net total of invoices
With approval	435	55.27%	2,835	54.58%
Without approval	352	44.73%	2,359	45.42%
Total	787	100%	5,194	100%

We built the Monte Carlo simulation using the excel-VBA programming language, see Appendix F for the produced code. Within the code it can be seen that the simulation consists out of different steps created in different subs. Based on the probability distribution of the contract duration, as depicted in Figure 9, contractors are given a duration, after this duration the contractor is not able to send invoice due to the fact that the spend plan has ended. Per month a certain percentage of contractors that still work stop earlier than this contract date. Once a contractor has stopped early, they do not go back to work again. The first month a contractor has stopped early, a small percentage sends a 'faulty' invoice. In 44.73% of the cases no approval is needed, see Table 6. We assume that if manual approval is needed, the invoice always gets removed while the invoice always gets processed when no approval is needed. If this previous 'faulty' invoice of a contractor is processed, there is a percentage chance that this contractor 'repeats' the action and sends one again. However, when the first 'faulty' invoice is removed, a contractor never sends one again. The repeating invoices are of a different amount, yet we assume the parameters of this spend plan is more flexible and thus no approval is needed again. All the invoices that get approved are given an invoice amount based on the probability function of invoices without approval as seen in Figure 8. The sum of these invoices is calculated per run.

The number of months and percentage of invoices where no approval is needed, are constant. The number of months is needed for the complete duration of these contractors. This does not mean that these contractors are the only ones working, because the hiring of contractors is a continuous process, however the simulation shows how much money per number of contractors is at risk. Other numbers and percentages are flexible and thus named as variables, see Figure 10.

K	L
Constants	
Approval	0.5527
No approval	0.4473
Number of months	80
Variables	
Number of contractors	100
Number iterations	100
Faulty	0.1
Repeat	0.8
Early quit per year	0.2017
Early quit per month	0.008751023
MonteCarlo	

Figure 10. Constants and variables in Monte Carlo simulation.

The variables can get adjusted, and sensitivity analyses can be performed. We ran seven scenarios, as can be seen in Table 7, and adjusted the probability for a contractor to send a faulty invoice first time. The scenarios were done with 1,000 iterations, see Figure 11 for results of Scenario 1. As can be seen

in Figure 11, over 94% of the cases, the total loss was €0. In order to show the distribution of the other total losses better, we excluded the cases where the losses were €0 in Figure 12. The results of Scenarios 2 up to and including 6 can be seen in Figure 21 to 25 in Appendix G. We choose to only include the distribution excluding the zero-loss outcome, in order to give a better overview. The results of the scenarios had between 90% and 60% of the runs, a total loss of €0.

Table 7. Scenarios Monte Carlo simulation.

Scenario	Iterations	Faulty
1	1,000	1%
2	1,000	2%
3	1,000	2%
4	1,000	3%
5	1,000	4%
6	1,000	5%

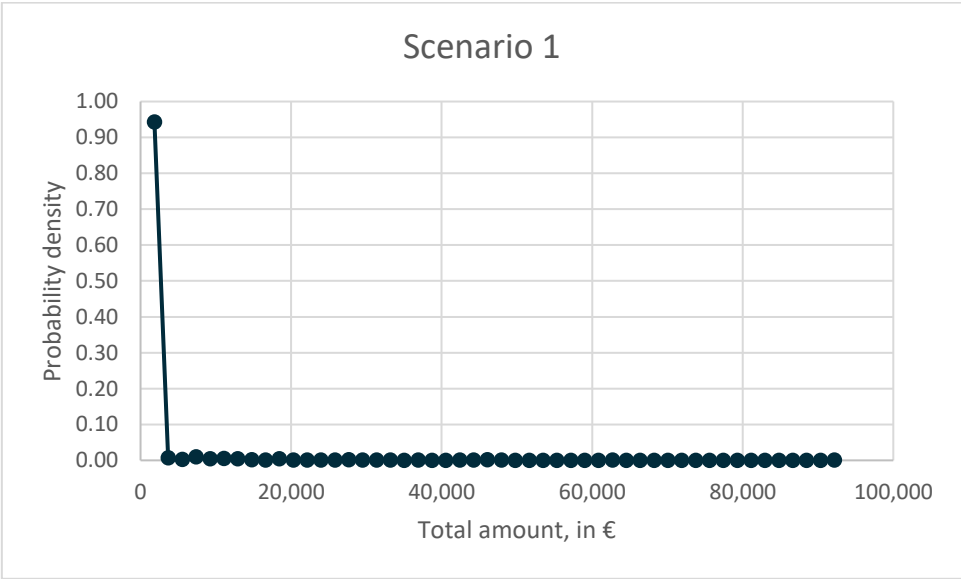


Figure 11. Losses due to the open spend plans.

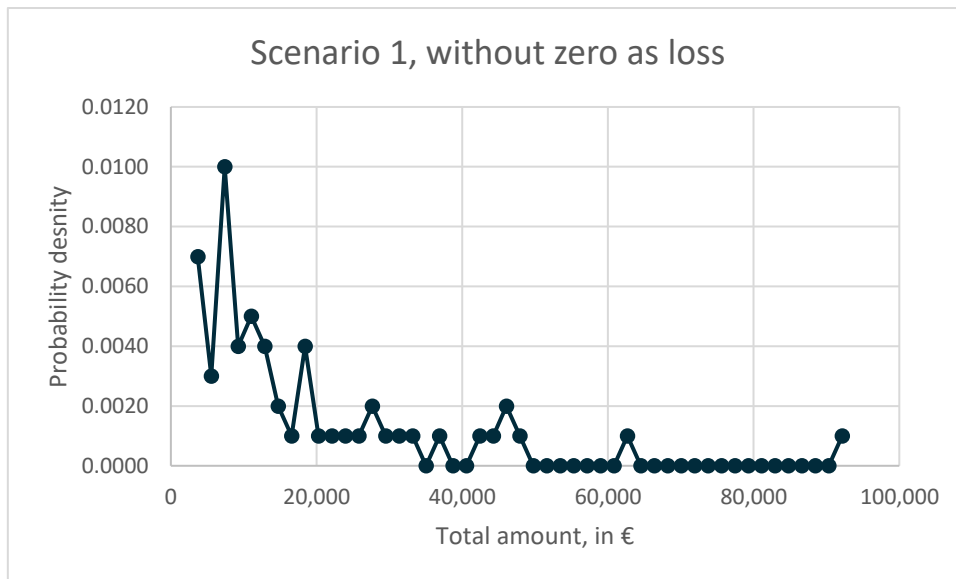


Figure 12. Losses due to open spend plans, excluding the probability of zero losses (94%) .

To conclude, the results of all scenarios indicate that the impact and probability of the risk of open spend plans depends on several variables, which are unknown. However, the used variables gave in most of the runs and scenarios a total loss of €0. This means that the risk can happen, yet the probability is small. Moreover, the impact of this operational risk, when it does happen, has no distinct distribution.

As mentioned, within the Monte Carlo simulation we used the assumption that all the incorrect invoices that exceed its parameters, and thus needs approval, are never approved. This would indicate that approvers would never approve an invoice of a contractor that has stopped early. In the data, we have found that in 2022 seven invoices were approved, transferred to Navision and later removed again. These seven invoices were actual duplicates, yet due to certain settings Basware did not mark these as duplicates. The fact that they were duplicates was discovered after the transfer to Navision, because the ERP system checks again for duplicates. The setting of Basware got changed early 2023 because other individuals already noticed the wrong settings, however these invoices show that individuals make errors while approving invoices. In the cases we discovered, the mistake was made regarding not recognizing and thus approving duplicate invoices. We believe that this mistake is different from the mistake of not noticing invoices of contractors that have already stopped. Therefore, we cannot use the statistics of this mistake for this risk. Nevertheless, this shows that mistakes are made during approving invoices and thus the calculations in the Monte Carlo simulation are optimistic.

4.2.2 Response

As mentioned in Section 3.4, there are multiple manners to respond to a risk after it is identified and analyzed. The response is chosen based on the severity of the risk, the costs of mitigation, the risk appetite of a company and how easy the risk can be avoided. The analysis in Section 4.2.1 indicates that Nedap risks losing money over a period of time if the procedure stays the same and spend plans do not get closed. This number is an estimation, meaning that reality can deviate.

An option to respond to this risk is to accept it, and risk paying invoices wrongly. This would be a good response when other responses are too expensive compared or because the consequences are within acceptable limits. Moreover, this response would be used when other responses are not possible.

Transferring a risk entails the relocation of the risk and thus consequences to a third party. It would not help to take out insurance for this risk, since Nedap would not notice if contractors that have stopped would send extra invoices within the existing spend plan. Another manner to transfer the risk is by hiring a third party to manage and control the contractors, yet this would be more expensive and would still need to be checked. Secondment agencies are already used to recruit and hire contractors, and spend plans are created for these expenses.

It is possible to avoid this risk by not using contractors or spend plans. However, the benefits of spend plans, less manual labor and more automated steps, are valuable. The risk can also be avoided by putting the maximum amount per invoice at €1, so that each invoice needs to be approved prior to the payment. This would however create more manual steps in the process, which is something Nedap wishes to minimize. Avoiding is possible in different manners, yet would not be beneficial for the company.

The last response for the risk is to mitigate, minimizing its probability and/or impact.

Assuming that invoices are only approved manually when they are indeed correct, which we did during the analysis, the risk is only present for contractors with spend plans that have a high maximum invoice total. All the spend plans with a maximum invoice number of €1 would always need approval, and thus would be removed. The impact of the risk can be reduced by lowering the maximum total per invoice of a spend plan, creating that an approval is needed by lower amounts of invoice totals. If a wrongly invoice of a stopped contractor gets sent and processed, the financial impact on Nedap will be smaller. However, it is also possible to reduce the probability of this risk by changing the process and include a step to make the financial controller aware that a contractor stops earlier, causing them to close the spend plan. There is still a chance that they do not close the spend plan for certain reasons, unwillingly or on purpose, yet the probability of the risk will be reduced.

The current process of offboarding someone who stops earlier than agreed is shown in Figure 13. During this process multiple messages go to several internal parties, however no message goes to the financial controller team. A simple message could let the financial controller know that a contractor has stopped, and that they need to check the connected spend plan. Depending on the preferences of the financial control team, the message can either be sent to a general e-mail address created for this purpose or to the e-mail address of the financial controller of that business unit. However, another risk can arise when this mitigation strategy is implemented: Risk 15 of having no backup plan when individuals are absent. When a message is sent to the e-mail address of a specific financial controller while this person is absent, the spend plan can stay open for longer. See Figure 14 for the desired process. The benefits of such an additional step are that it is sent automatically.

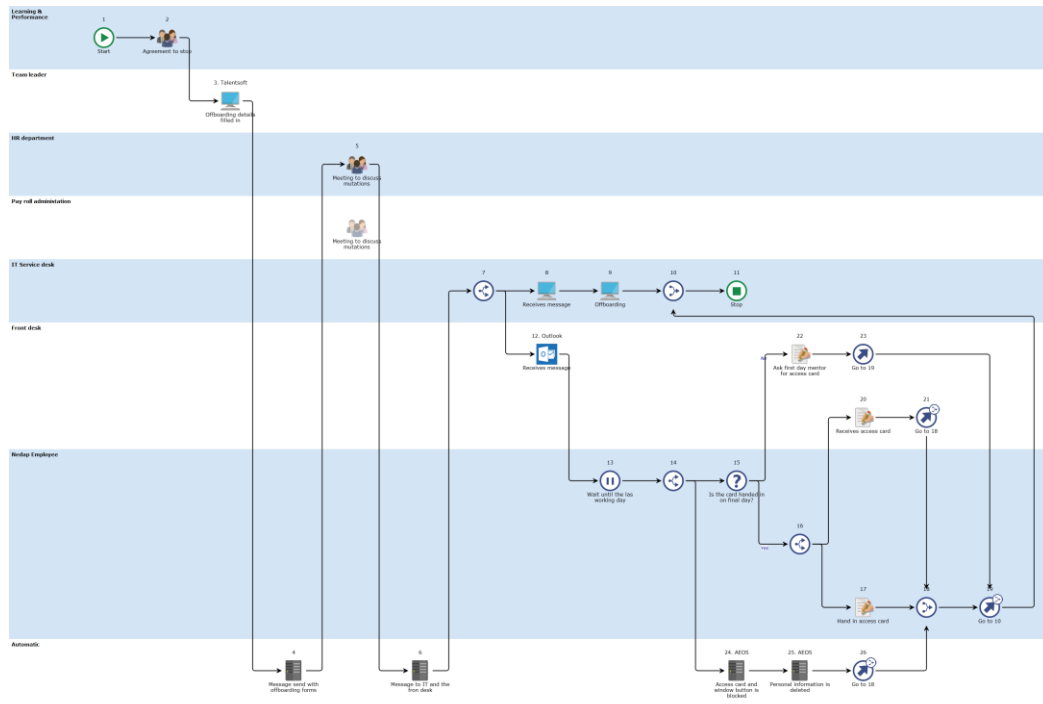


Figure 13. Current offboarding process.

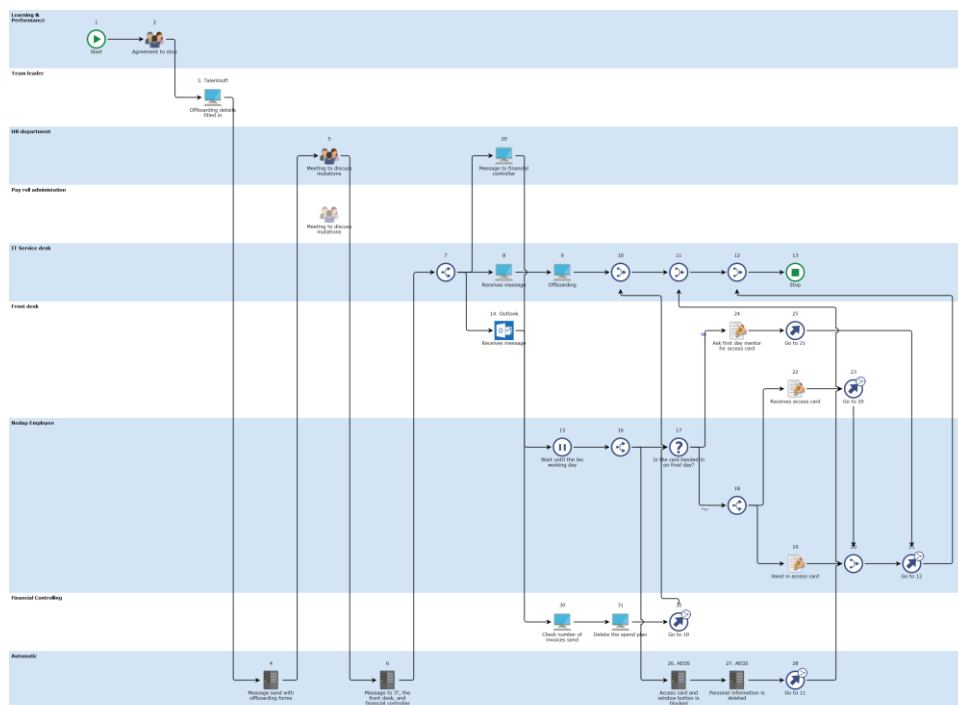


Figure 14. Desired offboarding process.

Another manner to communicate a leave of a contractor is by periodically sending an overview of all employees that stopped working at Nedap. This is already done indirectly when the HR department monthly sends a file to the financial controller team with the individuals currently employees at each business unit and those that left Nedap during that month. The financial controllers can, with the knowledge of this risk, look at this list differently and pay attention to contractors who stopped early.

Moreover, the HR department can simply send a message when they notice when a contractor stops earlier. Yet, this can be forgotten and is again manual activities.

A spend plan can either close by deactivation or by deleting it. The difference is that a spend plan can still be activated when it is deactivated while this is not possible for a deleted spend plan. A deactivated spend plan can be activated without approval if the parameters and budget does not get adjusted. In both cases it is still possible to see the spend plan and its parameters, so the information does not get deleted. Therefore, spend plans should be deleted when knowing a contractor stopped. Moreover, the financial controllers should decide when a spend plan should be deleted after a contractor has stopped. The last invoice is usually not sent at the last working day. It is desired that the spend plan is still open to include the last invoice, yet closed in time to reduce the probability that wrong invoices get processed and paid. Furthermore, no matter which mitigation strategy is used, the financial controllers should check the number of invoices sent in the period. One of the parameters of a spend plan is the maximum number of invoices in a period, meaning that an invoice falls out when this number is exceeded. However, when a contractor stops earlier, the maximum number of invoices in the contract period might not have been exceeded, but that period has become smaller and the maximum number of invoices a contractor was allowed to send might have decreased as well. For example, when a contractor was supposed to work eight months and they were allowed to send one invoice each month, the maximum number of invoices would be set to eight. Yet, this individual might stop after three months while having already sent six invoices, which would not be detected by Basware yet, since six invoices still falls within the parameters of the spend plan. This is an extra check the financial controller should do when closing a spend plan.

It is good to note that this risk does not only imply spend plans of contractors but also spend plans used for other expenses. When the company stops using the services of a company where a spend plan is used, the spend plans need to be deactivated or deleted as well. This is not the risk we identified nor analyzed, yet since the financial controller team has the ambition to work with spend plans more frequently for other expenses, it is good for Nedap to be aware of this and to review its procedure.

4.3 Semi-annual price increases

The semi-annual price increases of EMS partners are difficult to check if they are correct and justifiable. Every business unit has a different manner of controlling the price increases of components, and indicates that extra help or guidance is welcome. The risk is that Nedap is paying more than needed, both on the components and the markup for the EMS party which is a percentage of the cost price.

Twice a year, an EMS partner is allowed to increase the prices of products according to an open price calculation. Three weeks prior to the price change, the partner sends a file including each product and the cost prices of its components. The final price Nedap pays for a product is the sum of the cost price of the BOM plus a markup percentage for overhead costs and profit. The purchase department checks the open price calculation whether the price increases of the components are justifiable. Each business unit handles and checks these differently. It is not possible to check all the components due to time constraints, so only a part of the BOM gets checked. Since over 70 million euros were spend on POs in 2022, a relatively low price increase can still be multiple hundred thousands of euros.

4.3.1 Analysis

The cost prices per product is adjusted in Navision, where all prices are present. However, the open price calculation is sent to purchasers individually. Therefore, the data to analyze this risk is hard to collect. We asked an individual of the purchase department to send the negotiations after the open

price calculation was sent, see Table 14 in Appendix H for these differences in first proposed price by the EMS partner and the final agreed price. The average proposed price increase was 11.46% and the average price saving was 1.60%.

The data used for Table 14 was collected through the email correspondence of an employee and the price was checked in the ERP system. The old prices were equal to what was used in Navision, however the final price differed. A reason for this can be that the dollar to euro rate changed. This is done separately from the semi-annual price increases.

The total amount spent on POs in 2022 was approximately €70,314,000. If we assume that this individual from the purchase department did indeed find all unneeded price increases, we can calculate what the losses would be if this person would not have found it. We assume that this percentage is the same for all products of Nedap and each product would be bought equally, the potential losses for the company in a year are:

$$0.0160 * (70,314,000/2) * 1.1146 + 0.0160^2 * (70,314,000/2) * 1.1146^2 = 63,7467.47$$

This analysis has a lot of assumptions, yet it is not possible to verify if each product has the correct price, since the purchase department already has difficulties with this and because the data is not gathered efficiently.

4.3.2 Response

The first manner to respond is to accept the risk and its consequences. Nedap has chosen to outsource most of its production for certain reasons and is contractually agreed that the EMS partners have the right to increase the prices. It is difficult to check the price increases and might cost more manual labor when the open price calculations are analyzed in more detail. Therefore, Nedap can choose to accept the risk and proceed usually.

Another response option is to transfer the risk to a third party, and therefore also transfer the potential loss. It would not be beneficial to purchase insurance for this risk, because the financial losses would not be known.

Risk avoidance happens when a company eliminates the risk by not proceeding with an activity that is accompanied by a certain risk, or by trading the risk with other risks that are less threatening or easier to handle. The risk that the semi-annual price increases are not correct, which is not seen by the purchase department, cannot be easily avoided. This activity is agreed with the current suppliers and the products are needed for the continuation of Nedap's business.

The last response for this risk is to implement a mitigation strategy that reduces either the probability of the risk happening, the impact of the risk, or both. The impact of the price increase being too high can be minimized by Nedap buying the components that were valued too high themselves, and selling these to the EMS partners. This does already happen when the supply of components gets scarce or becomes more expensive to buy for the supplier which is communicated to Nedap. This requires a lot of manual labor and time, yet has financial advantages. In order to minimize the impact of this risk, this can also be done for components that were priced to be higher than the market price is. However, this again cost a lot of manual labor to go continuously review the component prices. Therefore, this is currently not favorable for Nedap.

The probability of this risk can be reduced, which is more favorable than reducing the impact as explained above. Interviewee 18 mentioned that many risks are "caused by the freedom everyone within Nedap is getting and taking, while management is giving no clear direction or guidance on how to work". Other purchasers agree with this by mentioning that there is no guidance regarding these

semi-annual price increases, while this guidance would be appreciated. This indicates that for the purchase departments, the departments that process the price increases, extra help or advice, is welcome. With more guidance, the probability that prices of components which are too high are not noticed could be reduced.

4.4 Liability of components

Nedap is financially liable for the components that EMS parties buy according to the sent forecast. However, when an EMS partner buys a component that has a minimum order quantity, Nedap becomes liable for the entire batch that is bought even though this quantity is more than the sent forecast. The risk is that Nedap needs to pay for unused components when components get replaced or when an entire product is stopped.

The logistic agreement between Nedap and EMS partners state that:

In case Nedap does not purchase the Product as forecasted ... Nedap shall ... purchase all forecasted Product(s) whereof a production batch has started at the unit price stated in the Purchase Agreement, insofar and to the extent that the Supplier can evidence that supplier had to start up a production batch, in relation with the agreed production lead times, in order to fulfill the delivery commitment. (Nedap, 2017, p.4)

This section is included in the agreement to ensure Nedap's commitment with respect to the forecast, by making it financially liable. This usually happens when a component is changed or when a product is at the end of the product cycle: its End Of Life (EOL). However, "the Supplier shall use best efforts to minimize the costs in case of a cancellation of a Product order, the modification of a Rolling Forecast or the termination of this Agreement" (Nedap, 2017, p.4). Multiple individuals of the purchase department have indicated that in case of excess stock, it is difficult to verify if the supplier indeed used best efforts to minimize the costs.

4.4.1 Analysis

All business units indicated using PCOs in Basware to buy excess stock from EMS partners. We reviewed Basware and searched for the PCOs in 2022 that were used to purchase components due to Nedap's liability. We first used certain keywords to find the PCOs, which were the following:

- Excess stock.
- Obsolete.
- EOL.
- Rest.

After finding these PCOs, we determined which individuals booked the excess stock, and examined their PCO's in 2022. The other PCOs we identified that are created for excess stock, included the words "excess" and "overname".

In total, according to this calculation, approximately 100¹ thousand euros was spent in 2022 for the purchase of excess stock from EMS partners and Nedap SMART. In the first half of 2023, approximately 40² thousand euros was spent for excess stock. These numbers do not include the costs of an engineering change request. The cost of an engineering change refers to a compensation that EMS partners receive when a product gets adjusted, for example when a component gets replaced and

¹ Number is fictitious due to confidential information.

² Number is fictitious due to confidential information.

therefore the production process needs to get adjusted. We did not include these costs because the risk we have identified includes the cost of excess components, and not the fixed compensation.

The best manner to compare the total costs in 2022 is to compare the excess stock bought per obsolete product and compare it to the profit Nedap made from its entire lifetime. This information is not available, nor does each PCO explain in detail for which product the excess stock is. Therefore, we cannot label this number as high or low. If we would like to compare it with a number, we can do this with the annual revenue. In 2022 the revenue of Nedap N.V., including Nedap SMART, was approximately 212.6 million euros (Nedap, 2023), making the costs for excess stock 0.047% of the revenue. Moreover, we can say that a total of six individuals selected this risk to be important for the company, which can indicate that the amount is higher than it could be. However, when the total cost of excess stock would be a x percent higher than it could be, it would still be only a small percentage of Nedap's revenue, at most 0,047 % if 100% of the cost could be avoided.

When components become obsolete, the purchase departments first look whether they can still be used by the EMS partner for other products, or by other business units within Nedap. If this is not possible, the components are bought from the supplier. It has happened in the past that a business unit made an agreement with an EMS party that the components could still be stored at the production facility until they might become useful again. In this case, part of the components was used again, and the EMS company gradually bought back them again. In other cases, the purchase department asks the supplier to throw away the components, hoping that it is being recycled. However, in some cases the components are transported to Groenlo and either stored until they can be useful again, or Nedap try to sell them using the services of a company called Greenchips located in Austria. This company acts as a broker to give electric parts a second life while making the excess stock profitable again. Nedap collects all the excess components, and periodically contacts Greenchips. Most of the business units at Nedap participate, yet not all of them. The person responsible for this initiative believes that this is a matter of time. See Figure 15 for the revenue of this concept for Nedap.

Figure is left out cause of confidential information.

Figure 15. Residual stock sold by Greenchips from 2018 to 2022

4.4.2 Response

This risk can be considered as part of Nedap's business that is present at the EOL of products. Since the total cost of excess stock in 2022 was 0.047% of the revenue and that the risk of having unnecessary components left is only a percentage of the total costs, we can say that the potential loss of this risk compared to Nedap's revenue is not significant. Therefore, a response for this risk can be to accept the potential losses and to continue with the process as it currently is.

The transfer of this risk to a third party is not possible for this risk since it is contractually agreed that Nedap is liable. When new agreements are made or a new EMS partner is contracted, Nedap can try to transfer this liability to the supplier. When the liability is transferred, the risk of excess stock is transferred as well. The only constraint is that the supplier needs to accept this.

The risk can only be avoided when Nedap does not stop with producing certain products and does not change components. However, this would probably be even more costly than the costs of the excess stock.

The last manner to respond to this risk is to mitigate the risk. Currently, Nedap tries to reduce the impact by selling the components either to its EMS partners, by reviewing whether the components can be used by other business units and by using the services of Greenchips. Moreover, a standardized and formal EOL process can help to minimize both the probability and impact of extra costs regarding excess stock.

As explained in Section 4.4.1, the data regarding the purchases of excess stock of EMS partners are located here and there without a structured organization. In order to analyze this risk better and to monitor it, we recommend keeping track of the EOL costs per obsolete product and compare its profit over its entire production life. Moreover, by doing this Nedap-wide the company can compare these costs per EMS partner and per business unit to see where and possible how improvement can be made.

4.5 KRI dashboard

Section 3.5.1 discussed KRIs extensively. Prior to the risk identification and analysis, we believed that this could be relevant and useful for Nedap to monitor both the known risks and the identified risks. This could have been done in a dashboard to convey the information in a visual manner.

However, the three operational risks identified were not suitable to be monitored by KRIs. The first risk, of open spend plans, cannot be monitored because once it is noticed that a spend plan is open while the contractor has stopped, it should be closed immediately. The second risk, of semi-annual price increases can be monitored in a manner of the effect of the price increases, which Nedap currently is doing. Yet, it cannot be monitored whether the price increases are too high. The last risk of having a lot of excess stock at the EOL of a product can be monitored, however the data is unstructured and not located in one place. Therefore, the first step if Nedap wished to monitor this specific risk is to structure the data and collect it somewhere.

Moreover, due the time horizon of this research it is not possible to determine KRIs and create a KRI dashboard for the known operational risks.

5. Conclusion and Recommendations

This chapter includes the conclusion, the recommendations for Nedap and the discussion.

5.1 Conclusion

The S2P process of Nedap includes the acquiring of products and services used for business and the buying of their outsourced products. The company uses several documents during this process, and the invoices can be divided into four categories depending on the kind of costs made. These four categories of invoices all have their own workflows that can be seen in the business process models.

A company such as Nedap will always face operational risks within its processes. This process is accompanied by different risks that Nedap is already aware of, and which are addressed by the company in several manners. The company has a Risk Management Framework on how to respond to a risk and does an annual risk update session with all business units. Moreover, a strategy has been made to battle the component shortage.

However, there are also additional operational risks which are not addressed yet. Risk management can gain insights into potential risks early and work to reduce potential negative effects that they might have. According to diverse literature, risk management usually consists of identifying, analyzing, responding, and monitoring. Nedap can minimize potential losses with risk management.

We identified 25 unaddressed operational risks within the S2P process. By means of interviews with 19 financial controllers and operational purchasers, three risks were identified as the most severe for Nedap. We analyzed these three in order to respond adequately to them. The first risk includes spend plans that stay open after a contractor leaves Nedap earlier than agreed up front, which can cause invoices to be processed when wrongfully send and paid. By using a Monte Carlo simulation, we analyzed that the chances that an invoice of wrongful invoices of early stopped contractor gets paid is low, but that the potential losses vary depending on unknown variables. We recommend changing the process and include a step so that the financial controllers close the spend plan. The second risk identified entails the semi-annual price increases that EMS partners are allowed to implement after having send an open price calculation. The purchase departments find this open price calculation difficult to verify, resulting in potential paying higher prices than in reality the cost price is. The potential loss for this risk is approximately 62 thousand euros, assuming the 1.60% price savings of the proposed price in the eleven products research is representative for the total sales and that the average price increase of all products is 11.46%. Because this potential loss is relatively not high compared to the annual sales revenue, we recommend accepting this risk. The last risk identified by the 19 interviewees is the potential loss that is incurred due to excess stock after a product is stopped or components get changed. When this happens, Nedap is financial liable for the stock of components EMS partners bought according to the send forecast. In 2022, approximately 100 thousands euros was lost due to this, while in the first half year of 2023 40 thousand euros. This risk impact of this risk can be reduced by creating a standardized and formal EOL process, which Nedap currently does not have. Moreover, the company can also choose to accept this risk as being part of outsourcing production.

Due to the time constraint of this research, we were not able to create a method to monitor the three above mentioned risks.

5.2 Recommendations

We recommend Nedap to respond to the three risks we have identified accordingly. The probability of the first risks that invoices of stopped contractors are processed due to open spend plans, is small, yet the impact varies. Since mitigation can be done easily without costs and minimal manual labor, or no manual labor if done automatically, this would be the best response option. The process of the offboarding of a contractor should include a message to financial control. We would recommend the company to mitigate the second risk of price increases by having more guidance on how to check the open price calculations. The third risk was that Nedap is spending more money than needed for excess stock. The total amount spent in 2022 was 0.2% of the revenue. If a percentage of the total amount could have been avoided, it would be an even smaller percentage of the revenue. However, interviewees did identify this risk as being important, which can indicate that the total amount spent can be lowered. A standardized procedure regarding the EOL of products and how to minimize excess stock would help. Therefore, Nedap can either choose to accept or mitigate this risk.

Furthermore, if Nedap wishes to standardize the S2P process regarding POs that the purchase department places, we recommend a general department that is not included in the business units to give more guidance and to keep a helicopter view. Many purchasers believe to have a lot of freedom and would be open for more guidance. Moreover, important decisions regarding EMS partners are currently made by business units themselves, and differ from each other while working with the same EMS party. By having such a department that also keeps track of certain statistics Nedap-wide, the company can analyze the process, and thus also the risks, better for the whole company.

As mentioned, KRIs are useful to monitor risks. Yet we did not determine these in this process due to the identified operational risks not being fit to analyze them in such a manner, and because the data are too unstructured. We recommend for Nedap to determine KRIs in the future in order to monitor risks in an objective manner, preferably Nedap-wide. By having a dashboard, the risks can be better communicated and risk owners are able to easily see when intervention is needed.

5.3 Discussion

Our research had some limitations which can influence its quality. Firstly, there was a fixed time horizon. This research was performed at Nedap in twelve weeks. This time limitation caused us to not be able to analyze all 25 identified operational risks, yet we solved this by choosing three according to the risk owners. This does mean that other operational risks might be more severe for Nedap while interviewees are not aware of them. Moreover, the interviewees could be biased towards the operational risks that belong to steps in the process they perform themselves. The time constraint also limited us in the creation of a KRI dashboard for known operational risks, as explained in Section 4.5.

Another limitation that we experienced was our own knowledge. We are not part of the S2P process and do not know the applications involved from top to bottom. We observed employees working with the systems, yet we believe that this does not convey all the knowledge needed to identify all operational risks present. We tried to manage this limitation by asking people involved to indicate operational risks they observe.

Furthermore, a limitation arose during data gathering for the risk analysis. Data regarding contractors were adjusted when someone stopped early, causing us to guess a percentage how many stops earlier than agreed. Since this risk was not known by the company, there are no historical data on whether and how often this has happened in the past. Therefore, assumptions were made for this risk. For the second risk, semi-annual price increases being higher than justified, data were limited so we only

looked at 11 products of Nedap. The third risk of Nedap being financially liable for components bought by an EMS partner based on the send forecast, was analyzed by calculating the total amount spent on excess stock. However, since the data of this excess stock were not located at one place, it is not known whether all costs for excess stock were included or that costs were wrongly included in this number. Moreover, the numbers used in the entire research were mainly based on data from 2022, which is just one year. When using data from multiple years, a better view of long-term trends can be seen. In addition to this, potential extraordinary circumstances can cause outliers in the data, of which the impact is minimized when using multiple years of data.

References

- Adrian T & HS Shin**, 2014, Procyclical leverage and Value-at-Risk, *The Review of Financial Studies* **27**, 373-403.
- Amédée-Manesme CO & F Barthélémy**, 2018, Ex-ante real estate Value at Risk calculation method, *Annals of Operations Research* **262**, 257-285.
- Baijal R**, 2021, Identification, quantification and monitoring of operational risk, *Journal of Securities Operations & Custody* **13**, 253-263.
- Basel Committee on Banking Supervision**, 2006, International convergence of capital measurement and capital standards, Bank for International Settlements, Basel. <https://www.bis.org/publ/bcbs128.pdf>
- Basel Committee on Banking Supervision**, 2011, Principles for the sound management of operational risk, Bank for International Settlements, Basel. <https://www.bis.org/publ/bcbs195.pdf>
- Best P**, 1999, "Implementing Value at Risk", John Wiley & Sons, NJ.
- Boddy D**, 2014, "Management: An Introduction", Pearson Education, London.
- Cambridge Dictionary**, n.d., Purchase order, <https://dictionary.cambridge.org/dictionary/english/purchase-order>
- CAS Enterprise Risk Management Committee**, 2003, Overview of Enterprise Risk Management. <https://www.bis.org/publ/bcbs128.pdf>
- Coderre D**, 2015, Quantitative key risk indicators: developing data-driven indicators of risk to support the ongoing assessment of risk, *EDPACS* **51**, 1-9.
- Coleman L**, 2009, "Risk Strategies: Dialling Up Optimum Firm Risk", Routledge, London.
- Cox LAT**, 2008, What's wrong with risk matrices? *Risk Analysis* **28**, 497-512.
- Dorofee AJ, JA Walker, CJ Alberts, RP Higuera, RL Murphy & RC Williams**, 1996, "Continuous Risk Management Guidebook", Carnegie Mellon University, PA.
- Eppler MJ & M Aeschmann**, 2008, Envisioning risk: A systematic framework for risk visualization in risk management and communication, *Risk Management* **11**, 67-89.
- Greselin F, F Piacenza & R Zitikis**, 2019, Practice oriented and Monte Carlo based estimation of the Value-at-Risk for operational risk measurement, *Risks* **7**, 1-20.
- Heerkens H & A Van Winden**, 2017, "Solving Managerial Problems Systematically", Noordhoff Uitgevers, Groningen.
- Horwitz R**, 2004, "Hedge Fund Risk Fundamentals: Solving the Risk Management and Transparency Challenge", Bloomberg Press, NY.
- Jallow AK, B Majeed, K Vergidis, A Tiwari & R Roy**, 2007, Operational risk analysis in business processes, *BT Technology Journal* **25**, 168-177.
- Jayantha CAC**, 2018, COSO Enterprise Risk Management (ERM) framework and a study of ERM in Indian context, *The Chartered Accountant* **67**, 82-90.

Jones R, 2016, Recycled bank accounts can mean sending money to the wrong person, <https://www.theguardian.com/money/2016/dec/17/recycled-bank-accounts-send-money-wrong-person>

Kirk J & ML Miller, 1986, "Reliability and Validity in Qualitative Research", SAGE Publications Inc., CA.

Kuusi O, 1999, "Expertise in the Future Use of Generic Technologies", Government Institute for Economic Research, Helsinki.

Linsmeier TJ & ND Person, 1996, Risk measurement: An introduction to Value at Risk, working paper 96-04, Department of Accountancy and Department of Finance, University of Illinois.

Markmann C, IL Darkow & H Von der Gracht, 2013, A Delphi-based risk analysis: Identifying and assessing future challenges for supply chain security in a multi-stakeholder environment, *Technological Forecasting & Social Change* **80**, 1815-1833.

Mordecai Y & D Dori, 2015, Integrating business process modeling with risk management: State-of-the-art.

NASA, 2011, "Probabilistic Risk Assessment Procedures Guide for NASA Managers and Practitioners", NASA, DC.

Nedap, 2017, Logistic agreement, *internal Nedap report: unpublished*.

Nedap, 2022, Code of Conduct, *internal Nedap report: unpublished*.

Nedap, 2022, Nedap risk management framework, *internal Nedap report: unpublished*.

Nedap, 2023, Annual report 2022, <https://annualreport2022.nedap.com/>

Nedap, n.d., Our story, <https://nedap.com/our-story/>

Nissen V, C Heyn & F Termer, 2014, Choosing an adequate level of detail in business process modelling, conference paper, *International Workshop on Enterprise Modelling and Information Systems Architectures*, Luxembourg.

Noble H & J Smith, 2015, Issues of validity and reliability in qualitative research, *Evidence-Based Nursing* **18**, 34-35.

Peček B & A Kovačič, 2019, Methodology of monitoring key risk indicators, *Ekonomski Istraživanja-Economic Research* **32**, 3485–3501.

Prewett K & A Terry, 2018, COSO's updated enterprise risk management framework: A quest for depth and clarity, *Journal of Corporate Accounting & Finance* **29**, 16-23.

Pritchard CL, 2015, "Risk Management: Concepts and Guidance", CRC Press, FL.

Project Management Institute, 1996, "A Guide to the Project Management Body of Knowledge", Project Management Institute, PA.

Shi C, Y Zhan, C Li, P Li & H Zhu, 2020, Using the Delphi method to identify risk factors contributing to adverse events in residential aged care facilities, *Risk Management and Healthcare Policy* **13**, 523-537.

Strzelczak S, 2008, operational risk management, Report z.21 Faculty of Management, Politechniki Warszawskiej.

Weske M, 2007, "Business Process Management: Concepts, Languages, Architectures", Springer, Berlin.

Zio E, 2013, "The Monte Carlo Simulation Method for System Reliability and Risk Analysis", Springer, Berlin.

Zur Muehlen M & DT Ho, 2006, Risk management in the BPM lifecycle, *Business Process Management Workshops* **3812**, 454-466.

Appendices

Appendix A. Current business process model

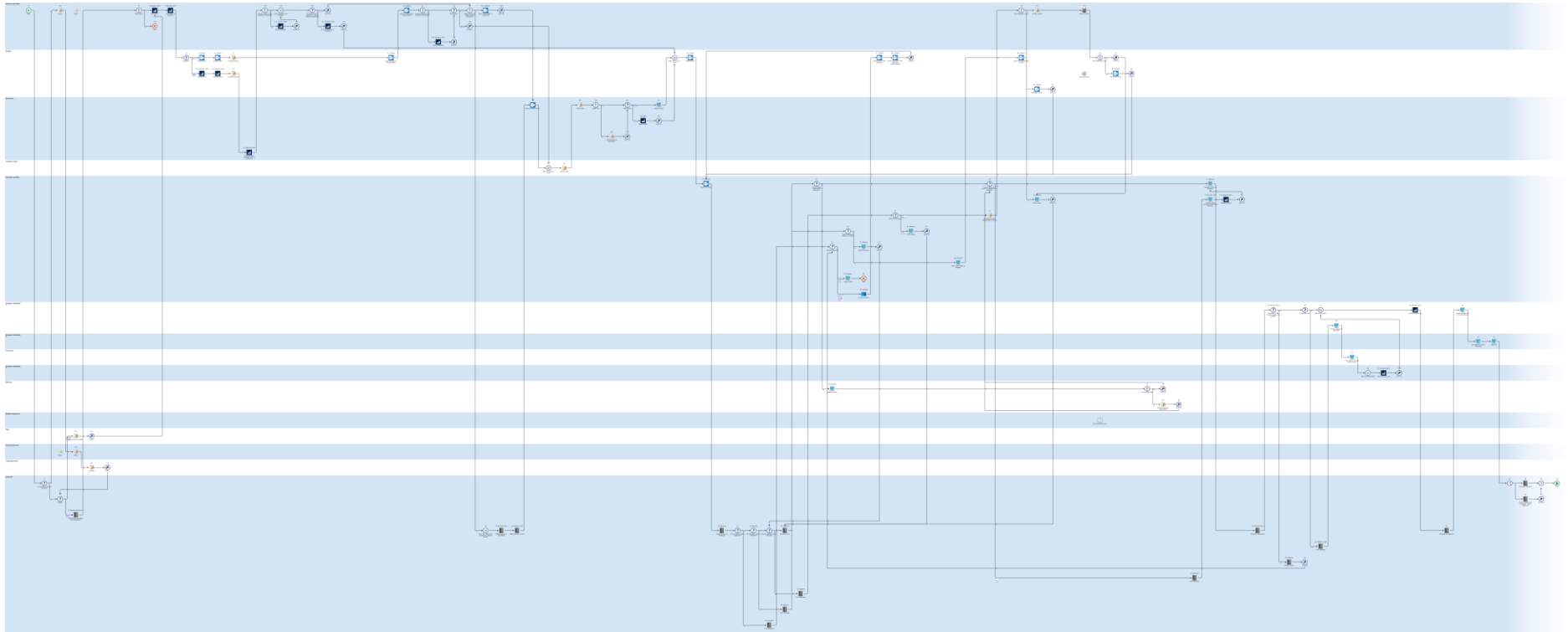


Figure 16. Business process model POs.

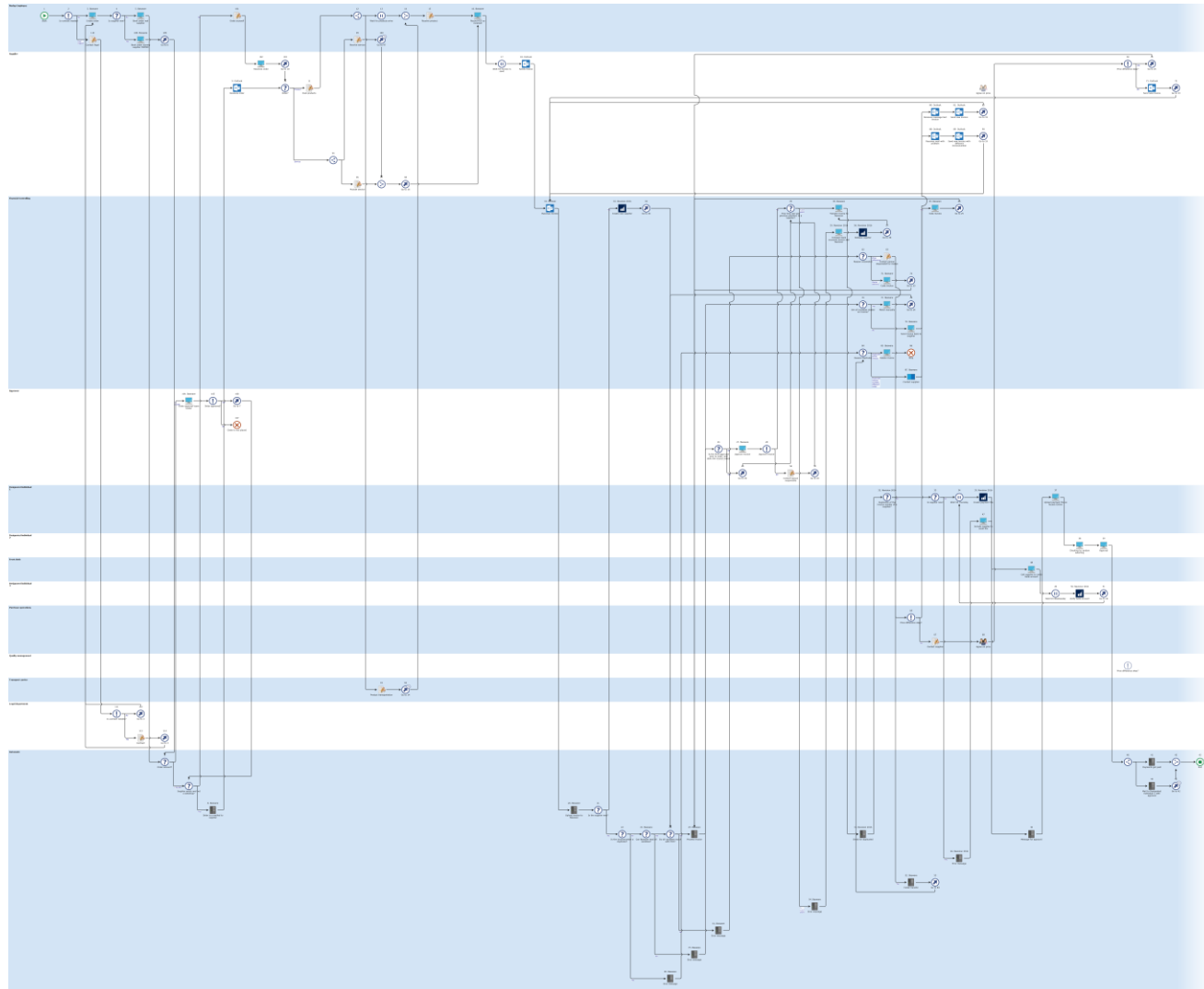


Figure 17. Business process model PCOs.

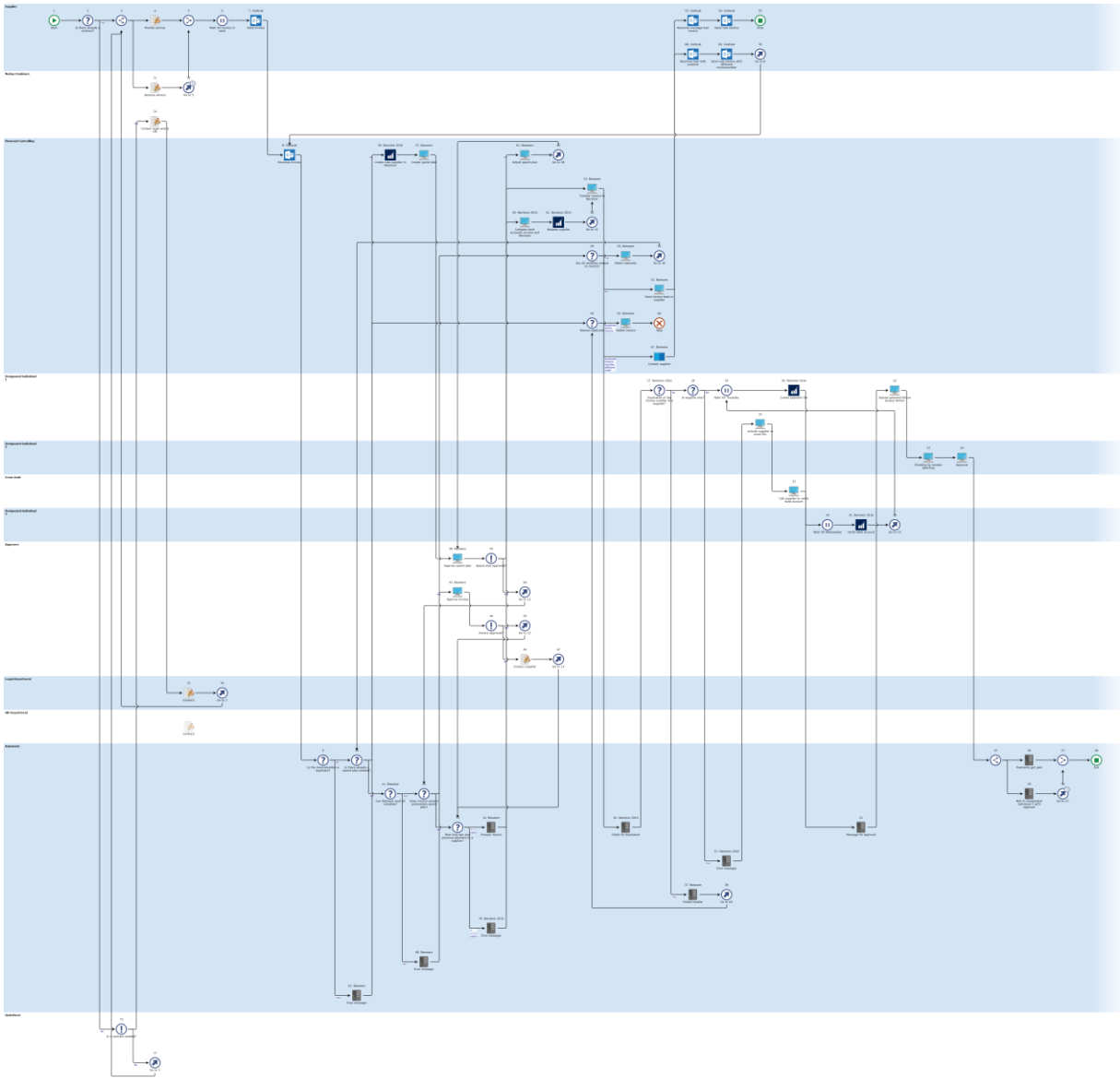


Figure 18. Business process model spend plans.

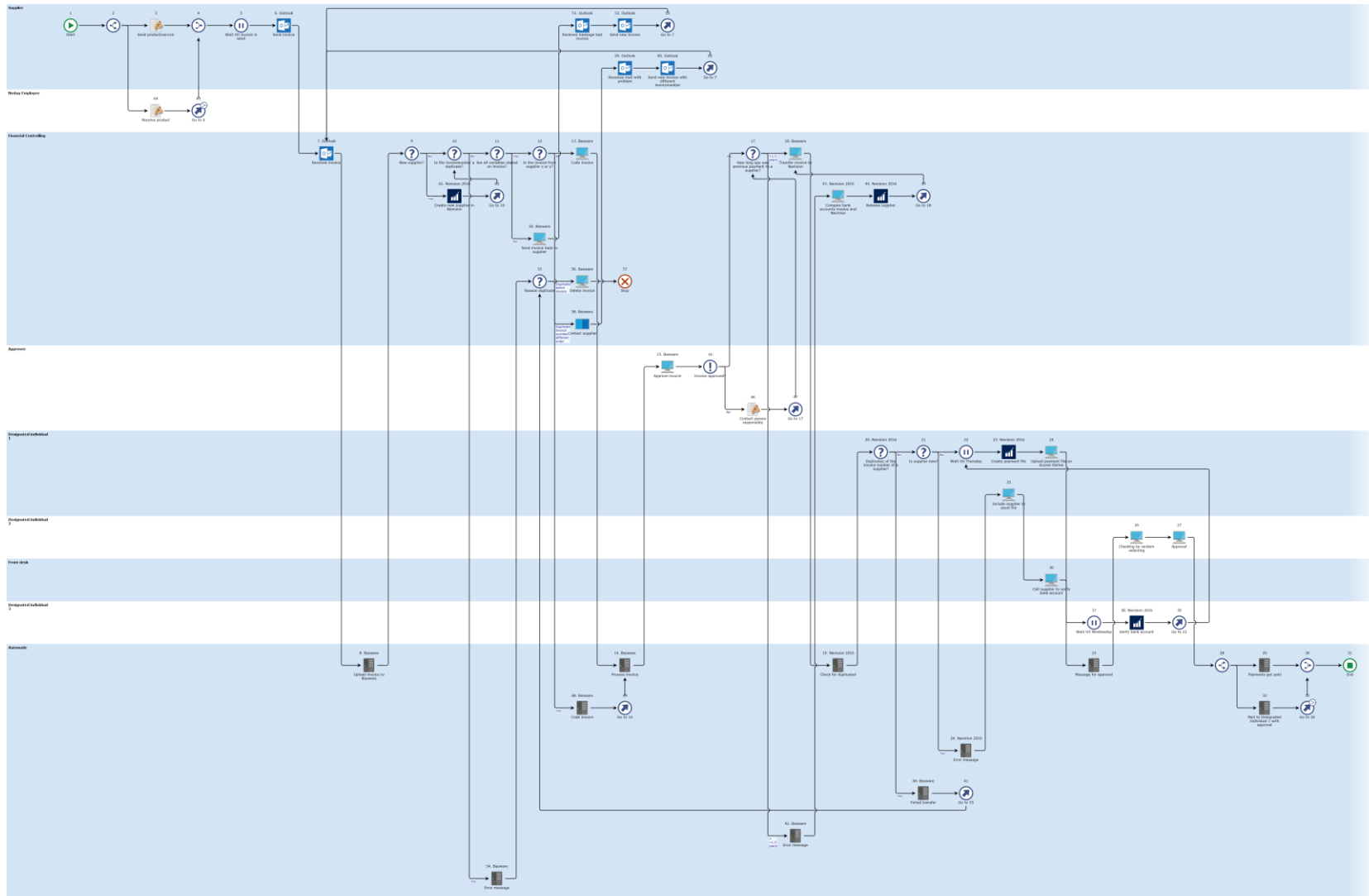


Figure 19. Business process model regular invoice.

Appendix B. Level of detail process model

professional criteria	lowest value	LOD 1 2 3 4 5	highest value	weighting	calculation	weighted LOD	LOD	highest value	LOD 5 4 3 2 1	lowest value	basic conditions
structuring	weak		strong	0.5	0.5 * LOD	1.5	2	low		high	employee qualification (I)
repetitiveness	low		high	0.3	0.3 * LOD	1.2	4	high		low	compliance
automation	manual		automated	0.3	0.3 * LOD	0.9	5	important		unimportant	relevance
modification frequency (I)	frequent		rare	0.3	0.3 * DetLev	0.6	2	low		high	urgency (I)
flexibility (I for D)	high (D) low (W)		low (D) high (W)	0.3 (D) 0.5 (W)	0.3 or 0.5 * LOD	0.9	3	high		low	LOD of best practice
knowledge intensity (I)	high		low	0.5	0.5 * LOD	1					
information and data intensity	low		high	0.5	0.5 * LOD	2					
security aspects	low		high	0.3	0.3 * LOD	1.2					
process KPIs	few		many	0.3	0.3 * LOD	0.3					
triggering and provisioning events	few		many	0.2	0.2 * LOD	0.8					
ressources in process (I)	non-ambiguous		ambiguous	0.2	0.2 * LOD	0.6					
Legend: W - process width D - process depth I - inverse scale to standardize calculation				sum	3.7 (D) 3.9 (W)	sum	11	16	sum		
sum weighted LOD						sum weighting	2.97	3.2	sum LOD	5	
model purpose:							identifying operational risks				
required level of detail:							minimal LOD of 3 required				

Figure 20. Scheme for determination of LOD.

The professional criteria that were identified to influence the adequate LOD can be seen in the scheme in Figure 20. The S2P process is foreseeable at a medium degree, resulting in it being medium structured. The repetitiveness of the process is high since the process is carried out often. As can be seen in Table 1, in 2022 24,935 invoices were processed. For this reason, the repetitiveness can be assumed to be high. Moreover, the automation of the S2P process is medium as well. This is because many steps in the process are automated, yet there are also many steps needed to be done manually. The modification frequency of this process is quite frequent, because of the changing customer demand and growing business. Additionally, the knowledge intensity is relatively high because different parties need to have adequate knowledge. For example, the operational purchase department requires adequate knowledge on when to place an order according to an automatic order recommendation. Moreover, the individuals approving invoices need a lot of knowledge about their departments to know what is going on, in order to approve invoices that are legitimate. The data and information intensity of this process is high, because data are the center of attention. Moreover, the security aspects of the process are a criterion that refers to the concern for the protection of internal company data. Nedap is “committed to and maintains a continuous focus on privacy and data security” (Nedap, 2023, p. 73), and therefore this criterion is categorized as high. Another professional criterion that has an impact on the adequate LOD, is the KPIs used for this process. When many KPIs are used, the LOD must be chosen in such a way that it is possible to calculate these KPIs. Within this process, Nedap does not use KPIs. The triggering events are seen as an input that starts the business process. There are many triggering events in this process. The use of resources in the S2P process is clear, because everyone has a certain task description and steps where this person is responsible for. However, it is not totally non-ambiguous because there is a lot of room and freedom in the job descriptions within Nedap.

The basic conditions that influence the adequate LOD are conditions outside of the specific process (Nissen et al., 2014). The LOD needs to be lower when employees taking part in the business process have a high qualification. If the LOD is too high, limitations of freedom or a reduced motivation can occur. At Nedap, all employees have a high qualification, and this freedom is part of the work culture.

Another condition is compliance of the company regarding rules and regulations. As stated by Nedap (2023), the company has a low risk appetite regarding compliance risk, and therefore this condition is considered high. Moreover, the relevance of the S2P process on the objectives of Nedap is considered high. A further basic condition is the urgency of the process model. If a process needs to be modeled for temporary purposes, the LOD should be lower. The urgency of this process is considered medium. The last condition refers to the LOD of an existing model which can be used. There has been an attempt done in the past to model the lead to cash process within Nedap, yet was never completed. This model had an approximately LOD of 3.

Therefore, as calculated according to Nissen et al. (2014), the minimum required level of detail is 3.

Appendix C. Classification loss events

Table 8. The BCBS classification of operational loss events (BCBS, 2006.).

Event	BCBS definition
Internal fraud	Losses due to acts of fraud involving at least one internal party.
External fraud	Same as internal fraud except that it is carried out by an external party.
Employment practices and workplace safety	Losses arising from violations of employment and health and safety laws.
Clients, products and business practices	Losses arising from failure to meet obligations to clients or from the design of a product.
Damage to physical assets	Losses arising from damage inflicted on physical assets by a natural disaster or another event.
Business disruption and system failures	Losses arising from disruptions to or failures in systems, telecommunication and utilities.
Execution, delivery and process management	Losses arising from failed transaction processing with counter-parties such as vendors.

Appendix D. Supplier duplicates

Table 9. Supplier duplicates according to the same exact name.

Supplier name	Number of duplicates	Explanation
Y ₁	2	One entirely blocked.
Y ₂	2	Both blocked for payment, one without VAT number and bank account number.
Y ₃	2	One entirely blocked.
Y ₄	2	One entirely blocked.
Y ₅	2	Both open, same VAT number, same bank account number, different contacts and addresses in the Netherlands.
Y ₆	2	Both blocked for payment, same contacts and address, one without VAT number and the other without bank account number.
Y ₇	2	Both open, one without VAT number, same bank accounts, same contacts, same address (only house number different).
Y ₈	2	One entirely blocked.
Y ₉	2	One entirely blocked.
Y ₁₀	2	One entirely blocked.

Y ₁₁	2	One blocked for payment and without a VAT number, different addresses in Germany and the Netherlands, different bank account.
Y ₁₂	2	One blocked for payment, same address, same bank account, both without VAT number.
Y ₁₃	2	Both open, both without VAT number, same address, one without bank account.
Y ₁₄	2	One entirely blocked.
Y ₁₅	2	Both open, same VAT number, different contacts, different bank accounts.
Y ₁₆	2	One entirely blocked.
Y ₁₇	2	Different VAT numbers.
Y ₁₈	2	Both open, one without VAT number, different contacts, different addresses in the Netherlands, same bank account.
Y ₁₉	2	Different VAT numbers.
Y ₂₀	2	Both without VAT numbers, different bank accounts, different addresses in different countries, both open.
Y ₂₁	2	One blocked for payment, the other without VAT number, different contacts, different bank accounts, different addresses.
Y ₂₂	2	One blocked for payment, both without VAT number, same address, different bank accounts.
Y ₂₃	2	Different VAT numbers.
Y ₂₄	2	Both without VAT number, both open, same address, same bank accounts, same contact.
Y ₂₅	2	Both without VAT number, both open, same address, same bank accounts, same contact.
Y ₂₆	2	One entirely blocked.
Y ₂₇	2	One entirely blocked.
Y ₂₈	2	Employee, one entirely blocked.
Y ₂₉	2	Employee, both open, one without bank account.

Table 10. Supplier duplicates according to the same VAT number.

VAT number	Number of duplicates	Reason
X ₁	3	Two of Nedap N.V., one incorrect which was changed after this discovery.
X ₂	2	Duplicate with similar supplier name.
X ₃	2	Both open, different bank accounts, similar supplier name.
X ₄	2	Both open, same address and bank account, different supplier name.
X ₅	2	One entirely blocked.
X ₆	2	Both open, similar supplier name, same bank account, different address.
X ₇	2	Similar supplier name, same bank account, one blocked for payment, different contacts.
X ₈	2	One entirely blocked.
X ₉	2	Somewhat different supplier name, both open, same address, same contact, different bank account.
X ₁₀	2	Exact same name, see Y ₅ in Table 9.
X ₁₁	4	All open, different bank accounts and different contacts, similar supplier name.

X₁₂	2	One is subcompany of the other.
X₁₃	2	Similar supplier name, one blocked for payment, different bank accounts, different contacts.
X₁₄	2	Different supplier name, both blocked for payments, one without bank account.
X₁₅	2	Similar supplier name, different bank accounts and contacts, one blocked for payments.
X₁₆	4	Similar supplier names, different addresses, all different bank accounts except two that have the same.
X₁₇	2	Different supplier name, one blocked for payments, different contacts and bank accounts.
X₁₈	2	Exact same name, see Y ₁₅ in Table 9.
X₁₉	2	One blocked entirely.
X₂₀	2	Different supplier name, both open, different bank account and contacts.
X₂₁	2	Different supplier name yet changed so the same entity, one blocked for payment, same bank account.
X₂₂	2	Similar supplier name, both open, different bank accounts and contacts.

Appendix E. Interviews

Table 11. Interviews.

Interview number	Department	Date of interview
1	Financial Control	Through e-mail
2	Financial Control	June 8 2023
3	Financial Control	June 8 2023
4	Financial Control	June 7 2023
5	Financial Control	June 7 2023
6	Financial Control	June 12 2023
7	Financial Control	Through e-mail
8	Financial Control	Through e-mail
9	Financial Control	June 8 2023
10	Financial Control	June 8 2023
11	Purchasing	June 9 2023
12	Purchasing	June 14 2023
13	Purchasing	June 15 2023

14	Purchasing	June 15 2023
15	Purchasing	June 12 2023
16	Purchasing	June 12 2023
17	Purchasing	June 12 2023
18	Purchasing	June 13 2023
19	Purchasing	June 19 2023

Table 12. Number of interviews according to corresponding teams.

Team	Number of interviews	% number of interviews	Number of selected risks	% number of selected risks
Financial control	10	52.63%	45	59.21%
Purchase	9	47.37%	31	40.79%
Total	19	100%	76	100%

Table 13. Number of interviews according to corresponding business units.

Business unit	Number of interviews	% number of interviews
Livestock Management	5	26.32%
Retail	4	21.05%
Light Controls	2	10.53%
Healthcare	2	10.53%
IDEAS	2	10.53%
Identification Systems	1	5.26%
Security Management	1	5.26%
Staffing Solutions	1	5.26%
General	1	5.26%
Total	19	100%

Appendix F. Code Monte Carlo simulation

Option Explicit

```
Dim NumberContractors, NumberMonths, NumberIterations As Integer
Dim Approval, NoApproval, Fault, Repeat, EarlyQuitMonth As Double
```

```
Sub Initialize()
```

```
Dim X, Y As Integer

NumberContractors = Cells(6, 12)
NumberMonths = Cells(4, 12)
NumberIterations = Cells(7, 12)
Approval = Cells(2, 12)
NoApproval = Cells(3, 12)
Fault = Cells(8, 12)
Repeat = Cells(9, 12)
EarlyQuitMonth = Cells(11, 12)
```

```
Range("N1:XX999999").ClearContents
Cells(1, 14) = "#"
Cells(1, 15) = "Contractduur / Maand"
```

```
For X = 1 To NumberContractors
    Cells(X + 1, 14) = X
Next X
```

```
For Y = 1 To NumberMonths
    Cells(1, Y + 15) = Y
Next Y
```

```
End Sub
```

```
Sub ContractDuration()
```

```
'The aim of this sub is to give each contractor a contract duration.
```

```
Dim X, K As Integer
Dim r As Double
```

```
For X = 1 To NumberContractors
```

```
'Loop over contractors.
```

```
    r = Rnd()
```

```
    For K = 1 To 31
```

```
        'Loop over 31 options for contract duration.
```

```
        If r <= Cells(1 + K, 9) Then
```

```
            'See if a random number is smaller or equal to the probability distribution.
```

```
            Cells(1 + X, 15) = Cells(1 + K, 6)
```

```
            'If this is the case, the contract duration is determined.
```

```
            Exit For
```

```
        End If
```

```
    Next K
```

```
Next X
```

```
End Sub
```

```

Sub StopEarly()
'The aim of this sub is indicate which contractors stop early and when.

Dim K, L, Y As Integer
Dim r As Double

For L = 1 To NumberMonths
'Loop over months
  For K = 1 To Numbercontractors
    'Loop over contractors.
    If L > Cells(1 + K, 15) Then
      Cells(1 + K, 16 + L) = "STOP"
      'STOP is used after end of contract duration and thus when the spend plan is closed.
    ElseIf Cells(1 + K, 15 + L) = "END" Then
      'END is used to indicate the prior leave of a contractor, which is automatically true if a
      'contractor already stopped early the month prior.
      Cells(1 + K, 16 + L) = "END"
    Else
      r = Rnd()
      If r <= EarlyQuitMonth Then
        Cells(1 + K, 16 + L) = "END"
        'x percentage of contractors stops early per month, indicated with END.
      End If
    End If
  Next K
Next L
End Sub

```

```

Sub FirstInvoice()
'The aim of this sub is to indicate which contractors send a first invoice when they stopped early.

Dim X, Y As Integer
Dim r As Double

For X = 1 To Numbercontractors
'Loop over contractors.
  For Y = 1 To NumberMonths
    'Loop over months.
    If Cells(X + 1, Y + 16) = "END" Then
      'Select the contractors that have stopped early
      r = Rnd()
      If r <= Fault Then
        Cells(X + 1, Y + 16) = "INVOICE"
        'In x% of the cases the contractor sends invoice, indicated with INVOICE.
      Else
        Cells(X + 1, Y + 16) = "NO INVOICE"
        'If contractor does not send invoice, the cell gets NO INVOICE.
      End If
      Exit For
    End If
  Next Y
Next X
End Sub

```

```

Sub SuccessfulInvoice()
'The aim of this sub is to check whether this first invoice that was send by a contractor gets processed or
'gets removed.

Dim X, Y As Integer
Dim r As Double

For X = 1 To Numbercontractors
'Loop over contractors.
  For Y = 1 To NumberMonths
    'Loop over months.
    If Cells(X + 1, Y + 16) = "INVOICE" Then
      'Select the cases an invoice is send.
      r = Rnd()
      If r <= NoApproval Then
        Cells(X + 1, Y + 16) = "PROCESSED"
        'In x% the invoice does not need manual approvement and thus gets processed.
      Else
        Cells(X + 1, Y + 16) = "REMOVED"
        'In the other (1-x)% of the cases, manual approvement is needed and thus always gets removed.
      End If
      Exit For
    End If
  Next Y
Next X
End Sub

```

```

Sub InvoiceRepetition()
'The aim of this sub is to check whether a contractor of which the first faulty invoice was processed,
'will send one again. We assume that due to the parameters of the spend plan, approval is not needed because
'approval was not needed for the first invoice.

Dim X, Y As Integer
Dim r As Double

For X = 1 To NumberContractors
'Loop over contractors.
  For Y = 1 To NumberMonths
'Loop over months.
    If Cells(X + 1, Y + 15) = "PROCESSED" And Cells(X + 1, Y + 16) = "END" Then
      'Only if a contractor has send an invoice which gets approved, the chance is present that they send
      'another invoice.
      r = Rnd()
      If r < Repeat Then
        'In 80% of the cases this contractor sends another invoice.
        Cells(X + 1, Y + 16) = "PROCESSED"
        'A repeating invoice gets automatically processed since the previous also did not need approval,
        'thus we assume the parameters of the spend plan are wider.
      Else
        Cells(X + 1, Y + 16) = "NO INVOICE"
        'In x% of the cases a contractor does not send an invoice again.
      End If
    End If
  Next Y
Next X

End Sub

```

```

Sub CleanUp()
'The aim of this sub is to clean all cells except for the cells regarding invoices that were processed.

Dim X, Y As Integer
Dim r As Double

For X = 1 To NumberContractors
'Loop over months.
  For Y = 1 To NumberMonths
'Loop over months.
    If Not Cells(X + 1, Y + 16) = "PROCESSED" Then
      'Clean the cells with content other than PROCESSED.
      Cells(X + 1, Y + 16) = ""
    End If
  Next Y
Next X

End Sub

```

```

Sub InvoiceAmount()
'The aim of this sub is to give an invoice amount to the cells of processed invoices.

Dim X, Y, K As Integer
Dim r As Double

For X = 1 To NumberContractors
'Loop over contractors.
  For Y = 1 To NumberMonths
'Loop over months.
    If Cells(X + 1, Y + 16) = "PROCESSED" Then
      'Select all processed invoices.
      r = Rnd()
      For K = 1 To 175
        'Loop over the possible invoice amounts.
        If r <= Cells(1 + K, 4) Then
          Cells(X + 1, Y + 16) = Cells(1 + K, 1)
          'Write the invoice amount in cell instead of PROCESSED.
        End If
      Next K
    End If
  Next Y
Next X

```

```

Sub MonteCarlo()
'This sub calls the previous subs.

Call Initialize

Dim X, Y, Z As Integer
ReDim Outcome(NumberIterations) As Double
Dim Sum As Double

Application.ScreenUpdating = False
'In order to speed up the macro code, the screen updating is turned off.

For X = 1 To NumberIterations
'Loop over iterations.

    Sum = 0
    Range("Q2:XX99999").Clear
    'Clear the data of previous iteration.
    Call ContractDuration
    Call StopEarly
    Call FirstInvoice
    Call SuccessfulInvoice
    Call InvoiceRepetition
    Call CleanUp
    Call InvoiceAmount

    For Y = 1 To NumberContractors
        For Z = 1 To NumberMonths
            Sum = Sum + Cells(Y + 1, Z + 15)
            'Sum the outcome of all faulty invoices that got processed.
            Outcome(X) = Sum
            'Write the sum in the corresponding cell in sheet.
        Next Z
    Next Y

Next X

Application.ScreenUpdating = True
'The screen updating is turned on again after the run in order to show the outcomes.

Sheets.Add After:=Sheets(Sheets.Count)
For X = 1 To NumberIterations
    Cells(X, 1) = X
    Cells(X, 2) = Outcome(X)
Next X

End Sub

```

Appendix G. Results Monte Carlo simulation

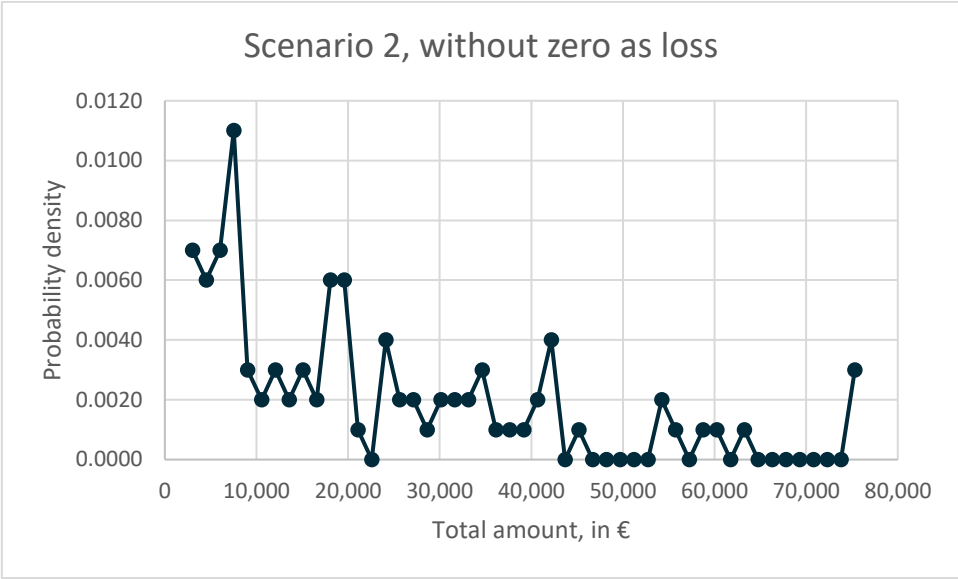


Figure 21. Simulation 1000 iterations, 2% faulty, excluding zero-loss probability (90%).

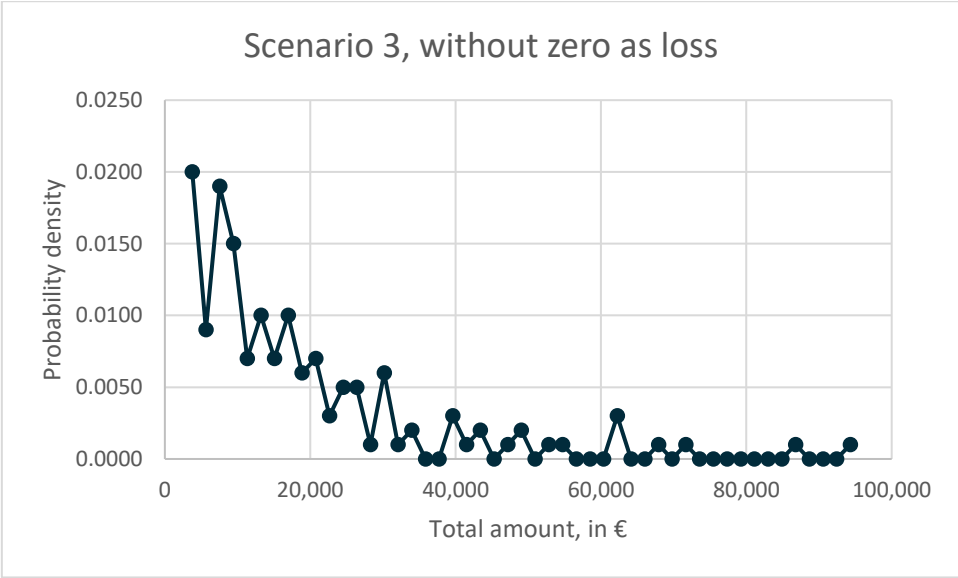


Figure 22. Simulation 1000 iterations, 3% faulty, excluding zero-loss probability (85%).

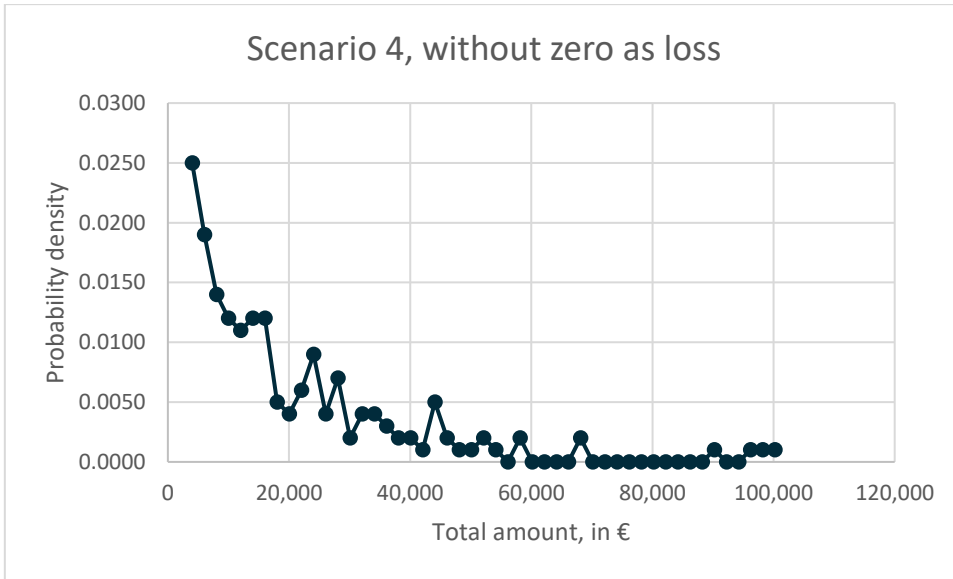


Figure 23. Simulation 1000 iterations, 4% faulty, excluding zero-loss probability (82%).

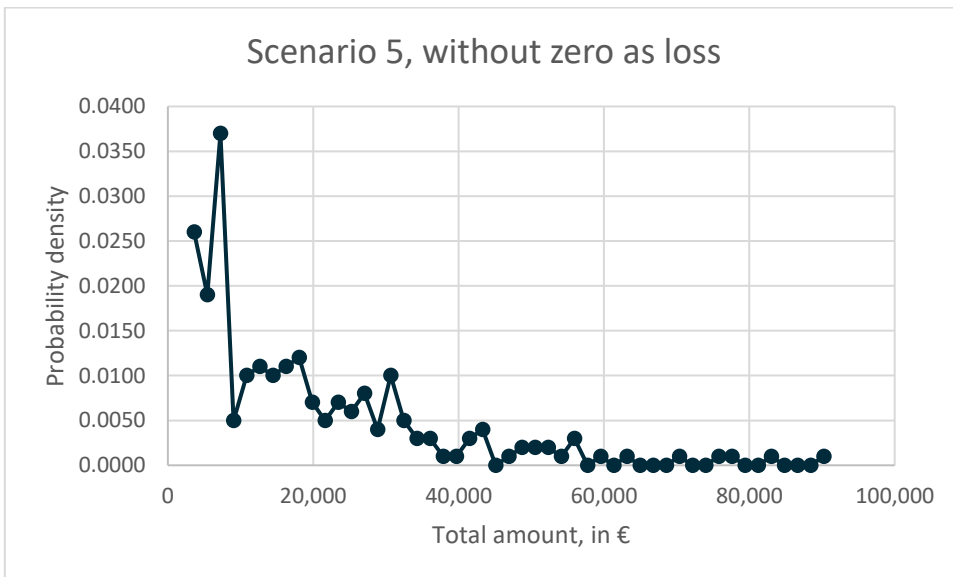


Figure 24. Simulation 1000 iterations, 5% faulty, excluding zero-loss probability (77%).

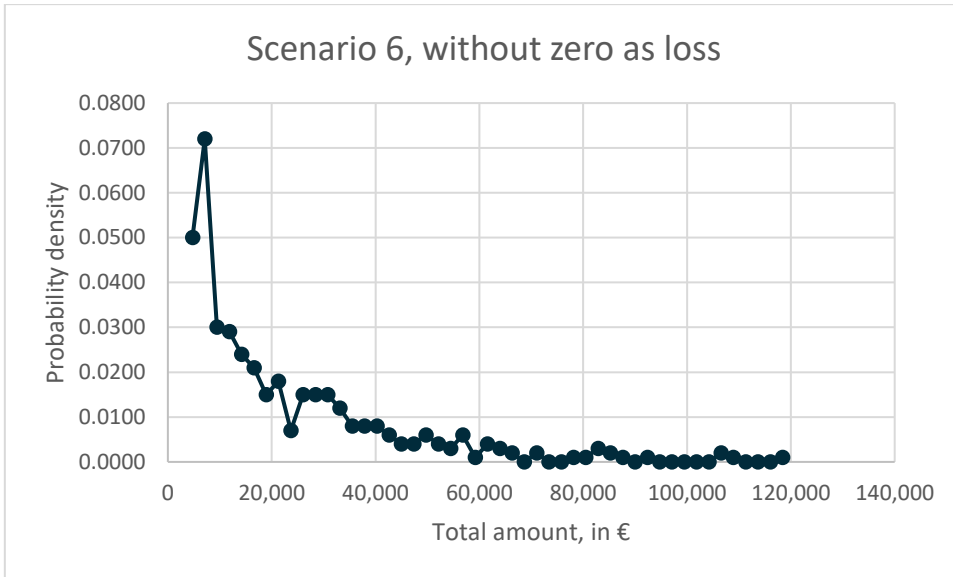


Figure 25. Simulation 1000 iterations, 10% faulty, excluding zero-loss probability (60%).

Appendix H. Semi-annual price increase

Table 14. Price increase.

Product	P ₁	P ₂	P ₃	P ₄	P ₆	P ₇	P ₉	P ₁₁
Old price	9.824609135	9.790026644	15.282963285	15.079159336	9.758272793	9.554468845	10.070589497	9.866785
Proposed price	11.41887541	11.38231678	16.8409749	16.71950363	11.04328429	10.92181302	11.39353844	9.622427
Final price	11.27515442	11.24057193	16.55250367	16.40016176	10.85942784	10.70708593	11.20968199	9.486307
% proposed price increase	0.162272743	0.162644106	0.101944341	0.108782211	0.131684318	0.143110433	0.131367577	-0.02477
% savings	0.012586265	0.012453075	0.017129129	0.019099961	0.016648712	0.019660389	0.016136906	0.014146

