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Master's Thesis

Method for estimating the impact of Robotic Process Automation
implementations on business processes.

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The societal situation surrounding the COVID-19 outbreak has had various implications for this research. The research project required rethinking on several levels, such as the multi-case study, data gathering, and method evaluation. Alternatively, I used secondary data and applied different evaluation techniques. Nevertheless, the faculty and the supervisors gave me and other students adequate guidance in making the necessary choices regarding the conduct of the research. My internship company also made sure that I had the right equipment at my disposal to carry out the research in the best possible way.

Abstract

This research set out to develop a tangible standardized method that can be used to effectively estimate the impact of RPA based on quantitative baseline measurements that can be readily applied in practice without leveraging other technologies. A multi-case study and an expert evaluation are carried out to structurally evaluate the method by applying the method in practice. With the developed method, I was able to address in the identified gaps in the literature. By combining scientific research with findings and hands-on expertise, this research has provided a deeper insight into a comprehensive approach to estimating the impact of RPA, which is tailored to the application of the method in practice

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1 Problem statement

Recently, Robotic Process Automation (RPA) is adopted by organizations that aim to increase their operational efficiency using IT initiatives [45]. Operational inefficiency exists due to the burden of simple work routines and repetitive tasks employees, i.e., human agents, have to deal with, which consume a vast amount of time [17]. Besides the inefficient resource utilization, operational tasks are susceptible to human error and poor performance results. Earlier approaches to cope with this issue still relied on human agents to trigger or terminate processes or to adapt to different cases [49]. RPA is a fast-emerging approach that has attracted a strong interest in the business process automation technology industry [23, 45].

Despite the industry's strongly growing interest in RPA, academic research on RPA is scarce, and most existing research focuses on case studies or market research [1, 23, 32, 43]. In addition, studies that have been published are primarily focused on the alleged benefits of RPA solutions. A number of studies show increases in profitability and productivity due to the implementation of RPA [3, 30, 31, 43, 51]. However, very little is known about how these benefits can be measured effectively and how these benefits can be estimated upfront. The aforementioned case studies either assessed the potential of the RPA impact based on subjective opinions, used other technologies, or assessed the savings after the completion of the RPA implementations [50]. According to Wanner et al. [50], "the full potential of RPA remains poorly understood". Currently, RPA business cases are primarily based on expert impact estimations. These estimations are predominantly based on a subjective amount of time employees are working on the business process's activities [8, 13, 37].

Rigorous evidence of achieving the estimated business cases of RPA solutions prior to the implementation is lacking. In order to create a common understanding of what an organization is aiming for with the use of RPA, they have to be clear about expected benefits. Thereby, the possibility of reaching the proposed goals is maximized [9]. Being clear about the expected benefits of RPA also paves the way for efficient and effective measurement of RPA ROI, thus, the actual impact of RPA. Therefore, the necessity of a method for indicating the potential benefits of RPA implementations through an estimation is evident.

Nevertheless, it is apparent that research on elaborate metrics and a practice-oriented approach for the expected impact of RPA on business processes before implementation rarely exist [45]. In line with that, recommendations from research suggest that a standardized method to quantify a reliable indication of the potential of RPA is needed [23, 33, 50]. Thus, evaluating the estimated impact of RPA implementations in comparison with the actual impact of RPA implementations, what metrics can be used for these estimations, and how to apply such an estimation in practice are worthy of further study. Therefore, a guiding method or best practices for the quantitative impact estimation of RPA solutions would contribute to the research domain.

To summarize, the problem at hand can be stated as follows:

- The need for quantifiable measures of the RPA potential of processes has arisen;
- Currently, baseline measurements such as process cycle times and process costs are assessed in a widely subjective manner;
- Defining an RPA business case based on impact estimations prevents poor expectation management in terms of costs and savings;
- Estimating the potential impact of RPA on business processes is a complicated task;

- A standardized RPA impact estimation method that supports that task should be researched and developed further.

1.1 Research objectives

To date, research has proposed a few high-level concepts to estimate the potential impact of RPA implementations. Concepts such as determining the automation potential of processes [50], an ROI analysis based on subjective statements [37], and a cost-benefit analysis that takes a detailed process assessment into account [46] are described. Typically, these approaches neglect quantitative measurements, in-depth FTE reduction calculation, and applicability in practice.

I seek to close this gap by developing and operationalizing a method to estimate the impact of an RPA implementation on a business process effectively, which can be used to guide companies in quantifying the potential of RPA implementations in practice without leveraging other technologies. The objectives of the research are, therefore, to clarify the relevant variables in performing an RPA impact estimation, to improve the effectiveness of impact estimations for RPA implementations, and to develop an RPA impact estimation method that is applicable in practice.

1.2 Research questions

In line with the research problem described in Chapter 1, the main research question (RQ) formulated for this thesis is:

RQ: How can one effectively estimate the impact of an RPA implementation?

In order to answer the main research question, four sub-research questions (SQs) are formulated. The SQs provide a more elaborate direction for this study. To define the scope of the research and to create a common understanding of the subject, SQ1 is selected. By doing so, SQ1 aims to describe what should be incorporated into a standardized RPA impact estimation method. SQ2 dives into the possibly existing state-of-the-art with regard to estimating the impact of RPA implementations and its challenges. SQ3 aims to identify the opportunity of using a standardized method to estimate the impact of RPA implementations. Besides that, it aims to identify essential components as part of the intended RPA impact estimation method. Lastly, SQ4 aims to describe how the estimated impact by the standardized RPA impact estimation method can be evaluated.

- **SQ1:** What are the indicators for the quantitative impact of an RPA implementation?
- **SQ2:** What approaches exist to estimate the impact of an RPA implementation?
- **SQ3:** How can the impact of an RPA implementation be estimated effectively using a standardized method?
- **SQ4:** How can the effectiveness of the RPA impact estimation using the standardized method be evaluated?

2 Research method

This chapter describes the research plan designed for this thesis. The research plan describes the research approach used to achieve the earlier defined objectives. The main research question and subsequent sub-research questions, that were presented in Section 1.2, provide an overview of the research goals for this thesis.

The aim of this research is to develop an effective RPA impact estimation method, in such a solid way that it can be used and applied in practice. The developed method is utilized to examine the impact of RPA implementations on business processes by analyzing a set of performance and cost indicators. Aside from developing a new RPA impact estimation method, the research includes a method evaluation set up that consists of two evaluation types. First, a multi-case study where the RPA impact estimation method is applied and studied for multiple cases [54]. This type of study is designed to collect data on multiple business processes at more than one point in time. The studied processes exist in their context and are executed separately. Nevertheless, executing the RPA estimation method is replicated for each case. Besides that, each case concerns a business process whose characteristics qualify for an RPA implementation. This replication makes the cases suitable for a multi-case study. Second, an expert evaluation is carried out according to the Method Evaluation Model by Moody [38] to evaluate the developed method on perceived efficacy and adoption in practice.

The research consists of three parts: creating an understanding of the context and current practices of RPA impact estimation, developing a standardized method for estimating the impact of RPA, evaluating the method by applying it to multiple processes during a multi-case study and carrying out an expert evaluation. Table 1 lists the high level research approach. Each of the three parts is elaborated on in the following subsections.

Table 1: High level research approach

Research parts	Outcomes
Create common understanding context	Theoretical framework
Develop standardized RPA impact estimation method	Initial estimation method
Evaluate RPA impact estimation method	Results + Revised estimation method

2.1 Create common understanding context

In the first part of the research, a multivocal literature review is carried out where RPA and possibly existing impact estimation methods are researched. Thus, sub-research questions 1 and 2 are addressed. A multivocal literature review emphasizes the inclusion of gray literature aside from formally-published literature [19]. Since RPA is a practitioner-oriented and an application-oriented field, where RPA-practitioners constantly produce gray literature, the multivocal literature review is an encompassing fit for this research.

The multivocal literature review aims to describe how this thesis fits into the current research landscape. In addition, the objective is to generate a thorough understanding of the concepts used in this study regarding RPA impact estimation. This review seeks to establish what has been researched so far in the field, what indicators for impact are currently used in practice, and what methods exist to estimate the expected impact of an RPA implementation. This is done through a review of available literature on research

that has already been conducted. By doing so, the existing gap in current knowledge can be pointed out. In order to perform the multivocal literature review, a literature review protocol is drawn up to define the strategy of the search. The protocol can be devised in five steps, which can be seen in Table 2.

Carrying out the literature review protocol results in a theoretical framework, respectively. This section elaborates on the strategy carried out during the literature review and the results of the literature review. The review questions to be addressed in the literature review are: “*What do RPA and its purpose entail according to existing research?*”, “*What are the indicators and metrics to analyze effective RPA implementations?*”, and “*What constitutes current best practice in relation to estimating the impact of RPA implementations?*”. During each step of the literature review, scientific publications, as well as gray literature sources, are assessed on their quality and relevance to this research. A complete overview of the sources used in the literature review is given in Table 27 in Appendix A.

Table 2: Part 1 research approach

Common understanding context

Create literature population

Select literature

Review literature

Identify estimation methods

Evaluate estimation methods

Select estimation methods

2.1.1 Create literature population

For the analysis, a search strategy is defined for creating the literature population. This search strategy defines how the search for relevant literature is performed in detail. Google Scholar is used to identify potentially relevant literature. This search engine offers papers, journal articles, and books from several outlets. Since Google Scholar solely focuses on published research, Google is used as an additional source. Google is consulted because gray literature sources provide a large number of RPA in practice related articles. Gray literature sources are leading research and advisory companies, and RPA practitioners such as RPA vendors and RPA re-sellers. The scope of the searches is guarded using a predefined set of keywords. The initial search keywords are ‘Robotic Process Automation’, ‘RPA impact’, ‘RPA impact estimation’, ‘RPA effectiveness’, ‘RPA performance’, ‘RPA performance metrics’ ‘impact estimation method’. If needed, the set of keywords can be expanded during the execution of the literature review. Reference lists and bibliographies of the collected articles, for which the inclusion is certain, are searched as well. This search is done using the snowballing approach [53]. For instance, a systematic literature review performed in 2019 [27] is used as a reference to other RPA literature. By using this search strategy, it is believed that ample perspectives on RPA and approaches for its estimation formulation are gathered.

During this first step in the literature review, a collection of literature eligible for this research is gathered. The population of literature that is created is listed in Table 3. A total of 56 sources are collected in the initial search. A distinction is made between scientific

publications and gray literature. The population consists of 29 scientific publications and 27 gray literature sources. Due to the nature of this multivocal literature review, the share of gray literature sources is evident.

Table 3: Literature review results

Literature review step	Number of sources	Scientific publication	Gray literature
Create literature population	56	29	27
Select literature	48	22	26
Review literature	44	20	24
Identify estimation methods	15	8	7
Evaluate estimation methods	8	2	6
Select estimation methods	3	1	2

2.1.2 Select literature

Not all papers found during the initial search are used during the study. Selection criteria are drawn up to select the literature applicable to this research. As mentioned before, the type of publications that are considered to be eligible for this review is published research studies as well as gray literature. Publications were only included in the analysis if they featured RPA as its main subject or if they featured proper estimation approaches for different technologies. The review considered all studies that evaluate the impact of an RPA implementation or the estimation of the impact of an RPA implementation. The primary outcomes of interest are RPA impact indicators or metrics and RPA impact estimation method elements. In the absence of these types of studies, existing estimation methods and impact indicators or metrics for other technologies that may be readily applied to this domain are considered as well.

Thus, a selection of sources from the population of literature that is created during the first step of the literature review is made. Sources that did not feature RPA as the main subject nor featured relevant content on impact estimation approaches for RPA or different technologies are excluded. From the initial population of sources, eight were found not relevant for the subject in question. The selection of relevant sources can be seen in Table 3 and results in a new total of 48 sources, from which 22 are scientific publications, and 26 are gray literature sources.

2.1.3 Review literature

During the review step, the selected literature is reviewed on its content and quality. Consequently, the reviewed content is used in the theoretical framework of this research. The review is carried out based on relevance regarding this research, quality of the papers, and content of the papers. The quality of the papers is assessed based on its novelty, the authority of the producer, the date, the used methodology, and its objectivity. This quality assessment is based on the guidelines defined by Garousi et al. [19].

The collection of relevant literature remaining from the selection is reviewed. The quality assessment resulted in a new total of 44 sources. The sources that are excluded from

the population during this step did not contain the required content and quality. This exclusion concerns merely four sources. The search strategy used during the initial search and the literature selection thus proves to have been efficient. Reviewing the literature results in a new total of 44 sources, which consists of 20 scientific publications and 24 gray literature sources, as listed in Table 3.

2.1.4 Identify estimation methods

Besides building the theoretical framework during the multivocal literature review, the collection is searched for estimation methods in particular. All reviewed content related to the estimation of the impact of technology on a business process is identified as potentially relevant for the new RPA impact estimation method. Aside from possible methods defined for such an estimation, impact indicators where the estimation is based upon are identified as well.

The scientific publications and gray literature sources in which an impact estimation method or an RPA impact indicator is identified are selected for evaluation. From the reviewed literature population, 15 sources with content related to the impact estimation of RPA were identified. Table 3 shows that from the 15 sources, eight are scientific publications, and seven are gray literature sources.

2.1.5 Evaluate estimation methods

The identified methods or method fragments from the previous paragraph are evaluated on correctness and usefulness for the RPA impact estimation method developed in this research. A combination of practitioner experience and earlier research on impact indicators and impact estimation determines what method fragments are eligible for the RPA impact estimation method.

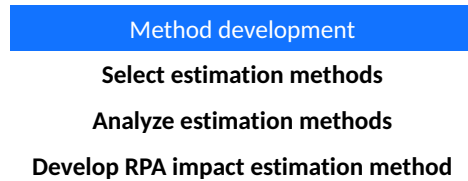
The collection of 15 sources which contain content on, or related to, RPA impact estimation are evaluated. Evaluation of the sources resulted in eight sources eligible to use in the development of the RPA impact estimation method. During the evaluation of the sources, two scientific publications and six gray literature sources are identified, as can be seen in Table 3. In the next section, the ultimate selection of estimation methods, as well as the analysis of these methods, are described.

2.2 Develop standardized RPA impact estimation method

A method is developed for estimating the impact of an RPA implementation on business processes. Developing the estimation method is done through a collection of analyzed method elements from selected similar literary studies or RPA practitioners. Therefore, literature sources related to estimation methods that are identified and evaluated in Section 2.1 are further elaborated on in this section. A selection of methods is made and described in the next paragraph. Lastly, these methods are exposed to extensive in-depth analysis. The methods, as described in this section, are used as building blocks for the initial RPA impact estimation method in Chapter 4. The creation of a method using a comparison of different method elements from other methods is derived from the method engineering approach defined by van de Weerd and Brinkkemper [47] and van de Weerd et al. [48]. Corresponding method elements are considered valuable and are therefore included in the initial method. Unique method elements that are considered value-adding are also included. These considerations are partly based on the literature and partly based on experience in practice. Table 4 illustrates the steps taken in the development of the RPA

impact estimation method. Thus, sub-research question 3 is addressed by this research step.

Table 4: Part 2 research approach



2.2.1 Select estimation methods

Several methods are evaluated during the multivocal literature review of this research. Selection criteria for eligible estimation methods are described in Section 2.1.5. A requirement is that they must contain methods or metrics to quantify the indicators for estimating the impact of RPA. The assessment of qualitative performance indicators that concern social and organizational implications are neglected in this study, thus are subject to future research.

From the remaining eight sources, the sources containing a suitable method or suitable method fragments are selected for analysis. During this step, solely those sources with proper methods or metrics to estimate the impact of RPA are selected. Proper methods or metrics entail that they can be directly used to quantify indicators of RPA impact. Thus it is clear which measurements are needed and which calculations can be performed to obtain the ultimate results from these measurements. Based on these criteria, the remaining sources consisted of merely three sources eligible for the analysis. The other sources consisted primarily of reasoning on why to use various indicators in the RPA impact estimation rather than how to use those indicators to get the needed results.

2.2.2 Analyze estimation methods

Besides selecting sources that consist of content eligible for this research in terms of quantitative methods and metrics, the content of the sources has to be analyzed on usefulness for the development of the RPA impact estimation method as well. Each method is modeled according to a similar template. The indicators used in each method are visualized and substantiated by formulas to calculate the results. By doing so for each method, it allows for an analysis of the used indicators and formulas. The results of the analyses are described in Chapter 4. Ultimately, the RPA impact estimation method is formed from elements that appear in each of the methods and elements that have been found indispensable in the estimation of the impact of RPA.

2.2.3 Develop RPA impact estimation method

Developing the RPA impact estimation method is done by assessing a collection of different method elements from similar literary studies or RPA practitioners. As mentioned in the previous paragraph, method elements from the analyzed methods are used to form the RPA impact estimation method. The development of a new method using these different method elements is done by reporting on the indicators used in each of the methods. These indicators are clarified using formulas. Based on these indicators and corresponding

formulas, a combination of the most appropriate indicators is chosen for the RPA impact estimation method. Chapter 4 shows the standardized RPA impact estimation method.

2.3 Evaluate RPA impact estimation method

The applicability of the RPA impact estimation method in practice is evaluated in the third phase of the research. The method evaluation is carried out by performing two types of evaluations; a multi-case study and an expert evaluation. First, the effectiveness of the method can be evaluated by performing the multi-case study. According to Rescher [41], increasing the effectiveness of the method relates to improving the quality of the result, i.e. the output of the estimation. Second, the method is evaluated by means of an expert evaluation, where RPA experts evaluate whether the method increases the efficiency of the task and whether the method will be used in practice. Thus, sub-research questions 3 and 4 are addressed by this research step.

Table 5: Part 3 research approach

Method evaluation	
Multi-case study	Expert evaluation
Retrieve expert time estimation	Retrieve actual efficacy
Validate baseline measurements	Retrieve perceived efficacy
Execute RPA impact estimation method	Retrieve intentions in practice
Retrieve post-measurements	
Compare measurements	

2.3.1 Multi-case study

In this research, business process data is collected at predefined time points for various process cases. The predefined time points are similar for each process case, namely before deployment and after deployment. This way of collecting data allows for an assessment of the performance of business processes over time, prior to and after the implementation of RPA. By measuring the performance before and after the implementation of RPA, the impact of RPA can be determined. By performing an RPA impact estimation using the developed method, the aim was to create an estimation that can define this impact before the implementation of RPA. Therefore, multi-case study serves as evaluation of the developed RPA impact estimation method. This section describes the specific research steps involving the multi-case study.

The multi-case study consists of seven different business processes as cases. The process selection is based on a criteria and convenience sampling strategy [44]. The first criterion is the estimated implementation time of the RPA project for each process. Since I needed to collect information about the process prior to the implementation of RPA and after the implementation of RPA, I needed to be able to complete the measurements at both time instances. Due to time constraints related to my thesis period, solely projects that do not take longer than a month to develop can be included in the multi-case study. The second criterion is the automation landscape in which the process is involved. The process can not be a part of other automation initiatives than RPA. Hence, external influences to the measurements can be excluded to the extent possible. The third criterion is

the case differentiation between process types. Since the RPA impact estimation method needs to be applicable to various types of processes, it is beneficial for the method to be evaluated for various types of processes as well. Last, convenience contributes to the sampling strategy as well. For the process selection I am dependent on the available ongoing projects within Ciphix. Hence, from all the RPA projects that meet the aforementioned criteria, the RPA projects that are conveniently available for this research are selected.

Each case consists of the execution of the five case study steps illustrated in Table 5. The protocol used to execute the multi-case study is described in Chapter 5. The case study approach is inspired by a study performed for a different technology by Reijers and van der Aalst [39], where the effectiveness of workflow management systems is researched by measuring performance indicators at two time instances. A within-case analysis and an across-case analysis is performed to evaluate the overall results of the multi-case study [54].

To determine at which time instances the baseline- and post-measurements for the process have to be made, four associated factors have to be taken into account. The first factor is the total volume of work. Comparison of, for example, process speed should be measured by anchoring the two measurements to periods that are similar in this respect. The second factor is process velocity. It is crucial to average out process velocities of the case studies across time intervals [16]. Process velocities are subject to seasonal factors or periods with deadlines. The third factor should ensure that no bias can arise within cases or SMEs. If cases are carried out by the same SME, the steps in the multi-case study must be carried out simultaneously for these cases. Thus, no bias can arise in the form that it is already known what I will be asking or how to answer the questions cleverly. Lastly, the measurements are taken are predefined phases of the RPA project. The interviews for the expert time estimation and the baseline measurements are collected when the scope has been set for the RPA project, because the scope determines which process steps have to be included in the baseline measurements and which not. Next to that, it is also of importance to gather the baseline data before the RPA implementation itself is final, since the SMEs can provide the most accurate baseline when they are still working according to their old routines. The post-measurements are taken once the robot is implemented and the SMEs are working together with their new digital colleague. The timing of the post-measurement after the implementation of RPA is based on practical experience. This partly depends on the type of process. Whether the process is carried out on a daily or weekly basis influences the rapidity of the implementation and trust in the robot.

The steps involved in the case studies are described more elaborately in the following paragraphs.

2.3.1.1 Retrieve expert time estimation Currently, being aware of how much time people need to execute the process is essential in evaluating the present process cycle time and process costs of business processes. This assessment is primarily based on subjective statements by the people performing the processes, also known as subject matter experts (SMEs). This expert estimation of the current state of the process cycle time of a business process is collected from, where possible, two SMEs as a starting point of the case study. By collecting an expert time estimation from two SMEs, the results are validated through cross-verification from two sources. Based on this, baseline measurements for the predefined impact indicators are defined.

2.3.1.2 Validate baseline measurements The present process cycle time of the business process serves as a baseline measurement for the RPA impact estimation method.

Since the expert time estimation is primarily based on subjective statements, it needs to be ensured the collected data for the baseline measurement is correct. Therefore, the data needs to be validated. This validation is done through real-time quantitative measurement of the time people need to execute a complete process cycle. This real-time quantitative measurement can be carried out by timing the SME during the execution of the process or by using a simulation [39]. Depending on the applications used in the process, time indications for triggers that start the process and triggers that end the process can be collected from the various applications as well. When a difference can be observed between the expert time estimation and the quantitative time measurement, the quantitative approach is taken as the final measurement. Besides that, a difference also indicates an inaccurate expert time estimation.

2.3.1.3 Execute RPA impact estimation method This step comprises the estimation of the impact of an RPA implementation on a specific process before its actual implementation. This prediction is formulated by applying the newly developed RPA impact estimation method as defined in Chapter 4. The application of the method is done by executing an R script based on the baseline measurements. The script can be found in Appendix H and represents the calculations in the method. The output of the method consists of a set of expected post implementation measurements for the predefined impact indicators. These measurements combined provide an estimation of the potential savings, the estimated impact of RPA, respectively.

2.3.1.4 Retrieve post-measurements After the implementation of RPA, the performance of the business process with respect to productivity is measured. The post-measurement is partly based on metrics, as stated in the previous paragraph on baseline measurements but predominantly based on metrics retrievable from the software robot performance logs. A definitive endpoint is indefinable for the performance of business processes. Nevertheless, in the case of an RPA implementation, the post-measurement consists predominantly of metrics related to software robot performance. These types of quantifiable metrics can be measured after the deployment of the RPA implementation. As explained earlier, the post-measurement should be carried out once the process is deployed and the employees are used to work together with the robot. This period ranges from weeks to months, depending on the type of process and the frequency of execution. The time for the post-measurement is determined separately for each process. A single post-measurement suffices.

2.3.1.5 Compare measurements Based on a comparison of the baseline measurements and the post-measurements, the difference in productivity indicators of the business process prior to and after the implementation of RPA can be determined. Consequently, the impact of an RPA implementation on the business process itself can be established. Other contextual factors that might influence the business process during this implementation are neglected in this research. These contextual factors might include improvements in the business process due to a critical evaluation of the process before implementing RPA.

After applying the RPA impact estimation method in practice, the results of the case studies are also used to evaluate the effectiveness of the method. A potential difference between the baseline measurements and post-measurements would indicate that the estimated results of implementing RPA for the process are not accurate for that particular measuring. The results of the post-measurements alongside the estimation indicate the effectiveness of the method. Therefore, this comparison allows for an evaluation of the

developed RPA impact estimation method. The evaluation of the RPA impact estimation method concludes the last case study step.

2.3.2 Expert evaluation

The success of the method in practice can be evaluated by applying the Method Evaluation Model (MEM) by Moody [38]. The evaluation of the estimation method is based on the concept that a method's success is dependent on two dimensions; efficacy and adoption in practice. The complete MEM can be seen in Figure 1. By means of the post-task survey, the experts are asked to evaluate the efficiency of the method and give their perceptions of using the method. The expert evaluation is added to the research approach in a later stage of the thesis. Due to unexpected societal circumstances, I was able to include seven cases in the multi-case study. An expert evaluation serves as an appropriate addition to the evaluation carried out by multi-case study. The objectives of the method are to clarify the relevant variables in performing an RPA impact estimation, to improve the effectiveness of impact estimations for RPA implementations, and to develop an RPA impact estimation method that is applicable in practice. These objectives are evaluated during the expert evaluation.

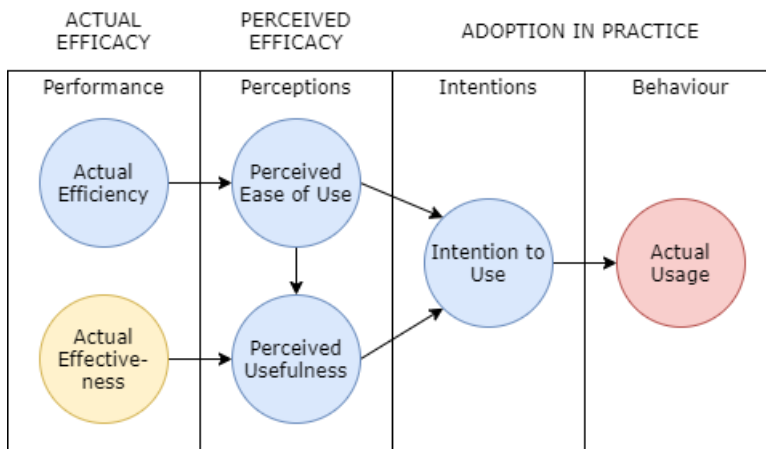


Figure 1: Method evaluation model (MEM) [38] adjusted to this research; blue is addressed by the expert evaluation, yellow is addressed by the multi-case study, and red is not addressed.

Since, the experts do not execute all the steps as done in the multi-case study, the experts are not able to state any details on the actual effectiveness of the method. However, the actual effectiveness (yellow circle) is already evaluated by the multi-case study. The actual efficiency, perceptions and intentions are evaluated by experts (blue circles). Due to the possibilities within the context of this research, actual usage in practice is not evaluated (red circle).

Due to time constraints, a decision is made to include expert evaluations by six RPA experts. These experts are all working at Ciphix in the positions of Implementation Lead and RPA Solution Architect. Therefore, they are considered experts regarding the estimation of the impact of RPA implementation and the potential use of the method in practice. During this method evaluation, RPA experts use the developed RPA impact estimation method to perform the estimation task in practice for one project each. Therefore, the RPA impact estimation method is the independent variable of the evaluation. The variables used in the

expert evaluation are listed in Table 6. The dependent variables of the evaluation consist of performance based dependent variables and perception based dependent variables.

Table 6: Evaluation variables

Independent	Dependent (performance)	Dependent (perception)
RPA impact estimation method	Efficiency	Perceived ease of use Perceived usefulness Intention of use

The measurement of the evaluation variables is done by means of a post-task survey, which is shown in Appendix E. In order to apply and evaluate the method, the experts are given access to a tool-set that provides all the necessary information on the method prior to answering the questions in the survey. Simultaneously, this tool-set serves as a guide for the implementation of the RPA impact estimation method in practice. The method information and survey are provided to the experts through means of a Google Form document. The Google Form is also given in Appendix E. First, the method is introduced and its goal is presented in a short summary. Next, the tools for applying and evaluating the method are described. The method implementation questions that can be seen in Appendix G are given. The checklist provides information on all the data that needs to be gathered prior to executing the method. The RPA impact estimation method itself is given with descriptions of the used metrics. In addition, the R script and an example output of the script, as shown in Appendix H, is given to show the experts how the method can be utilized. The method implementation questions in Appendix G provide guidelines for gathering all necessary data for the RPA impact estimation method. This checklist is based on the multi-case study questionnaire, where the questionnaire is filtered on questions and topics that are ultimately integrated into the method. Lastly, the actual survey is presented to the experts. The survey questions are listed in Appendix E. The questions within the survey are derived from study by Moody [38]. The questions are adapted to the objectives of the RPA impact estimation method. The items in the questionnaire were measured using a 5-point Likert scale with negative and positive statements on either side of the page. The results of the expert evaluation are listed in Chapter 6.

2.3.2.1 Retrieve actual efficacy The actual efficacy relates to performance dependent variables, since actual efficacy is related to the performance of the estimation task and whether this performance is improved by the developed method. As mentioned earlier, the effectiveness of the method is evaluated by performing the multi-case study. Results of the multi-case study are listed in Chapter 6. The efficiency of the method is evaluated using the post-survey completed by experts after using the method in practice. By doing so, the experts can evaluate the efficiency of the estimation task in relation to using the method instead of the existing estimation approaches at the company. This comparison allows them to identify variations in the results of both approaches. Efficiency of the method is measured by the amount of effort (time) that is needed to perform the estimation task.

2.3.2.2 Retrieve perceived efficacy Perceived efficacy relates to the first two primary constructs in the Technology Acceptance Model (TAM) [15], which are adopted in the MEM [38]. These constructs are perceived ease of use and perceived usefulness. Therefore,

the first two perception based dependent variables, ease of use and usefulness, relate to the perceived efficacy of the method. The experts are asked to evaluate the perceived efficacy of the method using the post-survey. The post-survey questions related to these perception based dependent variables can be found in Appendix E.

2.3.2.3 Retrieve intentions in practice Adoption in practice relates to which extent users intend to use the method in practice. This concerns the third primary construct in the TAM [15]. The intention to use variable measures the intention to use of the method in practice. Therefore, this is the third dependent variable within the expert evaluation. The post-survey questions related to these perception based dependent variables can be found in Appendix E.

3 Theoretical framework

This chapter elaborates on the common understanding of concepts used in this study, which serves as a theoretical foundation for this thesis. The performed literature review highlights the gap that currently exists in the literature.

3.1 Robotic Process Automation

The main review question addressed in this section of the theoretical framework is: *“What do RPA and its purpose entail according to existing research?”*.

3.1.1 What is RPA?

The primary focus of RPA is on mimicking repetitive, rule-based, standardized, computer-centered tasks across multiple business applications currently performed by human agents [14, 45, 51]. Implementing RPA implies that these tasks are performed by software robots, i.e., digital agents. Gartner, Inc. [21] defines RPA as: “a productivity tool that allows a user to configure one or more scripts (bots) to activate specific keystrokes in an automated fashion. The result is that the bots can be used to mimic or emulate selected tasks within an overall business or IT process”. The RPA software performs rule-based [if, then, else] statements on well-structured data, which typically uses GUI (Graphical User Interface) automation [22, 45]. RPA is particularly useful as a process automation approach where proper system integration, such as APIs, are not available [23].

Van der Aalst, et al. [49] states that RPA differs from other approaches by using an ‘outside-in’ approach, which means nothing is changed to the existing information systems. The adoption of RPA is reported to be growing fast. This growth is due to the ability of organizations to automate their processes without needing to replace their legacy computing systems [20, 51, 52]. The value associated with earlier technology investments can be unlocked with the use of RPA, as stated by Fabrizio Biscotti, research vice president at Gartner, Inc. [20]. Other approaches, such as STP (Straight Through Processing), consist of the redesign of existing systems, where RPA is centered around the replacement of human interactions with software agents [49].

3.1.2 Adoption of RPA

According to Gartner, Inc. [20], RPA software revenue grew 63,1% in 2018 to \$846 million. The biggest adopters are banks, insurance companies, telecommunications operators, and utility companies since they aim to ensure integration with their many legacy systems using RPA [20]. Growth predictions made by Forrester on RPA market revenue in 2017 [18] and 2018 [25] appeared to be projected lower than reported in April 2019 [34]. This vast growth in revenue reflects the general adoption of RPA. Where Forrester predicted 40% of enterprises to have automation centers and frameworks in place in 2019, by April 2019, they are mostly on track [34]. Looking forward to 2020, the vice president, principal analyst at Forrester, states that “adaptiveness is the key to future success in a world of automation and AI” [24].

3.2 Impact of RPA

The main review question addressed in this section of the theoretical framework is: *“What are the indicators and metrics to analyze effective RPA implementations?”*.

3.2.1 RPA impact analysis

Prior to the adoption of RPA, organizations should assess the economic viability of RPA [11]. This assessment can be done through a cost-benefit analysis. Crucial for the performance of such an analysis is the accuracy of the baseline measurements on which the expected return is based. The impact of RPA can be evaluated through measurable process cycle time and process costs of processes. Therefore, the process cycle time and process costs of a process should be evaluated on measurability during the process identification phase [12]. The process cycle time and process costs of processes define to what extent a reduction or saving will be achieved by implementing RPA. The savings are directly linked with FTE reduction, process cycle time improvement, and expansion of work capacity, which all play a vital role in the ROI of RPA. Evidently, this illustrates the primary drivers for RPA implementations [36]. According to Wanner et al. [50], expansion of work capacity relates to “enabling companies to free up resources and to reallocate them to activities with a focus on creating business value and customer satisfaction”. Anagnoste [2] confirms that RPA induces people to focus on high-value adding tasks. To summarize, industry practitioners advise using quantitative impact indicators that allow for accurate measurements on a set of predefined performance metrics [13].

With impact analysis, ‘before’ and ‘after’ situations are compared for automated processes with respect to productivity [13]. In general, organizations multiply the manual effort by the employee’s salary to refer to the ‘before’ situation. Therefore, manual labor costs might change as a result of productivity changes. The sum of the RPA tool costs, the RPA development costs, and the employees’ salaries who maintain RPA are used to refer to the ‘after’ situation. The comparison of these ‘before’ and ‘after’ measurements can be seen as the *generated ROI*, which is elaborated on in Section 3.2.2. A study by Wanner et al. [50] confirms that the profitability of RPA (ROI) is examined by comparing the fixed and variable cost of human labor versus the fixed and variable cost of RPA. Wanner et al. [50] included an exclusive number of determinants in their study that focused on the economic profitability of RPA.

In addition, other performance metrics can be utilized to compare quantitative productivity indicators before and after the use of software robots. Thus, these performance metrics can be utilized to assess the actual impact of an RPA implementation. Performance metrics related to productivity provide a clear quantitative demonstration of the financial, business, and operational impact on business processes and the organization itself [13]. Capgemini [7] published a report where they discussed the quantifiable indicators companies use to determine the success of their RPA implementation. Cost reduction, speed of the process, reducing risk and improving compliance, increasing the % of standardization, and improving the quality of work and data were quantifiable indicators identified as the most important when measuring the success of the RPA implementations. The indicators directed related to productivity are included in this research, which can be seen in Table 7.

Looking into earlier performed case studies [31, 52], it is suggested by Wanner et al. [50] that “the success of RPA projects depend significantly on the availability of a standardized method to quantify and compare the automation potential of process tasks”. Besides that, different viewpoints of relevant topics regarding success factors for RPA projects in practice were elicited through an expert survey. The need for economic efficiency is agreed on by all experts. Therefore, it is confirmed that a reliable estimation of the financial potential of RPA projects prior to the implementation is needed. The aforementioned indicators needed to develop a reliable RPA impact estimation method are elaborated on in the next section.

3.2.2 RPA impact indicators and metrics

Quantitative RPA impact indicators and performance metrics related to productivity were identified in the literature. These indicators and metrics are listed in Table 7. A comparison these indicators before and after the use of software robots indicates the impact of these robots. Explanations for each of the indicators are given in the following paragraphs.

Table 7: RPA productivity impact indicators and metrics specification

Nr	Impact indicator	Impact metric
1	Generated ROI	Cost of human labor - cost of RPA [50] Time taken to generate ROI [37]
2	Manual labor costs	FTE (number of hours saved per year) [36]
3	Process velocity/ cycle time	a) Process speed/execution time/lead time [9, 13, 50] b) Response time [10] c) Waiting time [50]
4	Execution frequency	Amount of times a process is executed within a specific time frame and its variance [50]
5	Resource utilization	Human agents downtime versus digital agents downtime. Human resources freed up. Number of hours robots and humans are efficiently used: busy hours/available hours [13, 50]

The Return On Investment (ROI) generated by implementing RPA indicates the general profitability of this implementation. Fixed and variable costs can be taken into account when the ROI is calculated. ROI is calculated by dividing the cost of human labor [6] by the cost of RPA [26]. ROI is expressed as a percentage. In this calculation, the time taken to generate ROI is included as well [37].

When implementing RPA, automated processes do not require human agents to perform manual labor anymore. With that, manual labor costs are saved. These manual labor costs can be measured in full-time equivalents (FTEs) [36]. Temporary labor can be saved as well for periods of high demand, which can be especially expensive. The utilization of software robots can be scaled appropriately against marginal costs, in comparison to the costs of human demand peaks [16]. However, looking at labor savings “does not do justice to the power of the software because there are multiple business benefits”, as Willcocks states in an interview with McKinsey [51].

Research by Wanner et al. [50] provided a quantifiable method for process selection in RPA projects. As far as the quantified indicators and the profitability analysis are concerned, their research is useful as groundwork for other methods that rely on quantified human labor variables such as execution time and frequency. Quantifiable indicators were defined based on existing case studies and an expert survey in which AutomationAny-Where, UiPath, Blue Prism, Ernst & Young, Brightcape, and Capgemini participated. Aside from its definition of a set of useful determinants, the research does not prescribe a way to measure and analyze these determinants accurately. The most commonly mentioned in-

dicators are process execution time and process execution frequency. Process speed and process execution time are measures of process velocity. Process velocity can be seen as process cycle time. The processing speed is related to how fast a human or robot is able to cycle through items [13]. Thus, process velocity concerns the amount of time it takes to complete a process from input to output [9, 16]. With human agents and digital agents working together, the expectation is for processes to be performed much faster [9, 16]. In other words, an increased process velocity is expected after the deployment of RPA.

In addition to an increased process velocity, improvements in average handling time (AHT) of processing a queue of items can be measured. The fact that software robots can be utilized 24/7, which human agents can not, enables this improvement. Typically, software robots can handle processing through a more significant number of processes faster [8]. This benefit can result in faster response time to clients [10] since waiting times for human agents to continue their work can shorten as well [50]. By comparing the amount of time humans need to execute a complete process cycle with the time it takes a software robot to execute a complete process, a possible increase in process velocity can be shown [9].

Process execution frequency is an indicator of the task suitability of RPA. Frequently performed tasks or tasks with high volumes are classified as suitable for RPA [3]. Process execution frequency is also an indicator used in the calculation of the FTE equivalent by multiplying it with the process velocity [50]. Process execution variance is an indicator that is particularly important when comparing before and after situations. The execution variance concerns the amount of work performed by a human agent or a digital agent. Therefore, this determines whether measurements constitute a valid comparison.

Process accuracy relates to correct data inputs, completion of all process steps, correct rule-application, and human errors [45]. By deploying RPA, organizations aim to optimize business processes in terms of these accuracy aspects.

Since human agents have needs for intermissions, the amount of downtime a human agent needs to sustain in order to complete a process differs from a digital agent [13]. The infrequent upgrade interruptions software robots need imply that the implementation of digital agents can result in increased continuous work instead of continuous human resource consumption [50]. The utilization of software robots enables companies to free up human resources to focus on value-adding activities [14]. Due to the reallocation of human agents, their productivity changes [10]. This reallocation can be conducted because of the digital agent enablement.

3.3 Impact estimation of RPA

The main review question addressed in this section of the theoretical framework is: “*What constitutes current best practice in relation to estimating the impact of RPA implementations?*”. Therefore, this section describes why the impact of RPA is estimated prior to implementations, what current problems are with these impact estimations and what approaches exist to estimate the impact of an RPA implementation.

3.3.1 Importance of upfront impact estimations

In an EY report on the impact of Robotics, RPA, and AI, Lamberton et al. [33] defined not having an RPA business case upfront as one of the ten common issues in failed RPA projects. Kuder [29], a principal at Deloitte Consulting LLP, states that “many RPA hiccups stem from poor expectation management”. Subsequently, Boulton [4] advocates that proper expectation management is needed to avoid infeasible claims upfront. For a

successful RPA implementation, it is essential to understand the RPA potential of business processes, prior to starting an RPA initiative [23]. By doing so, organizations can make sure the costs of RPA do not outweigh the acquired savings.

3.3.2 Existing approaches for RPA impact estimations

Studies have shown that process mining techniques can be used to identify processes with the highest automation potential automatically [49]. Leno et al. [35] and Jimenez-Ramirez et al. [28] took a step in improving the process analysis of the RPA lifecycle, by quantifying the baseline measurement of business processes using UI logs through a screen-mouse-key-logger. Using these logs and process discovery algorithms, process models that accurately map the current process could be developed. Unfortunately, practitioner experience has taught us that organizations are often not compliant in logging human agents' behavior [14]. Another approach used in current research to analyze business processes is simulation [39]. Although the research by Reijers et al. [40] showed that simulation is a valid initiative to validate measurements, they identified a number of problems with the application of simulation in this context.

A number of approaches have been carried out to facilitate accurate baseline measurements for an impact estimation [28, 35, 40, 49]. Besides that, research by Wanner et al. [50] described metrics to determine the automation potential of processes using process mining, Meda [37] described indicators for performing an ROI analysis, and UiPath Inc. [46] described an assessment of processes followed by a cost-benefit analysis.

3.3.3 Problems with RPA impact estimations

Currently, the impact of RPA is often measured using an estimation of the saved FTE that is achieved by automating a process. Saving FTE is linked to reducing costs and improving resource utilization. The problem is that most companies assess the potential impact of RPA based on data that is gathered through subjective statements of human agents involved in the execution of the process. These subjective statements are used, since most of the time, there is no quantitative log data available to base measures such as execution time on [50]. Besides that, the FTE reduction is often calculated by merely removing all FTE needed in the traditional process once RPA is implemented. A more thorough analysis of the amount of FTE that can be removed is necessary. In some cases, the impact of RPA was measured by the actual reduction in throughput time in the automated process measured after the implementation has been carried out [31]. This post-implementation analysis can serve as a confirmation of the purpose of the implementation. However, an estimate prior to implementation is still desirable.

Inadequate measurements jeopardize the company's decision quality when it comes to RPA implementations [32, 52]. Case studies show that companies, which at least use some measurable indicators, achieve better results [3, 31, 43]. This can be seen in studies where quantifying technologies as process mining are used [50]. Current research indicates that effective RPA implementations heavily rely on quantifiable measures of its potential prior to the project that go beyond a simple total FTE reduction. A tangible standardized method for effectively estimating the impact of RPA based on quantitative baseline measurements that can be readily applied in practice without leveraging other technologies is not yet defined in the literature. A next step would be to develop a method inspired by the previous examples to quantified baseline measurements, which results in an accurate indication of the business process performance after RPA implementation that can be deployed based on predefined guidelines.

4 Initial RPA impact estimation method

As described in the multivocal literature review in Chapter 3, several researchers described estimation approaches that are relevant to the development of the RPA impact estimation method.

An impact estimation can be performed based on three drivers of RPA. These drivers are accuracy, accountability, and productivity [5]. For this research, the focus lies with estimating the impact of RPA on productivity, hence the financial impact on an organization. Productivity comprises resource utilization, process velocity, and manual labor costs. These three productivity indicators contribute to an overall ROI-evaluation [16]. A quantitative approach is employed in this research, where the analysis is limited to a number of determinants exclusively focused on quantifiable measures. Thereby, solely those sources that include performance indicators that can be examined using quantitative methods are selected. The following methods are selected:

1. Method that describes indicators for performing an ROI analysis [37],
2. Method that describes a detailed expert assessment of processes and a cost/benefit analysis [46], and
3. Method that describes metrics for the automation potential of processes [50].

The selected methods are analyzed. Based on the analyses, a new standardized RPA impact estimation method is developed. The analyzed methods serve as building blocks for the standardized RPA impact estimation method. They serve as building blocks since there are valuable components in the fundamentals of these methods.

4.1 Estimation methods analyses

Three methods are selected for analysis. In order to analyze the methods, the methods are visualized according to an indicator and equation based template. The equations are based on my interpretation of the method descriptions provided by the authors. This visualization allows for a proper comparison between the various elements of the three methods.

Method 1

Meda [37], an RPA evangelist working for companies such as Automation Anywhere, designed a strategy for defining RPA performance metrics, which can be used to calculate the expected outcome of an RPA implementation. Savings due to manual labor reduction and benefits due to productivity gain are weighed against the total costs of an RPA solution. The expected impact of an RPA implementation in Equation 4 of Table 8 is calculated by the yearly benefits ($YB = ManualLaborSavings + ProductivityGain$) in Equation 1 and the yearly costs ($YC = EstimatedCostOfSolution$) in Equation 3. The indicators that are used in the analysis are described in Table 9. Although quality, business agility, regulatory compliance, and customer satisfaction are included in the calculation as well, they are based on estimations that are not quantitatively justified. Therefore, they are not considered eligible for the development of the RPA impact estimation method in this research.

Table 8: Equations for method 1 [37]

Number	Equation
1	$YB = MLS + (MLS * PP)$
2	$MLS = (PN * SH * EF) * 52 * VLCR$
3	$YC = TPC + AMS + CST$
4	$Impact = YB - YC$

Table 9: Indicators for the impact analysis of method 1 [37]

Indicator	Description
MLS	Yearly manual labor savings: $(PN * SH * EF) * 52 \text{ weeks} * VLCR$
PP	Percentage productivity gain: depends on case (15% on average)
PN	Number of processes automated
SH	Average saved hours per process run
EF	Average execution frequency per week: $PN * SH * EF = \text{saved hours per week}$
VLCR	Average cost rate of human labor per hour
TPC	Tool platform cost: initial cost
AMS	Annual maintenance and support: yearly cost
CST	Consultant services and training: initial cost

Method 2

Wanner et al. [50] proposed a quantifiable method to assess the automation potential of business processes. Part of this method is a profitability analysis that caters to the estimation of the impact of an RPA implementation on a business process. During the profitability analysis, they made use of various productivity metrics, as can be seen in Table 10. The difference between the cost analysis of human labor ($CA_{hl} = FixedLaborCosts + VariableLaborCosts$) in Equation 5 and the cost analysis of robotic labor ($CA_{rl} = FixedRoboticCosts + VariableRoboticCosts$) in Equation 6 results in the expected profit, the estimated impact of an RPA implementation respectively. The estimated impact is shown in Equation 7. The indicators that are used in the analysis are described in Table 11.

Table 10: Equations for method 2 [50]

Number	Equation
5	$CA_{hl} = FLCR + (VLCR * EF * ET * (1 - AR))$
6	$CA_{rl} = (FRCR * SD * ST * (1 - AR)) + (VRCR * (EF/FR))$
7	$Impact = CA_{hl} - CA_{rl}$

Table 11: Indicators for the equations of method 2 [50]

Indicator	Description
FLCR	Sum of execution-independent overhead costs
VLCR	Average cost rate of human labor per hour
EF	Average execution frequency of process
ET	Average execution time of process
AR	Automation rate of process: percentage of the process to be automated
FRCR	Cost of building the software robot
SD	Standardization of process: number of different prior and following activities
ST	Stability of process: sum of squared differences in ET, normalized on EF*ET
VRCR	Cost rate of executing a process: depends on RPA vendor
FR	Failure rate of process: throwbacks ratio of process transactions

Method 3

The RPA vendor UiPath developed a platform where the automation lifecycle of processes can be tracked [46]. Within this platform, users are able to discover, prioritize and track their automation ideas. Part of this is an elaborate cost benefit analysis, which can be performed for each process idea. The equations for this analysis are listed in Table 12. The automation costs (AC) in Equation 8 are based on the summation of the total implementation people costs (IPC) in Equation 9, the RPA software costs (SC) in Equation 10, and the human labor costs after automation ($HCLA$) in Equation 11 and 12. The automation benefits (AB) in Equation 14 are based on the running (human labor) costs before automation ($HLCB$) in Equation 13 divided by the automation costs in Equation 8.

Table 12: Equations for method 3 [46]

Number	Equation
8	$AC = IPC + SC + HCLA$
9	$IPC = \sum(PCT * IMD)$
10	$SC = LC * LN$
11	$HCLA = (FTE * APH) * EFC$
12	$FTE = ((V * ET) + (ER * RWT) + (RW * RVT)) / WD * WH$
13	$HCLB = FTE * EFC$
14	$AB (Impact) = HLCB - AC$

Table 13: Indicators for the equations of method 3 [46]

Indicator	Description
PCT	People cost type (Implementation Lead, Solution Architect, Developer)
IMD	Number of implementation days (for each cost type)
LC	License costs per year (based on license type)
LN	Number of licenses
FTE	Full-time equivalent
EFC	Average employee cost full year (1 FTE)
V	Average transaction volume per selected frequency (e.g. daily)
ET	Average execution time per transaction
ER	Average error rate of total volume of transactions
RWT	Average rework time per transaction
RW	Average percentage of total volume to be reviewed by a human agent
RVT	Average review time per transaction
WD	Average number of working days per year
WH	Average number of working hours per day: $WD * WH = 1 \text{ FTE}$
APH	Automation potential percentage handled by human agent after automation
HLCB	Total human labor costs before automation

4.2 RPA impact estimation method

Research by Wanner et al. [50] described metrics to determine the automation potential of processes, Meda [37] described indicators for performing an ROI analysis, and UiPath Inc. [46] described a detailed assessment of processes followed by a cost-benefit analysis. However, none of the methods are comprehensive enough to allow for an in-depth estimation based on a set of baseline measurements that can be readily applied in practice. The analysis in Section 4.1 showed that combined, they can serve as building blocks for a new standardized RPA impact estimation method. Experience in practice shows that a simple FTE reduction is not valid for most of the RPA projects. Often employees have to process transactions that are not processed by the robot based on business rule exceptions or employees have to assess the work of the robot based on reports. This time should also be taken into account in the impact assessment.

Consequently, a standardized RPA impact estimation method is developed that focuses on the impact estimation of RPA on a single process. The high-level structure of the method is visualized in Table 14. The method consists of three main steps; calculate current labor costs, calculate automation costs, and calculate the overall impact on costs, which are listed in the left column of Table 14. These main steps consist of various sub-steps, which reflect specific calculations. The corresponding formulas are displayed in the right column of the table. The metrics used in the formulas displayed in the figure are clarified in Table 15. In practice, a tool can be employed to implement the method. During the multi-case study, the method is executed by means of an R script. The script is based on a set of variables, which reflect the metrics in Table 15. This script can be found in Appendix H. An R script or any other type of tool is employable in practice to quickly retrieve the output of the method based on variable input data.

Table 14: RPA impact estimation method

Estimation method	Calculations
Calculate current labor costs	
Calculate needed FTE	$FTE = ((ET * EF) + (ER * RWT) + (RW * RVT)) / WD * WH$
Calculate cost of needed FTE	$CLC = FTE * CFTE$
Calculate automation costs	
Calculate software license costs	$SLC = LC * LN$
Calculate development costs	$DC = \sum PCT * IMD$
Calculate FTE costs after RPA	$ALC = (FTE * (1 - AR)) * CFTE$
Calculate overall impact on costs	
Current labor costs minus the automation costs	$Impact = CLC - AC$

Table 15: RPA impact estimation method metrics with original sources

Metric	Description
FTE	Full-time equivalent [37, 46, 50]
ET	Average execution time per transaction [46, 50]
EF	Average execution frequency of transaction per year [37, 46, 50]
ER	Average error rate of total volume of transactions [46]
RWT	Average rework time per transaction [46]
RW	Average percentage of total volume to be reviewed by a human agent [46]
RVT	Average review time per transaction [46]
WD	Average number of working days per year [46]
WH	Average number of working hours per day: $WD * WH = 1 \text{ FTE}$ [46]
CLC	Current labor costs [37, 46, 50]
CFTE	Average cost of 1 FTE [37, 46, 50]
AC	Automation costs [37, 46, 50]
SLC	Software license costs per year (based on license type) [37, 46]
LN	Number of licenses [46]
IMD	Number of implementation days [46]
DC	Development costs [37, 46, 50]
PCT	People cost type (Implementation Lead, Solution Architect, Developer) [46, 50]
AR	Automation rate of process [46, 50]

5 Multi-case study

The applicability and effectiveness of the new RPA impact estimation method are tested by applying it to several cases in practice. Therefore, the case study addresses the third and fourth sub-research questions defined in Chapter 2. By executing the RPA impact estimation method for the various cases, RQ3 is addressed. It addresses how the impact of an RPA implementation can be estimated using such a standardized method. The interpretation of the data resulting from the case analyses addresses the evaluation of the impact of RPA implementations, as mentioned in RQ4.

Each of the cases included in the research is executed according to the same case study protocol. The case study protocol is derived from the guiding paper by Runeson and Höst [42], which defines a case study protocol adapted to software engineering. The case study protocol describes what purpose the case study serves, what design decisions for the case study are made, and what the field procedures are for carrying out the case study. The data that is collected during the multi-case study is stored and combined in a local database folder. Subsections of this local database are included in Appendix D. The following section describes how the case study is used as an instrument to address the sub-research questions in detail.

5.1 Case study protocol

General

The research includes a multi-case study where the new RPA impact estimation method is applied and studied for multiple cases [54]. Thus, the object of study is the new RPA impact estimation method. This type of study is designed to collect data on multiple business processes at more than one point in time. The studied processes exist in their context and are executed separately. Nevertheless, executing the RPA estimation method is replicated for each case. Besides that, each case concerns a business process whose characteristics qualify for an RPA implementation. This replication makes the cases suitable for a multi-case study. The multi-case study allows for collecting evidence on the use of the method from multiple sources. Therefore, the findings can be easier to generalize.

The multi-case study consists of five steps, as described in Section 2.3. The cases start with retrieving expert time estimations of the process. Baseline measurements are retrieved to perform the RPA impact estimation method. Post-measurements are retrieved to evaluate the impact of the RPA implementation and to evaluate the estimate that the method provided.

Procedures

The research includes seven cases in which the RPA impact estimation method is examined. Each of these cases conforms to contextual factors relevant to the comparison between the cases, as described in Section 2.3.1. In order for the method to be applicable in various sectors and types of business processes, the seven cases include different types of processes. For the same reason, the processes included in the case study are carried out at several companies. The automation project must consist solely of an RPA implementation during the phase of measuring. If cases involved multiple automation initiatives, the post-measurement results would not reflect the exact impact of just the RPA implementation on the business process. Cases 6 and 7 are the only ones carried out by the same SME. Therefore, these cases are carried out simultaneously.

The interviews conducted in the first two steps of the case study are taken from the people performing the process in practice i.e., the Subject Matter Experts (SMEs). Their roles differ from business controllers and claim managers to engineers and operation officers. In every case, it boils down to the executive role in the various processes. The SMEs are asked to sign a consent form before the start of the interview. The consent form can be found in Appendix B. Since the cases concern processes that are usually carried out by one person, one SME is interviewed and monitored per case. The interviews are taken during a one-on-one conversation with the SMEs. Therefore, the answers, as well as the measures, are taken by me. The interviews are not written out, because this research deals with measures, not with contextual conversation during the interviews. So, for the questions aimed at obtaining certain measurements, I have only noted the measures. For the questions aimed at obtaining information that might be needed to interpret the measures correctly, I have noted these answers down concisely in a few words. This can be seen in the results in Appendix D. Where this interview data is stored, is explained in Section 5.1.

During the phases where the baseline measurements and the post-measurements are measured, two methods are used to measure the metrics in question. By monitoring the SME while he/she performs the process, the metrics can be measured by measuring the time people are engaged in a particular task. The post-measurements consists of data retrieved from the robot performance logs, such as the process execution time and the process execution frequencies. Besides that, the SMEs are asked again how much time they still need to be engaged in the process in order for the process to be completed.

Research instruments

Business process data for the various cases are collected at predefined time points, which are similar for each case. This way of collecting data allows for a consistent assessment of the performance of business processes over time, prior to and after the implementation of RPA. Table 16 refers to each of the case study steps as mentioned in 2.3 and the corresponding data collection method.

Table 16: Case study data collection methods

Case study step	Collection method
Retrieve expert time estimation	Interviews with SMEs
Validate baseline measurements	Interviews with SMEs + Monitoring SMEs
Execute RPA impact estimation method	Method execution
Retrieve post-measurements	Monitoring robot performance + Optional interviews with SMEs
Compare measurements	Compare baseline and post-measurements + Compare post-measurements with estimation method outcome

Data is collected for each of the variables used in the RPA impact estimation method.

An overview of the variables is listed in Table 17. A template is created which incorporates the questions to be asked to the SMEs. This template can be used for processing the cases at each company. The list of questions and techniques used to collect this data is described in Appendix C. The collected data is stored in a local database folder, whereafter the data for all cases is combined in a local database spreadsheet. A translation of this spreadsheet is included in Appendix D. Based on this data, the RPA impact estimation method is executed.

Table 17: Case study data collection metrics

Case study data collection variables			
Execution time (min)	Other people involved (Y/N)	Review rate (%)	Developer days
Cycle time (hours)	Involved time (min)	Review time (min)	Developer rate
Execution frequency (p.w.)	People still needed (Y/N)	Review removed (Y/N)	Solution Architect days
Time spend (h.p.w.)	Involved time saved (min)	Working hours (p.w.)	Solution Architect rate
Peak periods in volume (Y/N)	Error rate (%)	FTE needed	Implementation Lead days
Peak description	Reprocess time (min)	FTE cost	Implementation Lead rate
Velocity changes (Y/N)	Reprocess removed (Y/N)	Robot license type	
Velocity description	Automation rate (%)	License users	

Data analysis

During the first step of the case study, expert time estimations are retrieved for process cycle times, process execution frequencies, and the amount of time spent on the process daily. These measures are collected in a case-specific data input file. In order to validate the time estimations, baseline measurements are retrieved by monitoring the SMEs as they perform the process. With interviews as a qualitative method and measurements as a quantitative method, methodological triangulation is applied by using these different types of data collection methods in the first two steps.

Subsequently, the RPA impact estimation method is deployed to estimate the financial impact of the RPA implementation based on the retrieved data in the previous steps. The method is performed using an R script based on data in the input file. The R script can be found in Appendix H. Post-measurements are retrieved when the RPA implementation is final to measure how the robot performance has changed the process. Lastly, the results from the RPA impact estimation method execution in step 3 are compared with the results from the post-measurements to evaluate the effectiveness of the estimation method. The difference between the baseline and post-measurements is investigated to evaluate the impact of the RPA implementation. The results of the comparison step are used to determine the effectiveness and applicability of the RPA impact estimation method. Where necessary, the results can be used to alter the method or its components to a better fit.

5.2 Cases

During the multi-case study, seven cases were included in applying the designed RPA impact estimation method. I aimed for the inclusion of ten cases at varying types of companies. Due to the abnormal societal circumstances during my thesis period, I was able to complete seven case studies in varying types of companies. This is elaborated on more in

the discussion in Chapter 8. A description of the cases is provided in the following paragraphs.

Tables 18 and 19 list the core characteristics of the processes included in the multi-case study. The type of process is listed for each case, as well as which sector applies to the type of company at which the process is carried out. The table list how many transaction items are processed for each case weekly. Besides that, the employee hours needed to process these transaction items weekly are listed. The defined error rates before the implementation of RPA and afterward are listed. In addition, the table lists the automation rate of the process in terms of how much of the current process is carried out by the robot. The development time of the RPA implementation is listed as well to emphasize the short implementation time as a requirement for the chosen projects in the multi-case study. Next, the amount of employee hours that are saved weekly by implementing RPA is listed. An estimation that can be made according to the results from the RPA impact estimation method is the number of months needed to obtain a return on investment. This estimation is listed in the last column.

The case numbers correspond with the case numbers in Appendix D. Appendix D shows the results of the data collection for each of the cases as well as the results of applying the RPA impact estimation method. The data in the columns named "Hours needed", "Hours saved", and "Months to ROI" are based on the calculations made within the RPA impact estimation method. Therefore, these are part of the overall results of applying the RPA impact estimation method to these cases. All results regarding the execution of the method can be found in Table 30 in Appendix D.

Table 18: Cases included in the multi-case study (part 1)

Case	Type of process	Sector	Transaction items (weekly)	Hours needed (weekly) (pre)
1	Invoice claims	Insurance	5 items	0.9 hours
2	IT on-boarding	Commercial bank	8 items	8.8 hours
3	Sales orders	Airline	35 items	2.36 hours
4	Data validation	Airline	300 items	29.25 hours
5	Loan processing	Commercial bank	30 items	8 hours
6	Data back up	Investment management	7 items	1.17 hours
7	Server monitoring	Investment management	1 item	0.17 hours

Case 1 concerns a process for an insurer where intermediaries report claims for employees who have become incapacitated for work. The claims are retrieved through email. These emails are read and processed in an application. The application needs to load about three minutes before each transaction. During the process, the application often needs to load for a while as well. For this reason, processing these claims is a non-value adding task that unnecessarily takes up much time for the employees. Since the process concerns five transaction items per week, currently, the employees spend 3,5 hours per month on the process. Therefore, the number of transactions to be processed by the employees is not considerably high at the moment. The organization has decided to apply RPA in this case, as the demand for the processing of these transactions will increase significantly in the following months/years. An RPA solution is more scalable and cheaper than scaling up the number of employees involved in this process. The processing time

Table 19: Cases included in the multi-case study (part 2)

Case	Error rate pre/post	Automation rate	Development time	Hours saved (weekly) (post)	Months to ROI
1	5% / 0%	95%	4 weeks	0.8 hours	+2 years
2	5% / 0%	95%	2 weeks	7.6 hours	12 months
3	5% / 0%	100%	1,5 week	1.75 hours	14 months
4	2% / 0%	99%	3 weeks	24.75	17 months
5	0% / 0%	100%	2 weeks	7.5 hours	11 months
6	1% / 0%	100%	1 week	1.17 hours	+2 years
7	1% / 0%	100%	1 week	0.17 hours	11 months

does not decrease when the robot executes the process. The main advantage lies in the fact that employees no longer have to do this themselves. The automation rate is set at 95% since 5% of the claims are missing essential input data from the intermediaries. In that case, the employees have to make contact with the intermediaries in order to fill the gap in necessary input data.

Case 2 concerns a process at the IT department of a company where all IT-related set-ups are handled for their employees. Before the start day of a new employee, a number of steps have to be taken to set up the correct accounts and rights. This process consists of a large number of applications where data needs to be gathered and processed. However, the process steps are reasonably standardized. If a scenario occurs in which the robot is not able to complete the process, the employees can finish it themselves. The employees estimated the number of transactions that are considered not viable or partly not viable for the robot at 5% of the total amount. That is why an automation rate of 95% is defined.

Case 3 concerns a process that handles the registration of material deliveries in the SAP application. An Excel file with predefined orders is used to check if the material delivery has already been registered in SAP. If this is not the case, the corresponding values are entered into SAP. After the registration, the status of the previously used order number is changed in the Excel file. A report is sent to the interested party. The entire process flow is embedded in the RPA solution. Due to the high workload of the employees who carry out this process, this registration process is often neglected or carried out too late. Therefore, an increase in overall employee productivity and more continuity in the registration of deliveries are the main goals for implementing RPA for this business process.

Case 4 concerns a process where data is checked on completeness and possible errors. Data is retrieved from multiple source applications and then checked for mismatch. If necessary, the data is enriched or modified. This manual process is quite error-prone. Eventually, all the correct data is collected and entered into the SAP application. RPA is implemented to overcome the risks of data to be booked incompletely or data to be not booked at all due to this incompleteness. The RPA solution covers this entire process. 1% of the transaction items remain for the employees to process. These transaction items include those items where the robot did not succeed or where special business rule exceptions were defined.

Case 5 concerns a process where loans are created for organizations. In order to create loans, data has to be converted into an appropriate structure for the input application.

Based on the loans, payment orders are created, which have to be assigned to a work item. For each of the loans, collateral has to be created and approved. After creating the collateral, the work item is updated. This process consists of multiple inter-dependencies, which causes these tasks to be put on hold for employees at multiple times during the process. The complete process is taken care of by the robot, where the idle moments are efficiently spent on other transaction items or other processes.

Case 6 concerns a process that makes sure particular documents are uploaded daily to a secured data center. Prior to uploading the set of files to the data center, a check has to be performed to make sure the most recent files are uploaded. The employee checks if the files are not older than 24 hours. If the files are not up to date, they have to be exported from the source application. If the files are up to date, they are uploaded to the secured data center. After implementing RPA, these process steps are all performed by the robot. The difference is that the export from the source application is not retrieved by navigating to the source application but using an API request. Another change to the process is that the documents are not uploaded every day but every workday. This is a change that resulted from critically reviewing the process whilst determine the scope for RPA.

Case 7 concerns a process that checks the availability of all agents/servers. The monitoring of these agents is done every Sunday to prevent employees from running into problems when they start work on Monday. If an agent is not running, an incident issue has to be submitted. Currently, an employee is scheduled to monitor such availability checks on Sunday. This particular check is carried out once every Sunday. By deploying an RPA solution for this process, it is not necessary for an employee to perform this particular check manually anymore. Therefore, the main value of implementing RPA for this process is that it is not necessary to schedule an employee to perform these checks on Sunday. In addition, the check can easily be scaled up and carried out hourly in the future. Both the monitoring and reporting part of the process is in scope for the robot.

6 Results

In this chapter, the results of applying the developed RPA impact estimation method in practice are presented. The multi-case study and the expert evaluation are described. A short input data quality analysis is performed to describe the role that quality and accurateness in this regard have on the method outcome.

6.1 Multi-case study

The RPA impact estimation method is improved continuously during the execution of the multi-case study. These adjustments to the method are primarily focused on the calculations used for the metrics. Making the necessary changes to the method during the cases allowed me to iterate over all the cases using the most up-to-date version of the method. Therefore, a continuous evaluation flow of the method is enabled. The revised RPA impact estimation method, with its accompanying adjustments, can be found in Chapter 7.

The next section describes the results noted for each of the cases separately. The results are based on the values for the baseline measurements, post-measurements, and the execution of the estimation method for each case. These values can be found in Appendix D. The section after that describes the results based on an across-case analysis.

6.1.1 Within-case analysis

Case 1 results show that the desired reduction in the error rate has not (yet) been achieved. Missing input data from the intermediaries cause the error rate in this process. This causes business rule exceptions for a number of transactions that the employees of the insurance company have to reprocess the transactions. Currently, the company is guiding the intermediaries to provide complete and correct input data. This is an ongoing process, which will provide an increasing supply of useful input data. In the current phase of the RPA project, a brief verification of the results of the robot is being carried out. This verification is expected to be removed in the following weeks. In terms of robot performance, the robot is two times faster in performing the process than the employees. As a result, incoming claims are settled earlier than before. Once confidence in the robot's performance is established, the process will be offered as a service, and the execution frequency will increase.

Case 2 is missing post-measurements due to the cancellation of the project during this stage of my thesis period. The application that is at the heart of the process has offered new functionalities that the employees can use to such an extent that RPA becomes superfluous. These new functionalities were offered before the RPA project was completed. Therefore, the RPA project is canceled. Irrespective of the missing post-measurements, the RPA impact estimation method is applied to the baseline measurements. The results of the execution of the method show that the method is applicable to yet another process. No deviating results were expected, other than a confirmation of the results obtained from other cases. For these reasons, the case is included in the multi-case study.

Case 3 shows that the method execution is a reflection of the main goal for automation. The main purpose of implementing RPA, in this case, is not direct financial benefits, but rather the productivity of the employees and the continuity of the process. This affects the overall savings of the process, which shows an ROI of more than one year. Due to the simplicity of the process, a small amount of development costs is calculated. The small development costs contribute to the overall savings since these costs are in reasonable balance with the final benefits. The process is carried out on a monthly basis at a

predetermined date, ensuring that all necessary contracts are processed on time. In addition to improving process continuity, the faster execution time of the robot (currently ten seconds per item) also contributes to the accelerated process cycle time.

Case 4 shows promising results for the future of RPA within this department. During the post-measurements, the SME explicitly mentions that they are satisfied with the robot's performance and that expansion is already under consideration. By expanding the process with other related tasks that the SMEs are performing, one to two FTE can be saved ultimately. Currently, a particular type of complex transactions cannot be processed by the robot. The transactions that fail all correspond to the transactions that were identified as out-of-scope during the process definition phase. These transactions were not included in the baseline measurements in terms of execution frequency and execution time. Therefore, an error rate of 0% is listed.

Case 5 concerns a process that is deployed. However, the robot has to deal with performance issues of the internal systems, as the SME explains during the post-measurements. Currently, they are working on solving these internal infrastructure issues. The resulting error rate (10%) are expected to decrease or eliminate after the problems have been resolved. Due to this error rate, the SMEs are still spending on average 45 minutes per day on the process. This time includes monitoring the robot, assessing the reports of the robot, and handling the errors. Once the infrastructure issues have been solved, the SMEs expect to spend a maximum of ten minutes per day on the process. This means that the eventual time the people are involved in the process (50 minutes) is underestimated during the baseline measurements (30 minutes). The difference in the number of FTE needed after the implementation of RPA affects the costs and savings of the project. Case 5 is another example of the beneficial distinction between the impact in the first year of deployment and the subsequent years. The first year consists of a marginal saving, while the savings in the subsequent years will be more than ten times higher.

Case 6 is one of the cases where the post-measurements are carried out in a phase where all the work of the robot is still being assessed. Currently, the robot reports on all transactions that are processed. The results of each of these transactions are reviewed by the SME. Therefore, a review rate of 100% is defined. In the next stage, the SME wants the robot to only report on transactions that have failed or require the attention of the SME. Since the error rate is currently 0%, the involvement of the SME in terms of time per week will decrease once the overall assessment of the robot has come to an end. The processing time of one transaction is similar between the robot and the employees. A decrease in process execution frequency is observed. The SMEs explain that the process used to be carried out daily, including Saturday and Sunday. By asking critical questions about the process while determining the process scope for RPA, they came to the conclusion that running the process over the weekend is not necessary. Hence, the frequency has been reduced from seven to five. This is an example of how considering RPA for business processes can contribute to making existing processes more efficient.

Case 7 is another example of where the post-measurements are made in a phase where all of the robot's work is still reviewed. During the first phase of deployment, it is advisable to monitor the robot's performance closely. At that point, adjustments can be made promptly where necessary. This clarifies the review rate of 100%, with a short review time of one minute. The review rate will decrease as confidence in the robot increases. As expected, the error rate has dropped to 0%. The processing time by the robot does not differ from the processing time by the employees. Currently, the execution frequency is similar to before the implementation of RPA. The SME explains that the execution frequency will be increased in the foreseeable future. Other types of checks that are performed by em-

ployees on weekends can be performed by the robot as well. Those checks can easily be added to the current process steps taught to the robot. Even-though the savings that are calculated by the method are not yet in the positive figures, the SME emphasizes on the fact that relieving the employees of this task that has to be performed on weekends, is the main value of this implementation. Luckily, the upcoming increase in the number of transactions will provide a more positive impact.

6.1.2 Across-case analysis

First, the results of executing the estimation method are analyzed. The estimation method output can be found in Appendix D. I found that the results show relatively small-scale business cases for implementing RPA. All cases show an FTE saving of less than 1 FTE. Since the processes that are selected for the multi-case study consist of relatively short implementation time, smaller projects are expected in this sense. Another remark is that the division of costs/savings per year is beneficial for the overall view on ROI since not all projects have an ROI within 12 months. In addition, the output of the method neglects potential growth in the work volume for the robot. This potential growth in the execution frequency of the process is not explicitly incorporated into the method. In some cases, the RPA impact will be volatile when an increase in execution frequency is expected, especially within the first year. Despite the fact that I asked the SMEs about foreseeable changes regarding process frequency or process velocity during the multi-case study, in the interviews, it was found that, if applicable, the SMEs do not know how much these variables will change exactly. Therefore, it is not feasible to include these measures into the method directly during this phase. However, it is beneficial to mention these factors and give as complete a picture as possible of the future situation of the process.

Second, a comparison between the baseline measurements and post- measurements is made. Both the measurements can be found in Appendix D. As described in Section 2.3.1, the measurements are taken are predefined phases of the RPA project. The baseline measurements are taken accordingly for all cases. The post-measurements are taken accordingly to the extent possible within the time limits of my thesis. The estimations of error- and review rates, and the time employees are still involved in the process confirm the indication of a dependency on the timing within the implementation of the robot. In some cases (1, 5, 6, 7), these variables are measured in the start-up phase of the robot's use. These percentages will decrease at a later stage when employees feel they can rely on the robot and possible infrastructure issues are solved, as the SMEs confirm in the interviews during the post-measurements. In other cases (3, 4), these variables are measured at a more mature stage of the robot's use, where these rates have been reduced or resolved. In either case, the SMEs confirm that the estimations and post-measurements concerning the time spend, the involved time, the error rate and time, and the review rate and time are as expected. As for process execution time, in case 1, 3, 4, 6, and 7, the robot is faster in performing the process than the employees. The process execution frequency shows a similarity in volume between the baseline- and the post-measurements for all cases except case 4. This is related to the determination of measuring time instances, as described in Section 2.3.1. In case 4, the company had to deal with the extreme consequences the COVID-19 had on their running business processes. Therefore, it was not possible to measure an exact frequency during this phase of my thesis.

6.2 Expert evaluation

During the expert evaluation, the dependent variables, as described in Section 2.3.2 are evaluated. The results of the dependent variables that are evaluated during the expert evaluation are summarized in this section. Tables 20 and 21 list a summary of the results of the survey. Based on all the results in Appendix F, an average is derived for each of the questions that indicate what the experts' perception of the method is. Consequently, the summary is an indication of whether the method will be used in practice or not. Altogether there are no significant results retrieved from the expert evaluation. Due to the small number of experts, a statistical analysis is not feasible.

6.2.1 Performance variables

During the expert evaluation, one dependent performance variable is measured. The efficiency of the method is measured by questions 1 and 2, as is shown in Table 20. The efficiency of the estimation method depends on what is considered in scope for time measurement of the estimation method. According to expert 4, 5, and 6, executing all the steps involved in using the method, including the extensive question list, takes more time than previous approaches. According to expert 1, 2, and 3, that considered the method calculations, it takes less time compared to previous approaches to define the eventual costs and savings.

Due to the unclear scope of the estimation method in the survey, the answers of the experts were not uniform, as can be seen in Table 20 and Appendix F. The results and the experts' explanations indicate that considering the estimation method itself, meaning the calculations based on required information, the method is more efficient than the traditional method of the experts. Considering all the steps involved in using the method in practice, such as interviewing and monitoring the SMEs, the results indicate that the method is not more efficient.

Table 20: Summary of expert evaluation results - part 1

Number	Question	Mean value
1	Time needed using current practice	18,3 min
2	Time needed using new method	31,0 min

6.2.2 Perception variables

Three dependent perception variables are measured during the expert evaluation. The results of the evaluation of these three variables are described below and represented by their mean value in Table 21. Survey questions 3 to 16 were asked using a 5-point Likert scale ranging from strongly disagree (5) to strongly agree (1). The last two survey questions were asked using a 5-point Likert scale as well ranging from extremely unlikely (5) to extremely likely (1)

First, the perceived ease of use of the method was measured by questions 3 to 8. The results of these questions indicate that 5 out of 6 experts found the method easy to learn (5). The rules and procedures for the method and its application are clear and easy to understand according to 5 out of 6 experts (3, 7). From the surveyed experts, 5 out of 6 reported that the method is not difficult to use or apply to RPA initiatives (4, 6).

Overall the experts reported that they would be confident to apply the method in practice (8). Additional feedback from the experts was that to be able to apply the method in practice successfully; it is necessary to have the ability to interview people and listen to the SMEs carefully. This determines the quality of the input you receive from the SMEs. Aside from that, the SMEs and the business in general need to be comfortable with sharing information on their processes (qualitative and quantitative data).

Second, the perceived usefulness of the method is measured by questions 9 to 16. The experts reported that the output of the method is not difficult to understand (10). The results indicate that the output of the method makes it is easier for users to verify the impact of RPA (11), to create business cases for RPA (13), and to communicate the impact of RPA (16). Overall, the responses of the experts indicate that the method is an improvement to the current estimation practices (15), where the method would reduce the effort required to perform an estimation (9). Two-third of the participants indicated that the method provides an effective solution to the problem of estimating the impact of RPA (14).

Third, the intention to use the method is measured by questions 17 and 18. 100% of the surveyed experts said that they are open to using the method (17) and 83% of those surveyed reported that they intend to use the method in preference to the current practices (18).

Table 21: Summary of expert evaluation results - part 2

Number	Question	Mean value
3	Method procedure is complex and difficult to follow	1.7
4	Method is difficult to use	2.2
5	Method is easy to learn	4.2
6	Method is difficult to apply	1.8
7	Method rules are clear and easy to understand	4.2
8	I am not confident I am competent to apply the method	2.0
9	Method reduces effort for estimation	3.7
10	Method output results are more difficult to understand	2.0
11	Method makes it easier to verify impact of RPA	4.2
12	Method is useful	4.5
13	Method makes it more difficult to draft business case	2.2
14	Method does not provide an effective solution to problem	2.3
15	Method is an improvement to current practices	4.0
16	Method makes it easier to communicate impact of RPA	4.3
17	I will not use the method	1.5
18	I intend to use the method in preference to current practice	4.2

6.3 Input data quality analysis

This final part of the results section includes the analysis of the method input data quality. The input data quality analysis can be seen as an additional evaluation of the method. Experience in practice shows that it is possible that SMEs are not aware of specific input data values, or that the data cannot/will not be disclosed. I have evaluated whether the RPA impact estimation method can still be carried out in that case. Therefore, the availability and use of input data is taken into account. This means that the quality of the method is analyzed in the situation that data is missing, unavailable, or not disclosed. In addition, the use of estimates in the method is described.

Each metric in the RPA impact estimation method is evaluated by me for its role in the method and its data characteristics. The full metric descriptions can be found in Table 33. This evaluation is carried out by looking at the probability that the data is not known precisely and what effect estimated data will have on the method. I defined all of the metrics as required for the method to be performed. If data is unknown, then it is advised to first locate the data before using the method. A distinction is made between metrics that require precise values and metrics for which estimated values are sufficient if no precise values are available. Table 34 lists the metrics used in the RPA impact estimation method with their corresponding value assessments.

Table 22: Input data quality analysis

Metric	Metric name	Precise value	Estimated value
ET	Execution time	x	
EF	Execution frequency	x	
ER	Error rate	x	
RPT	Reprocess time	x	x
RV	Review rate	x	
RVT	Review time	x	x
OIT	Other people involved time	x	x
WH	Working hours	x	
CFTE	Cost of 1 FTE	x	x
LC	License costs	x	
LU	License users	x	
PCT	People cost type	x	x
IMD	Involved days	x	x
AR	Automation rate	x	

The metrics required for the method to be defined precisely are listed as require a 'precise value'. These metrics have been identified as required for the method to meet a minimum quality level. Without precisely defining these values, the outcome of the method will not be able to achieve a certain level of accuracy. The metrics for which estimated values are sufficient in case the exact value is unknown are listed as require at least

an 'estimate value'. These are metrics for which it can be difficult in practice to define a conclusive value. The decisions for classifying the metrics are based on knowledge gained both in practice and during the implementation of the multi-case study. The potential estimated values for these metrics are either based on practical knowledge or experience from previous RPA projects.

In this regard, it should be noted that the more precise the values, the more accurate the method for estimating the impact will be. Evidently, it is possible to enter a value of '0' for one of the metrics. In that case, the method can be executed, but this will have a negative effect on the accuracy of the outcome of the method. Therefore, it is necessary to address the need for precise values to the people providing these data. Accordingly, the method implementation guidelines in Appendix G emphasize the quantitative approach to the collection of these data.

7 Final RPA impact estimation method

Based on the results from the multi-case study and expert evaluation performed in this study, the initially developed RPA impact estimation method is revised. In Section 7.1 the changes that were made to specific sections of the method, and on what empirical data these changes are based, are listed. The following paragraphs describe how the adjustments have been incorporated into the method. The final RPA impact estimation method can be seen in Section 7.2.

7.1 Method revisions

Four adjustments have been made to the calculation of the labor costs, which can be seen in Table 23. The first adjustment concerns the addition of a metric for other people that are involved in the process. Since the SME might not be the only employee involved in a particular process, I added a metric for the time other people than the SME are involved in the process. This time increases the overall process time. Whether the time other people are involved is reduced or removed entirely due to the RPA implementation is added as a metric as well. The second adjustment concerns the calculation of the FTE that is needed before the implementation of RPA. To calculate the FTE needed for the process, a calculation is made based on dividing the total process time (in hours per week) by 31,25 hours instead of 40 hours. If not mentioned otherwise, an average of 1250 productive working hours per year is set as a baseline for one FTE. The total number of working hours per year is 1680. However, practical experience has shown that employees are only 75% productive. The third adjustment concerns a general improvement to the retrieved measures and calculations. All the formulas are optimized by correctly converting the measures into minutes or hours. The fourth adjustment concerns the addition of metrics to make the method calculations more transparent and understandable. Instead of long formulas, a few have now been split up. The intermediate results of those calculations are also of value, as can be seen in the example output of the method in Appendix H.

Table 23: Method adjustments

Revision	Empirical input
Calculate current labor costs	
Metric addition involved people (OIT & OIR)	Case 1 observations
Changed productive work hours FTE	Experience in practice & RPA expert feedback
Optimization calculation FTE needed before RPA	Cases method execution
Added metrics for intermediate results	Cases method execution
Calculate automation costs	
Optimization calculation FTE needed after RPA	Cases method execution
Changed infrastructure cost metric	Case 1 observations
Added automation cost over years	Experience in practice & Cases method execution
Added metrics for calculation FTE needed after RPA	Experience in practice
Added metrics for intermediate results	Cases method execution
Calculate overall impact on costs	
Added impact savings over years	Experience in practice & Cases method execution

In addition, five adjustments have been made to the calculation of automation costs. The first adjustment concerns the calculation of the FTE that is needed after the implementation of RPA. The total process time is diminished with time savings by reducing or removing reprocessing, reviewing, and other people involved. Next, the resting process time is multiplied with the automation rate to define what part of the process is automated and what part rests for the employee to perform. The resting process time for the employee to perform is used to calculate the FTE needed after the RPA implementation. The second adjustment concerns the infrastructure cost metric. It has to be taken into account that infrastructure costs do not repeat for each RPA implementation at the same company or department. Therefore, license costs are calculated by taking the total license costs required by the process and dividing it by the number of processes that make use of these licenses. Except for when a particular RPA project is the first RPA initiative, multiple processes make use of the same licenses. By adjusting these calculations as such, not all license costs will be passed on to one process. The third adjustment concerns the calculation of the total automation costs. I divided automation costs in costs for the first year and costs for the subsequent years. Development costs only occur once, while the license costs are yearly recurring. By dividing these costs in years, a more realistic overview will be given of the yearly costs related to the RPA implementation. The fourth adjustment concerns the addition of metrics to make the method calculations more transparent and understandable. According to the same reasoning as in the calculate current labor costs part, a few of the long formulas are now split up. The intermediate results of those calculations are also of value, as can be seen in the example output of the method in Appendix H. The fifth adjustment concerns the addition of metrics for the portions of the review time, reprocess time, and time other people are involved that have actually been eliminated (RPR, RVR, OIR). It is not necessarily that these values are entirely omitted as a consequence of RPA. This is often not the case in practice. The cases confirm this experience in practice.

Lastly, an adjustment has made been to the impact savings on a yearly basis. This adjustment concerns the calculation of the overall impact savings. The eventual impact of RPA on costs are segregated in the amount saved in the first year and the amount saved in the subsequent years. This separation provides a more realistic overview of the yearly costs and, thus, savings.

7.2 Revised method

Table 32 shows the revised RPA impact estimation method and its corresponding metrics are shown in Table 33. The guidelines for implementing the method are presented in the accompanying tool-set in Appendix I.

Table 24: RPA impact estimation method

Estimation method	Calculations
Calculate current labor costs	
	$PT = ((ET * EF) / 60)$
Calculate needed FTE	$TPT = PT + ((ER * EF) * RPT / 60) + ((RV * EF) * RVT / 60) + ((OIT * EF) / 60)$
	$FTE = TPT / WH$
Calculate cost of needed FTE	$CLC = FTE * CFTE$
Calculate automation costs	
Calculate software license costs	$SLC = LC / LU$
Calculate development costs	$DC = \sum PCT * IMD$
Calculate FTE costs after RPA	$TPTS = TPT - ((ER * EF) * RPR / 60) - ((RV * EF) * RVR / 60) - ((OIR * EF) / 60)$
	$EFTE = (TPT - (PT * AR)) / WH$
	$ALC = EFTE * CFTE$
Calculate cost of automation	$AC1 = SLC + DC + ALC$
	$AC2 = SLC + ALC$
Calculate overall impact on costs	
Current labor costs minus	Impact first year = $CLC - AC1$
the automation costs	Impact subsequent years = $CLC - AC2$

Table 25: Revised RPA impact estimation method metrics with original sources

Metric	Description
FTE	Total full-time equivalent currently needed [37, 46, 50]
PT	Process time (hours per week)
ET	Average execution time per transaction (in minutes) [46, 50]
EF	Average execution frequency of transaction (per week) [37, 46, 50]
TPT	Total process time (hours per week)
ER	Average error rate of total volume of transactions [46]
RPT	Average reprocess time per transaction in case of an error (in minutes) [46]
RV	Average percentage of total volume to be reviewed by a human agent [46]
RVT	Average review time per transaction (in minutes) [46]
OIT	Average time other people are involved in the process (in minutes)
WH	Average number of working hours (per week): equivalent to 1 FTE [46]
CLC	Current labor costs [37, 46, 50]
CFTE	Average cost of 1 FTE (per year) [37, 46, 50]
SLC	Software license costs based on license type (per year) [37, 46]
LC	License costs [46]
LU	License users (amount of processes running on that license)
DC	Development costs [37, 46, 50]
PCT	People cost type (Implementation Lead, Solution Architect, Developer) [46, 50]
IMD	Number of involved days in implementation [46]
TPTS	Total process time saved (hours per week)
RPR	Average reprocess time per transaction saved (in minutes)
RVR	Average review time per transaction saved (in minutes)
OIR	Average involvement time per transaction saved (in minutes)
ALC	Labor costs after automation
EFTE	Full-time equivalent needed after automation
AR	Automation rate of process [46, 50]
AC1	Automation costs in the first year [37, 46, 50]
AC2	Automation costs in the subsequent years

8 Discussion

As shown in the theoretical framework, a thorough estimation of the impact of RPA implementations on business processes, which is readily applicable in practice, is lacking in the literature studied. The aim of this work was thus to create a tangible standardized method that enables practitioners to estimate the impact of RPA on business processes using quantitative measurements prior to the implementation of RPA without leveraging other technologies. This chapter discusses the findings for the sub-research questions posed at the start of this research, the main contributions of this research, and the limitations of this research.

8.1 Research questions

The sub-research questions of my thesis are answered here, which leads to a concluding answer to the main research question in Chapter 9. To this end, the sub-research questions and the main research question are listed below. Each of these questions is accompanied by an answer that embodies a conclusion.

SQ1: What are the indicators for the quantitative impact of an RPA implementation?

In order to estimate the impact of RPA on business processes, the indicators that are of importance are generated ROI, needed FTE for the process, manual labor costs, process execution time, process execution frequency, the error rate of the process, the review rate of the process, the involvement of other people in the process, the automation rate of the process, robot license costs, robot development costs, and automation costs of years. Most of the indicators are identified in the literature, as shown in Table 7. The involvement of other people in the process and the automation costs of years are added as indicators based on experience in practice. All indicators identified as relevant within the scope of this research are combined in the final RPA impact estimation method, which can be seen in Table 33. For the indicators concerning the needed FTE for RPA, the difference between the indicator before and after the implementation of RPA is of relevance.

SQ2: What approaches exist to estimate the impact of an RPA implementation?

A number of approaches exist that are leveraging other technologies to estimate the automation potential of processes. Technologies such as process mining [49, 50], UI logging [28, 35], and simulation [39] are applied in this respect. Approaches that do not leverage other technologies are primarily focused on the relevant indicators that can be used in cost-benefit analyses [37, 46]. However, no guidance is given on the acquisition and exploitation of the measures for these indicators. Besides that, research and experience in practice indicate that effective RPA implementations heavily rely on quantifiable measures of its potential prior to the project that go beyond a simple total FTE reduction. Analysis of these existing approaches shows that these approaches typically neglect an explanation on how to gather quantitative measurements, an in-depth FTE reduction calculation, and a tool-set that can be utilized to apply the estimations in practice.

SQ3: How can the impact of an RPA implementation be estimated using a standardized method?

The next step was to develop an initial RPA impact estimation method inspired by existing approaches. A set of calculations based on a predefined set of metrics is utilized to estimate the impact of an RPA implementation on costs and savings. In light of the shortcomings of current approaches identified in the literature, a number of elements have

been added to the overall estimation approach. First of all, the method utilizes quantified baseline measurements that ensure all required data are collected and validated. This data enables the method execution to result in an accurate indication of the business process and its associated savings after the implementation of RPA. Additionally, the method is supplemented with metrics arising from personal experience in practice, as explained in Section 7.1. The output of the RPA impact estimation method represents the financial savings estimated to be achieved in the first year after implementing RPA and in the subsequent years. Furthermore, the method is complemented with the tool-set in Appendix I that enables practitioners to apply the method in practice based on predefined guidelines. This tool-set consists of method implementation questions to collect the required data and a method implementation example script to execute the method. The method implementation script can be adjusted to any type of tool preferred by the practitioner. Lastly, the method is formatted in such a way that it can be applied to all types of processes and RPA projects. The multi-case study results in Section 6.1 showed that the method is indeed applicable to various types of processes and RPA projects. Standardizing the method contributes to the overall applicability of the method in practice. These elements combined result in the final RPA impact estimation method. In summary, a tangible standardized method for effectively estimating the impact of RPA based on quantitative baseline measurements that can be readily applied in practice without leveraging other technologies is developed.

SQ4: How can the effectiveness of the RPA impact estimation using the standardized method be evaluated?

The estimated impact of RPA on business processes is evaluated by conducting a multi-case study and by having an expert evaluation carried out. During the multi-case study, the effectiveness of the RPA impact estimation method is evaluated. By doing so, the estimated impact resulting from executing the method is evaluated as well. Post-measurements were used to evaluate if the correct measures were defined beforehand to use in the RPA impact estimation method. This evaluation determined whether the output of the estimation method was adequate, considering the actual implementation of RPA. The estimated impact of an RPA implementation can only be evaluated in the short term within the scope of this thesis. The purpose of the expert evaluation was to evaluate the objectives of the RPA impact estimation method. The objectives of the method are to clarify the relevant variables in performing an RPA impact estimation, to improve the effectiveness of impact estimations for RPA implementations, and to develop an RPA impact estimation method that is applicable in practice. Taking into account the aforementioned results in Section 6.2, the expert evaluation indicates that the method and its procedures are perceived clear and understandable and that the method contributes to the way RPA impact estimations are performed. Overall, the experts surveyed are willing to use the RPA impact estimation method in practice.

8.2 Main contributions

The main contribution of this research is the availability of an effective RPA impact estimation method that is tested in practice, is evaluated by RPA experts, and can be applied in practice using the provided guidelines in Appendix I.

Syed et al. [45] stated that research on elaborate metrics and a practice-oriented approach for the expected impact of RPA on business processes before implementation is lacking. The findings of my research complement those of earlier studies into the impact

of RPA and the calculation involved [23, 37, 50]. Research by Geyer-Klingeberg et al. [23] and Wanner et al. [50] investigates the utilization of additional technologies such as process mining to identify the potential of RPA processes. Besides the fact that these studies utilize external technologies, these studies neglect in-depth FTE reduction calculations and applicability in practice. My research addresses these issues and complements their research by examining potential RPA processes without the use of alternative technologies. In addition, it complements estimation approaches such as published by UiPath Inc. [46] that lack systematic evaluations. The problems with current RPA impact estimation practices were assessed against what was possible to address within the scope of my thesis.

The main elements that were missing in existing approaches were addressed in the development of my method. These elements consist of an in-depth quantified FTE reduction calculation and guidance to apply the method in practice. Therefore, the research consisted of an extensive analysis of the required variables regarding a quantified FTE reduction calculation and other indicators related to the automation costs of the RPA implementation. The developed method is evaluated using an extensive assessment of the process before and after the implementation of RPA. The RPA impact estimation method and its corresponding variables are evaluated systematically. Thus, this research provides a newly developed, evaluated artifact which will be a fruitful area for future work, as is described in Section 9.3. In addition, the method's accompanying tool-set in Appendix I makes sure the study provides a guiding method that is applicable in practice. In summary, the empirical findings in this study provide a new understanding of effective impact estimations for RPA implementations. By combining literature with practical experience, this research contributes to the scientific domain with a study that takes the most recent practical developments and findings into account.

The results of this study can be generalized to other RPA projects and industries. I have not found any indication that the indicators cannot be transferred to other industries than those surveyed as the method is not industry-specific. Besides that, the impact estimation method can be applied to other domains where impact estimations are of importance. These domains include automation technologies and initiatives where the aim is to measure the extent to which employees are relieved of a time-consuming task and for which automation involves various fixed and variable costs. In that case, domain specific indicators can be added to enhance the outcome of the estimation method.

Taking into account the business area to which the method applies, the study also includes practical impact. The RPA impact estimation method contributes to the approach the vast majority of companies are using to define the impact of RPA in the form of business cases for RPA projects, if companies apply some form of impact assessment at all. While considering to draft business cases for RPA projects based on the estimated impact calculated by the RPA impact estimation method, practitioners have to keep in mind what the initial goal is for implementing RPA for a specific process. If, for example, solely employee experience is the main goal of the implementation, a business case might not result in substantial savings based on the used RPA impact estimation method, due to the absence of these variables in the method. Nevertheless, it is crucial for the business to be aware of the potential costs and savings of automating the actual process to manage expectations and opportunities.

Concluding, the insights gained from this study may be of assistance to both the scientific and the practical domain. With the developed method, I was able to fill in the identified gaps in the literature to a certain extent. Since the research is not without limitations, these limitations are described in the following subsection.

8.3 Limitations

This section outlines the limitations that were part of this research. First, limitations to the RPA impact estimation method are presented. Second and third, limitations to the multi-case study and the expert evaluation are discussed.

8.3.1 RPA impact estimation method

The scope of this study was limited in terms of available thesis execution time. Due to the scope of the research, the output of the RPA impact estimation method i.e., the financial impact of RPA, can not be validated in the long term. Comparing the estimated impact with the actual impact once the RPA solution is implemented a year is not feasible within the time limits of my thesis. Therefore, long-term effects are unaccounted for.

The method developed in this study was limited by the absence of a method variable for growth in the volume of work. The result of the method provides a representation of the potential savings by implementing RPA based on a single data point in terms of execution frequency. Growth in execution frequency is not incorporated into the method explicitly. Short-term growth in execution frequency can result in more savings. In order to have the most up-to-date estimation of costs and savings, the method has to be executed repeatedly once the specific growth in the volume of work for the employees/robot is known.

Other factors that influence the impact of RPA, like employee experience, resource utilization, and customer service, are not incorporated in the method. Their complexity makes it more difficult to express these factors in values. In addition, this research has focused on productivity.

8.3.2 Multi-case study

Despite the potential limitations of a case study, this research consists of a multi-case study that is carried out in an attempt to mitigate the potentially little basis for generalization of results to the wider population of business processes and companies. Other remarks about the threats to the validity of the multi-case study are described below.

Due to the COVID-19 outbreak, the multi-case study had to be carried out remotely. This had various implications for the research in general and, specifically, the multi-case study. I was not able to perform the case studies at the participant's office. Visiting the SMEs to monitor them while working was not allowed. This threatened the collection of valid quantitative input data for the method. The data retrieved as baseline measurements during the multi-case study are second-handed data points. Nevertheless, I have received the expert time estimations, which they validated by application logs if they were available. In spite of the limitation, the study contributes to our understanding that the required data must be collected quantitatively.

An additional uncontrolled factor is a possibility that processes are influenced by factors other than RPA. One of the criteria in case selection for the multi-case study is that the processes solely include an RPA implementation in the current phase of the automation project. This decision is made to exclude external influences to the post-measurements e.g., by other automation initiatives. However, I can not exclude the possible influence that critically reviewing the process before implementing RPA has. Experience in practice shows us that processes are often improved in terms of efficiency during an RPA project. During the evaluation of an existing process to outline the process for RPA, it can be decided to remove or change specific process steps. These decisions influence the

post-measurements; consequently, the validity of the comparison of the baseline measurements and the post-measurements.

8.3.3 Expert evaluation

As for the expert evaluation, the research approach consists of some limitations as well.

Since the study was limited to a small size expert evaluation data-set, it was not possible to investigate the significant relationships of the RPA impact estimation method and its ease of use, usefulness, and the intention to use the method in practice. Statistical analysis can not be applied to this number of evaluations. Therefore, the expert evaluation results consist of solely indications.

One source of weakness in the study, which could have affected the measurements of the expert evaluation, was the potential bias from the RPA experts. In the expert evaluation, there is a potential for bias from the experts when answering questions on the new method in relation to the current practices for RPA impact estimation. Depending on the experts' experience with the current practices, their perceptions on applying a new method might be biased.

9 Conclusion

This chapter includes an answer to the main research question, the conclusions obtained after conducting the research, and the proposed future work.

9.1 Main research question

RQ: How can one effectively estimate the impact of an RPA implementation?

Using the developed RPA impact estimation method in this research, practitioners are enabled to estimate the impact that RPA will have on their business processes. The focus has been placed on integrating all the necessary metrics to determine the exact situation prior to the implementation of RPA and after the implementation of RPA. We specifically look at how much time employees put into the process in both situations and what costs are involved in robotizing the process. The guiding tool-set in Appendix I offered by this research allows the method to be directly implemented in practice. One of the main goals of the research has thus been achieved. The metrics used in the method have been elaborated. This allows the user to easily collect the necessary data. Subsequently, the execution of the estimation method is done by using a tool, according to the wishes of the user, that can execute the script. This eliminates the need for them to do the calculations themselves. By standardizing the method and the associated tool, the results are given as accurately as possible for each instance in a consistent manner. The RPA impact estimation method results in two outcomes. The estimated impact on costs in the first year implementing RPA and the impact on costs in the subsequent years. Ultimately, the impact of RPA on costs is dependent on the volume of work transferred from employees to the robot. A subsequent calculation may, therefore, be necessary in order to obtain an updated estimation of the costs and savings of implementing RPA.

9.2 Conclusion

Since starting RPA projects that lack a proper impact estimation or business case is one of the common issues in failed RPA projects, the development of a standardized approach to estimate the impact of RPA prior to the implementation that is easily applied in practice is necessary. This research set out to develop a tangible standardized method that can be used to effectively estimate the impact of RPA based on quantitative baseline measurements that can be readily applied in practice without leveraging other technologies. Comparing the estimated and actual impact of an RPA implementation provides us with information on whether the actual impact of an RPA implementation reflects the estimation made upfront. By doing so, we can verify that the RPA impact estimation method is developed right. After the effectiveness of the RPA impact estimation method is evaluated, the method is evaluated in terms of its applicability in practice. The evaluated method can assist in determining how the business process will be affected by RPA. Thus, how we can indicate this influence by RPA prior to the implementation. This approach focuses on concepts such as process velocity, manual labor, and automation effort for the impact assessment. The evaluations performed in this study confirm that the developed RPA impact estimation method, as is presented in Chapter 7, addresses and fills this gap in the literature.

By combining scientific research with findings and hands-on expertise, this research has provided a deeper insight into a comprehensive approach to estimating the impact of RPA, which is tailored to the application of the method in practice. In doing so, this

study adds to the growing body of research into RPA, the technology's benefits, and the technology's implementation.

Although the current research is based on a small sample of cases and experts, the findings suggest that the RPA impact estimation method is applicable to various process types and RPA projects. Therefore, the RPA impact estimation method can be employed as a standardized approach for estimating the impact of RPA implementations on business cases. For that reason, the method is useful for drafting business cases for RPA projects. The method can be applied within companies that are striving for clarity in the automation potential of their business processes. Alternatively, the method can be applied by RPA specialists who use the method to draw up business cases for their customers' processes.

9.3 Future work

This study lays the groundwork for future research into the impact that RPA has on business processes. A number of remarks for future research are described in this section.

Further study could assess the long-term impact of RPA on business processes, by validating the impact estimated using the RPA impact estimation method. More clarification on whether this estimated impact is valid on the long-term would help us to establish a greater degree of accuracy on this matter.

In addition, future studies regarding the role of the volume of work would be worthwhile. Incorporating the growth in volume into the method, without having to execute the method multiple times, would be beneficial. The role of other factors than productivity that play a role in the implementation of RPA and its impact should be investigated as well.

In future studies, it would be beneficial to evaluate the RPA impact estimation method by monitoring the SMEs while performing the tasks involved in the business process. By doing so, the secondary data points used in the evaluation are eliminated.

Lastly, future research, using a broader range of experts, could shed more light on the usability and applicability of the method in practice. By using a broader range of RPA experts, the potential bias can be diminished among the participants.

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Appendices

Appendix A - Literature Review Results

A complete overview of the sources used in the literature review is given in this Appendix. The alphabetic characters in the last six columns of Table 27 indicate the corresponding characters in Table 26.

Table 26: Literature review steps

A	B	C	D	E
Create literature population	Select literature	Review literature	Select estimation methods	Evaluate estimation methods

Table 27: Literature review population

Author	Title	Year	A	B	C	D	E	F
Aguirre, S.; Rodriguez, A.	Automation of a Business Process Using Robotic Process Automation (RPA): A Case Study	2017	1	1	1			
Anagnoste, S.	Robotic Automation Process - The next major revolution in terms of back office operations improvement	2017	1	1	1			
Asatiani, A.; Penttinen, E.	Turning robotic process automation into commercial success – Case OpusCapita	2016	1	1	1	1		
Boulton, C.	What is RPA? A revolution in business process automation	2018	1	1	1			
Brinkkemper, S.	Method engineering: engineering of information systems development methods and tools	1996	1					
Bryan, J.	Realize the Value of RPA in Financial Reporting	2019	1	1	1			
Callahan, K.R.; Stetz, Gary S.;	Project Management Accounting: Budgeting, Tracking, and Reporting	2011	1	1	1			
Brooks, Lynne M. Capgemini	Costs and Profitability Robotic Process Automation - Robots conquer business processes in back offices	2016	1	1	1			
CiGen	8 Expert Tips for Successful Robotic Process Automation (RPA) Implementation	2019	1	1	1			
CiGen	Measuring RPA: 10 Performance Metrics for Assessing Robotic Process Automation Benefits	2019	1	1	1	1	1	
CiGen	Efficiency - A Key Benefit of RPA	2017	1	1	1			

Table 27: Literature review population

Author	Title	Year	A	B	C	D	E	F
CiGen	8 Questions to Ask about Processes before Implementing Robotic Process Automation	2018	1	1	1	1	1	
CiGen	9 Step Guide to a Successful Robotic Process Automation (RPA) Implementation	2019	1	1	1			
CiGen	5 Ways to Measure the ROI of Your Robotic Process Automation Deployment	2018	1	1	1	1	1	
Ciphix	Take the robot out of the human	2019	1	1	1			
CPB	Macro Economische Verkenning (MEV) 2020	2019	1					
Doddala, H.	How To Measure RPA - Key RPA Performance Metrics UiPath	2019	1	1	1	1	1	
Flechsig, C.; Lohmer, J.; Lasch, R.	Realizing the Full Potential of Robotic Process Automation Through a Combination with BPM	2017	1	1	1			
Gardner, C.; Gownder, J.P.; Le Clair, C.	Predictions 2018: Automation Alters The Global Workforce	2019	1	1	1			
Garousi, V.; Felderer, M.; Mäntylä, M.V.	Guidelines for including grey literature and conducting multivocal literature reviews in software engineering	2019	1					
Gartner, Inc.	Robotic Process Automation (rpa)	2019	1	1	1			
Gartner, Inc.	Robotic Process Automation Software	2019	1	1	1			
Gartner, Inc.	Gartner Says Worldwide Robotic Process Automation Software Market Grew 63% in 2018	2018	1	1	1			
Geyer-Klingeberg, J.; Nakladal, J.; Baldauf, F.; Veit, F.	Process Mining and Robotic Process Automation: A Perfect Match	2019	1	1	1			
Gownder, J.P.	The Future Of Work Is An Adaptive Workforce	2018	1	1	1			
Gownder, J.P.	Predictions 2019: Automation Will Become Central To Business Strategy And Operations	2019	1	1	1			
Grand View Research	Robotic Process Automation Market RPA Industry Report, 2019-2025	2019	1	1	1			
Ivančić, L.; Suša Vugec, D.; Bosilj Vukšić, V.	Robotic Process Automation: Systematic Literature Review	2019	1	1	1			

Table 27: Literature review population

Author	Title	Year	A	B	C	D	E	F
Jimenez-Ramirez, A.; Reijers, H.A.; Barba, I.; Del Valle, C. Kuder, D.	A Method to Improve the Early Stages of the Robotic Process Automation Lifecycle	2018	1	1	1	1	1	
Lacity, M.; Willcocks, L.	What is RPA? A revolution in business process automation	2016	1	1	1			
Lacity, M.; Willcocks, L.	A New Approach To Automating Services	2015	1	1	1			
Lacity, M.; Willcocks, L.; Craig, A.	Robotic Process Automation at Telefónica O2	2015	1	1	1			
Lacity, M.; Willcocks, L.; Craig, A.	Robotic Process Automation: Mature Capabilities in the Energy Sector	2017	1	1	1	1		
Lamberton, C.; Brigo, D.; Hoy, D.	Impact of Robotics, RPA and AI on the insurance industry challenges and opportunities	2019	1	1	1			
Le Clair, C.	Predictions 2019 Update: How Automation Technology Impacts Enterprises	2019	1	1	1			
Leggett, K.	Use RPA To Make Customer Service Agents More Effective	2018	1	1				
Leno, V.r; Dumas, M.; Maggi, F.M.; Rosa, M.	Multi-Perspective Process Model Discovery for Robotic Process Automation	2018	1	1	1	1		
Mayer, D.	RPA & AI Technology Evaluation	2018	1	1	1	1		
Meda, A.S.	How to design RPA performance metrics	2018	1	1	1	1	1	1
Morneau, D.	Ghost In The Machine? No, It's A Robot, And It Is Here To Help	2005	1	1				
Reijers, H.A.; van der Aalst, W.M.P.	The effectiveness of workflow management systems: Predictions and lessons learned	2016	1	1	1	1		
Reijers, H.A.; Vanderfeesten, I.; van der Aalst, W.M.P.	The effectiveness of workflow management systems: A longitudinal study	2019	1	1	1	1		
Schmitz, M.; Dietze, C.; Czarnecki, C.	Enabling Digital Transformation Through Robotic Process Automation at Deutsche Telekom	2019	1	1	1	1		
Schmitz, M.; Stummer, C.; Gerke, M.	Smart Automation as Enabler of Digitalization? A Review of RPA/AI Potential and Barriers to Its Realization	2019	1	1				

Table 27: Literature review population

Author	Title	Year	A	B	C	D	E	F
Syed; Suriadi;	Robotic Process Automation:	2019	1	1	1			
Adams; Bandara;	Contemporary Themes and							
Leemans;	Challenges							
Ouyang;								
Hofstede; van								
der Weerd;								
Wynn; Reijers								
UiPath Inc.	Connect Enterprise Hub - Track		1	1	1	1	1	1
	Automation Lifecycle UiPath	2009						
van de Weerd, I.;	Meta-Modeling for Situational		1					
Brinkkemper, S.	Analysis and Design Methods	2007						
van de Weerd, I.;	Developing a Reference Method	2018	1					
de Weerd, S.;	for Game Production by Method							
Brinkkemper, S.	Comparison							
van der Aalst,	Robotic Process Automation	2019	1	1	1			
W.M.P.; Bichler,								
M.; Heinzl, A.								
Wanner, J.;	Process Selection in RPA Projects –	2014	1	1	1	1	1	1
Fischer, M.;	Towards a Quantifiable Method of							
Janiesch, C.;	Decision Making							
Hofmann, A.;								
Imgrund, F.;								
Geyer-								
Klingeberg,								
J.								
Wieringa, R.J.	Design Science Methodology for	2015	1					
	Information Systems and Software							
	Engineering							
Willcocks, L.;	The IT Function and Robotic	2015	1	1				
Lacity, M.;	Process Automation							
Craig,								
A.								
Willcocks, L.;	Robotic Process Automation at	2017	1	1	1			
Lacity, M.;	Xchanging							
Craig,								
A.								
Willcocks, L.;	The value of robotic process	2014	1	1	1			
McKinsey	automation							
Wohlin, C.	Guidelines for snowballing in	2017	1					
	systematic literature studies and a							
	replication in software engineering							
Yin, R.K.	Case Study Research and		1					
	Applications: Design and Methods							
Total			56	48	44	15	8	3

Appendix B - Case Study Consent Form

Consent form

Consent Form

By completing this form, you give us permission to use this case study for academic purposes and potential publications.
Thank you for helping.

Introduction

Research Title: Method for estimating the impact of Robotic Process Automation implementations on business processes.

Researcher: Bo van den Oever

Research period: 01/02/2020 – 31/05/2020

Objective: Based on this case study, I hope to validate a standardized RPA impact estimation method that supports the creation of business cases that serve expectation management in terms of costs and savings in RPA projects.

Risks of participation: We foresee no risks of participation. Although the participant is always, during the research period, free to withdraw from participating without giving any reason.

Data protection: Your personal data will only be used within the context of this research and will not be shared with any other parties that are not already involved (Ciphix & University Utrecht). Any personal data will be anonymised in further (potential) publications.

Personal information

Full name	
Team	
Function	
Telephone	
Email	

Agreement

I have read and understand the conditions of participating in this research. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. I declare the above to be true and agree to participate by signing this consent form.

Signature

Date

Figure 2: Participant Consent Form

Appendix C - Case Study Questions

Retrieve expert time estimation

Questions to ask the Subject Matter Expert about the process:

1. How much time does it on average take to process one transaction?
2. How much time does it on average take to complete the entire process cycle?
3. How many transactions are processed each day/week?
4. How much time do you on average spend on this process daily/weekly?

Validate baseline measurements

Measurements to take while the Subject Matter Expert performs the process:

5. Measure how much time it takes to process one transaction.
6. Measure how much time it takes to complete the entire process cycle.
7. Check at what time the transaction enters the application (if possible).
8. Check at what time the transaction completed in the application (if possible).

Questions to ask the Subject Matter Expert about the process:

9. Does the example we just measured represent the most common situation of the process?
10. Are there peak periods in the transaction volume?
11. Are there significant changes in the process velocity between periods of time?
12. Are there other people involved in the process of a transaction?
13. If yes, what do they do and is this step still necessary after the implementation of the robot?
14. If yes, how much time does it take for that other people involved?
15. What percentage of the total amount of transactions on average need to be reprocessed (due to human error)?
16. How much time does it on average take to reprocess a transaction?
17. What percentage of the total amount of transactions has to be reviewed by a human agent?
18. How much time does on average it take to review a transaction?
19. What is the average number of working days per year of the person that executes the process?
20. What is the average number of working hours per day of the person that executes the process?

21. (What is the average cost of one FTE?)

Questions to ask the RPA Process Owner about the chosen RPA solution and infrastructure landscape:

22. What kind of robot license is chosen for the implementation of this process?

23. How many processes make use of this robot license?

Questions to ask the RPA Solution Architect about the implementation of the project:

24. What is the automation rate of the process?

25. How many days is a developer needed for this project?

26. What is the hourly rate of a developer?

27. How many days is a solution architect needed for this project?

28. What is the hourly rate of a solution architect?

29. How many days is a implementation lead needed for this project?

30. What is the hourly rate of a implementation lead?

Retrieve post-measurements

Questions to ask to Subject Matter Expert about the process after the implementation of RPA:

1. How much time do you on average still spend on this process daily/weekly?

2. Will that amount of time change in the foreseeable future?

3. Is it still necessary for other people to be involved in the process?

4. If yes, how much time does it take for them to be involved?

5. Did the amount of items that needs reprocessing change?

6. If yes, how much time does it take to reprocess a transaction?

7. Did the amount of items that needs reviewing change?

8. If yes, how much time does it take to review a transaction?

Data to retrieve from the robot- and application logs:

9. Processing time of one transaction.

10. Processing amount of transactions daily/weekly.

11. Check at what time the transaction enters the application (if possible).

12. Check at what time the transaction completed in the application (if possible).

Note: make sure to check the measurements at a time similar in transaction volume and usual process velocity as for the baseline measurements.

Appendix D - Case Study Results

Table 28: Case study results - part 1

Process case number	1	2	3	4
Baseline measurements				
Execution time (min)	10	10	3	1
Cycle time (hrs)	n/a	1	24	n/a
Frequency (p.w.)	5	8	35	300
Time spend (hrs p.w.)	1	8	0.75	n/a
Peak periods in volume	Yes	Yes	Yes	Yes
Peak description	Begin month	Twice monthly	Begin month	Begin week
Velocity changes	No	No	No	Yes
Velocity description	n/a	n/a	n/a	# errors
Other people involved	No	Yes	No	No
Involved time (min)	0	5	0	0
People still needed	No	Yes	No	No
Involved removed	0	0	0	0
Error rate (%)	5	5	5	2
Reprocess time (min)	10	15	1	1
Reprocess removed	Yes	No	Yes	Yes
Review rate (%)	0	0	100	15
Review time (min)	0	0	1	1
Review removed	0	0	0,5	0
Working hours per year	1250	1250	1250	1512
FTE needed	0,03	0,2	0,01	0,625
FTE cost	60000	75000	90000	30000
Robot license type	Unattended	Unattended	Unattended	Unattended
Nr processes on license	2	2	n/a	n/a
Automation rate (%)	95	95	100	98
Development costs*	25560	12140	5760	30720
Post-measurements				
Execution time (min)	5	x	0.17	0.8
Frequency (p.w.)	5	x	29	n/a
Time spend (hrs p.w.)	0.1	x	0	0
Foreseeable change	Freq. upscale + review/reprocess decrease	x	n/a	Expansion + freq. upscale
Other people involved	No	x	No	No
Involved time (min)	0	x	0	0
Error rate (%)	5	x	0	0
Reprocess time (min)	10	x	0	0
Review rate (%)	100	x	0	0
Review time (min)	1	x	0	0

* The specific development rates are not disclosed, hence the development costs are provided as a total amount.

Table 29: Case study results - part 2

Process case number	5	6	7
Baseline measurements			
Execution time (min)	15	10	10
Cycle time (hrs)	6	n/a	n/a
Frequency (p.w.)	30	7	1
Time spend (hrs p.w.)	7.5	n/a	n/a
Peak periods in volume	Yes	No	No
Peak description	Varies	n/a	n/a
Velocity changes	Yes	No	No
Velocity description	Check each other	n/a	n/a
Other people involved	Yes	No	No
Involved time (min)	1	0	0
People still needed	Yes	n/a	n/a
Involved removed	0	0	0
Error rate (%)	0	1	1
Reprocess time (min)	0	2	5
Reprocess removed	0	0	5
Review rate (%)	1	100	0
Review time (min)	3	0.1	0
Review removed	3	0	0
Working hours per year	1250	1250	1250
FTE needed	0.2	0.04	0,0054
FTE cost	75000	75000	75000
Robot license type	Unattended	Unattended	Unattended
Nr processes on license	2	10	10
Automation rate (%)	100	100	100
Development costs*	11360	1400	840
Post-measurements			
Execution time (min)	10	10	10
Frequency (p.w.)	30	5	1
Time spend (hrs p.w.)	3.75	0.08	0.01
Foreseeable change	Fix performance issues internal systems	Review removed + frequency upscale	Review removed
Other people involved	No	No	No
Involved time (min)	0	0	0
Error rate (%)	25	0	0
Reprocess time (min)	30	0	0
Review rate (%)	0	100	100
Review time (min)	0	1	1

Table 30: Case study results - part 3

Process case number	1	2	3	4
Method execution results				
Total process time (h.p.w.)	0.9	8.8	2.4	29.25
Total needed FTE (yearly)	0.03	0.28	0.08	0.94
Cost of needed FTE (yearly)	1720	21040	6804	28080
Software license costs (yearly)	5000	5500	0	0
Development costs (once)	25560	12140	5760	30720
Eventual process time (h.p.w.)	0.1	1.17	0.6	4.5
Eventual FTE needed (yearly)	0.003	0.04	0.02	0.14
FTE costs after RPA (yearly)	200	2800	1764	4320
Total cost first year	30760	20440	7524	35040
Total cost subsequent years	5200	8300	1764	4320
Impact/savings first year	-29040	600	-720	-6960
Impact/savings subsequent years	-3480	12740	5040	23760
Process case number	5	6	7	
Method execution results				
Total process time (h.p.w.)	9.5	1.2	0.17	
Total needed FTE (yearly)	0.3	0.04	0.005	
Cost of needed FTE (yearly)	22800	2850.40	402	
Software license costs (yearly)	5500	1100	1100	
Development costs (once)	11360	1400	840	
Eventual process time (h.p.w.)	2	0.02	0.0008	
Eventual FTE needed (yearly)	0.06	0.0006	0.00002	
FTE costs after RPA (yearly)	4800	50.40	2	
Total cost first year	21660	2550.40	1942	
Total cost subsequent years	10300	1150.40	1102	
Impact/savings first year	1140	300	-1540	
Impact/savings subsequent years	12500	1700	-700	

Appendix E - Expert Evaluation Survey

The expert evaluation is carried out by enabling a number of RPA experts to apply the method in practice. Afterwards, they are asked to complete a survey. The method and the survey are provided to the experts by means of a Google form. The link to the Google form is as follows: <https://forms.gle/Fo2tsqat9t6DTAT3A>.

In summary, the objectives of the RPA impact estimation method are to clarify the relevant variables in performing an RPA impact estimation (O1), to improve the accurateness of impact estimations for RPA implementations (O2), and to develop an RPA impact estimation method that is applicable in practice (O3). After applying the method in practice, the experts are asked to answer the questions listed below.

D1 - Efficiency

1. Measure how much time it takes to complete the estimation task using current practices.
2. Measure how much time it takes to complete the estimation task using the RPA impact estimation method.

Sections D2 and D3 are measured by means of a 5-point Likert scale.

Strongly disagree Disagree Neutral Agree Strongly Agree

D2 - Perceived ease of use

3. I found the procedure for applying the method complex and difficult to follow.
4. Overall, I found the method difficult to use.
5. I found the method easy to learn.
6. I found it difficult to apply the method to RPA initiatives.
7. I found the rules of the method clear and easy to understand.
8. I am not confident that I am now competent to apply this method in practice.

D3 - Perceived usefulness

9. I believe that this method would reduce the effort required to estimate the impact of RPA.
10. The output data results of using this method would be more difficult for users to understand.

11. This method would make it easier for users to verify what the impact of RPA on a business process will be.
-
12. Overall, I found the method to be useful.
-
13. Using this method would make it more difficult to draft business cases for RPA.
-
14. Overall, I think this method does not provide an effective solution to the problem of estimating the impact of RPA.
-
15. Overall, I think this method is an improvement to the current estimation practices.
-
16. Using this method would make it easier to communicate RPA impact to end users.
-

Section D4 is measured by means of another 5-point Likert scale.

Extremely unlikely Quite unlikely Neutral Quite likely Extremely likely

D4 - Intention to use

17. I would definitely not use this method to estimate the impact of RPA on business processes.
-
18. I intend to use this method in preference to the current practices if I have to draft business cases in the future.
-

Appendix F - Expert Evaluation Survey Results

Table 31 lists the results from the survey that was filled in by six RPA experts. This concerns the survey in Appendix E. The first two survey questions were numerical questions, where the experts answered a number of minutes. Survey questions 3 to 16 were asked using a 5-point Likert scale ranging from strongly disagree (5) to strongly agree (1). The last two survey questions were asked using a 5-point Likert scale as well ranging from extremely unlikely (5) to extremely likely (1).

Table 31: Expert evaluation results

Question	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Score /5
1	5	5	5	60	15	20	18,3
2	5	1	30	30	60	60	31,0
3	2	1	1	2	3	1	1,7
4	2	2	2	2	2	3	2,2
5	4	5	5	4	3	4	4,2
6	2	1	2	3	1	2	1,8
7	4	3	5	4	4	5	4,2
8	2	1	2	3	2	2	2,0
9	2	5	5	4	2	4	3,7
10	3	2	2	2	2	1	2,0
11	3	3	5	4	5	5	4,2
12	4	5	5	4	5	4	4,5
13	1	2	1	3	3	3	2,2
14	3	2	2	2	2	3	2,3
15	3	4	4	4	5	4	4,0
16	4	5	5	4	4	4	4,3
17	2	1	1	2	1	2	1,5
18	3	5	4	4	5	4	4,2

Appendix G - Method Implementation Questions

Ask the Subject Matter Expert the following questions during the process intake:

1. Measure how much time it takes to process one transaction.
2. Does the example we just measured represent the most common situation of the process?
3. Check how much transactions are processed each week.
4. Check at what time the transaction enters the application (if possible).
5. Check at what time the transaction completed in the application (if possible).
6. How much time do you on average spend on this process weekly?
7. Are there peak periods in the transaction volume?
8. Are there significant changes in the process velocity between periods of time?
9. Are there other people involved in the process of a transaction?
10. If yes, how much time does it take for that other people involved and is this step still necessary after the implementation of the robot?
11. What percentage of the total amount of transactions on average need to be reprocessed (due to human error)?
12. How much time does it on average take to reprocess a transaction?
13. What percentage of the total amount of transactions has to be reviewed by a human agent?
14. How much time does on average it take to review a transaction?
15. What is the average number of working days per year for one FTE?
16. (What is the average cost of one FTE?)

Discuss these topics with the RPA Project Owner during the process intake:

17. What is the automation rate of the process?
18. What kind of robot license is chosen for the implementation of this process?
19. How many processes make use of this robot license?

Note: infrastructure costs do not repeat for each RPA implementation. This has to be taken into account.

As RPA Solution Architect, think about the implementation of the project:

20. How many days is a developer needed for this project? Multiply this with the rate.
21. How many days is a solution architect needed for this project? Multiply this with the rate.
22. How many days is a implementation lead needed for this project? Multiply this with the rate.

Appendix H - Method Implementation Script

```

ExecutionTime <- 1 #min
CycleTime <- #hours
ExecutionFrequency <- 1500 #per week
TimeSpent <- #hours per week
OthersInvolvedTime <- 0 #minutes per execution
InvolvedTimeSaved <- 0 #minutes per execution
ErrorRate <- 0.02 %
ReprocessTime <- 1 #minutes
ReprocessRemoved <- 1 #minutes
ReviewRate <- 0.15 %
ReviewTime <- 1 #minutes
ReviewRemoved <- 0 #minutes
WorkingHours <- 40 #hours per week
FTENeeded <- #number of FTE
CostFTE <- 30000 #EUR per year
LicenseNumber <- 0 #number of licenses
LicenseCost <- 0 #EUR per year
AutomationRate <- 0.99 %
ILCost <- 0 #EUR per hour
ILDays <- 0 #number of days
SACost <- 120 #EUR per hour
SADays <- 12 #number of days
DevCost <- 100 #EUR per hour
DevDays <- 24 #number of days

PT <- (ExecutionTime*ExecutionFrequency / 60)
RWT <- ((ErrorRate*ExecutionFrequency)*ReprocessTime / 60)
RVT <- ((ReviewRate*ExecutionFrequency)*ReviewTime / 60)
PIT <- (OthersInvolvedTime*ExecutionFrequency / 60)
TPT <- (PT + RWT + RVT + PIT)
FTE <- TPT / 31.25
CLC <- FTE * CostFTE

RPTS <- ((ErrorRate*ExecutionFrequency)*ReprocessRemoved / 60)
RVTS <- ((ReviewRate*ExecutionFrequency)*ReviewRemoved / 60)
ITS <- ((InvolvedTimeSaved*ExecutionFrequency) / 60)
PTS <- TPT - RPTS - RVTS - ITS
FTR <- PT*AutomationRate
DPT <- TPT - FTR
EFTE <- DPT / 31.25
ECLC <- EFTE * CostFTE

# license costs / license users/processes
SLC <- LicenseCost*LicenseNumber
DC <- (ILCost*8*ILDays)+(SACost*8*SADays)+(DevCost*8*DevDays)

AC <- SLC + DC + ECLC
AC2 <- SLC + ECLC

ImpactFirst <- CLC - AC
ImpactSecond <- CLC - AC2

```

(a) Assigning method variables

(b) Performing method calculations

Figure 3: R script used for method execution - part 1

```

cat("Process time:", PT, "hours per week \n")
cat("Total time spend on process:", TimeSpent, "hours per week \n")
cat("Total reprocess time:", RWT, "hours per week \n")
cat("Total review time:", RVT, "hours per week \n")
cat("Total time others involved:", PIT, "hours per week \n\n")

cat("Total process time:", TPT, "hours per week \n")
cat("Total current FTE:", FTE, "\n")
cat("Total current cost of FTE:", CLC, "EUR per year \n\n")

cat("Process time saved by automation:", PTR, "hours per week \n")
cat("Reprocess time saved by automation:", RPTS, "hours per week \n")
cat("Review time saved by automation:", RVTS, "hours per week \n")
cat("Involved people time saved by automation:", ITS, "hours per week \n\n")

cat("Eventual process time with time savings:", DPT, "hours per week \n")
cat("Eventual FTE needed:", EFTE, "based on 1250 productive hours a year \n")
cat("Eventual FTE costs after RPA implementation:", ECLC, "\n\n")

cat("Total cost of licenses:", SLC, "EUR per year \n")
cat("Total cost of development:", DC, "EUR \n")
cat("Total cost of automation:", AC, "EUR the first year \n")
cat("Total cost of automation:", AC2, "EUR per each following year \n\n")

cat("Impact of RPA:", ImpactFirst, "EUR saved the first year \n")
cat("Impact of RPA:", ImpactSecond, "EUR saved per each following year \n")

Process time: 25 hours per week
Total time spend on process: 0 hours per week
Total reprocess time: 0.5 hours per week
Total review time: 3.75 hours per week
Total time others involved: 0 hours per week

Total process time: 29.25 hours per week
Total current FTE: 0.936
Total current cost of FTE: 28080 EUR per year

Process time saved by automation: 24.75 hours per week
Reprocess time saved by automation: 0.5 hours per week
Review time saved by automation: 0 hours per week
Involved people time saved by automation: 0 hours per week

Eventual process time with time savings: 4.5 hours per week
Eventual FTE needed: 0.144 based on 1250 productive hours a year
Eventual FTE costs after RPA implementation: 4320

Total cost of licenses: 0 EUR per year
Total cost of development: 30720 EUR
Total cost of automation: 35040 EUR the first year
Total cost of automation: 4320 EUR per each following year

Impact of RPA: -6960 EUR saved the first year
Impact of RPA: 23760 EUR saved per each following year

```

(a) Assembling method output results

(b) Printing example method output

Figure 4: R script used for method execution - part 2

Appendix I - Method Implementation Guidelines

9.3.1 Introducing the method

The RPA impact estimation method is a tangible standardized method that can be used to effectively estimate the impact of RPA based on quantitative baseline measurements that can be readily applied in practice without leveraging other technologies. The output of the RPA impact estimation method represents the financial savings estimated to be achieved in the first year after implementing RPA and in the subsequent years. Using the guidelines below, the method can be applied to various types of processes and RPA projects in any organization.

Table 32 shows the revised RPA impact estimation method and its corresponding metrics are shown in Table 33. Using a set of questions that can be asked during a process intake, values for the set of necessary metrics for the method are retrieved. With the gathered data, the calculations can be performed which result in the estimated impact on costs. These steps are elaborated on in the following sections.

Table 32: RPA impact estimation method

Estimation method	Calculations
Calculate current labor costs	
	$PT = ((ET * EF) / 60)$
Calculate needed FTE	$TPT = PT + ((ER * EF) * RPT / 60) + ((RV * EF) * RVT / 60) + ((OIT * EF) / 60)$
	$FTE = TPT / WH$
Calculate cost of needed FTE	$CLC = FTE * CFTE$
Calculate automation costs	
Calculate software license costs	$SLC = LC / LU$
Calculate development costs	$DC = \sum PCT * IMD$
Calculate FTE costs after RPA	$TPTS = TPT - ((ER * EF) * RPR / 60) - ((RV * EF) * RVR / 60) - ((OIR * EF) / 60)$
	$EFTE = (TPT - (PT * AR)) / WH$
	$ALC = EFTE * CFTE$
Calculate cost of automation	$AC1 = SLC + DC + ALC$
	$AC2 = SLC + ALC$
Calculate overall impact on costs	
Current labor costs minus the automation costs	Impact first year = $CLC - AC1$ Impact subsequent years = $CLC - AC2$

Table 33: Revised RPA impact estimation method metrics with original sources

Metric	Description
FTE	Total full-time equivalent currently needed [37, 46, 50]
PT	Process time (hours per week)
ET	Average execution time per transaction (in minutes) [46, 50]
EF	Average execution frequency of transaction (per week) [37, 46, 50]
TPT	Total process time (hours per week)
ER	Average error rate of total volume of transactions [46]
RPT	Average reprocess time per transaction in case of an error (in minutes) [46]
RV	Average percentage of total volume to be reviewed by a human agent [46]
RVT	Average review time per transaction (in minutes) [46]
OIT	Average time other people are involved in the process (in minutes)
WH	Average number of working hours (per week): equivalent to 1 FTE [46]
CLC	Current labor costs [37, 46, 50]
CFTE	Average cost of 1 FTE (per year) [37, 46, 50]
SLC	Software license costs based on license type (per year) [37, 46]
LC	License costs [46]
LU	License users (amount of processes running on that license)
DC	Development costs [37, 46, 50]
PCT	People cost type (Implementation Lead, Solution Architect, Developer) [46, 50]
IMD	Number of involved days in implementation [46]
TPTS	Total process time saved (hours per week)
RPR	Average reprocess time per transaction saved (in minutes)
RVR	Average review time per transaction saved (in minutes)
OIR	Average involvement time per transaction saved (in minutes)
ALC	Labor costs after automation
EFTE	Full-time equivalent needed after automation
AR	Automation rate of process [46, 50]
AC1	Automation costs in the first year [37, 46, 50]
AC2	Automation costs in the subsequent years

9.3.2 Gathering data

In order to use the method and its calculations, the necessary input data has to be gathered. This can be done according to the questions listed below. These questions can be asked during, for example, a process intake. For each of the metrics/input values, a threshold has been set. These are listed in Table 34. The metrics required for the method to be defined precisely are listed as require a 'precise value'. These metrics have been identified as required for the method to meet a minimum quality level. Without precisely defining these values, the outcome of the method will not be able to achieve a certain level of accuracy. The metrics for which estimated values are sufficient in case the exact value is unknown are listed as require at least an 'estimate value'. These are metrics for which it can be difficult in practice to define a conclusive value. If data is unknown, then it is advised to first locate the data before using the method.

Table 34: Input data quality analysis

Metric	Metric name	Precise value	Estimated value
ET	Execution time	x	
EF	Execution frequency	x	
ER	Error rate	x	
RPT	Reprocess time	x	x
RV	Review rate	x	
RVT	Review time	x	x
OIT	Other people involved time	x	x
WH	Working hours	x	
CFTE	Cost of 1 FTE	x	x
LC	License costs	x	
LU	License users	x	
PCT	People cost type	x	x
IMD	Involved days	x	x
AR	Automation rate	x	

Ask the Subject Matter Expert the following questions during the process intake:

1. Measure how much time it takes to process one transaction.
2. Does the example we just measured represent the most common situation of the process?
3. Check how much transactions are processed each week.
4. Check at what time the transaction enters the application (if possible).
5. Check at what time the transaction completed in the application (if possible).
6. How much time do you on average spend on this process weekly?
7. Are there peak periods in the transaction volume?
8. Are there significant changes in the process velocity between periods of time?
9. Are there other people involved in the process of a transaction?
10. If yes, how much time does it take for that other people involved and is this step still necessary after the implementation of the robot?
11. What percentage of the total amount of transactions on average need to be reprocessed (due to human error)?
12. How much time does it on average take to reprocess a transaction?
13. What percentage of the total amount of transactions has to be reviewed by a human agent?
14. How much time does on average it take to review a transaction?
15. What is the average number of working days per year for one FTE?
16. (What is the average cost of one FTE?)

Discuss these topics with the RPA Project Owner during the process intake:

17. What is the automation rate of the process?
18. What kind of robot license is chosen for the implementation of this process?
19. How many processes make use of this robot license?

Note: infrastructure costs do not repeat for each RPA implementation. This has to be taken into account.

As RPA Solution Architect, think about the implementation of the project:

20. How many days is a developer needed for this project? Multiply this with the rate.
21. How many days is a solution architect needed for this project? Multiply this with the rate.
22. How many days is a implementation lead needed for this project? Multiply this with the rate.

9.3.3 Performing calculations

An R script, or any other type of tool, is employable in practice to quickly retrieve the output of the method based on variable input data. The script is based on a set of variables, which reflect the metrics in Table 15. The script can be found in the figures below. Figure 6b shows an example of the method output.

<pre> ExecutionTime <- 1 #min CycleTime <- #hours ExecutionFrequency <- 1500 #per week TimeSpent <- #hours per week OthersInvolvedTime <- 0 #minutes per execution InvolvedTimeSaved <- 0 #minutes per execution ErrorRate <- 0.02 #% ReprocessTime <- 1 #minutes ReprocessRemoved <- 1 #minutes ReviewRate <- 0.15 #% ReviewTime <- 1 #minutes ReviewRemoved <- 0 #minutes WorkingHours <- 40 #hours per week FTENeeded <- #number of FTE CostFTE <- 30000 #EUR per year LicenseNumber <- 0 #number of licenses LicenseCost <- 0 #EUR per year AutomationRate <- 0.99 #% ILCost <- 0 #EUR per hour ILDays <- 0 #number of days SACost <- 120 #EUR per hour SADays <- 12 #number of days DevCost <- 100 #EUR per hour DevDays <- 24 #number of days] </pre>	<pre> PT <- (ExecutionTime*ExecutionFrequency / 60) RWT <- ((ErrorRate*ExecutionFrequency)*ReprocessTime / 60) RVI <- ((ReviewRate*ExecutionFrequency)*ReviewTime / 60) PII <- (OthersInvolvedTime*ExecutionFrequency / 60) TPT <- (PT + RWT + RVI + PII) FTE <- TPT / 31.25 CLC = FTE * CostFTE RPTS <- ((ErrorRate*ExecutionFrequency)*ReprocessRemoved / 60) RVIS <- ((ReviewRate*ExecutionFrequency)*ReviewRemoved / 60) ITS <- ((InvolvedTimeSaved*ExecutionFrequency) / 60) PTS <- TPT - RPTS - RVIS - ITS PTR <- PT*AutomationRate DPT <- TPT - PTR EFTE <- DPT / 31.25 ECLC <- EFTE * CostFTE # license costs / license users/processes SLC = LicenseCost*LicenseNumber DC = (ILCost*8*ILDays)+(SACost*8*SADays)+(DevCost*8*DevDays) AC = SLC + DC + ECLC AC2 = SLC + ECLC ImpactFirst = CLC - AC ImpactSecond = CLC - AC2 </pre>
--	---

(a) Assigning method variables

(b) Performing method calculations

Figure 5: R script used for method execution - part 1

```

cat("Process time:", PT, "hours per week \n")
cat("Total time spend on process:", TimeSpend, "hours per week \n")
cat("Total reprocess time:", RWT, "hours per week \n")
cat("Total review time:", RVT, "hours per week \n")
cat("Total time others involved:", PIT, "hours per week \n\n")

cat("Total process time:", TPT, "hours per week \n")
cat("Total current FTE:", FTE, "\n")
cat("Total current cost of FTE:", CLC, "EUR per year \n\n")

cat("Process time saved by automation:", PTR, "hours per week \n")
cat("Reprocess time saved by automation:", RPTS, "hours per week \n")
cat("Review time saved by automation:", RVTs, "hours per week \n")
cat("Involved people time saved by automation:", ITS, "hours per week \n\n")

cat("Eventual process time with time savings:", DPT, "hours per week \n")
cat("Eventual FTE needed:", EFTE, "based on 1250 productive hours a year\n")
cat("Eventual FTE costs after RPA implementation:", ECLC, "\n\n")

cat("Total cost of licenses:", SLC, "EUR per year \n")
cat("Total cost of development:", DC, "EUR \n")
cat("Total cost of automation:", AC, "EUR the first year \n")
cat("Total cost of automation:", AC2, "EUR per each following year \n\n")

cat("Impact of RPA:", ImpactFirst, "EUR saved the first year \n")
cat("Impact of RPA:", ImpactSecond, "EUR saved per each following year \n")

```

(a) Assembling method output results

```

Process time: 25 hours per week
Total time spend on process: 0 hours per week
Total reprocess time: 0.5 hours per week
Total review time: 3.75 hours per week
Total time others involved: 0 hours per week

Total process time: 29.25 hours per week
Total current FTE: 0.936
Total current cost of FTE: 28080 EUR per year

Process time saved by automation: 24.75 hours per week
Reprocess time saved by automation: 0.5 hours per week
Review time saved by automation: 0 hours per week
Involved people time saved by automation: 0 hours per week

Eventual process time with time savings: 4.5 hours per week
Eventual FTE needed: 0.144 based on 1250 productive hours a year
Eventual FTE costs after RPA implementation: 4320

Total cost of licenses: 0 EUR per year
Total cost of development: 30720 EUR
Total cost of automation: 33040 EUR the first year
Total cost of automation: 4320 EUR per each following year

Impact of RPA: -6960 EUR saved the first year
Impact of RPA: 23760 EUR saved per each following year

```

(b) Printing example method output

Figure 6: R script used for method execution - part 2