

**MASTER**

**Data quality monitoring within the real estate business chain**

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*Award date:*  
2012

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Eindhoven, September 2012

**Data quality monitoring within the  
real estate business chain**

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in partial fulfilment of the requirements for the degree of

**Master of Science**

**in Business Information Systems**

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# Data quality monitoring within the real estate business chain



A thesis submitted for the degree of  
Master of Science at  
Eindhoven University of Technology

September 2012

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Master thesis titled

**“Data quality monitoring within the real estate business chain”**

As an element of the master Business Information Systems at the

**Eindhoven University of Technology**  
**Department of Mathematics and Computer Science**  
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## ACKNOWLEDGMENTS

This thesis is the result of my graduation project, which concludes the master program Business Information Systems at Eindhoven University of Technology. The project was carried out within the Systems and Process Assurance Department of PwC Netherlands.

PwC provided me the opportunity to apply my industrial engineering skills within a very challenging environment. During the research within my thesis, I was allowed to speak and meet a wide variety of interesting and inspiring people. This is the place to thank them for their support and their role in the development of this master thesis research project. I want to thank all the people that were involved in this project, whom I have interviewed, and my colleagues at PwC SPA FS for their stories on, and off duty.

I would like to thank Martijn van Zomeren, my company supervisor, in particular. I would like to thank him for the inspiring and motivating meetings. With his excellent guidance he provided me challenging thoughts with which he not only contributed to the project, but also definitely to my personal development. Also the input of Maurits Cammeraat and Cor Treure were valuable for this project. The meetings with Maurits helped me to pursue the topic and find the right angle to tackle its challenges. The meetings with Cor were inspiring and sharpened my ideas.

At the Eindhoven University of Technology, I would like to thank Rik Eshuis for his guidance, patience, and support. He always made time for me and helped me in writing the report that you see today. I also want to thank Marco Comuzzi for his time to make valuable comments on my master thesis and Fabrizio Maggi for his time to read my report.

Last, but definitely not least, I would like to thank my parents, brother, and friends, who have supported me during my time as a student, and especially during my graduation!

Joost Hendriks  
September 2012

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## MANAGEMENT SUMMARY

We are currently living within a debt crisis. The confidence within the real estate market seems to have reached a new low point. Due to the value development within the real estate sector, enormous depreciations have taken place. Because of mutual distrust, financial institutions are lending less money to each other. Even several large banks went bankrupt.

The sector aims to return the confidence within the market. Therefore, transparency is an important condition. Transparency makes it possible for stakeholders to improve risk identification and reporting.

Partly for this reason, the REIM CBRE Global Investors has set up the data exchange platform REDEX. The purpose of REDEX is to share both financial and non-financial data within the real estate business chain in a structured and consistent manner. This is required for a proper valuation of real estate properties and the identification of risks.

Besides facilitating the exchange of data and providing a clear data structure, REDEX also performs quality checks on the exchanged data. These checks are carried out to ensure the accuracy, completeness, and timeliness, of the data, as much as possible. Because the platform only exchanges data, and does not actually store it, it can only perform data checks based on the information available within a data transaction.

The research within this thesis was focused on the determination of the opportunities of an additional add-in tool between REDEX and the information system of a REIM. An add-in tool within the domain of the REIM, that makes it possible to check relations between data transactions. In this way the tool can guarantee the accuracy and completeness of the exchanged data even better.

This thesis determines data check scenarios that could potentially replace the current used assurance methods. More important is that those checks can give more frequent assurance than the current methods and can conduct a full survey. Current methods like the vastgoedverklaring uses sample surveys that are performed manually.

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A proof of concept is given by both a functional and a technical validation. Besides the determination of data check scenarios a functional design is given for a tool that can perform those data checks.

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## 1.1 List of abbreviations

IS	Information System;
ISAE3402	International Standards for Assurance Engagements No. 3402;
PM	Property manager;
REDEX	Real Estate Data Exchange platform;
REIM	Real Estate Investment Manager;
REMS	Real Estate Management System;
SAS70	Statement on Auditing Standards (SAS) No. 70;
SLA	Service Level Agreement;
SOA	Service Oriented Architecture;
XML	Extensible Markup Language;
XPath	XML Path Language;
XSD	XML Schema Document;

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# 1. INTRODUCTION

This thesis is about real-time monitoring of the quality of real estate data exchanged between property managers (PMs) and Real Estate Investment Managers (REIMs). In particular, data related to real estate properties exchanged via the Real Estate Data Exchange (REDEX) platform. The project is carried out at the System and Process Assurance department of PwC Netherlands. The chapter starts with the company description and in introduction to the project. Then, the problem statement is introduced and the research significance is stated. The chapter concludes with the used research method that includes the structure of the report.

## *1.1 Company description*

PwC is one of the world's largest providers of assurance, tax, and business consulting services. Together with Deloitte, Ernst & Young, and KPMG, it is part of the 'Big Four' accountancy firms. PwC has more than 161,000 employees located in 154 countries. PwC's overall gross revenue over the financial year 2010 is 26.6 billion US dollars. Many PwC firms have a leading position in their market.

The clients of PwC range from large global organizations, to start-ups, governments and other non-profit organizations. More than 80 percent of the Fortune Global 500 companies work with PwC.

The Systems and Process Assurance (SPA) department is part of the business unit Business Assurance Services (BAS). The department provides reviewing services related to the internal controls of organizations around the financial reporting process. This includes the financial business processes and the IT management controls of their clients.

IT and financial reporting processes are becoming increasingly complex while even greater reliance is being placed on the information produced by these systems and processes. Furthermore, new regulations in many countries put a greater emphasis on internal controls and often require independent assurance on the effectiveness of internal controls environment. SPA provides the assurance.

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## *1.2 Project background*

Ever since the financial crisis started during the summer of 2007, the real estate sector faces a decrease in confidence from the market. The crisis is mainly initiated by the sudden drop in value of mortgages, packed as bonds, in the subprime category. This was caused by the bad circumstances within the American housing market. Devaluation of bonds led to enormous depreciations at the financial institutions. As it was unclear what institutions were in big problems because of the depreciations, financial institutions stopped lending money to each other and several banks went bankrupt.

Before the financial crisis the real estate sector had not really a good image. Money-laundering was concerned to be related with real estate (Duyne & Soudijn, 2009) and there was a big real estate fraud case within the Netherlands in 2007 concerning a fraud of 250 million Euros related with among others the large project developer 'Bouwfonds' and the pension fund of Philips (NRC, 2007) (Elsevier, 2009). Also the authorities regulate the sector very strictly.

Transparency is of great importance to regain the confidence in real estate and to return the stability in the market. It leads to an increased level of risk identification. To improve the level of transparency within the real estate sector, but also the operating efficiency and consistency within the exchange of data, ING Real Estate Investment Management NL (ING REIM NL) started the REDEX project back in 2006. Since October 2011 ING REIM NL is acquired by CB Richard Ellis (CBRE) Global Investors. PwC has been involved with the design and implementation of REDEX since 2006.

In the first section of this chapter a short overview of the real estate stakeholders and their relations is sketched to provide necessary background information. Next, the REDEX platform is introduced. The third section zooms in at the problems of one of those stakeholders, the REIMs. Then, the relation between assurance and IT auditing is described. The section ends with a statement about the research significance.

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### **1.2.1 Real estate market**

The real estate market has several stakeholders connected with each other, each with its own role. This section gives an overview of the real estate stakeholders and their roles to provide some basic background information.

#### **Investor**

Real estate investors invest their money in real estate funds in return for a potential profit. The investors could be institutions (e.g. insurance companies, pension funds, corporations, etc.) and/or private investors.

#### **REIM**

Real Estate Investment Managers (REIMs) cope with the management of real estate funds in order to meet specified investment goals for their investors. REIMs need to be transparent to show their investors how they are investing their money. A Real Estate Investment Manager (REIM) contains three different roles; the fund managers, the portfolio managers, and the asset managers.

#### **Fund manager**

The fund manager makes investment decisions, based on the internal rate of return (IRR) of portfolios, using the money investors placed under his control. He is responsible for the financial performance of the fund and needs to justify the results to the investors. The fund manager makes a forecast of the expected rate of return of the fund. He determines the investment directions and their influence on return and risk profile. He is aware of the solvability of the fund and whether it is necessary to offer extra fund participations to attract additional external financing.

#### **Portfolio manager**

The portfolio manager selects appropriate investments within his portfolio and allocates the investments properly for an asset-management vehicle. This is done based on diversification of risk. He allocates what proportion of his portfolio should contain e.g. retail, offices, and residential properties. It is expected portfolio managers know the latest market developments.

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### **Asset manager**

The asset manager is specialized in an asset class (e.g. retail, offices, residential etc.) and manages those assets within their specialization. He has knowledge about what is the position of certain properties within their asset class, what is the rental availability of the properties, and what are the needs of the potential end-users.

### **Service providers**

Besides the investors and the three roles within the REIMs there are also property managers, appraisers and realtors. The property managers are in their role responsible for operating issues concerning to the real estate assets. Issues like dealing with tenants, and repairing and improving of real estate properties. The appraisers are the one who set a value upon real estate properties. Realtors, also known as real estate brokers, are the intermediary party between buyers and sellers of real estate properties.

Between the stakeholders described above a lot of information is shared within the business chain. REIMs regularly request information from the property managers about their properties to perform cash and liquidity management. To facilitate this exchange and to increase the level of transparency between stakeholders, REDEX is designed.

### **1.2.2 REDEX**

REDEX stands for Real Estate Data Exchange and is an IT platform with the objective to connect REIMs with their service providers (i.e. realtors, property managers, and appraisers). By using this platform data can easily be passed between systems and it makes seamless and real time data collection possible for reporting of both financial and non-financial information. Besides the transport of data the platform also performs data quality checks over the exchanged data between parties. These quality checks remove some potential errors that have occurred in the past.

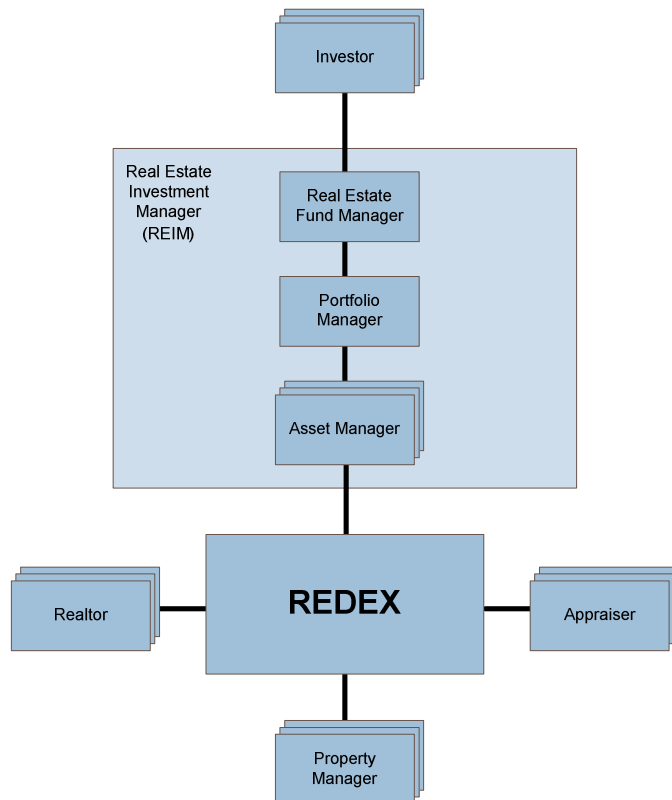
An advantage of the platform is that it enables stakeholders to keep using their own reporting system because working with REDEX does not force organizations to switch information systems. It uses an application that could be plugged into the organization's current information system (PwC, 2011).

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REDEX makes use of the world-wide available open source standard OSCRE (Open Standard Consortium for Real Estate). Besides the name of the standard, OSCRE is an international non-profit collaboration network of real estate organizations, who wants to make the real estate sector more efficient by using digital data exchange. The REDEX platform makes use of XML requests to exchange data between the stakeholders. REIMs send data requests, that contain a set of requested attributes, to their service providers. Within a request there is a set of mandatory attributes and a set of optional attributes. The attributes are defined within the OSCRE standard and contain information related to real estate properties (e.g. type of property, valuation, rent, depreciation, occupation/vacancy, maintenance costs, etc.). The platform logs the data transactions between parties but does not actually store the real estate data, which is exchanged between stakeholders. The data is not stored in a central database at the REDEX platform because of security reasons. It is absolutely no option for the REIMs that their data is stored outside their IT landscape because of the confidentiality of the data. Because REDEX does not store any data it can only perform checks within data transactions. It cannot perform quality checks between transactions. Within this thesis the term transaction is used for an instance of a data transfer between PMs and REIMs. This includes the whole REDEX process from sending a request from the REIM to the PM till receiving the data response from the PM at the REIM.

The quality control within REDEX checks whether the mandatory attributes are present in the retrieved data (also called; response) by using the XSD (XML Schema Document) language. By using this language can also be checked whether the attribute values within the response are according request. This means whether the attribute values are correct regarding the enumeration values within OSCRE/REDEX and whether the attributes have the right type of value (e.g. integer, string, date). The XPath (XML Path) query language checks whether the requested optional attributes are present in the response. When a response on a request is incorrect, REDEX does not transfer the response to the sender of the request, but instead, returns an error to both parties. The request structure itself regulates the data exchange between stakeholders. Only when a request is sent by the REIM, he will retrieve information from the service providers. The requests are scheduled within REDEX based on the SLAs between the REIM and the service providers.

*Figure 1* shows an overview of the data communication flows (including the REDEX platform).



*Figure 1: Overview of the data communication flows including the REDEX platform*

The Real Estate Investment Manager (REIM) as shown above is a group of roles that are often combined within organizations. As described in section 1.2.1, when the term REIM is used within this research the roles real estate fund manager, portfolio manager, and asset manager, are meant.

The overview in *Figure 1* is designed from the perspective of the real estate fund manager. In relation to a single real estate fund most stakeholders have multiple instances on average. This is indicated with the three shifted boxes per stakeholder. The figure shows the common situation. This means e.g. although the figure shows multiple investors it could be the case that only one single investor is involved with a real estate fund.

Furthermore, looking at *Figure 1*, it looks like that only asset managers use the retrieved data from REDEX. This is not true. Asset managers use the retrieved data within their analyses and portfolio managers use that data in an aggregated form. Once again fund managers use



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aggregated data from the portfolio managers. In this way the controls within REDEX influence the use of data within the whole business chain upstream.

Nowadays, besides CBRE Global Investors, also ASR Vastgoed Vermogensbeheer, Syntrus Achmea and Vastgoed Management Nederland (VGM NL) participate within the REDEX foundation. The platform is in use since 2009.

### **1.2.3 REIMs**

Real Estate Investment Managers (REIMs) regularly request information from the PMs about their properties to perform cash and liquidity management. This information need is based on content and frequency.

REIMs request the following types of information regarding their properties from their PMs (OSCRE REDEX PMR NL v.2.4.8c, 2011):

- Financial transaction      Information like references to the lease contract, to the bailiff, and to the real estate unit. Also financial entries like the effective date of the transaction, the service charge period, and the net amount;
- Interest (lease)            Information about the lease and the tenant like lease charges and name and address of the tenant;
- Unit                            Information about the unit such as address, number of square metres and quality labelling.

Before REIMs start their analyses they need assurance about whether the received data is accurate and complete. The PwC Audit Guide 6012 (2011) gives the following definitions for the terms accurate and complete:

- Accurate:                    The transactions are recorded at the correct amount, in the appropriate account, and proper period;
- Complete:                  All occurred transactions are recorded and accepted for processing once and only once and in the proper period.

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The accurateness and completeness of data is very important within this research. Section 2.2 about data quality introduces some additional definitions. For now, above definitions give enough background.

Some REIMs have set up their own controls with which they perform quality checks over the received data transactions to cover themselves against inaccurate and incomplete data. Not all REIMs have set up these kinds of controls. The REDEX foundation wants to provide an additional level of comfort over the received data transactions to the REIMs themselves.

Like explained within the REDEX section additional checks could not be done at the REDEX platform itself because the platform does not store the transferred data. On the other hand those additional checks to validate the accuracy and completeness of the transferred data can be done at the information systems of the REIMs.

#### **1.2.4 Assurance**

This section explains the need of assurance certificates within business value chains. Like explained in section 1.2.1 the real estate market is built up on several stakeholders; from investors to PMs (see *Figure 1*). Each stakeholder's role could be a user organization or a service organization depending on the relation with other stakeholders.

User organizations need assurance that the service organization's controls are properly designed, implemented, and are working effectively. Service organizations could share a Third Party Assurance Report (e.g. ISAE3402) regarding the effectiveness of their relevant controls with their clients.

An ISAE3402 is a Third Party Report that enables user organizations (and its auditors) to acquire assurance regarding the design and operating effectiveness of those controls they find relevant. The Type I report describes the service organization's description of controls at a specific point of time and a Type II report adds detailed testing of the service organization's controls over a period of minimal six months.

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It is an auditing standard and not a pre-determined set of standards that a service organization must meet to pass the test (isae3402.com). The statement assures that the data distributed by the service organization is sound. This means, with reasonable assurance, the service organization distributes their data complete and accurate. An independent accountant documents his observations, which guarantee complete transparency. The ISAE3402 replaced the SAS70 report. SAS70 only addressed the financial reporting requirements of users of service organizations and was limited to controls regarding the processing of financial transactions.

Currently, both PMs and REIMs need an ISAE3402 statement for their users. Besides the ISAE3402 statement the REIMs also need an 'independent auditor's report' (in Dutch: vastgoedverklaring) to give their user organizations assurance about their controls. A solution to the problem definition (see section 1.3) could cover parts of those assurance statements.

At this moment the issuance of a vastgoedverklaring is realized on a yearly basis. Because data is exchanged more frequently than before, and is going to a real-time exchange, there is a need for assurance on a shorter time interval. Real-time financial reporting requires continuous auditing because there is a need for continuous assurance over the quality and credibility of the information presented. Improving the internal controls and thereby the quality and accuracy of information within financial reports, helps to improve corporate governance and investor confidence.

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### 1.3 Problem definition

This section introduces the problem definition that is central in this thesis. Based upon interviews with Maurits Cammeraat (Senior Advisor, PwC Real Estate), Stefan Verweij (Partner, PwC SPA Financial Services), Daan Padmos (Manager, PwC SPA Financial Services) and Cor Treure (Chairman, REDEX Foundation) the following problem definition is defined:

During the exchange of data between property managers and real estate investment managers (REIMs) the REDEX platform cannot guarantee the accuracy and the completeness of data between transactions.

REIMs need to be assured about the accuracy and completeness of the exchanged data via REDEX before they start their cash and liquidity management practices. REDEX checks a number of aspects within data transactions using the definitions within OSCRE, XSD and XPath. Because REDEX does not store the actual real estate data itself it cannot perform relational checks between transactions. The REDEX foundation would like to have the option to provide REIMs an add-in tool that assures the accuracy and completeness of data between transactions.

Figure 2 gives an indication of the position of the add-in tool. Within this figure the dotted lines between the information systems of the stakeholders indicate their organizational boundaries.

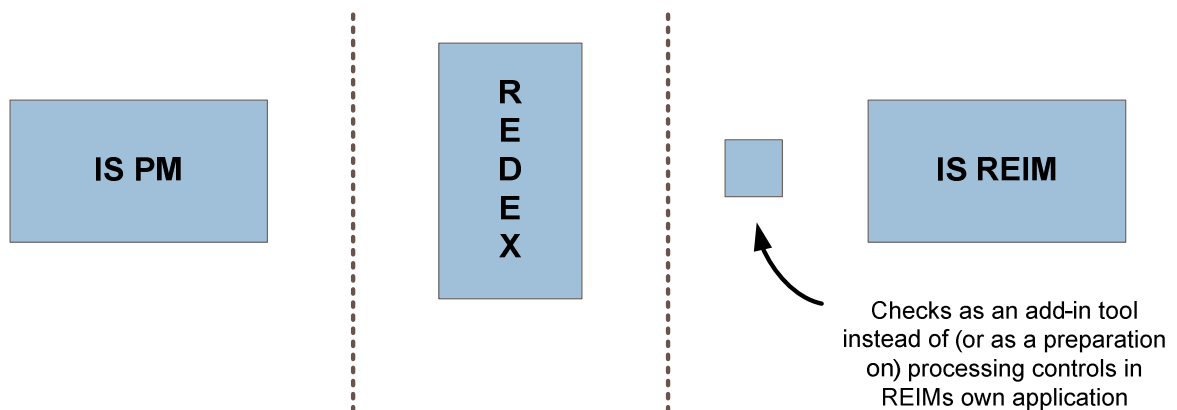


Figure 2: Concept draw of position add-in tool

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## Project goal

The goal of this project is to design an add-in tool that performs data quality checks. These data quality checks can be used instead (or as a preparation on) the controls within the REIM's own application. This tool should give the REIM more frequent assurance about the completeness and accurateness of the received data from the PM (compared with the current situation).

The ambition of the above stated project goal is that this project contributes to 'data quality monitoring within the real estate business chain', the title of this master thesis.

## Research questions

In order to reach the above stated project goal the following research questions are formulated:

Q1: What checks are needed from the perspective of the accountant of a REIM to be confident about the accuracy and completeness of data between transactions?

Q2: How could a tool collaborating with REDEX perform these checks?

These research questions are divided in the following sub questions:

- Q1.1: What data checks are important?
- Q1.2: How can the determined data checks be translated into business rules?
- Q2.1: What are the requirements for this tool?
- Q2.2: What is a good architecture to develop such a tool?

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### **Scope and focus**

The focus of this project is on the checks that could be performed on the relation between data transactions. This means the project is not focussed on the checks that could be done within data transactions as these data checks could be implemented with an extension to the REDEX platform.

Also this research is focussed on data checks that could be deduced from the current used practices within the field of assurance. The research is not focussed on the data checks that could be formulated from the perspective of the real estate business field itself. Some REIMs have set up controls within their own systems to assure the accuracy and completeness of the exchanged data via REDEX based on their own expertise.

### ***1.4 Research significance***

The significance of this research is that there are no known previous researches that look at this problem from the assurance field perspective from an academic point of view. As data is exchanged more frequent with the use of REDEX, the REIMs need more frequent assurance about the completeness and accuracy of the data received from PMs via REDEX. This assurance is needed to be able to perform cash and liquidity management based on the correct data. REDEX popularity is increasing within the real estate sector and more and more stakeholders are participating.

Recommendations about process improvements are interesting for REDEX because it further improves the use and acceptance of the platform. PwC is involved with REDEX since the design and implementation of the platform and by facilitating this project, PwC remains their leading position as a key player in knowledge according real estate information management. Last but not least, the Eindhoven University of Technology extends their experience with data quality and compliancy of processes in practice and for them it is an opportunity to add scientific value to practice.

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## 1.5 Research method

This project aims at the design of a specific solution for a specific problem. Because it is an improvement problem, and not a pure knowledge problem, a design-focused business problem-solving methodology should be used according Van Aken *et al.* (2007).

This is why this project is executed according to the solution oriented approach of Keizer and Kempen (2006). The approach contains 10 sequential steps that can be divided in the 5 phases of the regulative cycle (Van Strien, 1997). The phases of the regulative cycle are orientation, analysis, design, implementation and evaluation. *Figure 3* gives an overview of the research method and provides the structure of the report as well.

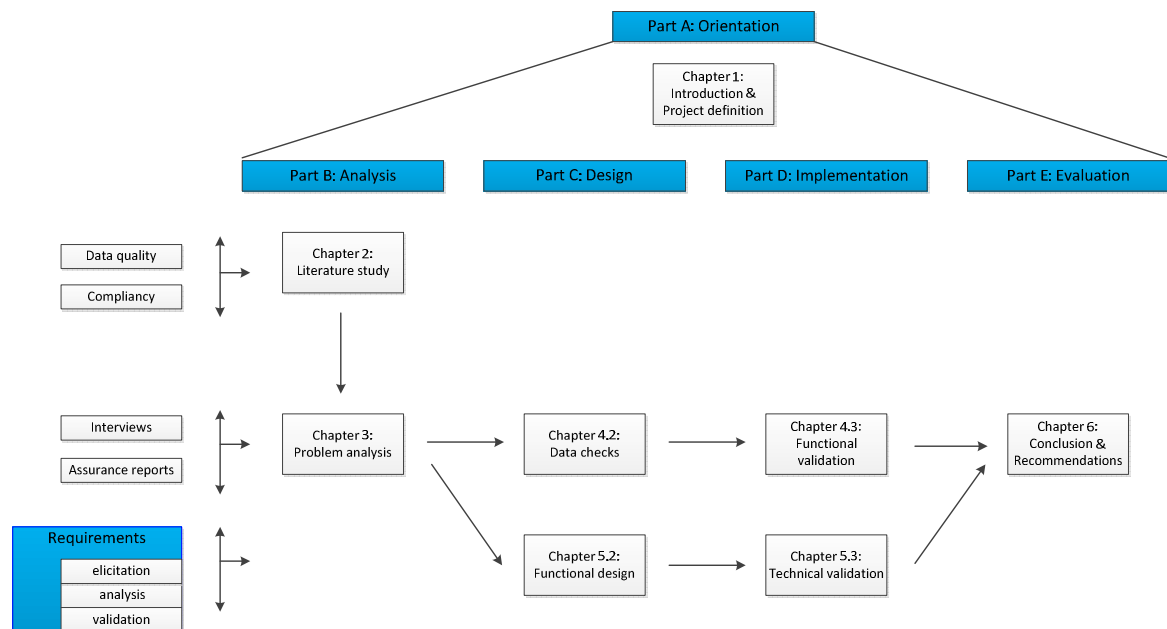


Figure 3: Research model

The orientation phase is used to become familiar with the organization PwC and the REDEX platform. Interviews are conducted with key stakeholders of the REDEX platform. Based on these interviews the project definition is set up.

During the analysis phase a more detailed insight is gained regarding the problem statement. A literature study is used to become more aware of the already available knowledge within the field of data quality and compliance. Interviews and assurance reports are used to get a better

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understanding of the situation in practice. The analysis phase results in the determination of the important quality aspects within the exchange of real estate data in practice.

Based on the results of the analysis phase, the design phase is started. The required data checks, from the perspective of the accountant of a REIM, to be confident about the accuracy and completeness of data between transactions are defined (Q1). Also a functional design of a tool which collaborated with REDEX to perform these checks is set up (Q2). During the creation process of the functional design the elicitation, analysis and validation phase of Kotonya & Sommerville (1998) are used to define the requirements.

The implementation phase validates the solution from the design phase. Because of security and confidentiality reasons it was not possible to implement the solution in practice at a REIM. Therefore, as an alternative there is chosen to test the data checks locally by using synthetic test data. Besides this technical validation, the data check scenarios are functionally validated during several meetings with a financial auditor of a REIM.

In the evaluation phase the conclusions and recommendations of this research are given together with limitations and subjects for further research.

During the project, data has been gathered by interviews with employees within several departments within PwC, within the REDEX Foundation, and within a REIM. The list with the interviewed employees can be found in Appendix I. If data appeared to be controversial, the interviewees were confronted with this and they were asked for an explanation.



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## 2. LITERATURE STUDY

The main issues within this research are data quality (Q1) and continuous auditing (Q2). This chapter describes state of the art techniques and methods within those fields of research.

The goal of this research is to design an add-in tool that performs data checks instead of (or as a preparation on) the processing controls within the REIMs own application. This tool should give the REIM more frequent assurance about the completeness and accurateness of the received data from the PM (compared to the current situation).

The data that is checked by the tool at the REIM is set up by the processes at the organization of the PM. In order to reduce the risk on incompleteness and inaccuracy it is important that these processes comply to internal requirements and external regulations. Within this chapter first the concept compliance is introduced. Then, it describes more about data quality itself and the auditing of processes and data.

### 2.1 Compliance

Before going deeper into this subject it is needed to introduce the definition of compliance. According to Foorthuis & Bos (2011) compliance is:

*A level of accordance between an actor's behaviour or products on the one side, and predefined explicit rules, procedures, conventions, standards, guidelines, legislation or other norms on the other.*

This essentially means ensuring that business processes, operations and practices are in accordance with a prescribed and agreed set of norms (Lu *et al.*, 2008). The compliance rules itself are formally expressed regulatory requirements (Liu *et al.*, 2007). In practice, businesses typically deal with a number of regulations and standards at one time, which may have overlapping and even conflicting requirements (Lu *et al.*, 2008).

To minimize the influence of the human factor within business processes, (large) organizations often use systems which restrict the actions employees could perform within their processes (Breux *et al.*, 2009). The systems enable business practices while limiting the improper use of

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resources that would otherwise violate the law. A technique used to implement those restrictions is Role-Based Access Control (RBAC). A role can be seen as a set of permissions. Users are assigned to appropriate roles based on their responsibilities and qualifications. RBAC also implements the appropriate security engineering principles such as Separation of Duties (SoD) to enforce risk reduction (Colantonio *et al.*, 2011).

Process gatekeepers are often used to encourage compliance with processes by strictly enforcing data completeness at critical points within a process. They are often used to encourage compliance with processes associated with enterprise systems (Berente *et al.*, 2010).

## 2.2 Data quality

The quality of data is recognized as a relevant performance issue of operating processes, of decision-making activities, and of interorganizational cooperation requirements (Batini *et al.*, 2009).

Information systems change from hierarchical and monolithic to a network-based structure. The set of potential data sources that organization can use increased in size and in scope. Processes are involved with complex information exchanges and often operate on input obtained from external sources (Batini *et al.*, 2009).

Batini *et al.* (2009) state that as a consequence of this the overall quality of the data that flows across information systems can rapidly degrade over time if the quality of both processes and information inputs is not controlled. But networked information systems also offer new opportunities for data quality management. The availability of a broader range of data sources and the ability to select and compare data from different sources to detect and correct errors, improves the overall quality of data.

Methods provided in literature are record linkage, business rules, and similarity measures.

The quality of data can be expressed in terms of the accurateness and completeness of data. A definition of both terms is given from the PwC perspective. Within research literature the following definitions are given:

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- Accurate: The transactions are recorded at the correct amount, in the appropriate account, and proper period;
  - Complete: All occurred transactions are recorded and accepted for processing once and only once and in the proper period.

### 2.3 Auditing

Auditors are hired by the management of organizations to verify whether the organizational controls are set like required. The auditors need to ascertain the accuracy of financial records and the reliability of the systems that store, transport and process those financial transactions (Flowerday *et al.*, 2006).

Often audits require both financial auditors and IT auditors. Financial auditors are concerned with how financial information is captured, aggregated, contextualized, and disclosed to public (Julisch *et al.*, 2011). And IT auditors verify the correctness and integrity of the financial information. Correctness and integrity refer to the completeness, accuracy, validity of, and restricted access to the financial data (Julisch *et al.*, 2011).

Auditors provide an assessment of a system's internal control after which they provide reasonable assurance about the correctness of the way of process execution. IT audits focus on the control structures in systems designed to prevent, detect, and correct any erroneous, abnormal, or illegal transaction from occurring (Carlin & Gallegos, 2007). They assess the operating effectiveness of process controls, and when these controls are not in place or functioning as expected, they typically check samples of factual data (Aalst *et al.*, 2010).

Heterogeneity between business practices in different organizations makes it difficult to develop a single, de facto implementation of standards and regulations to achieve compliance. Consequently, auditors and external reviewers must certify that a set of business practices comply with a set of standards or regulations at a specific point in time. This process of certifying business practices is called certification (Breaux *et al.*, 2009).

As explained above an auditor looks for assurance that the business processes have performed within the boundaries determined by the business rules, by either auditing the design, i.e. the implementation and effectiveness of controls, or by looking substantively at the data generated

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by the system. The last approach is considered as very costly if done in the traditional way (Aalst *et al.*, 2011). That is why the next two sections explain the use of process mining techniques and the use of continuous auditing.

### **Process mining**

To facilitate the analysis of business processes in an automatic way, process mining tools are developed. The IEEE Task Force on Process Mining (2011) has the following definition for process mining:

*Process mining are techniques, tools, and methods to discover, monitor and improve real processes by extracting knowledge from event logs commonly available in today's (information) systems.*

Process mining techniques could help auditors check factual data. Thanks to powerful process mining tools and increasingly available high-quality event logs it is possible to check not only samples of factual data but even the whole data population. Besides this advantage other main advantages above the traditional methods are (Jans *et al.*, 2011):

- Use of log data is beyond the auditee's influence. Auditors could objectively reconstruct the executed process that precedes a transaction;
- Auditors do not need to rely anymore on the designed model, but can use the discovered, actual process model.

Although process mining has traditionally focused on offline analysis and is seldom used for operational decision support, process models based on historic data could be used to make predictions about running cases (Aalst *et al.*, 2010). The section OLAT describes this in more detail.

### **Continuous auditing**

When companies financially report continuously, auditors must monitor and audit on a continuous basis (Dull & Tegarden, 2004). Provision of continuous assurance about the quality and credibility of the information presented is needed. Using auditing methods within a

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continuous auditing system can improve their current effectiveness, as all transactions are analysed in real-time.

The most widely used definition of continuous auditing is (Flowerday *et al.*, 2006):

*Continuous auditing is a methodology that enables independent auditors to provide written assurances on a subject matter using a series of auditors' reports issued simultaneously with, or a short time after, the occurrence of events underlying the subject matter.*

The next sections describe the use of continuous auditing by the use of controls, online auditing tools, and complex event processing.

### **Use of controls**

Continuous auditing processes give real time insights into violations of business rules. One of the current approaches to check business rules automatically is to embed controls in the information system. These controls are strongly related to the functions of the information system (Aalst *et al.*, 2011). An example of such a control is the four-eye principle. This means two specific tasks for the same case should be handled by different employees.

### **OLAT**

Instead of using automated tasks as controls in an information system, the Online Auditing Tool (OLAT) is another solution. When an information system is equipped with a logging mechanism then an OLAT could be connected with the information system.

*Figure 4* shows an OLAT. The next paragraphs explain the functionality of the different components within the architecture of an OLAT.

The defacto models are models derived from historic data. The models are according to the observed situation. The dejure models are the models like designed on paper. These models represent the desired or official situation.

The conformance checker module checks whether the run time data conforms to the dejure models. In particular it complies with the dejure business rules. Queries run on the database and

when the result of the query is empty, the rule is not violated. When the rule is violated an exception report is generated which needs to be checked by the management and the auditors.

When the situation should be allowed the rule promoter can be used to add the newly discovered model to the dejure model. This eliminates the 'false positives' in the conformance checker (Aalst *et al.*, 2011).

Discovery programs derive models from the run time data by using techniques like data mining and process mining. Besides the control flow, also authorization rules, business data models, organizational models, and business rules could be discovered. The obtained models are the defacto models (Aalst *et al.*, 2011).

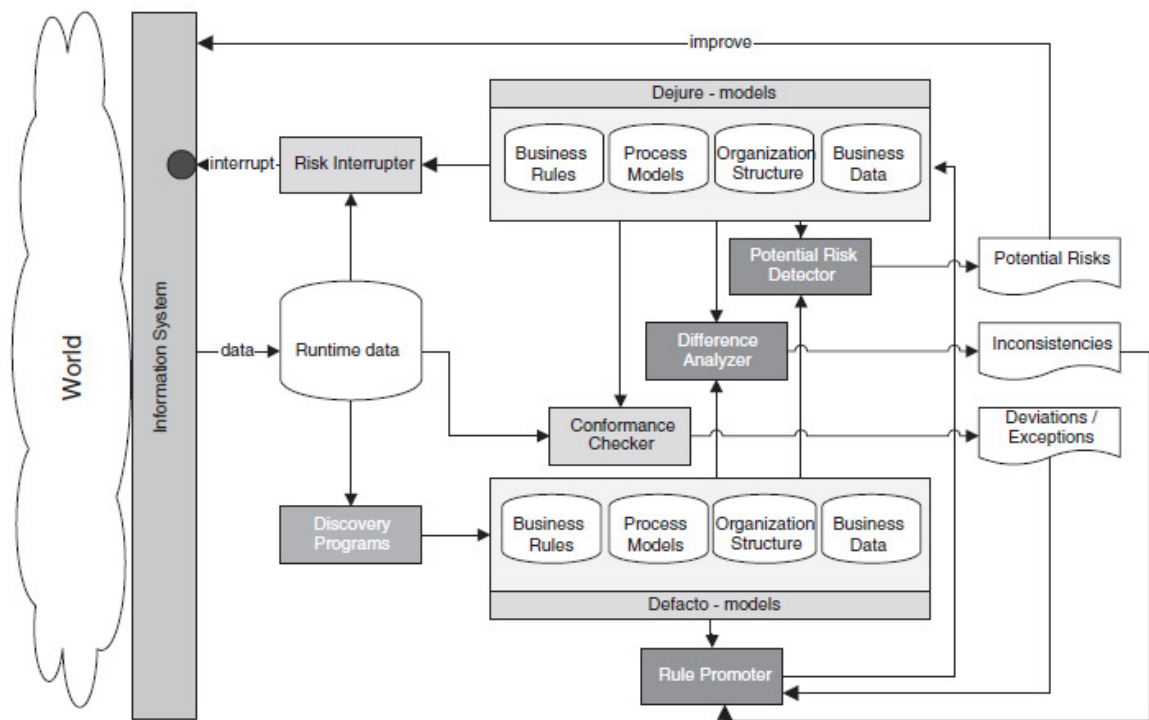


Figure 4: A top-level architecture of an Online Auditing Tool (OLAT) (Aalst *et al.*, 2011)

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The risk interrupter module serves as an external guard for tasks in an information system. The module interrupts the information system to prevent further processing of the case in consideration until issues are resolved and risks mitigated. The model interrupts the running process based on the business rules within the dejure models (Aalst *et al.*, 2011).

For analyzing the differences between the dejure and the defacto models the difference analyzer module can be used. It can be seen as a quality check for the models. Inconsistencies are reported. The potential risk detector module is able to detect potential risks by analyzing the run time data, the defacto and the dejure models (Aalst *et al.*, 2011).

The next section discusses a method that could be used within an OLAT to recognize complex events. The complex event processing (CEP) technique could analyze business processes while they are running. Those complex events can be used within business rules as a control.

### **Complex event processing**

Complex event processing (CEP) is a technology capable of matching events with predefined contexts and patterns. It is able to produce additional complex events that can have an impact on the system (Etzion *et al.*, 2011).

According Etzion *et al.* (2011) an event is 'a programming entity that represents an actual occurrence in the real world'. An event could be seen as a change in state. By analysing and correlating events, CEP could recognize the occurring of a complex event. A complex event is an event that corresponds to other events that are defined as patterns. These patterns are event-specific and are based on event algebra, which expresses temporal and causal relationships among individual and collective events (Sharon & Etzion, 2008).

The difference between CEP and Business Intelligence (BI) techniques (like e.g. process mining) is that BI techniques are request driven and perform their analyses over a set of data after events happened. CEP is event-driven and performs its analyses online, triggered by events. BI could be seen as data-centric and CEP could be seen as activity-centric. CEP is also sometimes called Operational Intelligence (OI) (Etzion *et al.*, 2011).

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## Synthesis

This literature study was used as an explorative study to become more aware of the general concepts that are important within the world of auditing. With the above background knowledge it is easier to conduct an in-depth problem analysis instead of coming to a standstill because of the gap in professional language.

During the literature study there were no previous research articles found that look at the following aspect from an assurance field perspective with an academic point of view:

- What checks are needed from the perspective of the accountant of a REIM to be confident about the accuracy and completeness of data between transactions?

This is considered as a white spot in research.



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### 3. PROBLEM ANALYSIS

During the exchange of data between PMs and REIMs the REDEX platform cannot guarantee the accuracy and the completeness of data between transactions. Like explained within the introduction, the REDEX platform does not store any real estate data itself. This means the REDEX platform cannot perform relational checks between transactions themselves. Before a solution could be designed it is necessary to gain a better understanding of the situation in practice. First, the conducted process is described, where after the results of those performed steps are given. The chapter results with a solution direction about how to determine the data checks to which the exchanged real estate data needs to conform in practice.

#### *3.1 Process*

To gain a better understanding of the situation in practice the following steps are taken:

- Analysis of the stakeholders and involved systems and their relations;
- Analysis of the data transaction process using REDEX;
- Analysis of the current use of assurance methods;
- Determination of the solution direction.

Above steps are performed by conducting several interviews with Maurits Cammeraat (Senior Advisor, PwC - Real Estate Services), Cor Treure (Chairman, REDEX Foundation), and Anonymous person A (Senior Service Manager, REIM). This was an iterative process. During the meetings conclusions were made that are validated and fine-tuned during follow-up meetings.

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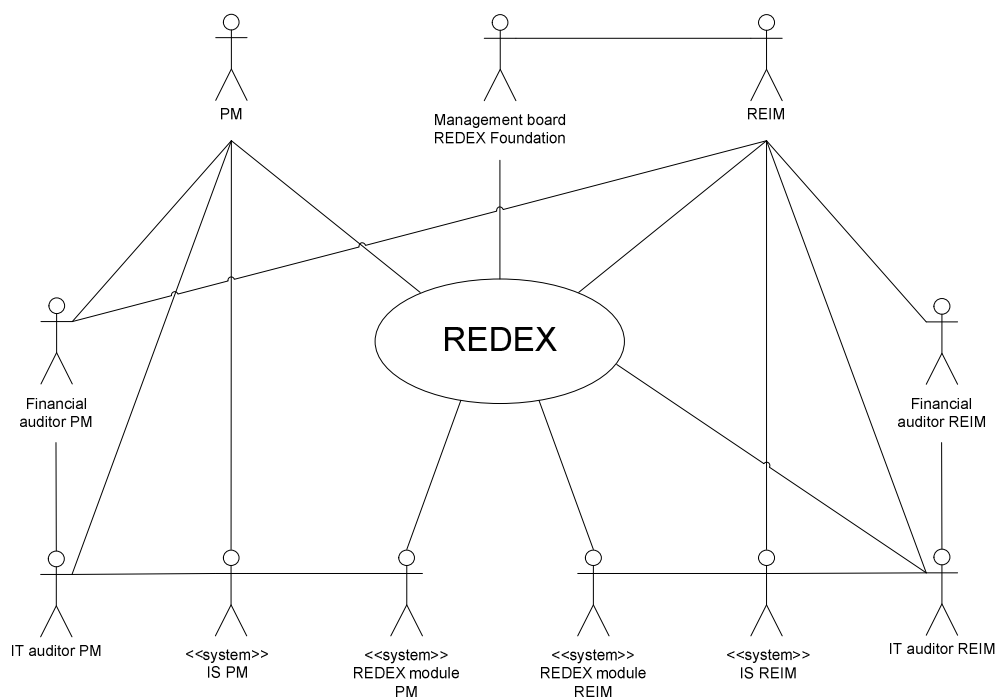
## 3.2 Results

This section describes the results of the process described above. First, an analysis of the stakeholders and involved systems is given. Also their interrelations are described. Then, a description of the data transaction process using REDEX is given. And third, an analysis of the current assurance methods used by the stakeholders.

### 3.2.1 Scoping statements

This section identifies the various stakeholders involved with the exchange of data between PMs and REIMs via REDEX. It also describes the relations between the stakeholders.

The set of stakeholders that are (direct or indirect) involved with the exchange of data via REDEX are listed in Appendix II. These stakeholders are involved within the processing of the data transactions itself, as the management of the REDEX platform, or as an auditor of one of the stakeholders. Appendix II also lists the set of systems that are involved. *Figure 5* gives an overview of the stakeholders and systems and their relations.



*Figure 5: Context statement of the exchange of data between PMs and REIMs using REDEX*

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Now an overview of the involved stakeholders and systems is given, it can be explained how they are connected with each other.

The PM and REIM use the REDEX platform to exchange their data. The REDEX platform is connected with the system 'IS REIM' via the application 'REDEX module REIM'. This application builds the data request for the required attributes from the PM and sends the built request to REDEX. When the 'REDEX module REIM' receives a response, the application converts the data to the REIMs' data structure and transfers it to the system 'IS REIM'. Based on the data available in the system 'IS REIM' the REIM performs cash and liquidity management analyses regarding their real estate funds.

On the side of the PM the REDEX platform is connected with the system 'IS PM' via the application 'REDEX module PM'. This application receives the requests from REDEX and builds a response based on the required attributes. The 'REDEX module PM' retrieves the required attributes from the system 'IS PM'. The system 'IS PM' facilitates the PM in its operational activities and contains all the available data relating the real estate assets where they provide service for. When a response is built the 'REDEX module PM' sends it to the REDEX platform.

The REIM is also directly connected with the REDEX platform. The REIM sets the time schedule for the sending of data requests and receives error messages when data transactions are blocked. Also the PM is directly connected with the REDEX platform. The PM could upload a response to a data request manually to REDEX and receives error messages when a data transaction is blocked as well.

All the involved REIMs, as a group, are owner of the REDEX platform. The REIMs finance the required resources and set the mission statement of the REDEX foundation. The management board of the REDEX foundation manages the operating tasks relating the REDEX platform. They arrange the maintenance and further development of the platform and acquire potential participants.

Like explained in the introduction section about assurance, user organizations need assurance that the service organization's controls are properly designed, implemented, and are working

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effectively. REIMs need this assurance from the PMs. The PMs use external auditors to provide this assurance to their REIMs.

Within our context there can be distinguished between the following types of auditors:

- IT auditor PM;
- Financial auditor PM;
- IT Auditor REIM.
- Financial auditor REIM;

The 'IT auditor PM' audits the controls used within the organization of the PM and the controls implemented within the system 'IS PM'. The 'financial auditor PM' relies on the diligences done by the 'IT auditor PM' and performs some additional diligences themselves. Within these additional diligences the financial auditor needs to interact with both PM and REIM. The result of these diligences should be an assurance report that gives reasonable assurance about the fact that the controls at the PM are properly designed, implemented, and are working effectively.

The 'financial auditor REIM' evaluates whether the processes of the REIM are in control. Because the REIM makes use of processes of the PM, the 'financial auditor REIM' also checks the assurance reports provided by the PMs of the REIM. The 'financial auditor REIM' also relies on the diligences done by the 'IT auditor REIM'. The 'IT auditor REIM' audits the controls used within the organization of the REIM and the controls implemented within the systems 'IS PM' and REDEX.

Within section 4.2 the performed diligences by the auditors are described in more detail.

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### 3.2.2 Work analysis refinement model

This section describes the process for the exchange of data between PMs and REIMs via REDEX in more detail than the previous section.

PMs and REIMs arrange with each other what the frequency of data exchange will be. They document this explicitly within a SLA. Based on the SLA the REIM imports the moments of data exchange to the scheduler within REDEX.

The application 'REDEX module REIM' builds the data request and when this application receives a trigger from the scheduler within REDEX, the application sends this request to the REDEX platform. REDEX stores and copies this request. The copy of the request is sent to the application 'REDEX module PM'. Then the 'REDEX module PM' retrieves the required data attribute values from the system 'IS PM' and builds a response. Then the application 'REDEX module PM' sends this response to REDEX automatically or the PM uploads this response manually. Then REDEX performs his checks using among others the stored request. When the response does not pass the checks within REDEX the response will be erased and both the PM and the REIM receive a message of this failure. When the response passes the checks within REDEX, REDEX sends the response to the application 'REDEX module REIM'. The application extracts this response and writes the data to the system 'IS REIM'.

Appendix III shows the above described process within a work analysis refinement model. The modelled process starts after the REIM imported the arranged moments of data exchange to the scheduler within REDEX. Appendix IV shows the above described process using a use cases.

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### 3.2.3 Current use of assurance methods

In the current situation REIMs use third party assurance (TPA) reports to become confident about the fact that the data distributed by each PM is sound with reality. The assurance reports give the REIMs confidence that the received data from the PMs is accurate and complete.

Like explained in the section about assurance (section 1.2.4), TPA reports are written by independent external auditors to guarantee complete transparency about the current state of the considered organization. The auditors perform their research at the organization and document their observations within a report.

At this moment the 'financial auditor REIM' yearly requests a vastgoedverklaring from the REIM's PMs as a reliance that the processes of the PM, relating the services offered to a REIM, are in control. PMs need to deliver a vastgoedverklaring to each REIM with which they are working with. The vastgoedverklaring contains diligences regarding both system oriented controls and data oriented controls and are issued by the 'financial auditor PM'. The system oriented and data oriented controls are described below:

System oriented controls            Internal controls that are created as a boundary for tasks (or a set of tasks) within business processes where a human actor is involved. These controls make it harder to defraud an organization for an individual acting alone.

Data oriented controls            Controls that are created to check the validity of the data, based on the data alone.

An example of a system oriented diligence is checking whether a business process like the payment of bills above 5,000 euros followed the four-eye principle. Using a sample, the auditor checks whether the required two signatures are present on archived hard-copy papers. Another example is checking whether during the payment of bills above 20,000 euros, authorization is given by an authorized employee.

An example of a data oriented diligence is checking whether there are non-explainable differences between the current profit and loss statement and the one of previous year.

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Instead of performing the system oriented diligences for each vastgoedverklaring (which is related to a specific REIM) separately, most of the PMs choose to use an ISAE3402 to cover the relevant processes within the vastgoedverklaring. The ISAE3402 is not focused on the reporting processes related to a single REIM but is focused on the processes related to REIMs in general.

When an ISAE3402 report is issued this assures that the internal controls of the PM are properly designed, implemented, and are working effectively. The scope of an ISAE3402 is tailor made and contains sets of standards that PMs must meet in order to receive their engagement. The controls within the scope of an ISEA3402 must be checked every 6 months by the 'IT auditor PM'.

Because the system oriented diligences within the vastgoedverklaring alone does not give the REIM enough assurance about the data received from the PM, the 'financial auditor PM' also needs to perform data oriented diligences. As the scope of an ISAE3402 does not always cover all the for a REIM relevant processes, the data oriented diligences are also used to cover missing aspects.

*Figure 6* and *7* give an overview of two scenarios of risk management methods used by REIMs to cover the required system and data oriented controls. These controls reduce the risk of exchanging inaccurate and incomplete data.

The vertical axis shows the transactions over time and the horizontal axis the system and data oriented controls. The transactions are displayed as long horizontal blocks and represent each time that data is exchanged between a PM and a REIM over a one year time period. The risk management methods used are displayed as blocks in front of or behind the transactions. When the used method is transaction-driven then the method is displayed in front of the transactions and when the used method is not transaction-driven behind the transactions.

Transaction-driven                      A control is transaction-driven when it is safeguarding its process continuously, each time the state of the system changes.

The working of the system oriented controls is in both scenarios covered by two ISAE3402 reports, one for each 6 months. Within the current situation where REIMs do not use REDEX to exchange data with their PMs (see *Figure 6*), the data oriented controls are covered by the

vastgoedverklaring and the controls within the information system of the REIM himself. The data oriented diligences within the vastgoedverklaring are only done once a year. The controls of the REIM are displayed in front of the transactions because they are transaction driven.

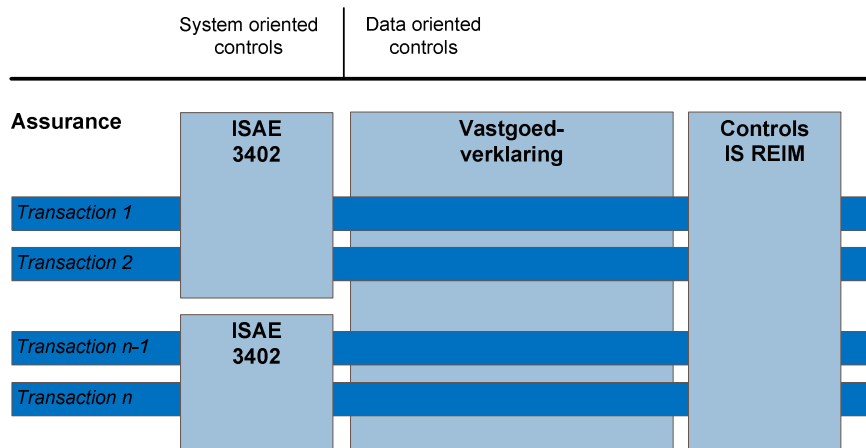


Figure 6: Risk management at REIMS without using REDEX

Figure 7 gives an overview of the current situation where REIMs do use REDEX to exchange data with their PMs. The controls covered by REDEX overlap with the controls covered by the vastgoedverklaring. The difference is that the controls within REDEX are transaction-driven. This means the data oriented controls are not only checked every year but also every transaction.

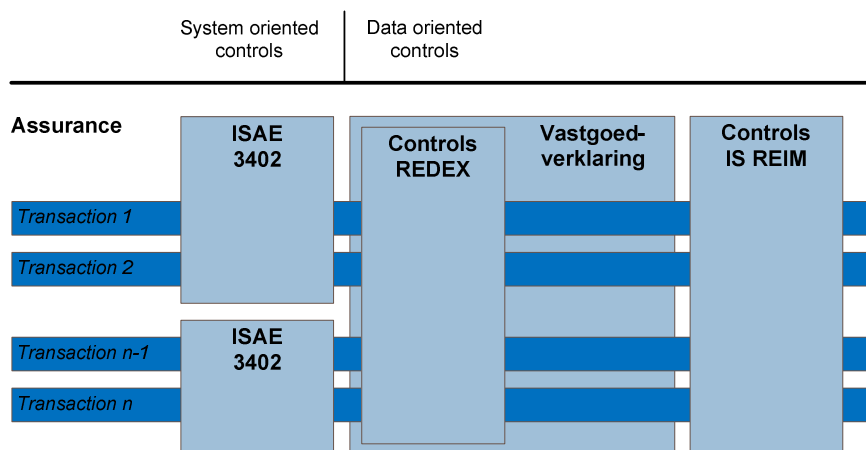


Figure 7: Risk management at REIMs using REDEX



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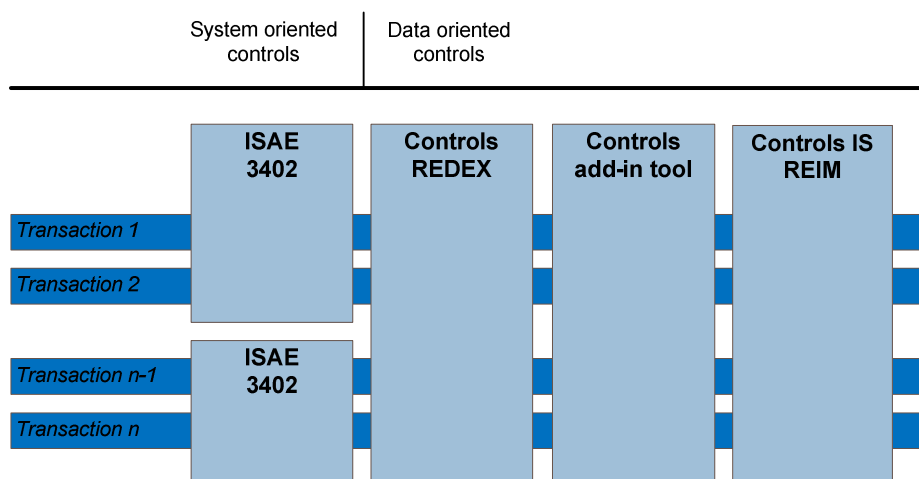
### 3.3 Conclusion

Like explained in the introduction of this chapter, the REDEX platform cannot guarantee the accuracy and completeness of the exchanged data between PMs and REIMs. *Figure 7* shows it guarantees part of required controls, but not all of them.

Within the current situation the vastgoedverklaring is used to assure the accuracy and completeness of the exchanged data. The system oriented diligences are hard to automate because the evidence for the correct use of internal controls is often not digitally stored. Although there are advanced workflow management systems available on the market, which stores the evidence of the controls, the systems are not commonly used in practice at PMs.

As a result of this problem analysis it can be concluded that the in the problem definition proposed add-in tool (see *Figure 2*) should cover the data oriented controls within the vastgoedverklaring. Controls that are already present within the control set of REDEX can be passed over.

Chapter 4 focuses on the diligences within the vastgoedverklaring that cover those controls to design data checks for the proposed add-in tool. *Figure 8* shows an overview of how the proposed scenario looks like. The controls within the add-in tool are transaction-driven.



*Figure 8: Proposed scenario of risk management at REIMs using REDEX*

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## 4. DATA CHECKS

The previous chapter gave a solution direction to answer the following research question:

Q1: What data checks are needed from the perspective of the accountant of a REIM to be confident about the accuracy and completeness of data between transactions?

The data checks should cover the data oriented controls within the vastgoedverklaring that are not covered by the controls within REDEX. In order to answer the above stated research question, this research makes a distinction between the following sub questions:

Q1.1: What data checks are important?

Q1.2: How can the determined data checks be translated into business rules?

The first sub question determines the important relational checks that are needed to be confident about the accuracy and completeness of the data exchanged via REDEX between PMs and REIMs. The second sub question looks at those data checks from a more technical perspective. How those data checks could be used within the proposed add-in tool.

The chapter starts with a description of the followed process. Then the results of this process are given. The third section describes the performed validation of the results and the chapter ends with a synthesis of the results.

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## 4.1 Process

To determine the important data checks the following steps are taken:

- Analysis of the data oriented diligences within the vastgoedverklaring;
- Determination of data checks;
- Translation of those data checks in a way that they can be used within the proposed add-in tool;
- Functional validation of the determined data checks.

To analyse the data oriented diligences within the vastgoedverklaring, the at PwC available vastgoedverklaringen are investigated. Due to scarcity of this type of practices within PwC, the vastgoedverklaringen of two PMs are analysed. Both practices are issued in 2011 and are related to services for the same REIM.

To get an understanding of the diligences done both the responsible financial auditors are interviewed. In the practice of PM A this is Laura Huijbens-Vlaar (Manager, PwC – Assurance) and in the practice of PM B this is Jelle van Zanden (Assistant Manager, PwC – Assurance). After those interviews access to the audit files was granted. The audit files document the performed diligences during the audit and are used to determine the important aspects within those diligences.

After the analysis of the data oriented diligences within the vastgoedverklaring the data checks are determined and translated to operational data checks that can be used within the proposed add-in tool.

Within multiple interviews with the responsible accountant of several REIMs, Sidney Herwig (Director, PwC – Assurance), the determined checks are functionally validated.

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## 4.2 Results

This section describes the results of the process described above. The first section describes the analysis of the data oriented diligences within the vastgoedverklaring. Based on this analysis the data checks are determined. Then, these checks are translated to a form in which they can be used within an operational setting. The chapter ends with the functional validation of the determined checks.

### 4.2.1 Data oriented diligences within the vastgoedverklaring

During this analysis two different audit files are investigated. The audit files can be viewed within a special for PwC developed software package, Aura. Within an audit trail each diligence is described in detail. The files could not be exported and are not included within this thesis. A list with the most important conducted diligences during the issuance of the vastgoedverklaring at PM A can be found in Appendix V. There is not such an overview available of the performed diligences during the issuance of the vastgoedverklaring at PM B though it has been determined from the audit files that the data oriented diligences matches.

The data oriented diligences within a vastgoedverklaring are generally based on:

- A. Connection between the information system of the PM and the annual statements of the REIM in order to compare differences between both stakeholders;
- B. Substantive analytics on the annual statements of the PM (compared to statements released in previous years).

The following two sections describe the diligences in more detail.

#### A. Connection between 'IS PM' and annual statements REIM

Within this diligence a financial auditor checks whether the PM did send the complete data set over the last year and the REIM did actually receive the complete data set over that year. The REIM receives several times a year an update of his properties and the accumulated sum of those updates must equal the data over the year.

Currently the financial auditor checks this manually by comparing the following statements:

- The actual statements regarding a REIM's real estate objects as present at the information system of the PM;
- The annual statements as present at the REIM regarding real estate objects serviced by the PM in perspective.

The statements contain rent settlement, combustion and service costs, and promotion costs (in Dutch respectively: huurafrekening, stook- en servicekosten, promotiekosten). The classes and their attributes of the annual statements are shown in *Figure 9*. Example documents of the annual statements cannot be found within this thesis due to confidentiality. Though, the attribute types are shown in Appendix VI.

Huurafrekening	Stook- servicekosten	Promotiekosten
-TP	-Current property manager ID	-TP nummer
-Port	-Current property manager name	-Naam property manager
-Entity	-PropertyID	-PropertyID
-Theoretische huur	-Property name	-Property name
-Leegstand	-Service costs financial bill period	-Laatste aanlevering
-Huurderiving	-Period	-Income
-Onderhoud	-Service costs bill period	-Income VAT
-Promotiekosten	-Income	-Expenses
-Beheerkosten	-VAT Income	-Expenses VAT
-Overige exploitatiekosten	-Expenses	-Total (including VAT)
-Overloopkosten	-VAT Expenses	-Total liability (excluding VAT)
-Met derden te verreken kosten	-Saldo	
-Waarborgsom		
-Investeringsen		
-Rente te late betaling		
-BTW huur		
-BTW kosten		
-Totaal		

*Figure 9: Classes and attributes of the annual statements at the REIM*

Differences between the above described data positions are further investigated by the financial auditor.

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## **B. Substantive analytics on the annual statements of the PM**

Within this diligence the financial auditor investigates for each category within the profit and loss (P&L) statement of the PM whether there is incorrectness compared to the statements of last year. In other words, he checks whether there are non-explainable differences between both statements. Using samples the financial auditor investigates whether the processes performed by the PM are in control.

To allocate incorrectness as significant, a threshold is used, materiality. Incorrectness is called 'material' within the accountancy when it is that big that it would influence the decision-making of users of the annual statements. The financial auditor identifies and assesses the risks of material misstatement through understanding the entity and its environment.

The materiality can be determined based on several aspects. Some examples of methods that are used to determine the materiality are given below (PwC, 2011):

- Percentage of assets;
- Percentage of revenues;
- Percentage of gross profit;
- Percentage of current assets;
- Professional judgement.

Differences above the materiality need further investigation.

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## 4.2.2 Determination of data checks

This section describes how the above described data oriented diligences could be covered with alternative data checks. The checks do not overlap with the checks that are already present within REDEX. The checks within REDEX cannot be found within this report because of the confidentiality. The alternative data checks are described per category.

### A. Connection between 'IS PM' and annual statements REIM

At this moment this diligence is performed manually by the 'financial auditor PM'. This diligence could be conducted by the proposed tool by comparing the annual data regarding specific properties from 'IS PM' with the accumulated data over that year present at 'IS REIM' on a yearly basis.

The check looks like:

$$A1) \quad |x_{PM}(t) - x_{REIM}(t)| \leq c_x$$

Where:

$x_{PM}(t)$	Aspect within the financial statements of the PM in month $t$ ;
$x_{REIM}(t)$	Aspect within the financial statements of the REIM in month $t$ ;
$c_x$	Threshold for $x$ that is determined by an independent party, e.g. auditor;
$t$	Time in months with $t = 0$ is the last month.

Examples of  $x$  are:

- Theoretische huur;
- Huurderving;
- Onderhoud;
- Promotiekosten;
- Beheerkosten.

Currently, the statements are compared at a yearly basis. Automation of these checks gives the opportunity to perform the tests over a smaller period. Differences should be reported to the

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REIM (and possible to the PM). Dependent on the number of reported differences, it may be smart to not perform this check every month but for example every 3 months.

### B. Substantive analytics on the annual statements of the PM

The diligences can be done by comparing the values of the attributes within the annual statements rent settlement, combustion and service costs, and promotion costs (shown in *Figure 9*), with the values that the REIM received in earlier periods. This can be done by using one (or more in parallel) of the following scenarios:

$$B1) \quad |R(t) - A(t - 1)| \leq c_x$$

$$B2) \quad |R(t) - A(t - 12)| \leq c_x$$

$$B3) \quad \left| \frac{R(t)+A(t-1)+\dots+A(t-n)}{n+1} - \frac{A(t-12)+A(t-13)+\dots+A(t-(n+12))}{n+1} \right| \leq c_x$$

Where:

$R(t)$	Response data in month $t$ ;
$A(t)$	Aggregate data of month $t$ ;
$t$	Time in months with $t = 0$ is the last month, $t = -1$ is the month before last month, etc.;
$n$	Number of months within rolling horizon minus 1, integer value $\geq 3$ .

The data received from the PM is called 'response data' and the data that is already available at the REIM is called 'aggregate data'.

Using scenario 1 the absolute difference between the response data of month  $t$  and the aggregate data month  $t-1$  can be determined. Scenario 2 compares the response data of month  $t$  with the aggregate data of the same month a year earlier, month  $t-12$ . And scenario 3 determines the absolute difference between an average month response data of the last  $n$  months (using the rolling horizon method) and the average of the  $n$  months aggregate data in the same period a year earlier.



---

The REIMs can choose to block the transferred data when the difference is above a determined threshold. A more friendly way is to alert the REIM (and PM). The observed differences need to be clarified afterwards.

The aspects within the annual statements that have a stable behaviour over time can be checked with the method described above. Examples of aspects with a stable behaviour are the theoretical rent and management costs (in Dutch respectively: 'theoretische huur' and 'beheerkosten').

When aspects within the statements do not have a stable behaviour, but are very dynamic over time, the above described scenarios are not sufficient. An example of an aspect that is very dynamic is maintenance (in Dutch: onderhoud). Every month a PM executes small maintenance tasks but once in a while there are also large (unexpected) maintenance tasks involved. When compared on a yearly basis the costs of the large maintenance tasks are averaged with the small maintenance tasks. Comparing the maintenance costs of a specific year with the year before does not lead to problems however the purpose of this research is to offer more frequent assurance.

A solution for this problem is making use of the available budget plans at the REIMs. Often REIMs know when large maintenance takes place and this information is integrated within their budget plans. Comparing the actuals against these budgets creates additional control over the processes at the PM. When large differences between planned and actual costs are observed the REIM needs to reveal the cause.

This can be done by using one (or more in parallel) of the following scenarios:

$$B4) \quad |R(t) - B(t)|$$

$$B5) \quad \left| \frac{R(t)+R(t-1)+\dots+R(t-n)}{n+1} - \frac{B(t)+B(t-1)+\dots+B(t-n)}{n+1} \right|$$

Where:

$B(t)$  Budget data of month  $t$ ;

---

Scenario 4 compares the response data of month  $t$  with the budget data of month  $t$ . Because the actual costs could deviate from the budgeted month a rolling horizon can be used. This is described in scenario 5.

The determined data checks mentioned within this section are functionally validated. More information about this functional validation can be found in section 4.3.

### **4.2.3 Determination of operational data checks**

The in section 4.2.2 determined data check scenarios are translated to operational data checks. There is chosen to convert the checks to data checks in the programming language C#. The operational data checks are given in Appendix VII.

The determined operational data checks mentioned above are technically validated. More information about this validation can be found in section 5.3.

## **4.3 Functional validation**

It is important to validate whether the in section 4.2.2 determined checks are a good alternative for the current data oriented diligences within the vastgoedverklaring. This means whether the determined checks give the same, or a better level of, assurance compared with the current situation using the vastgoedverklaring. The in *Figure 8* proposed scenario is only valid when this condition is met.

Within multiple interviews with the responsible financial auditor of several REIMs, Sidney Herwig (Director, PwC – Assurance), this issue is discussed. The issue is discussed with this person because he is the one who requests the vastgoedverklaring from the PMs and knows what aspects are important.

During the second interview it became clear that it is not actually needed to replace current controls with a direct translation. It is just very important the REIM shows they have control over the outsourced processes at the PM's side.

The outcome of the discussions is that besides the determined checks a uniform scope for the ISAE3402 needs to be in place in order to replace the vastgoedverklaring. At this moment there

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is no uniform scope of the ISAE3402 regarding PMs. The PM and his IT auditor determine together what processes are within the scope and what are beyond. In general PMs chose to keep processes that are not performing well (yet) outside the assurance scope. The 'financial auditor REIM' wants all the processes of the PM that influence the reporting process towards the REIM in scope of the ISAE3402. Because of this possible mismatch the data oriented diligences within the vastgoedverklaring are performed to cover this gap.

Together with additional data checks at the REIM, an ISAE3402, which covers all relevant processes, could replace the vastgoedverklaring. The additional data checks can be implemented within the proposed design of the tool.

A third important aspect is the mind-set of the financial auditor. The 'financial auditor REIM' needs to have the necessary trust in the alternative data checks in order to not demand a vastgoedverklaring from the PMs. The trust aspect was not mentioned by Sidney Herwig but after a few meetings his attitude towards replacing the vastgoedverklaring changed visibly. In the beginning he was against alternative automated data checks instead of the vastgoedverklaring. During the last meeting he was actively thinking about the possibilities. When he was confronted with this aspect he totally agreed this is really important as well.

---

## 4.4 Conclusion

This chapter gave an answer to the following research question:

Q1: What data checks are needed from the perspective of the accountant of a REIM to be confident about the accuracy and completeness of data between transactions?

It determined what data checks are important and translated those into data check scenarios that can operate within an operational setting.

Most of the determined scenarios for data checks are derivatives from the current checks within the data oriented diligences of the vastgoedverklaring. The checks within the vastgoedverklaring are converted to a manner in which they could be used in an automated way. This gives the opportunity to shorten the time interval. Using data check scenario A1, differences in data positions are revealed in an early stage. Using data check scenarios B1-3, for aspects with a stable behavior over time, relations with aggregate data could be tested for every transaction. Data check scenarios B4-5 make it possible to monitor the dynamic aspects within a transaction against the available budget data at the REIM. This creates the opportunity to increase budgets in an early stage or to cut planned activities. In this way the budgets give a better impression of the reality what makes the risk analyses of the REIMs more accurate.

This chapter was focused on the data checks that the add-in tool should perform. The next chapter focuses not on the 'what' but on the 'how' the tool should perform.

---

## 5. FUNCTIONAL DESIGN

This section gives an answer to the following research question:

Q2: How could a tool collaborating with REDEX perform these checks?

The above stated research question is divided in the following sub questions:

Q2.1: What are the requirements for this tool?

Q2.2: What is a good architecture to develop such a tool?

The section that answers Q2.1 describes the requirements for the tool. Within the section that answers Q2.2 a good architecture to develop such a tool is described.

The chapter starts with a description of the followed process. Then, the results of this process are given. The third section describes the performed technical validation.

---

## 5.1 Process

The requirements for the add-in tool are determined by using the following phases (Kotonya & Sommerville, 1998):

- Requirements elicitation;
- Requirements analysis;
- Requirements validation.

During the requirements elicitation phase the requirements are discovered. Based on meetings with Maurits Cammeraat (Senior Advisor, PwC Real Estate Advisory Services), Cor Treure (Chairman, REDEX Foundation), and Anonymous person A (Senior Service Manager, REIM), an initial draft of requirements is set up.

The requirements are analysed for incompleteness, inconsistency, relevance and practicality during the requirements analysis phase. During a meeting with Cor Treure and Anonymous person A the requirements within the initial draft are discussed and processed into an agreed draft set of requirements that is complete and consistent. During the requirements validation phase the draft set is made final.

Based on those requirements a use case is given and modelled using a work analysis requirement model. Also a good architecture is described in which the add-in tool could be developed. One of the components within the architecture of the tool performs the data checks scenarios determined in section 4.2.3. These checks are technically validated in section 5.3.

## 5.2 Results

This section describes the results of the process described above.

### 5.2.1 Context statement

*Figure 10* shows the systems and stakeholders that are involved with the exchange of data between PMs and REIMs. As an addition to the context statement within section 3.2.1 this context statement includes the proposed add-in tool. Besides the added relations with this tool there are no other additional relations involved.

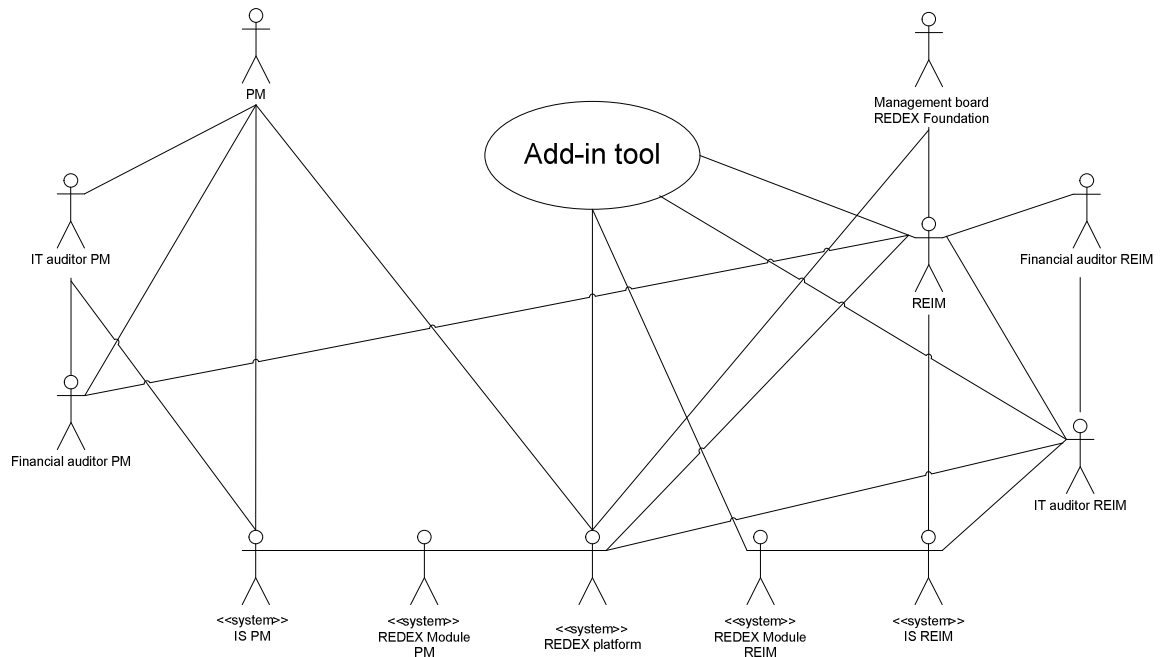


Figure 10: Context statement of the exchange of data between PMs and REIMs

## 5.2.2 Requirements

The requirements elicitation, analysis and validation phase described in section 5.1 results in the list with requirements given in Appendix X.

The requirements are prioritized using the MoSCoW method. This prioritization uses the following categories:

- Must: Requirement that must be satisfied;
- Should: Requirement should be included when possible;
- Could: Requirement is considered desirable but not necessary;
- Won't: Requirement will not be implemented.

The list contains both functional and non-functional requirements for the add-in tool. The functional requirements determine what the tool exactly should do and thus describe the functions that the tool will facilitate. The non-functional requirements determine how the tool shall perform.

### 5.2.3 Work analysis refinement model

The position of the tool is determined within the problem definition section but there are several scenarios possible regarding the data flows. Several potential scenarios were discussed during meetings with Cor Treure (Chairman, REDEX Foundation) and Anonymous person A (Senior Service Manager, REIM). Examples can be found within Appendix XI.

Figure 11 shows a work analysis refinement model of the preferred scenario. Because the REIM knows what data is present in the response data it can build the necessary aggregate and budget data (for the defined data check scenarios within the add-in tool) before the response reaches the add-in tool. Using estimation it manages to arrive about in the same time as the response data at the add-in tool. When a check fails the REIM will be warned about it but also in this scenario the response data is sent to IS REIM. The REIM investigates the difference afterwards.

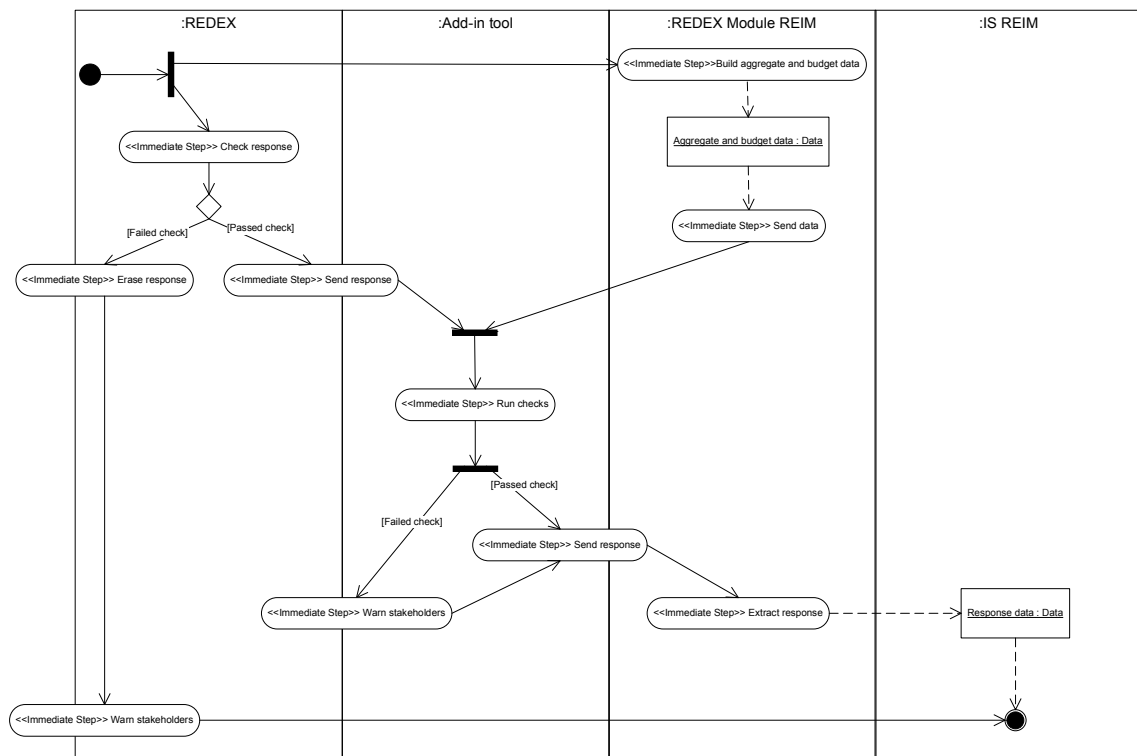


Figure 11: Work analysis refinement model of the checking process of the add-in tool



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## 5.2.4 Architecture add-in tool

A Service Oriented Architecture (SOA) is a good architecture for the development of the proposed add-in tool. SOA represents an agile and flexible architecture that is comprised of autonomous, interoperable, and potentially reusable services. SOA can establish an abstraction of business logic and technology, resulting in a loose coupling between these domains. The loose coupling of services makes it easy to change services without consequences for other components.

Figure 12 shows a conceptual model of a service oriented architecture.

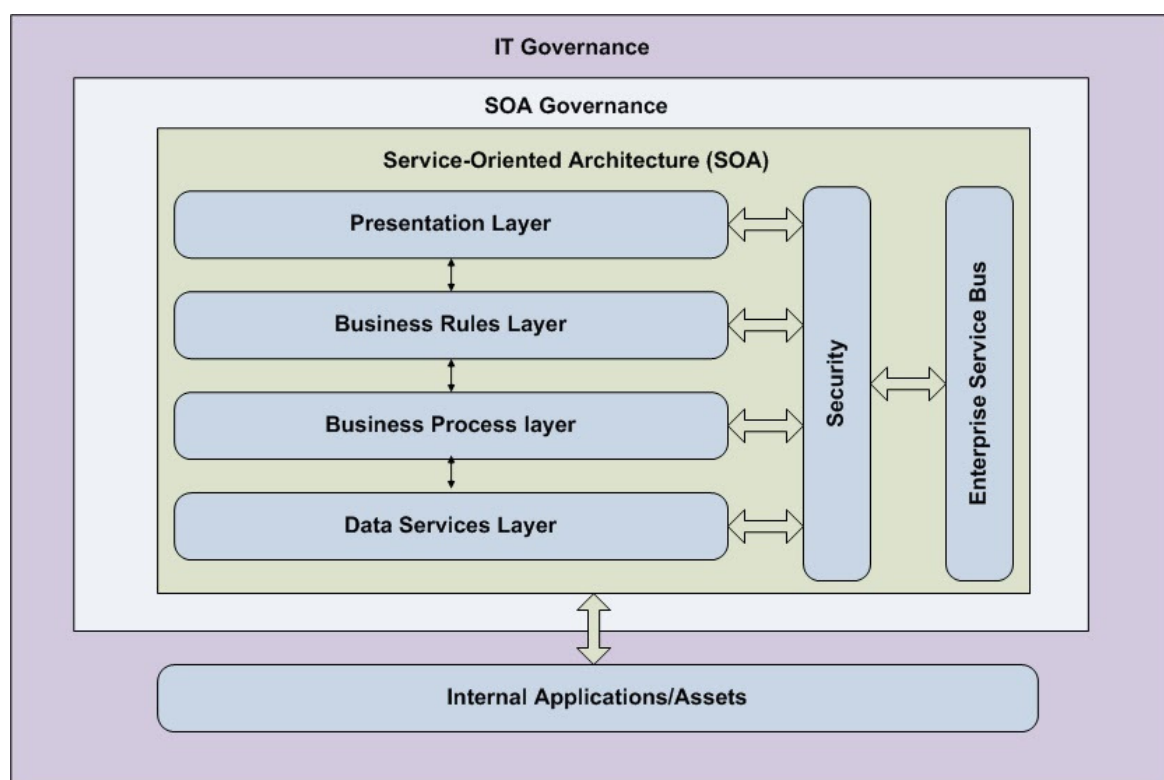


Figure 12: Conceptual model SOA

Regarding the design of the proposed add-in tool SOA can distinguish between the following functionalities:

- Receiving of XML files with response data from REDEX;
- Receiving of XML files with aggregate and budget data from REDEX module REIM;
- Sending of XML files with response data to the REDEX module REIM;

- 
- Temporary storing of response, aggregate, and budget data;
  - Storing of log results of data check scenarios;
  - Sending of log results to responsible stakeholders;
  - User interface to add/change/remove data checks;
  - User interface to configure what data checks should be used on which aspects and to set the threshold ( $c_x$ ) values;
  - Security;

And last but not least:

- Checking of the data check scenarios on the data.

This last component is technically validated within section 5.3.

The SOA architecture could be implemented by using e.g. the JBoss Enterprise SOA Platform.

### **5.2.1 Business resource models**

To define the main concepts within the data exchange via REDEX a business resource model is given in Appendix VIII and Appendix IX. The UML class diagram explains the data structure of the XML responses. The complete structure is much larger but this simplified model explains the most significant data classes used within this thesis. Appendix VIII shows the general structure of the responses and Appendix IX zooms in on the data classes used for the data checks within the add-in tool. The models are derived from the internal document 'PMR 1.0 versie dd 4 mei 2012' (2012).

---

### 5.3 Technical validation

This section shows the feasibility of the data checks determined in section 4.3. A proof of concept is given by the following performed steps:

- Syntax check of the determined data checks;
- Testing of the data check scenarios using synthetic data.

The in section 4.2.3 determined data checks are validated on their syntax by using Microsoft Visual C# 2010 Express v10.0. This integrated development environment has a built-in debugger.

Also, the data checks are validated on their functionality. A boundary check is conducted to verify whether the data checks act in a correct way. It is validated that the results of the data checks are positive when below the thresholds and negative when above. The validation process is described in Appendix XII and the screenshots of this validation can be found in Appendix XIII.

For testing purposes, no test data was available from practice because of the confidentiality of the data. Therefore, synthetic data is used. During the validation of data check scenarios B1-5 an example response data file is used that is received from the REDEX Foundation. The used XML file is FINANCIEL.xml. For the aggregate data and budget data from 'IS REIM' the XML files 'REIM scenario B1-3.xml' and 'REIM scenario B4-5.xml' are used. These files are invented and contain financial data regarding a specific property, period, and aspect.

During the validation of the data check scenario A1 the data files 'Pmdata.xml' and 'REIMdata\_FOUT2' are used. Both files are invented based on the current comparison between 'IS PM' and the annual statement of the REIM.

The above proof of concept demonstrates the feasibility of the determined data check scenarios. The following steps have to be taken by PwC to complete the proof of concept:

- Validation of additional scenarios for data checks;
- Validation with the aggregate and budget data structures used in practice;
- Validation using real test data from practice.

---

## 6. CONCLUSIONS AND RECOMMENDATIONS

This chapter addresses the main conclusions that can be derived from this study. After the conclusions the main limitations are described and further research directions are provided.

### 6.1 Conclusions

By combining the insights from academic scholars on data quality and continuous monitoring, practical experiences inhibited in the tacit knowledge of auditors and REIMs, and assurance practices, this research attempted to increase the insight of potential assurance solutions within the real estate business chain, thereby fulfilling the goal of the research:

*The goal of this project is to design an add-in tool that performs data quality checks. These data quality checks can be used instead (or as a preparation on) the controls within the REIM's own application. This tool should give the REIM more frequent assurance about the completeness and accurateness of the received data from the PM (compared with the current situation).*

By analyzing and discussing the tensions and organizational issues related to data quality and compliancy from both theoretical and practical points of view, this master thesis attempted to answer the following research questions:

*Q1: What checks are needed from the perspective of the accountant of a REIM to be confident about the accuracy and completeness of data between transactions?*

*Q2: How could a tool collaborating with REDEX perform these checks?*

Based on the data oriented diligences within the vastgoedverklaring, data check scenarios are determined and converted to programming language. The data check scenarios are functionally and technically validated

The functional validation concludes, that, besides the determined data check scenarios, the following aspects need to be in place in order to make the data oriented diligences within the vastgoedverklaring unnecessary (to provide the scenario as in *Figure 13*):

- Uniform scope ISAE3402;
- Confidence financial auditor in alternative data checks.

At this moment there is no uniform scope of the ISAE3402 regarding PMs. The PM and his IT auditor determine together what processes are within the scope and what are beyond. In general PMs chose to keep processes that are not performing well (yet) outside the assurance scope. The ‘financial auditor REIM’ wants all the processes of the PM that influence the reporting process towards the REIM in scope of the ISAE3402.

The second aspect is the mind-set of the financial auditor. The ‘financial auditor REIM’ needs to have the necessary trust in the alternative data checks in order to not demand a vastgoedverklaring from the PMs. When the decision is made to implement those additional controls it is important to inform the auditors extensively. Workshops could help to make them more familiar with the concept.

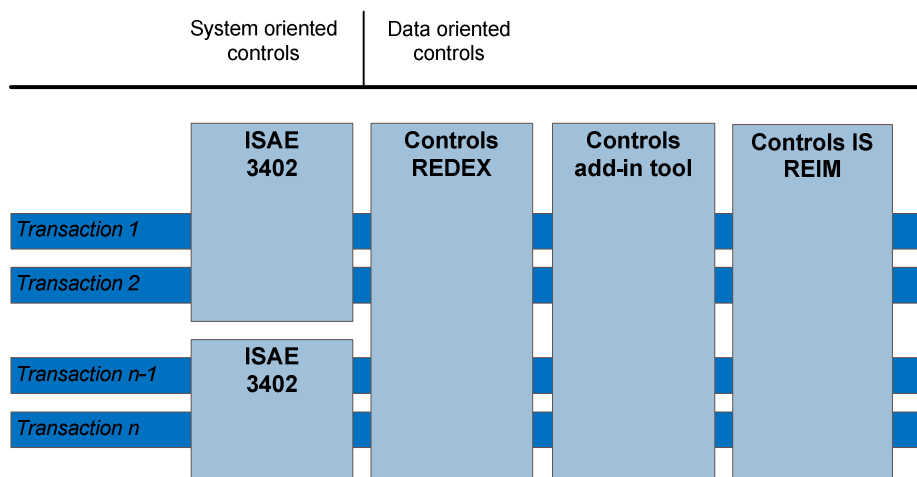


Figure 13: Proposed scenario of risk management at REIMS using REDEX and add-in tool

Besides the determination of the data check scenarios there is also looked at how these data check scenarios could be used in practice. Therefore requirements for an add-in tool are constructed. The tool could be implemented using a Service Oriented Architecture. A proof of concept is given for the determined data check scenarios that can be performed by one of the components within the SOA.

---

The following table gives an overview of the differences between using the add-in tool or the data oriented diligences within the vastgoedverklaring.

<b>Add-in tool</b>	<b>Vastgoedverklaring</b>
- Transaction driven checks	- Annual checks
- Complete survey	- Sample survey
- Automated checks	- Manual checks

*Table 1: Comparison between assurance via add-in tool and assurance via vastgoedverklaring*

The add-in tool offers a lot of significant advantages but there is still additional research required. For now the vastgoedverklaring is the proven method but what about in a few years?

## **6.2 Recommendations**

One of the findings during the research is that in order to replace the data oriented diligences within the vastgoedverklaring a uniform scope of the ISAE304 is needed. A uniform scope of the ISAE304 means that all relevant processes that influence the financial reporting to the REIM are covered. In the current situation the scope of the ISAE3402 differs between PMs. To cover this in the future a general standard for PMs must be designed.

The data checks that are determined within this research can be used for continuous monitoring of the data received via REDEX. The checks can be implemented using the proposed add-in tool to perform data quality checks or can be implemented as additional controls within the current information system of the REIM as well.

Besides above mentioned aspects it is important that the accountant of the REIM has enough confidence in the alternative data checks. Financial auditors are used to work with vastgoedverklaringen and in the proposed situation they need to have enough confidence in the replacing checks. When the auditors do not have this confidence they will keep requesting the vastgoedverklaringen from the PMs. A lot of attention needs to be paid towards this aspect. It was experienced that it needs time and moments of discussion to change their minds. Workshop settings could help reaching this new mindset.

---

### 6.3 Limitations and further research

A general limitation lies in the fact that there is only looked at the business problem from the assurance perspective. Further research could be done from the business perspective, which could lead to the determination of additional (maybe even alternative) checks.

Another limitation is that the determined data checks are mainly defined based on two practices of the issuance of the vastgoedverklaring. Based on those two cases (although the data oriented diligences were the same), data checks are developed and functional validated with a financial auditor of several REIMs.

The checks themselves are not validated with real-time data. The data was not available because of confidentially reasons. Therefore the syntax of the checks is validated using a C# parser and the functionality of the checks is validated by testing those using synthetic data.

Also the fact that the study is partly exploratory in nature is a limitation. Interviews are used as an important way of retrieving tacit knowledge of field experts. However, the validation of the data checks increases the feasibility of the findings.

#### Further research

The following topics need to be further researched:

- Uniform ISAE3402 for PMs. According my findings there are a lot of best practices but there is not a uniform standard designed;
- Determination of the threshold ( $c_x$ ) values within the data check scenarios. Within the vastgoedverklaring a trade-off is made for every data aspect regarding which method to use;
- When to use what data check scenario? Research on the performance of the data check scenarios need to be researched. Which scenario acts in what situation the best?;
- How to determine whether an aspect has a stable behaviour or a dynamic behaviour?;
- Exploration of more advanced data check scenarios. This study explored the topic and could be used as input for further research.

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## APPENDIX I - Overview interviews

### *Internal interviewees*

<b>Name</b>	<b>Position</b>	<b>Organization - department</b>
Maurits Cammeraat	Senior Advisor	PwC - Real Estate Services
Bram Heusinkveld	Associate	PwC - System and Process Assurance
Marcel Smit	Director	PwC - Business Technology Assurance
Daan Padmos	Manager	PwC - System and Process Assurance
Laura Huijbens-Vlaar	Manager	PwC - Assurance
Jelle van Zanden	Assistant Manager	PwC - Assurance
Sidney Herwig	Director	PwC - Assurance
Tanja van de Lagemaat	Manager	PwC - Assurance
Sander Landzaat	Senior Associate	PwC - System and Process Assurance
Stefan Veweyj	Partner	PwC - System and Process Assurance

### *External interviewees*

<b>Name</b>	<b>Position</b>	<b>Organization - department</b>
Cor Treure	Chairman	REDEX Foundation
Anonymous person A	Senior Manager	REIM - Asset Management Offices
Anonymous person B	Senior Associate	REIM - Functional Management

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## APPENDIX II - Stakeholders and systems relating REDEX

The following tables list the set of stakeholders and systems that are (direct or indirect) involved with the exchange of data via REDEX.

Stakeholder	Description
PM	The property manager (PM) is responsible for the operating issues concerning to real estate assets. Issues like dealing with tenants, and repairing and improving of real estate properties. A PM provides this service to a REIM.
Financial auditor PM	The financial auditor of a PM is concerned with how financial information of the PM is captured, aggregated, contextualized, and disclosed to public (e.g. to a REIM). Within his audit he often needs to rely on the diligences done by the IT auditor PM.
IT auditor PM	The IT auditor of a PM performs system oriented diligences in order to assure whether information systems are maintaining data integrity and safeguarding assets. In practice IT auditors check the management of information systems based on logical access to programs and data, change management, and the compliancy of operations.
Management board REDEX	The management board of the REDEX Foundation manages the operating tasks related to the REDEX platform. They arrange the maintenance and further development of the platform and acquire potential participants.
REIM (owner)	The real estate investment manager (REIM) copes with the management of real estate funds in order to meet specified investment goals for their investors. A REIM outsources the operating issues concerning real estate assets to PMs.  As owner of REDEX, REIMs finance the required resources and set

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the mission statement of the foundation.

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Financial auditor REIM	The financial auditor of a REIM is concerned with how financial information of the REIM is captured, aggregated, contextualized, and disclosed to public (e.g. to investors). Within his audit he needs to rely on assurance reports received from the PM and on the diligences done by the IT auditor REIM.
IT auditor REIM	The IT auditor of a REIM performs system oriented diligences in order to assure whether information systems are maintaining data integrity and safeguarding assets. In practice IT auditors check the management of information systems based on logical access to programs and data, change management, and the compliancy of operations.

---

*Table 2: Stakeholders in the data exchange context between PMs and REIMs*

<b>System</b>	<b>Description</b>
IS PM	IS PM is the information system of the property manager.
REDEX module PM	This application receives the copy of the data requests from the REIM via REDEX. It retrieves the requested data attributes from IS PM and answers the data request with a created response that is sent back to the REIM via REDEX.
REDEX	The real estate data exchange platform.
REDEX module REIM	This application builds the data request for the required attributes from the PM. The data requests are sent based on the schedule in REDEX. When a response is received the application converts the data to the REIMs' data structure.
IS REIM	IS REIM is the information system of the REIM.

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*Table 3: Systems and applications in the data exchange context between PMs and REIMs*

## APPENDIX III - Work analysis refinement model REDEX

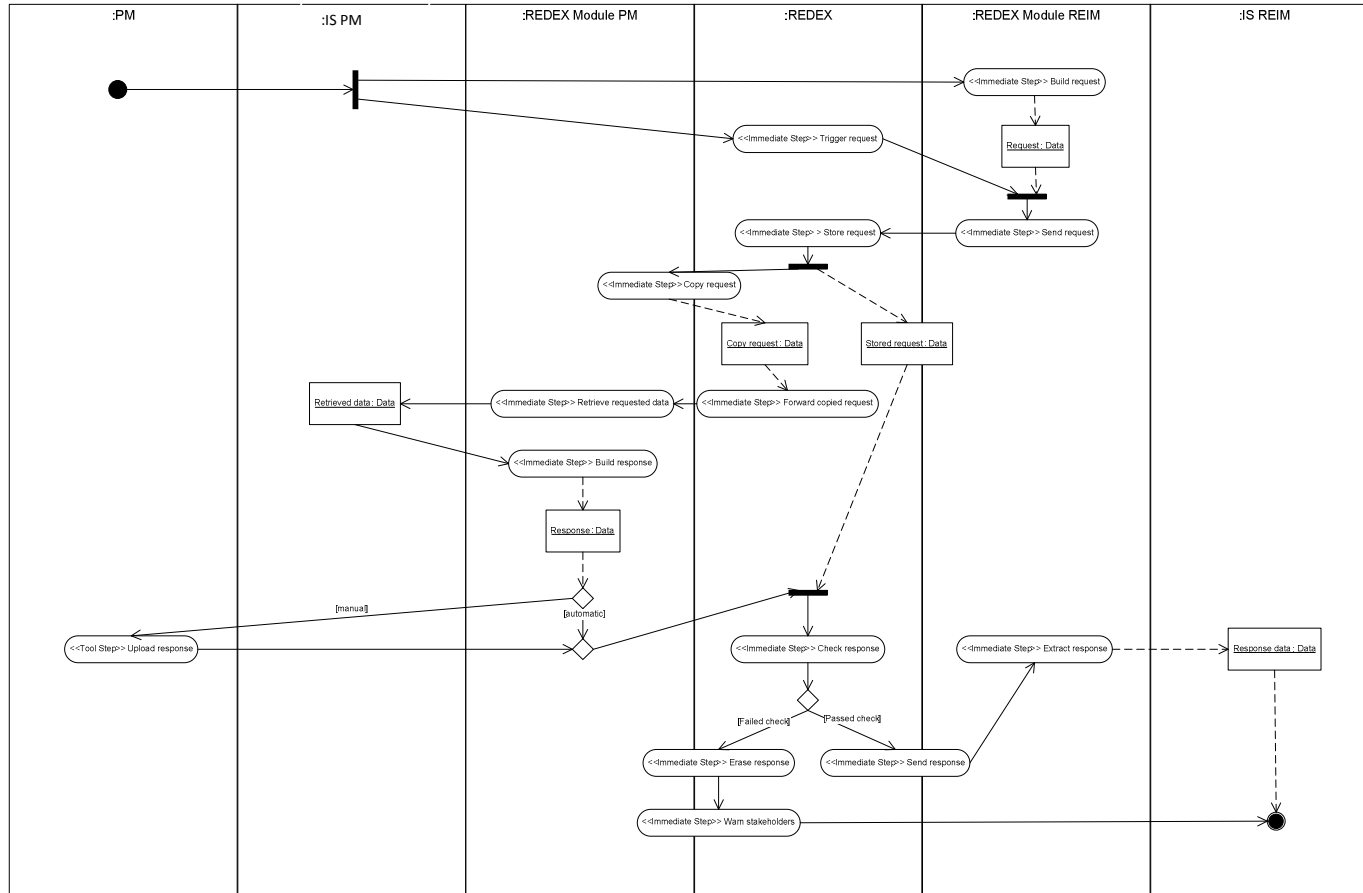


Figure 14: Work analysis refinement model of the data exchange between PMs and REIMs via REDEX

## APPENDIX IV - Use cases REDEX

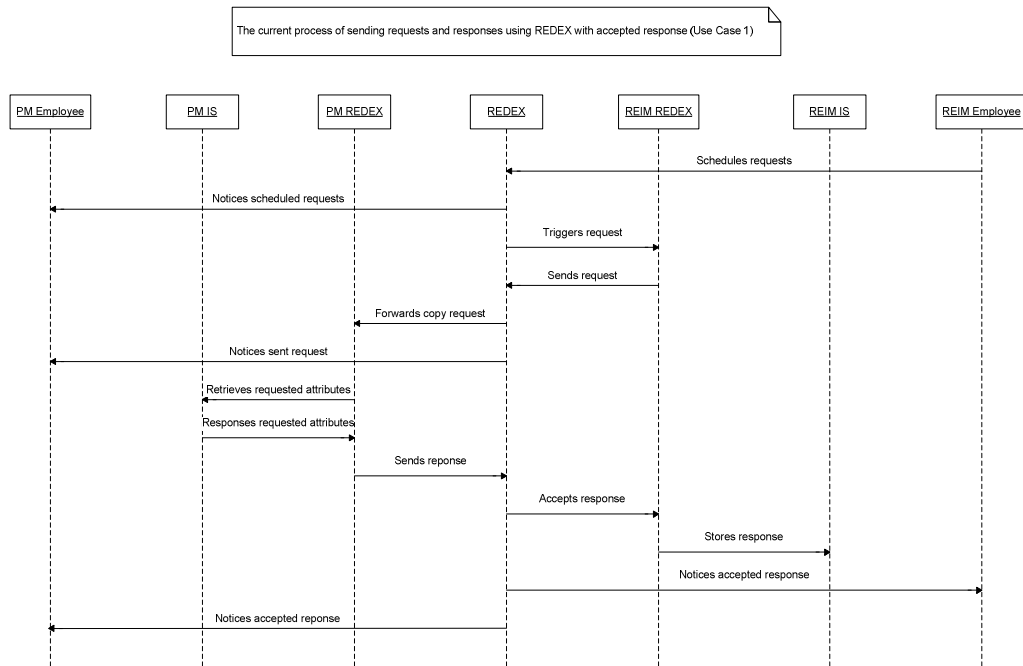


Figure 15: Use case 1 - accepted response

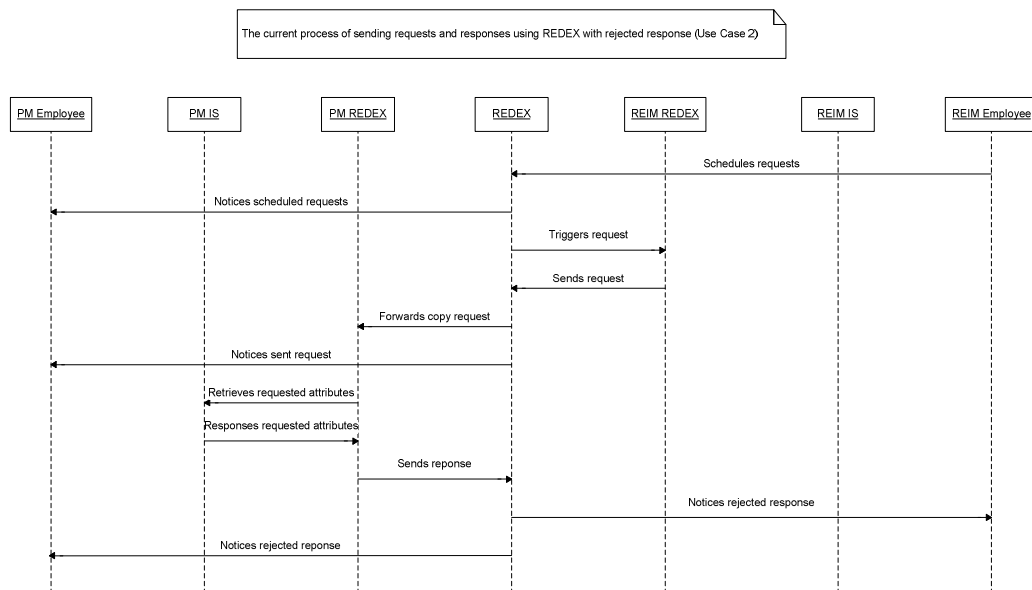


Figure 16: Use case 2 - rejected response

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## APPENDIX V - Vastgoedverklaring PM A (Dutch)

Within the vastgoedverklaring of PM A the following diligences are performed:

### Data oriented diligences:

Gezien de verkregen zekerheid op de beheersingsaspecten kan worden volstaan met de volgende gegevensgerichte werkzaamheden:

- Aansluiting REMS met Jaaropgave vastgoedverklaringen;
- Vergelijken verschillen tussen REIM en PM;
- Cijferbeoordeling op de Jaaropgave (t.o.v. vorig jaar);
- Aansluiting servicekosten en promotiekosten uit REMS met REIM standen en de betrouwbaarheid van de cijfers uit REMS vaststellen.

### System oriented diligences:

Voor wat betreft de systeemgerichte werkzaamheden is gebruik gemaakt van de werkzaamheden verricht binnen de ISAE3402.

Hierbij wordt er voornamelijk op de volgende controls gesteund:

<b>Control</b>	<b>Beschrijving</b>
A1.1 - 1.4	Beheerovereenkomst zijn juist volledig en tijdig vastgelegd.
A10.1	Checklist in en uit beheer.
A7.2	De medewerker huurafrekening controleert of de afboekingen zijn goedgekeurd door de Account manager.
A8.6	Service & verwarmingskosten; halfjaarlijks wordt het saldo van de kosten versus de voorschotten gecontroleerd.
AM1.2	Alle beheerovereenkomsten worden goedgekeurd door de directie.
V1.2	Maandelijks maakt de Account manager een aansluiting tussen leegstand in REMs en de voor verhuur beschikbare woningen.
V2.2	De Account manager controleert of de afwikkeling van de huuropzegging juist en tijdig heeft plaatsgevonden.
IT1 -3	General controls, change management, operations.



## APPENDIX VI - Statements and their attribute types

### Rent Settlement

Standard identifiers:

Attribute	Value	Example
TP	INT(4)	0219
Port	INT(3)	401
Entity	[CHAR(2)INT(4)]	PR0278

Entities to check:

Attribute	Value	Example
Theoretische huur	DECIMAL( $\infty$ ,2)	241.418,87
Leegstand	DECIMAL( $\infty$ ,2)	884,00
Huurderving	DECIMAL( $\infty$ ,2)	200,00
Onderhoud	DECIMAL( $\infty$ ,2)	12.233,08
Promotiekosten	DECIMAL( $\infty$ ,2)	362,50
Beheerkosten	DECIMAL( $\infty$ ,2)	5.567,10
Overige exploitatiekosten	DECIMAL( $\infty$ ,2)	80,41
Overloopposten	DECIMAL( $\infty$ ,2)	-766,00
Met derden te verreken kosten	DECIMAL( $\infty$ ,2)	1.107,82
Waarborgsom	DECIMAL( $\infty$ ,2)	-5.304,00
Investerings	DECIMAL( $\infty$ ,2)	280,84
Rente te late betaling	DECIMAL( $\infty$ ,2)	-26,27
BTW huur	DECIMAL( $\infty$ ,2)	-559,05
BTW kosten	DECIMAL( $\infty$ ,2)	3.196,81
Totaal	DECIMAL( $\infty$ ,2)	-3.925,73

---

## Combustion and service costs

Standard identifiers:

<b>Attribute</b>	<b>Value</b>	<b>Example</b>
Current property manager ID	INT(4)	0219
Current property manager name	CHAR	PM A
PropertyID	[CHAR(2),INT(4)]	PR0278
Property name	CHAR	Kerkstraat

Entities to check:

<b>Attribute</b>	<b>Value</b>	<b>Example</b>
Service costs financial bill period	INT(4)	2007
Period	INT(6)	201111
Service costs bill period	INT(4)	2007
Income	DECIMAL( $\infty$ ,2)	4.228,84
VAT Income	DECIMAL( $\infty$ ,2)	0,00
Expenses	DECIMAL( $\infty$ ,2)	4.228,84
VAT Expenses	DECIMAL( $\infty$ ,2)	0,00
Saldo	DECIMAL( $\infty$ ,2)	0,00

---

---

## Promotion costs

Standard identifiers:

<b>Attribute</b>	<b>Value</b>	<b>Example</b>
TP nummer	INT(4)	1841
Naam property manager	CHAR	PM A
PropertyID	[CHAR(2),INT(4)]	PR9250
Property name	CHAR	Woonboulevard Kaatsheuvel

Entities to check:

<b>Attribute</b>	<b>Value</b>	<b>Example</b>
Laatste aanlevering	INT(6)	201112
Income	DECIMAL( $\infty$ ,2)	985890,33
Income VAT	DECIMAL( $\infty$ ,2)	182971,02
Expenses	DECIMAL( $\infty$ ,2)	736074,78
Expenses VAT	DECIMAL( $\infty$ ,2)	82424,71
Total (including VAT)	DECIMAL( $\infty$ ,2)	350361,86
Total liability (excluding VAT)	DECIMAL( $\infty$ ,2)	249815,55

---

---

## APPENDIX VII - Operational data check scenarios

### Data structure

Structure to store data of the REIM and PM in scenario A:

```
public struct ScenA_data
{
    //data:
    public int TP,Port;
    public string Entity;
    public double Theoretische_Huur, Leegstand, Huurderving, Onderhoud,
        Promotiekosten, Beheerkosten,
        Overige_Exploitatiekosten, Overloopkosten,
        Met_Derden_Te_Verreken_Kosten, Waarborgsom,
        Investerings, Rente_Te_Late_Betaling, BTW_Huur,
        BTW_kosten,
        Totaal;
}
```

Structure to store data of the REIM scenario B:

```
public struct ScenB_data_REIM
{
    public string prop_ref;
    public string account_code;
    public date_amm[] month_amount;
}

public struct date_amm
{
    public int period_year, period_month;
    public int amount;
}
```

Structure to store data of the PM in scenario B:

```
public struct ScenB_data_PM
{
    public string NominalLedgerAccountCode;
    public double NetAmount;
}
```

---

## Scenario A

Covers scenario A:  $|x_{PM}(t) - x_{REIM}(t)| \leq c_x$

Created method:

```
public double[] compare_data_A(Cxmldata PM_data, Cxmldata REIM_data)
//Pre: data of PM and REIM is inserted
//Post: Returns an array of the differences
{
    double[] d = {0,0,0,0,0,0,0,0,0,0,0,0,0,0,0};

    //compare all data of the PM and REIM and get the difference
    d[0] = Math.Abs(PM_data.ScenA_Xmldata.Theoretische_Huur -
        REIM_data.ScenA_Xmldata.Theoretische_Huur);
    d[1] = Math.Abs(PM_data.ScenA_Xmldata.Leegstand -
        REIM_data.ScenA_Xmldata.Leegstand);
    d[2] = Math.Abs(PM_data.ScenA_Xmldata.Huurderving -
        REIM_data.ScenA_Xmldata.Huurderving);
    d[3] = Math.Abs(PM_data.ScenA_Xmldata.Onderhoud -
        REIM_data.ScenA_Xmldata.Onderhoud);
    d[4] = Math.Abs(PM_data.ScenA_Xmldata.Promotiekosten -
        REIM_data.ScenA_Xmldata.Promotiekosten);
    d[5] = Math.Abs(PM_data.ScenA_Xmldata.Beheerkosten -
        REIM_data.ScenA_Xmldata.Beheerkosten);
    d[6] = Math.Abs(PM_data.ScenA_Xmldata.Overige_Exploitatiekosten -
        REIM_data.ScenA_Xmldata.Overige_Exploitatiekosten);
    d[7] = Math.Abs(PM_data.ScenA_Xmldata.Overloopkosten -
        REIM_data.ScenA_Xmldata.Overloopkosten);
    d[8] = Math.Abs(PM_data.ScenA_Xmldata.Met_Derden_Te_Verreken_Kosten -
        REIM_data.ScenA_Xmldata.Met_Derden_Te_Verreken_Kosten);
    d[9] = Math.Abs(PM_data.ScenA_Xmldata.Waarborgsom -
        REIM_data.ScenA_Xmldata.Waarborgsom);
    d[10] = Math.Abs(PM_data.ScenA_Xmldata.Investeringen -
        REIM_data.ScenA_Xmldata.Investeringen);
    d[11] = Math.Abs(PM_data.ScenA_Xmldata.Rente_Te_Late_Betaling -
        REIM_data.ScenA_Xmldata.Rente_Te_Late_Betaling);
    d[12] = Math.Abs(PM_data.ScenA_Xmldata.BTW_Huur -
        REIM_data.ScenA_Xmldata.BTW_Huur);
    d[13] = Math.Abs(PM_data.ScenA_Xmldata.BTW_kosten -
        REIM_data.ScenA_Xmldata.BTW_kosten);
    d[14] = Math.Abs(PM_data.ScenA_Xmldata.Totaal - REIM_data.ScenA_Xmldata.Totaal);

    return d;
}
```

Compare the array d with a chosen c to see if it passes the test.

---

## Scenario B1

Covers scenario B1:  $|R(t) - A(t - 1)| \leq c_x$

Created method:

```
public double compare_data_B1(Cxmldata scenB_data, string date)
    //Pre: scenB_data is filled with data for scenario B of PM and REIM
    //    date has format of "YYYY-MM"
    //post: returns delta of scenario B1 ---> d = |R(t)-A(t-1)|
{
    double R, A = 0;
    int month;
    int year;

    //read RM data net amount of the given month
    R = scenB_data.ScenB_PM_Xmldata.NetAmount;

    //convert date to int
    year = Convert.ToInt16(Convert.ToString(date[0]) +
        Convert.ToString(date[1]) +
        Convert.ToString(date[2]) + Convert.ToString(date[3]));
    month = Convert.ToInt16(Convert.ToString(date[5]) +
        Convert.ToString(date[6]));

    //set date as month before inserted date
    if (month == 1)
    {
        month = 12;
        year = year - 1;
    }
    else
    {
        month = month - 1;
    }

    //Get the data of the month of the REIM data to get A(t-1)
    for (int i = 0; i < scenB_data.ScenB_REIM_Xmldata.month_amount.Length; i++)
    {
        if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_year == year)
        {
            if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_month ==
                month)
            {
                A = scenB_data.ScenB_REIM_Xmldata.month_amount[i].amount;
            }
        }
    }

    //return difference
    return Math.Abs(R - A);
}
```

Compare the returned value with a chosen c to see if it passes the test.

---

---

## Scenario B2

Covers scenario B2:  $|R(t) - A(t - 12)| \leq c_x$

```
public double compare_data_B2(Cxmldata scenB_data, string date)
//Pre: scenB_data is filled with data for scenario B of PM and REIM
//    date has format of "YYYY-MM"
//post: returns delta of scenario B1 ---> d = |R(t)-A(t-12)|
{
    double R, A = 0;
    int month;
    int year;

    //read RM data net amount of the given month
    R = scenB_data.ScenB_PM_Xmldata.NetAmount;

    //convert date to int
    year = Convert.ToInt16(Convert.ToString(date[0]) +
        Convert.ToString(date[1]) +
        Convert.ToString(date[2]) + Convert.ToString(date[3]));
    month = Convert.ToInt16(Convert.ToString(date[5]) +
        Convert.ToString(date[6]));

    //set date as a year before inserted date
    year = year - 1;

    //Get the data of the month of the REIM data to get A(t-12)
    for (int i = 0; i < scenB_data.ScenB_REIM_Xmldata.month_amount.Length; i++)
    {
        if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_year == year)
        {
            if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_month ==
                month)
            {
                A = scenB_data.ScenB_REIM_Xmldata.month_amount[i].amount;
            }
        }
    }

    //return difference
    return Math.Abs(R - A);
}
```

Compare the returned value with a chosen c to see if it passes the test.

---

## Scenario B3

Covers scenario B3:  $\left| \frac{R(t)+A(t-1)+\dots+A(t-n)}{n+1} - \frac{A(t-12)+A(t-13)+\dots+A(t-(n+12))}{n+1} \right| \leq c_x$

```
public double[,] compare_data_B3(Cxmldata scenB_data, string date, int n)
//Pre: scenB_data is filled with data for scenario B of PM and REIM
// date has format of "YYYY-MM", n for how many months to look at
//post: returns delta of scenario B3 ---> d[0,0] = |(R(t)+A(t-1)+...+A(t-
n))/(n+1)-(A(t-12)+A(t-13)+...+A(n-12))/(n+1)|
// d[0,i] (i>0 & i<n) -> A(t-i) d[0,n] -> (R(t)+A(t-1)+...+A(t-
n))/(n+1)
// d[1,i] (i>0 & i<n) -> A(t-(i+12)) d[1,n] -> (A(t-12)+A(t-13)+...+A(n-
(12+n)))/(n+1)
{
    double[,] array = new double[2, n + 1];
    double R;
    int month;
    int temp_month;
    int year;

    //read RM data net amount of the given month
    R = scenB_data.ScenB_PM_Xmldata.NetAmount;

    //convert date to int
    year = Convert.ToInt16(Convert.ToString(date[0]) +
        Convert.ToString(date[1]) +
        Convert.ToString(date[2]) + Convert.ToString(date[3]));
    month = Convert.ToInt16(Convert.ToString(date[5]) +
        Convert.ToString(date[6]));

    //create the month before given month
    if (month == 1)
    {
        temp_month = 12;
        year = year - 1;
    }
    else
    {
        temp_month = month - 1;
    }

    //Get the data of the months of the REIM data to get A(t-1)... A(t-n)
    for (int i = 0; i < scenB_data.ScenB_REIM_Xmldata.month_amount.Length; i++)
    {
        if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_year == year)
        {
            if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_month ==
                temp_month)
            {
                for (int j = 0; j < n; j++)
                {
                    array[0, j + 1] =
                        scenB_data.ScenB_REIM_Xmldata.month_amount[i+j].amount;
                }
            }
        }
    }
}
```



---

```

    }
  }
}

//Get the data of the months of the REIM data to get A(t-12)... A(t-(12+n))
for (int i = 0; i < scenB_data.ScenB_REIM_Xmldata.month_amount.Length; i++)
{
  if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_year == year-1)
  {
    if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_month ==
        month)
    {
      for (int j = 0; j < n; j++)
      {
        array[1, j] =
          scenB_data.ScenB_REIM_Xmldata.month_amount[i+j].amount;
      }
    }
  }
}

//calculate the sum of (R(t)+A(t-1)+...+A(t-n))
array[0, n] = R;

for (int i = 1; i < n; i++)
{
  array[0, n] = array[0, n] + array[0, i];
}

//divide sum with n+1
array[0, n] = array[0, n] / (n + 1);

//calculate the sum of (A(t-12)+A(t-13)+...+A(n-(12+n)))
for (int i = 0; i < n; i++)
{
  array[1, n] = array[1, n] + array[1, i];
}

//divide sum with n+1
array[1, n] = array[1, n] / (n + 1);

//calculate delta
array[0, 0] = Math.Abs(array[0, n] - array[1, n]);

return array;
}

```

Compare the returned value in array[0,0] with a chosen c to see if it passes the test.

---

## Scenario B4

Covers scenario B4:  $|R(t) - B(t)| \leq c_x$

```
public double compare_data_B4(Cxmldata scenB_data, string date)
//Pre: scenB_data is filled with data for scenario B of PM and REIM
//    date has format of "YYYY-MM"
//post: returns delta of scenario B1 ---> d = |R(t)-A(t)|
{
    double R, A = 0;
    int month;
    int year;

    //read RM data net amount of the given month
    R = scenB_data.ScenB_PM_Xmldata.NetAmount;

    //convert date to int
    year = Convert.ToInt16(Convert.ToString(date[0]) +
        Convert.ToString(date[1]) +
        Convert.ToString(date[2]) + Convert.ToString(date[3]));
    month = Convert.ToInt16(Convert.ToString(date[5]) +
        Convert.ToString(date[6]));

    //Get the data of the month of the REIM data to get A(t)
    for (int i = 0; i < scenB_data.ScenB_REIM_Xmldata.month_amount.Length; i++)
    {
        if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_year == year)
        {
            if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_month ==
                month)
            {
                A = scenB_data.ScenB_REIM_Xmldata.month_amount[i].amount;
            }
        }
    }

    //return difference
    return Math.Abs(R - A);
}
}
```

Compare the returned value with a chosen c to see if it passes the test.

---

## Scenario B5

Covers scenario B5:  $\left| \frac{R(t)+B(t-1)+\dots+B(t-n)}{n+1} - \frac{B(t-12)+B(t-13)+\dots+B(t-(n+12))}{n+1} \right| \leq C_x$

```
public double[,] compare_data_B5(Cxmldata scenB_data, string date, int n)
//Pre: scenB_data is filled with data for scenario B of PM and REIM
// date has format of "YYYY-MM", n for how many months to look at
//post: returns delta of scenario B1 ---> d[0,0] = |(R(t)+B(t-1)+...+B(t-
n))/(n+1)-(B(t-12)+B(t-13)+...+B(n-12))/(n+1)|
// d[0,i] (i>0 & i<n) -> B(t-i) d[0,n] -> (R(t)+B(t-1)+...+B(t-
n))/(n+1)
// d[1,i] (i>0 & i<n) -> B(t-i) d[1,n] -> (B(t)+B(t-1)+...+B(t-
n))/(n+1)
{
    double[,] array = new double[2, n + 1];
    double R;
    int month;
    int temp_month;
    int year;

    //read RM data net amount of the given month
    R = scenB_data.ScenB_PM_Xmldata.NetAmount;

    //convert date to int
    year = Convert.ToInt16(Convert.ToString(date[0]) +
        Convert.ToString(date[1]) +
        Convert.ToString(date[2]) + Convert.ToString(date[3]));
    month = Convert.ToInt16(Convert.ToString(date[5]) +
        Convert.ToString(date[6]));

    //create the month before given month
    if (month == 1)
    {
        temp_month = 12;
    }
    else
    {
        temp_month = month - 1;
    }

    //Get the data of the months of the REIM data to get A(t-1)... A(t-n)
    for (int i = 0; i < scenB_data.ScenB_REIM_Xmldata.month_amount.Length; i++)
    {
        if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_year == year)
        {
            if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_month ==
                temp_month)
            {
                for (int j = 0; j < n; j++)
                {
                    array[0, j + 1] = scenB_data.ScenB_REIM_Xmldata.month_amount[i
                        + j].amount;
                }
            }
        }
    }
}
```

---

---

```

    }

    //Get the data of the months of the REIM data to get A(t-12)... A(t-(12+n))
    for (int i = 0; i < scenB_data.ScenB_REIM_Xmldata.month_amount.Length; i++)
    {
        if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_year == year - 1)
        {
            if (scenB_data.ScenB_REIM_Xmldata.month_amount[i].period_month ==
                month)
            {
                for (int j = 0; j < n; j++)
                {
                    array[1, j] = scenB_data.ScenB_REIM_Xmldata.month_amount[i +
                        j].amount;
                }
            }
        }
    }

    //calculate the sum of (R(t)+A(t-1)+...+A(t-n))
    array[0, n] = R;

    for (int i = 1; i < n; i++)
    {
        array[0, n] = array[0, n] + array[0, i];
    }

    //divide sum with n+1
    array[0, n] = array[0, n] / (n + 1);

    //calculate the sum of (A(t-12)+A(t-13)+...+A(n-(12+n)))
    for (int i = 0; i < n; i++)
    {
        array[1, n] = array[1, n] + array[1, i];
    }

    //divide sum with n+1
    array[1, n] = array[1, n] / (n + 1);

    //calculate delta
    array[0, 0] = Math.Abs(array[0, n] - array[1, n]);

    return array;
}

```

Compare the returned value in array[0,0] with a chosen c to see if it passes the test.

## APPENDIX VIII - Business resource model (general structure)

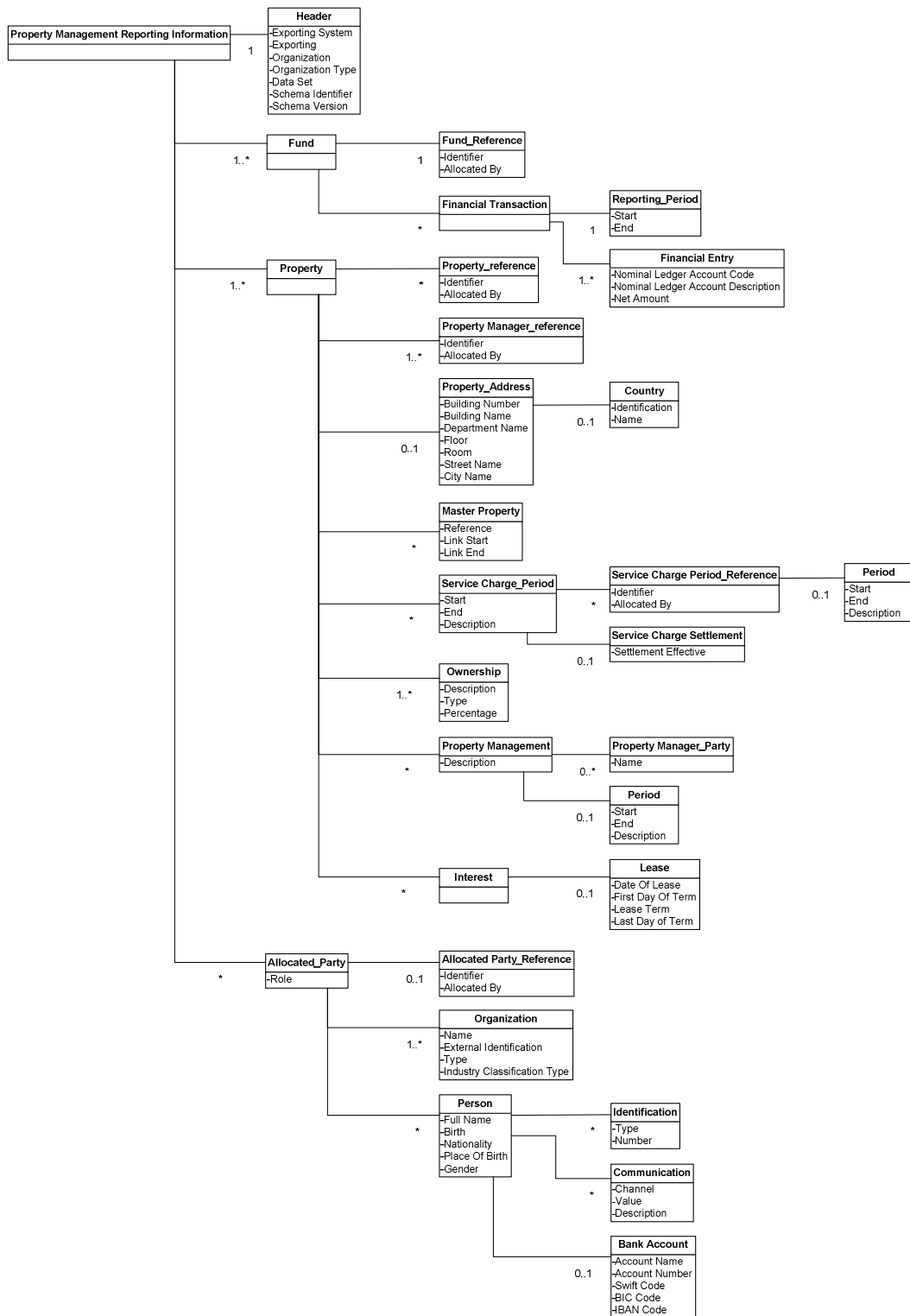


Figure 17: Simplified UML diagram of the general structure of a data response

## APPENDIX IX - Business resource model (classes data checks)

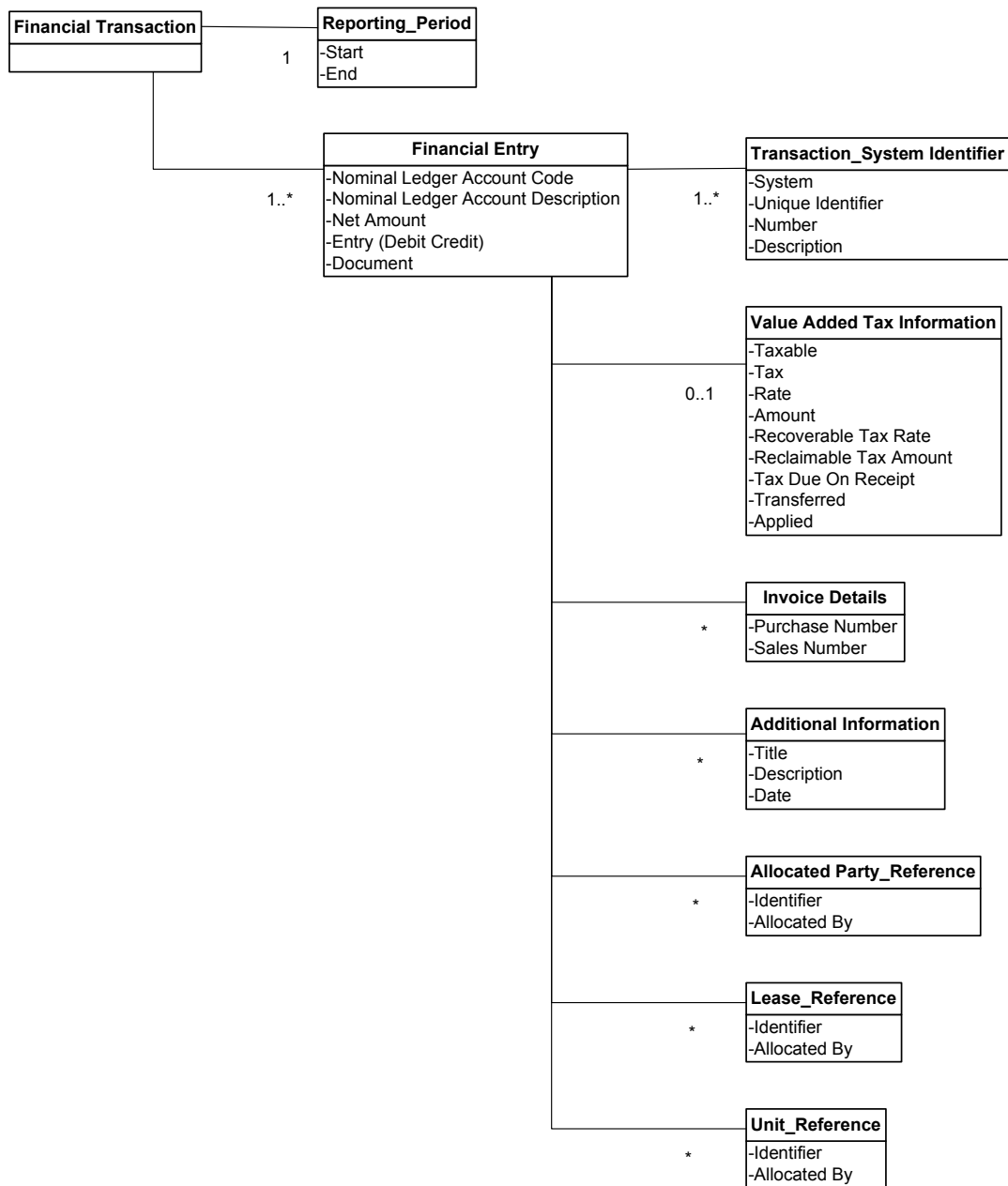


Figure 18: UML diagram of the most significant classes used within the determined data checks

---

## APPENDIX X - Requirements

### Functional requirements:

#### Must:

1. have the possibility to import XML Schemas;
2. have the possibility to export XML Schemas;
3. combine REDEX response with related aggregated data;
4. have a possibility to temporally store the response data;
5. have a possibility to temporally store the aggregated data;
6. check whether the responses comply with defined business rules within the tool;
7. block responses that violate one or more business rules;
8. notice when a business rule is violated;
9. include the reason when a business rule is violated within the notification;
10. send the notification (of business rule violation) to both PM, REIM, (and external accountant);
11. send a notification to both PM, REIM, (and external accountant) when response is successfully processed;
12. log the checking of business rules, including:
  - a. case instance;
  - b. reference to a REIM;
  - c. reference to a PM;
  - d. timestamp;
  - e. result of the check;
  - f. when result is negative: reason of violation business rule.
13. be compatible with all versions of the OSCRE language (XSDs);

#### Should:

14. have a possibility to export the log-file;

#### Could:

#### Won't:

---

## Non-functional requirements:

### Must:

1. have the possibility to add new business rules without consequences for the underlying architecture (*extensibility*);
2. be located within the IT landscape of the REIM;

### Should:

3. be not platform specific;

### Could:

### Won't:

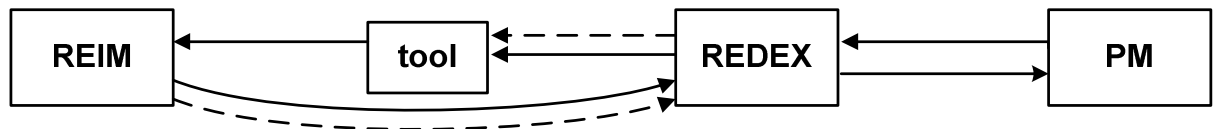


---

## APPENDIX XI - Scenarios data flows tool WIP

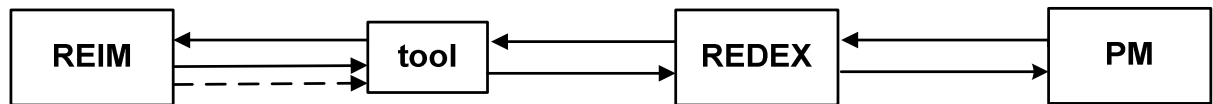
In order to perform the necessary checks both the response and the aggregated data need to be present at the tool. The following sections describe the potential scenarios. The solid arrows mean request/ response data and the dotted arrows stand for the aggregated data.

### Scenario I



The REIM sends the aggregated data inside the data request to REDEX. REDEX sends a copy of the data request to the PM. When the response data from the PM is arrived and checked by REDEX, REDEX sends the response and the aggregated data to the tool. After the tool performed his checks he sends the response data to the REIM and deletes the aggregated data.

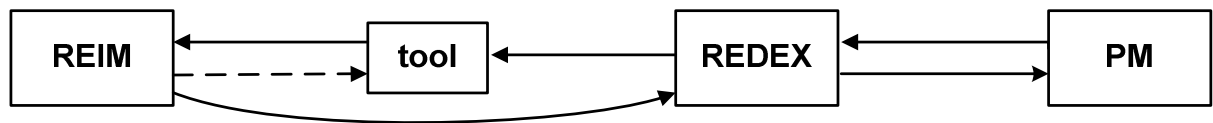
### Scenario II



The REIM sends the aggregated data inside the data request to the tool. The tool stores the filtered aggregated data and forwards the data request (excluding the aggregated data) to REDEX. REDEX sends a copy of the data request to the PM. When the response data from the PM is arrived and checked by REDEX, REDEX sends the response data to the tool. The tool performs his checks using the stored aggregated data. After the checks the tool sends the response data to the REIM and deletes the aggregated data.

---

### Scenario III



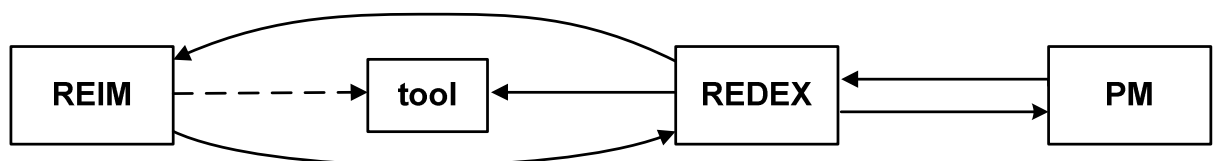
#### Scenario IIIa

The REIM sends the data request to REDEX. REDEX sends a copy of the data request to the PM. When the response data from the PM is arrived and checked by REDEX, REDEX sends the response data to the tool. While the response data is waiting at the tool, the tool requests the aggregated data at the REIMS. When the aggregated data is received the tool performs his checks. After these checks the tool sends the response data to the REIM and deletes the aggregated data.

#### Scenario IIIb

The REIM sends the data request to REDEX and the aggregated data to the tool. REDEX sends a copy of the data request to the PM. When the response data from the PM is arrived and checked by REDEX, REDEX sends the response data to the tool. The tool performs his checks using the stored aggregated data. After the check the tool sends the response data to the REIM and deletes the aggregated data.

### Scenario IV



The REIM sends the data request to REDEX. REDEX sends a copy of the request to the PM. When the response data from the PM is arrived and checked by REDEX, REDEX sends a copy of the response to the tool. Then the tool requests the aggregated data at the REIMS and when this

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data is received the tool performs his checks. When the checks are successfully accomplished the tool sends this status update to REDEX. Then REDEX sends the response data to the REIM and deletes the aggregated data.

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## APPENDIX XII - Settings validation data check scenarios

### Data check scenarios A1

This data check scenario compares the determined data aspects available at 'IS PM' with the data at 'IS REIM' at a specific moment in time.

### Data check scenarios B1-3

The data checks B1-3 are specific for aspects with a stable behaviour. Within the technical validation there is chosen to validate the aspect scheduled maintenance for the real estate property PR9056 with for period September 2011. For scenario B3 a rolling horizon of 10 months is used.

For the stable aspect scheduled maintenance the following steps need to be performed:

1. Query for the following attribute values within the Response data:
  - Nominal ledger account code = 631;
  - Property ID = PR9056;
  - Period ( $t = 0$ ) = 2011-09;
  - B3: Rolling horizon ( $n$ ) = 10;
2. Retrieve the amount from the result of above query;
3. Compare the result with the amount of scheduled maintenance costs for the same Property ID in period  $t=1$  (or  $t=12$ , or rolling horizon) retrieved from the aggregate data at IS REIM;
4. Run the data check.

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### Data check scenarios B4-5

The data checks B4-5 are specific for aspects with a dynamic behaviour. Within the technical validation there is chosen to validate the aspect corrective maintenance for the real estate property PR9056 with for period September 2011. For scenario B5 a rolling horizon of 5 months is used.

For the stable aspect corrective maintenance the following steps need to be performed:

1. Query for the following attribute values within the Response data:
  - Nominal ledger account code = 671;
  - Property ID = PR9056;
  - Period ( $t = 0$ ) = 2011-09;
  - B5: Rolling horizon ( $n$ ) = 5;
2. Retrieve the amount from the result of above query;
3. Compare the result with the amount of scheduled maintenance costs for the same Property ID in period  $t=1$  (or  $t=12$ , or rolling horizon) retrieved from the budget data at IS REIM;
4. Run the data check.

## APPENDIX XIII - Boundary checks

This appendix shows screenshots of the validation of the data check scenarios A1 and B1-5. Boundary checks are conducted and per scenario two outcomes are shown.

### Data check scenario B1:

	PM	REIM	C	delta	
Theoretische Huur	24141887	24141987	99	100	TP: 1234
Leegstand	884	897	12	13	Port: 4321
Huurderving	176	134	41	42	Entity: AS1232
Onderhoud	1225508	1225202	305	306	
Promotiekosten	3825	3815	9	10	
Beheerkosten	55671	55741	69	70	
Overige Exploitatiekosten	8041	8241	199	200	
Overlooptkosten	1	1	5	0	
Met Derden Te Verreken Kosten	1	1	5	0	
Waarborgsom	-5304	-5312	7	8	
Investeringen	1	1	5	0	
Rente Te Late Betaling	-2627	-1827	799	800	
BTW Huur	1	1	5	0	
BTW kosten	321487	321887	399	400	
Totaal	22420718	22420518	199	200	

Figure 19: Figure 21: Boundary check data check scenario A1 with result false.

	PM	REIM	C	delta	
Theoretische Huur	24141887	24141987	100	100	TP: 1234
Leegstand	884	897	13	13	Port: 4321
Huurderving	176	134	42	42	Entity: AS1232
Onderhoud	1225508	1225202	306	306	
Promotiekosten	3825	3815	10	10	
Beheerkosten	55671	55741	70	70	
Overige Exploitatiekosten	8041	8241	200	200	
Overlooptkosten	1	1	0	0	
Met Derden Te Verreken Kosten	1	1	0	0	
Waarborgsom	-5304	-5312	8	8	
Investeringen	1	1	0	0	
Rente Te Late Betaling	-2627	-1827	800	800	
BTW Huur	1	1	0	0	
BTW kosten	321487	321887	400	400	
Totaal	22420718	22420518	200	200	

Figure 20: Figure 21: Boundary check data check scenario A1 with result true.

## Data check scenario B1:

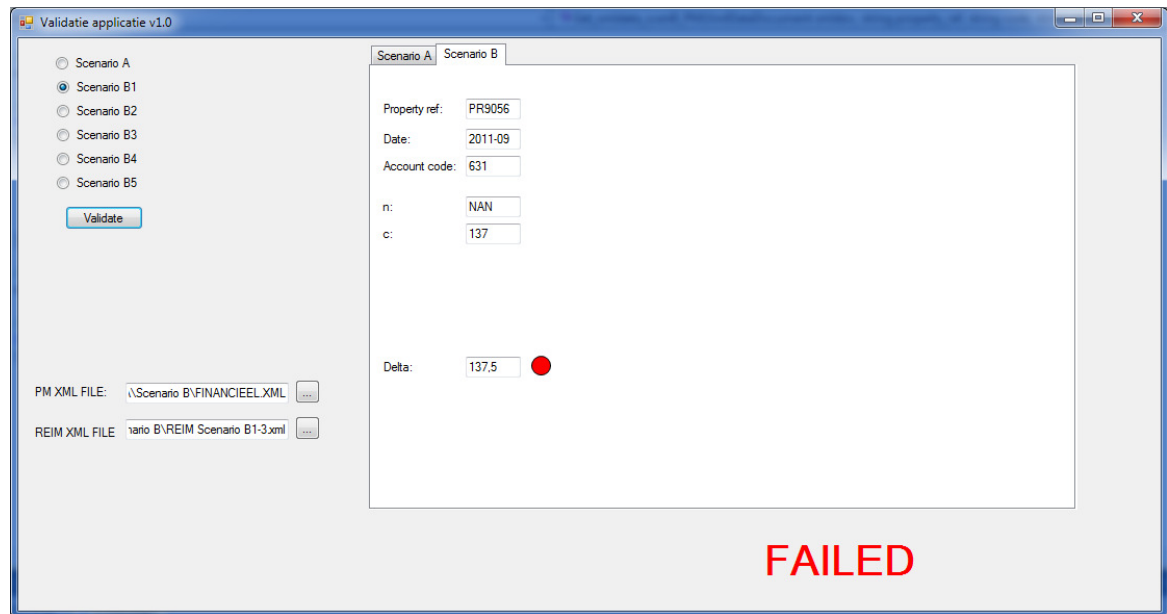


Figure 21: Boundary check data check scenario B1 with result false.

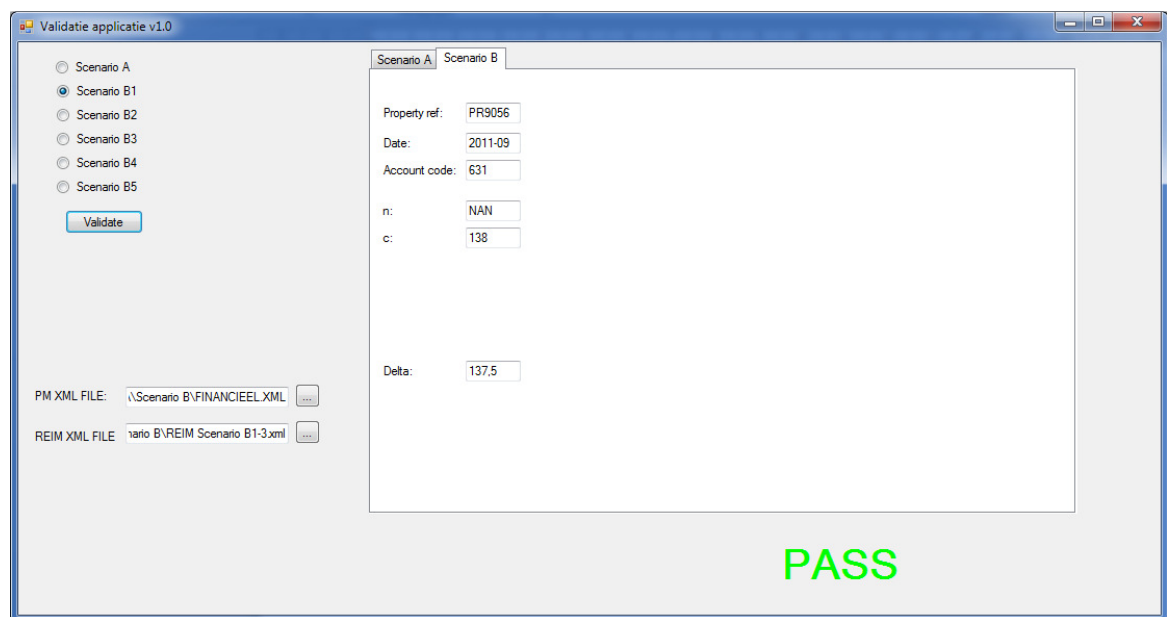


Figure 22: Boundary check data check scenario B1 with result true.

## Data check scenario B2:

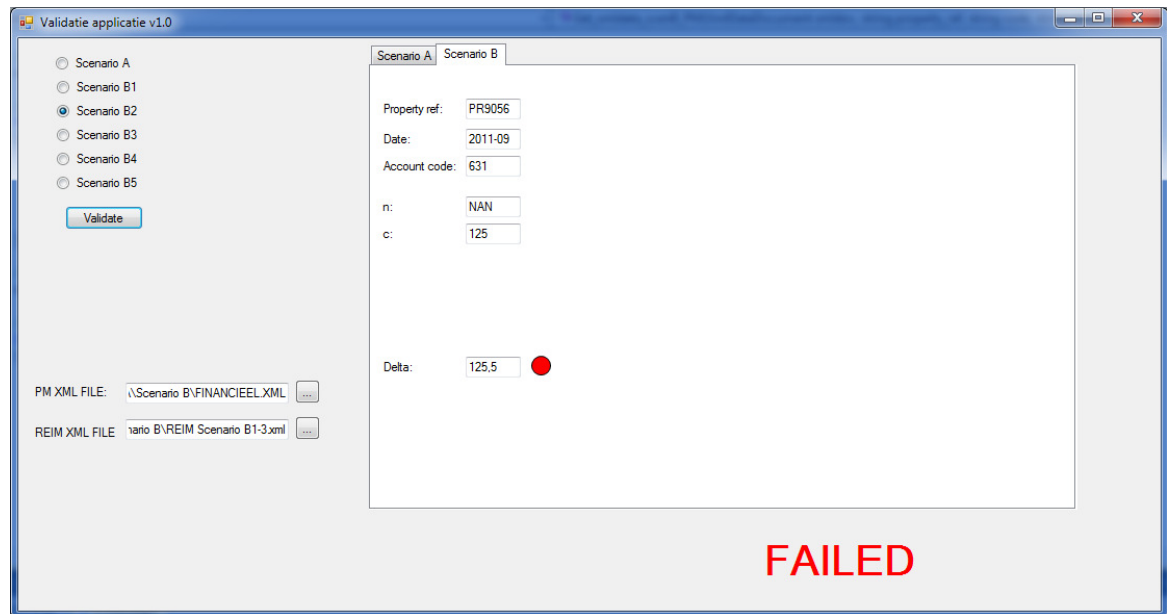


Figure 23: Boundary check data check scenario B2 with result false.

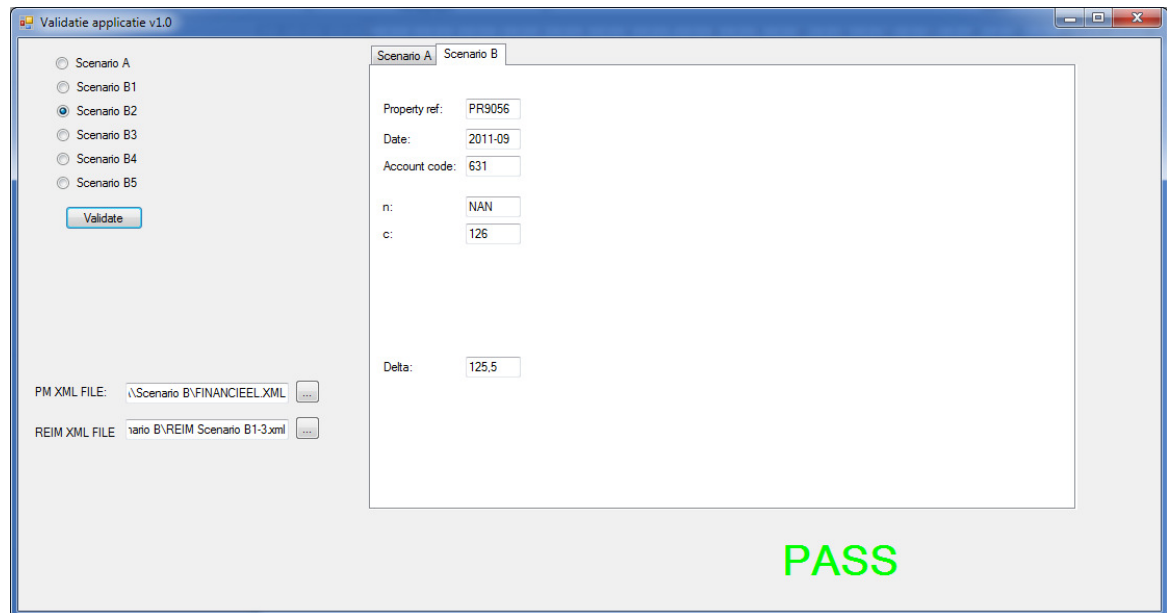


Figure 24: Boundary check data check scenario B2 with result true.



## Data check scenario B3:

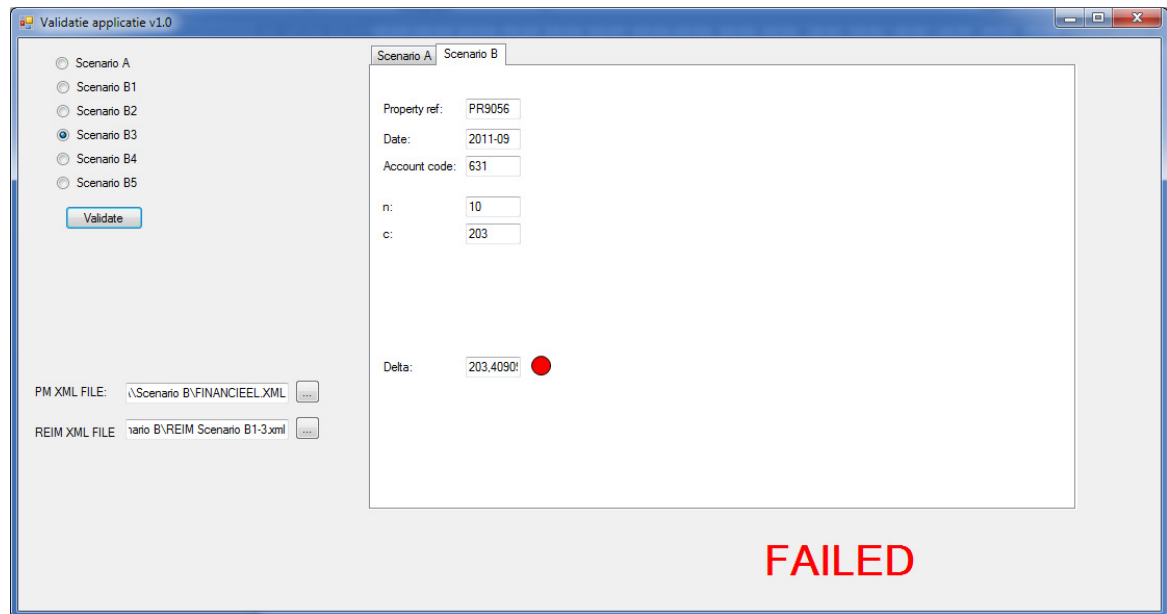


Figure 25: Boundary check data check scenario B3 with result false.

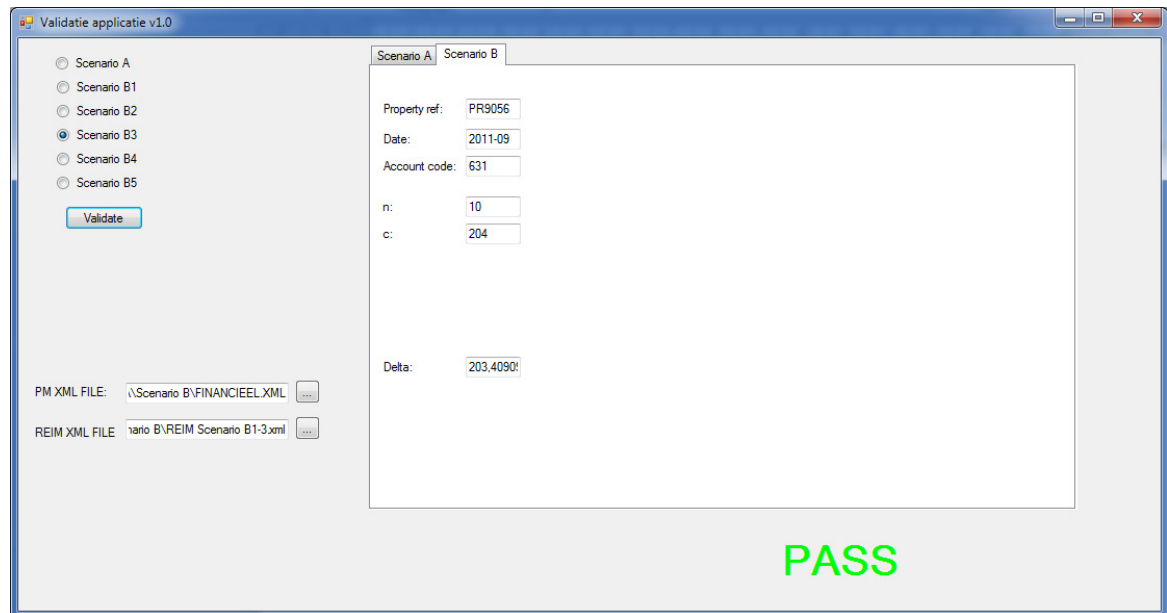


Figure 26: Boundary check data check scenario B3 with result true.

## Data check scenario B4:

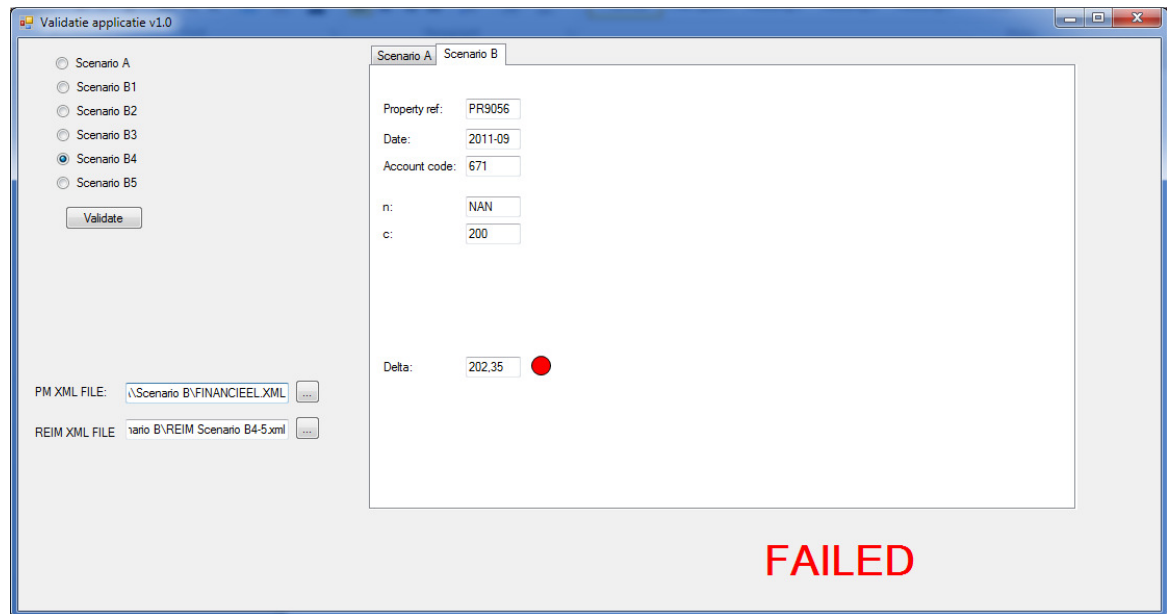


Figure 27: Boundary check data check scenario B4 with result false.

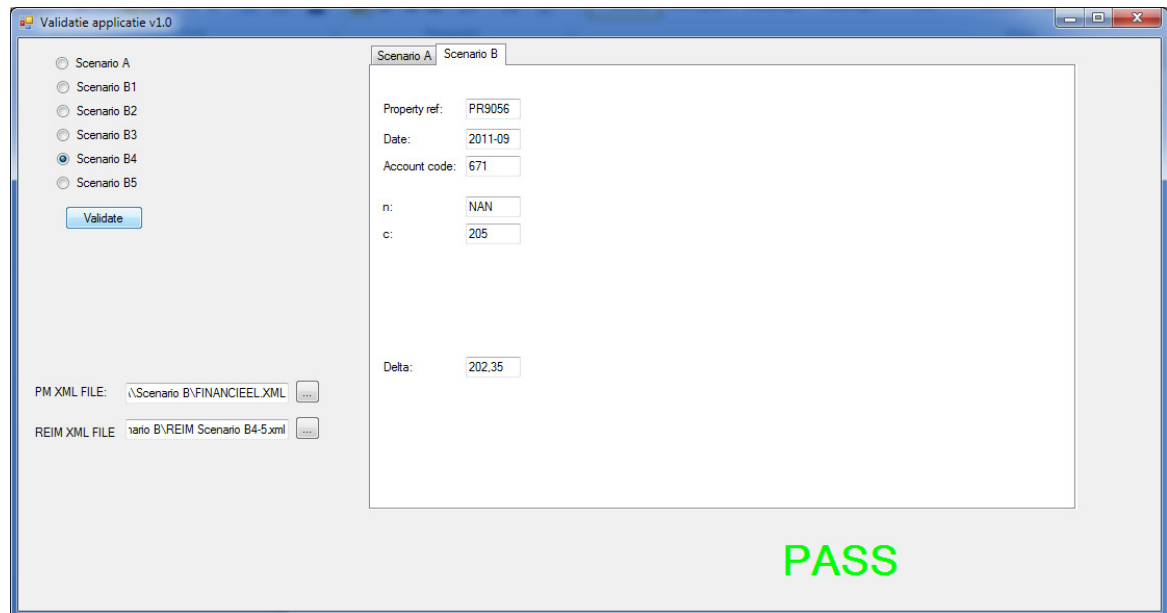


Figure 28: Boundary check data check scenario B4 with result true.

## Data check scenario B5:

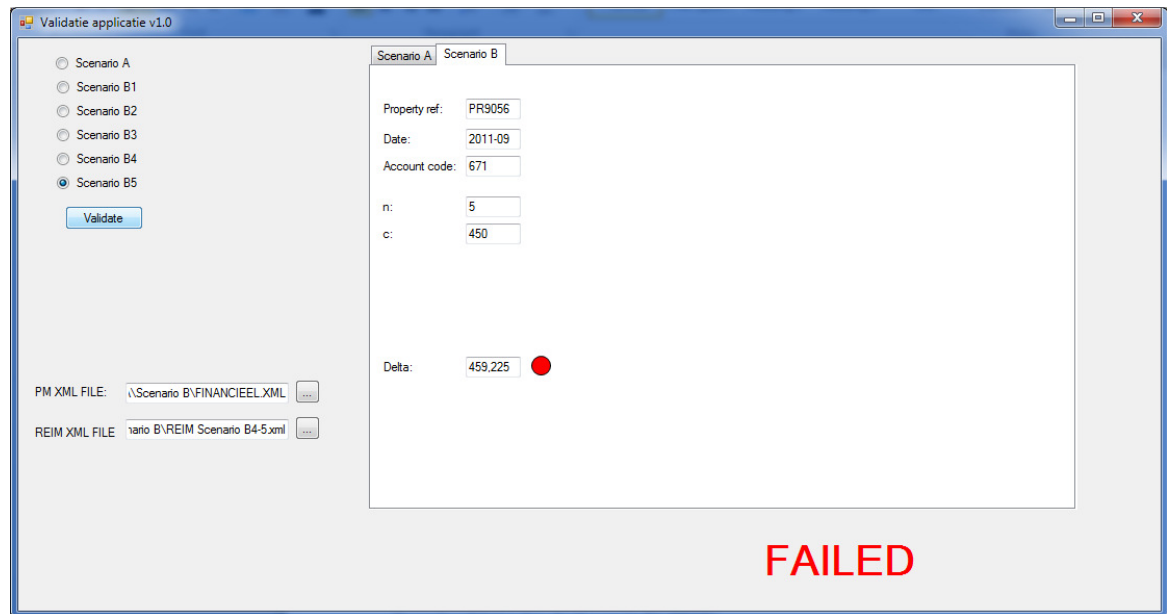


Figure 29: Boundary check data check scenario B5 with result false.

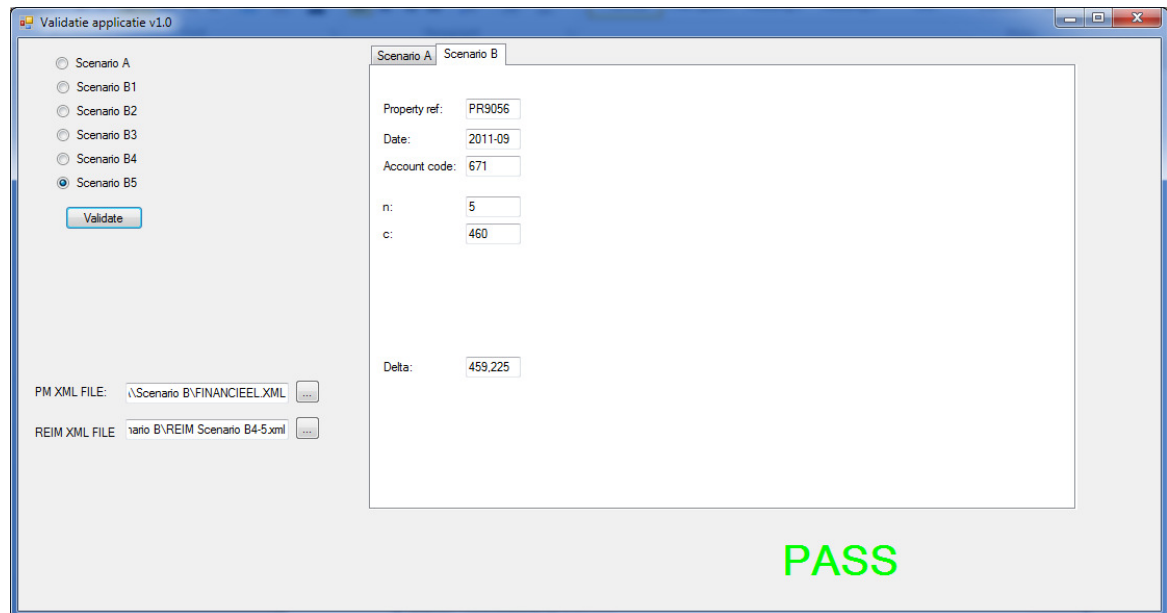


Figure 30: Boundary check data check scenario B5 with result true.