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Analyzing Productivity Increases from Robotic Process Automation (RPA): A Case Study of Acutec Precision Aerospace

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I hereby recognize and pledge to fulfill my responsibilities as defined in the Honor Code and to maintain the integrity of both myself and the College as a whole.

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Summary of AI Use by Author

AI use within this project was limited to general idea generation, increasing clarity of my written work, and comparing my work to rubrics and other materials to ascertain areas of improvement.

Abstract

This research examines Robotic Process Automation (RPA) implementation at Acutec Precision Aerospace, a small precision manufacturing company in northwestern Pennsylvania. RPA is a software technology that allows business practices traditionally done by a human to be executed by a computer.

To evaluate RPA's effect on processes at Acutec, RPA was implemented and compared to manual processes in terms of the difference in execution time. Next, Return on Investment (ROI) was calculated, and a Net Present Value (NPV) analysis was done to determine the financial impact on Acutec Precision Aerospace. At Acutec, results showed that RPA significantly reduced processing times across all four implementations and delivered a strong return on investment. The net present value (NPV) was positive in the short, medium, and long term, highlighting sustained financial benefits. In addition to these measurable gains, RPA also brought qualitative improvements, including reduced human error, increased employee productivity, and greater process standardization.

CHAPTER 1: Introduction

Employee acquisition and retention is an issue plaguing precision manufacturing and most other businesses. As skilled worker pools shrink and wages rise, businesses seek to accomplish necessary tasks with fewer resources (Herm et al., 2023; Lam et al., 2024; Hsing-Hua Hsiung & Wang, 2022). Doing more with less is not only a goal of these firms but is increasingly becoming a requirement for firm survival and growth. Acutec Precision Aerospace, a small precision aerospace manufacturer in Meadville, Pennsylvania, is such a firm. According to the Human Resources Director at Acutec, Austin Rock, the chief concern for Acutec is getting enough skilled employees to run machines to meet a seemingly infinite demand for parts[1], a concept sometimes seen in economic theory but rarely seen in the real world.

As a supply chain intern at Acutec Precision Aerospace, management assigned me to automate purchasing processes. Automating these tasks would give department managers more time to work on value-adding tasks. After learning the manual purchase order creation and distribution process, I began researching, selecting, presenting, and implementing Robotic Process Automation(s) (RPA) software in the Acutec Supply Chain Department.

RPA is a software technology that allows computers to complete tasks performed by humans (Bogoevici, 2024, p. 3171). In much the same way as the robotic arms on the Acutec production floor accomplish tasks like placing raw material into machines and completed parts on pallets, RPA allows business practices to be completed automatically, with little to no input from the user.

RPA software companies hail the increase in the efficiency of tasks from automation for their marketing[2]. They frequently tout the use of their products in Fortune 500 companies[3]. They also use quotes from Chief Information Officers[4] about how much better off their company is for having implemented the software.

[1] Information obtained from Acutec HR director (6/12/2024)
[2] https://www.uipath.com/
[3] https://www.uipath.com/gallery-customer-achievement#uber
[4] https://www.automationanywhere.com/resources/customer-stories/petrobras

While these companies are advertising concrete data and are not fabricating quotes, the field of academia studying small businesses will tell you that small and large firms are different. What works in a large firm is not guaranteed to bear fruit in a small firm. While researching RPA software and developing automations at Acutec, two questions arose:

(1) Does RPA increase productivity when implemented in small manufacturing firms?

(2) Do RPA implementations have a positive ROI in small manufacturing firms?

Existing literature addresses RPA usage in many industries, including multiple aspects of the manufacturing industry. The literature falls short regarding the size of the enterprises that researchers examine. Large and medium enterprises in all industries are often more accessible from a data perspective (public filings, for example), as well as the ability for employees to participate in surveys and extensive interviews. Large firms have more resources than their smaller counterparts as well. These resources may be financial, but they also could include assets such as managerial bandwidth to take on new projects and the technical capabilities to implement and maintain RPA software and the automations themselves.

Large enterprises are often synonymous with successful firms, which warrant study as proverbial cities on a hill casting a light on other firms. Regardless of their success, large firms are often structurally different from their smaller counterparts, and what works in one place may not translate to another. The research question seeks to evaluate the claims of RPA software development companies in the context of use in small businesses. Small companies must leverage technology to achieve economies of scale and compete with larger firms that have already done so. At the same time, small companies must invest in technologies that allow them to reap more than they sow. In addition, small firms are often more agile than large firms and arguably have a greater incentive to automate, as they do not have the manpower and existing economies of scale to run effectively without technology.

Using the existing research, the automations I created in my time at my Acutec internship, and the data generated within the reporting for these automations, I will answer this research question using Acutec Precision Aerospace as a case study. I hypothesize that RPA leads to an increase in productivity in small manufacturing firms. The paper is made up of five chapters. After the introduction in Chapter One,

Chapter Two discusses the current literature regarding RPA. Due to the breadth of the topics covered, Chapter Two is divided into subsections, including RPA definition, implementation considerations, benefits, drawbacks, effect on job loss, and effect on employee job satisfaction. Chapter Three presents the empirical analysis, utilizing a case study of Acutec Precision Aerospace and integrating data visualization. Lastly, Chapter Four is the project's summary and conclusions.

CHAPTER 2: Literature Review

Definition:

To assess the performance of a piece of software, one must understand what the software is and what it does. RPA is a technology that arranges software to complete repetitive tasks like humans (Bogoevici, 2024, p. 3171). These tasks are frequently rule-based and are often completed repetitively by employees (Bogoevici, 2024, p. 3170). These tasks are also frequently already digital tasks that are done manually (Herm et al., 2023, p. 14). Herm et al. (2023, p. 1), like Bogoevici, describes RPA as "mimic[ing] human behavior." Turcu & Turcu (2021, p. 71), in line with both Herm and Bogoevici, describe RPA as the "emulation of actions taken by human users." These processes may begin with some manually created material, for example, a document, but often require more action than decision-making to complete the task.

While the completion of manual tasks by RPA software is a key component, the increased processing speed of the automated tasks requires explanation as well. Due to the rule-based nature of the automated tasks, RPA can complete tasks rapidly (Herm et al., 2023, p. 4). Herm et al. (2023, p. 1) describe the RPA as a "disruptive technology" because of its ability to accomplish these existing processes quickly. Additionally, Flechsig (2022, p. 6) finds that RPA allows organizations to process data more quickly, accurately, and with better outcomes.

RPA accomplishes tasks in much the same way a human does. To complete a task, humans respond to different inputs on a screen with the correct sequence of steps (including clicking, data entry, page navigation, etc.). RPA accesses the "presentation layer of IT systems" (Herm et al., 2023, p. 4), meaning that it does not interact with software or websites internally, but uses peripherals like the mouse, keyboard, and computer monitor to complete tasks. This is not a physical manipulation of the keyboard, mouse, and computer monitor but a built-in capability within the RPA software that mimics these actions.

Because of the ability of RPA to interact like a human does, Herm et al. (2023, p. 18) call the technology "lightweight" in contrast to other automation technologies which require more access to IT infrastructure.

While the actual implementation of RPA is discussed later, when understanding Robotic Automation, one should know the different forms it can take once implemented. Bogoevici (2024, p. 3171) outlines two main types of automations: attended (or supervised) and unattended (unsupervised). The literature uses several terms interchangeably to describe these types of automations, but they boil down to the names above. Attended automations, as their name suggests, often involve a "human in the loop", which may complete tasks requiring human decision-making, review data accuracy, and ensure outputs are correct (Bogoevici, 2024, p. 3171). Bogoevici (2024, p. 3171) continues by saying that RPA provides employees (and the businesses they work for) with fast and accurate work, increasing productivity.. Attended automations can allow the best of both worlds when utilizing RPA: increased efficiency for rote tasks and human decision-making if or when needed.

On the other hand, unattended RPA automations run without human interaction and can conduct many tasks done by humans. These tasks, such as moving data between different systems, require no human counterpart to accomplish them (Bogoevici, 2024, p. 3171). Because they do not need a human counterpart, unattended automations can run independently, conceivably twenty-four hours a day, seven days per week. Radke et al. (2020, p. 7) note this 24/7 potential in practice in a company they surveyed, which saw a reduction of up to "80% of process duration." Radke et al. (2020, p. 7) continue by saying that this 24/7 runtime reduced peak workloads and eliminated poor data quality costs. Acutec utilizes attended RPAs that require employees to start them when needed and, in some cases, require checkbox or option selection for RPAs that incorporate multiple potential RPA actions. Once these introductory actions are taken, the RPAs operate without human interaction, much like an unattended RPA would.

Building on the discussion by Herm et al. (2023) about RPA not requiring extensive access to IT infrastructure, Bogoevici (2024, p. 3171) remarks that many of the systems humans (and therefore RPA)

interact with do not have an API[5]. At Acutec, some systems, like software for tracking vendor performance, have an API. Other systems, like the ERP system, do not have a built-in API but instead rely on custom-built solutions to mimic the capability of an API. Without an API, interacting with systems is complicated, but RPA allows this interaction. Though attended and unattended RPAs accomplish similar goals, their differences allow a wider variety of tasks to benefit from RPA. To this end, Turcu & Turcu (2021, p. 71) say that businesses can implement RPA into functions in departments like Human Resources, Finance & Accounting, Production, Sales & Marketing, Supply Chain, and Information Technology.

Non-Process-Related Implementation Considerations

Not every RPA consideration relates to the process itself. The considerations that dictate whether process automation is successful could result from the behind-the-scenes decision-making and support for the RPA software. These considerations are less direct than the decision-making when designing the process automation itself, yet can heavily influence the initial implementation and longer-term success of the processes. A system can automate a task well, but if the support to implement and maintain the software is absent, that system will not function well.

The definition section discusses unattended and attended RPA. While these two forms are similar, they differ, making them more or less suitable for specific applications. The non-process-related aspects of RPA implementation are no different, with different forms suiting different needs. Depending on multiple factors, these non-process-related aspects can impact the success of RPA in a business.

Software and Development

Companies looking to leverage RPA have two main choices when deciding which type of software they will utilize and how they will conduct development. Companies can purchase a commercial

[5] An API (Application Programming Interface) is a structured set of rules and protocols that allows different software applications to communicate and interact, enabling one system to request data or functionality from another without needing to understand its internal workings, much like a translator facilitates interactions between two languages.

offering or develop their own RPA software internally (Asatiani et al., 2023). When developing internally, companies can develop from scratch or use an open-source framework, which they can customize (Asatiani et al., 2023). Asatiani et al. (2023, p. 116) remark in their analysis of choices made by companies who utilize RPA that companies decide based on licensing cost, usability, customer support, and add-on services. These factors are considerations when determining trade-offs between buying or building an RPA solution.

When utilizing a commercial offering, companies can pay to leverage the experience of the software provider. According to Asanti et al. (2023, p. 116), companies that utilized a commercial RPA system wanted external developers and RaSS (robot as a service) providers to integrate RPA into their businesses without burdening their IT resources. Asanti et al. (2023, p. 117) found that companies without experience relied on vendors to recommend and support a system.

As noted above, commercial offerings include add-ons and customer support (Asatiani et al., 2023, p. 116). For businesses that do not possess internal capabilities, these add-ons and customer support can be necessary for success. Additionally, license costs can be far less than creating software in-house. To this end, Asanti et al. (2023, p. 113) report that fewer resources and expertise lead businesses to rely on external developers.

Companies also have the option to build and develop their RPA solutions themselves. With the requisite experience and support already in place (as discussed in the commercial software section), companies found that they could achieve lower costs and forgo features they did not find valuable (Asatiani et al., 2023, p. 116). Similar to the concept that attended and unattended automations can be used to cover a wider variety of business practices, companies can choose to take a hybrid approach to their software and development.

Companies may use external developers or consultants to begin their RPA implementation (Asatiani et al., 2023, p. 113) and then take advantage of the long-run benefits of an insourced solution (Asatiani et al., 2023, p. 111). Companies can also approach it from the opposite direction, developing their system internally and leveraging third parties when needed (Asatiani et al., 2023, p. 114). As

organizations become more familiar with RPA, according to Asatiani et al. (2023, p. 111), they favor internal development. One respondent said that they use a hybrid approach, patching up commercial offerings with open-source solutions to make sure that technological limitations are not a limiting factor (Asatiani et al., 2023, p. 117).

Hardware

Companies must also decide where to house the servers and other hardware required for RPA. Companies can deploy on-site or in the cloud. On-site hardware is typically favored by those with experience in on-site deployment (Asatiani et al., 2023, p. 114). These companies cite greater control and ability to deal with performance issues or downtime as reasons for choosing an on-site deployment (Asatiani et al., 2023, p. 114). Beyond ease and control, companies, especially those in the public sector and those who deal with the government, have restrictions on what information they can send or store in the cloud. Many organizations have detailed policies about deploying IT in the cloud, which can make off-site applications infeasible (Asatiani et al., 2023, p. 115). For companies that took a cloud-based approach, Asatiani et al. (2023, p. 115) found that their primary focus, similar to the reasoning for utilizing commercial software and external developers, was "seen as an expeditious and cost-effective solution that would not require substantial maintenance efforts or prior knowledge of RPA work." Overall, companies looking to utilize RPA have several non-process-related considerations. These considerations stem from the needs of a company and its ability to develop, deploy, and maintain the RPA software.

RPA Current Applications

Businesses in multiple industries use RPA to facilitate increased efficiency in various tasks across multiple departments. These tasks differ by industry and business requirements, but all seek to reduce manual human effort in necessary business processes. While RPA usage extends beyond the current applications detailed here, the industries and processes outlined in the current literature demonstrate current applications and provide similar examples to those used in a general business context. Current

applications discussed include Accounting, Supply Chain, Human Resources, Manufacturing, and Miscellaneous business practices. At Acutec, these RPAs are centered within the Supply Chain department, encompassing activities like order creation and audit compliance.

Accounting

Accounting processes, especially those within auditing, require processing large quantities of data, often by hordes of employees conducting tasks. Hsing-Hua Hsiung & Wang (2022, p. 2) report that Big-4 accounting firms leverage technology and their larger workforces to lessen the burden of these tasks while small firms face a hard time recruiting employees and leveraging technology like RPA. Additionally, time and cost pressures result from client expectations and regulatory changes within the accounting industry (Perdana et al., 2023, p. 11). Despite these challenges, both researchers conclude that accounting organizations can successfully implement and leverage RPA to deal with high workloads and create new value for customers (Perdana et al., 2023, p. 19; Hsing-Hua Hsiung & Wang, 2022, p. 16). Businesses surveyed had similar conclusions, with all four firms surveyed by Perdana et al. (2023, p. 14) saying time investment into RPA was worthwhile and benefits, like long-term savings, exceeded costs.

Unlike Hsing-Hua Hsiung & Wang, Perdana et al. (2023) detail the actual RPA within the accounting firms they studied. Due to the number of tasks addressed, they are presented below in table form.

Table 2.1: Accounting Tasks

Task	Description
Employee Loan Auditing	Ensuring that loans given to employees are non-fraudulent
Bank Reconciliation Checks	Comparing the cash account balances in an

	entity's general ledger (GL) with the corresponding figure indicated on the bank statements
Analytical Procedures	Estimating the figures for predictable accounts and comparing them to actual amounts
Three-Way Match	Using three documents to ensure the accuracy, occurrence, and completeness of transactions
Search for Unrecorded Liabilities	Using documents to determine if a company is under-reporting liabilities
Audit of Statutory Records	Ensuring compliance with the legal requirements relating to the company's secretarial records

Source: Perdana et al. (2023, pp. 3-11)

After implementing RPA in the tasks above, RPA increased the efficiency compared to manual processing (Perdana et al., 2023). In applications like bank reconciliation checks and three-way match, efficiency and employee output doubled (Perdana et al., 2023, p. 6).

Like Perdana et al., Bogoevici (2024) also highlights the different RPAs used by multiple businesses in the accounting sector. Within their research, Bogoevici (2024) identifies processes, quantifies cost savings, and determines ROI compared to manual processes. Within the invoice processing automation, procure-to-pay, and vendor reconciliation processes examined, Bogoevici (2024) finds that RPA implementation results in massive cost savings and high ROI, detailed in the table below.

Table 2.2: Accounting Task ROI

Process	Cost Savings (€)	ROI (%)
Invoice Processing	168,849	958.55
Vendor Reconciliation Process	158,558	800.80
Employee Onboarding Process	87,368	412.96

Source: Bogoevici, 2024, pp. 3179, 3181.

Unsurprisingly, Bogoevici (2024, p. 3181) calls the results "incredibly profitable" and emphasizes the efficiency and productivity increases.

Herm et al. (2023) find similar RPA application results in the companies they surveyed. According to Herm et al. (2023, p. 14), SYSTHEMIS AG, a software company based in Germany, uses RPA to facilitate faster and more accurate report creation. The manual process involves gathering data, generating a report, and sending it along with the invoice to the client. After implementing the RPA, the company could have employees focus on more critical tasks while reducing errors stemming from human error (Herm et al., 2023, p. 14). Other applications mentioned include on-demand early termination fee calculations for customers of a German bank called SBH (Herm et al. 2023, pp. 14-15) and liquidity forecasts for a German sink manufacturer (Herm et al. 2024, pp. 15-16), both of which saw improvements like the SYSTHEMIS application detailed above. In addition to applications in accounting, RPA literature discusses applications in Supply Chain departments.

Supply Chain

Supply Chain departments, regardless of their industry, manage the flow of goods into and out of a business. Managing these inflows and outflows requires constant vigilance, action, and reaction to ever-changing variables. In pursuit of this management, RPA can automate repetitive supply chain tasks (Hartley & Sawaya, 2019, p. 3). Several researchers delve into the usage of RPA within different supply chain operations.

To begin, Lam et al. (2024) discuss the application of RPA in the logistics industry. The company examined by Lam et al. (2024) utilized RPA to increase process efficiency and accuracy while releasing employees to expand the business (Lam et al. 2024, p. 7). The company examined by Lam et al. (2024, pp. 4-6) utilized three different automations systems: Bot 1, Bot 2, and Bot 3.

Bot 1, a shipment tracking bot, utilized company data and external cargo tracking websites to provide automatic updates on shipments as they occur (Lam et al., 2024, pp. 4-5). Bot 2, a product list creation bot, extracted data from shipping documents to create a product list used for order picking (Lam et al., 2024, pp. 5-6). Bot 3, a data verification bot, is a partner to Bot 2. It compares the output of Bot 2 to the data found in the company's system. If the data matches, the document from Bot 2 moves onto the floor or prompts for a manual check so that any issues can be corrected (Lam et al., 2024, p. 6). The company applied these bots to improve operations (Lam et al., 2024, p. 6). In their analysis, Lam et al. (2024) found that with all three bots, "operation time has been improved between 84% and 94% compared with manual work" (Lam et al., 2024, p. 16). The authors also note that the RPA bots reduced errors (Lam et al., 2024, p. 11) and improved the processes they were a part of by eliminating some steps and simplifying others (Lam et al., 2024, p. 16).

In a similar paper, Lam and Tang (2023) analyze a freight-forwarding company that utilizes RPA. Chevalier AOC Freight Express Holding Limited (Chevalier AOC), a freight-forwarding company, utilizes RPA to improve several manual processes (Lam and Tang, 2023). Like Bot 1 from the previous example, Chevalier AOC utilizes an RPA, Bot-Status, to check the status of shipped goods and provide notifications (Lam and Tang, 2023, p. 6). Chevalier AOC also utilizes an RPA, Bot-Temperature, that works similarly to Bot-Status. Bot-Temperature logs temperature data from shipper websites and writes it to an Excel file (Lam and Tang, 2023, p. 6). A comparison of the performance of these two bots and the manual processes are shown in the table below.

Table 2.3: Freight Forwarding RPA Time Comparisons

(Per 100 documents)	Manual Time	RPA Time	Improvement
Status Checking	90 min 49 s	10 min 35 s	88.35%
Temp Checking	6 hrs 50 min	10 min 52 s	97.35%

Source: Lam and Tang, 2023, pp. 8-9

From these results, using RPA to replace the manual process benefited Chevalier AOC (Lam and Tang, 2023, p. 8). Lam and Tang (2023, p. 8) also note that the RPA gives management access to data previously too labor-intensive to extract regularly, improving their decision-making.

Lastly, RPA applications in procurement are examined. Hartley & Sawaya (2019, p. 3) discuss a packaging company, which the authors call Packaging, which utilizes RPA for customer order management. Because of the success seen in order management, Packaging plans to expand RPA into several applications like compliance with spending limits, reviewing and responding to supplier emails, creating and updating purchase orders (POs), and entering data into spreadsheets automatically (Hartley & Sawaya, 2019, p. 3). Beyond these applications and planned applications, Hartley & Sawaya (2019, p. 3) also note supplier management, purchase catalog maintenance, supplier email reading, and document sharing are “ripe for automation.” Along with applications in Supply Chain departments, researchers also study current applications in Human Resources.

Human Resources

Human resource (HR) departments manage employees from pre-employment hiring activities to the parting of ways between an employee and the business. These activities, referred to by Turcu & Turcu (2021, p. 73) as “the general hire-to-retire (H2R) process,” involve a significant amount of data entry and data reconciliation, much of which is done manually (Turcu & Turcu, 2021, p. 70). HR departments in small and medium-sized enterprises are particularly affected because they often rely on disjointed and

aging IT systems that require employees to transmit data between these systems (Turcu & Turcu, 2021, p. 73). These tasks are good candidates for RPA solutions, according to Turcu & Turcu (2021, p. 73).

Two automatable HR processes highlighted in the literature are recruiting and onboarding. According to Turcu & Turcu (2021, p. 73), recruitment involves manual screening and recording of documents like applications and resumes, which makes it a prime candidate for RPA adoption. When assessing resumes, Turcu & Turcu (2021, p. 73) found that software robots were used to gather application data and compare it with a precise list of job requirements, outputting rankings of candidates compared to the job requirements. Within their research, Turcu & Turcu (2021, pp. 74-75) found that RPA can fulfill preprocessing tasks in human resources departments. Though some processes require human intervention, they concluded that RPA could streamline HR processes (Turcu & Turcu, 2021, pp. 74-75). Onboarding, the next step in the process, also experiences benefits from RPA implementation. One company, referred to as "Company B" by Šimek & Šperka (2019, p. 214), found that the "improvements in partial activities performed by robots are astonishing… reduced from 15 minutes to 3 minutes (data entry), and from 5 minutes to 1 minute (OFAC[6] check)." With the benefits seen in these HR applications, it is no surprise that Turcu & Turcu (2021) and Šimek & Šperka (2019, pp. 206, 214) both conclude that RPA's decreased process times, errors, management workload, and exhibition of a high scalability potential benefit businesses. One respondent in the Šimek & Šperka (2019, p. 214) study commented that the time savings was not the most important benefit of RPA, but rather the error reduction, which saw errors fall to near zero compared to the manual processes. Together with applications in HR, researchers study RPA applications in Manufacturing.

Manufacturing

Like HR, manufacturing has many dull, data-entry-related tasks that can benefit from automation. Manufacturing enterprises run around an Enterprise Resource Planning (ERP) system. An ERP system is, according to Chirvase & Zamfir (2023, p. 1919), a system combining the various aspects of a business, like accounting, stock control, sales, and HR, in one encompassing system. ERP systems facilitate most

[6] Office of Foreign Assets Control

aspects of an organization, and increases in efficiency when entering or changing within an ERP system can increase the potential of the business utilizing it. To this end, Chirvase & Zamfir (2023, p. 1927) state that data entry and change can be facilitated by integrating RPA technology and even call RPA integration the “pearl in the crown" (Chirvase & Zamfir, 2023, p. 1927) for Internet of Things (IoT) integration into ERP systems.

Radke et al. (2020) find markedly similar results in their analysis of RPA use in master data management. They highlight two examples of companies with long, painful processes that are made better by utilizing RPA. First, Radke et al. (2020) discuss Company 1, whose RPA application was the management of repair part orders. This process involved a manual process utilizing multiple systems, manual processing, and frequent errors due to data inaccuracy and process breakdown. With the application of an RPA, Company 1 had “time taken to complete a request reduced by approximately 80%” (Radke et al., 2020, p. 6). The researchers also found increased accuracy, fewer production halts due to missing material, raised job satisfaction, and increased customer satisfaction, among other benefits (Radke et al., 2020, p. 6).

Second, Radke et al. (2020) discuss Company 2, whose complex master-data management tasks require multiple systems and are plagued by missing, incorrect, outdated, and improperly formatted data. In addition to the impact of this data irregularity on production, fixing these errors requires frequent support tickets for clarification, straining IT resources while complicating data consistency and integration across platforms (Radke et al., 2020). After implementing RPA, Radke et al. (2020, p. 7) note that master data quality improves because the RPA has 100% process adherence. The authors note that buy-in to RPA was high among employees because they saw the potential benefit for a painful process (Radke et al., 2020, p. 7) and the knowledge that this would help solve the data integrity problems that manual processing creates (Radke et al., 2020, p. 7). In addition to the current applications listed above, some RPA applications in the literature are worth discussing but do not fit neatly into a category.

Miscellaneous.

The first is data visualization, which is critical for management in any industry. Herm et al. (2023, p. 15) report that the data aggregation from multiple data sources, required for an effective data visualization, benefited mightily from RPA, resulting in a task that was once so tedious that it was only done weekly, to be done daily, with RPA.

Another example is the use of RPA in document validation. With RPA, the company studied by Hyun et al. (2021, p. 16) could evaluate and correct multiple features within documents. The authors found that RPA reduces working time compared to manually processing documents and increases document quality (Hyun et al., 2021, p. 14). On average, RPA reduced errors by "100%" in four out of five features, with the remaining feature improving error rate by "88.2%" (Hyun et al., 2021, p. 14). The authors note that a discrepancy between the dictionary provided to the RPA and the standard Microsoft dictionary was the cause of this issue, not the automation itself. (Hyun et al., 2021, p. 14). The automation also cut the average processing time from 2278.9 minutes to 1535.1 minutes, a 56.7% efficiency improvement (Hyun et al., 2021, p. 14).

Benefits and Drawbacks

RPA offers organizations significant opportunities to streamline operations and reduce costs, but it also comes with its share of challenges. The benefits and drawbacks of RPA extend beyond the surface-level efficiency gains, touching on areas such as scalability and long-term maintenance to the betterment or detriment of a company. While the technology can automate repetitive tasks speedily and accurately, its implementation may disrupt existing workflows or require significant upfront investment and organizational change. Understanding these benefits and drawbacks is essential for making informed decisions about whether and how to adopt RPA effectively.

Benefits

To begin, the benefits of RPA will be discussed. In the literature, RPA benefits fall into two main categories: organizational benefits and process benefits. While process benefits undoubtedly impact the

organization, RPA's impact in these cases primarily affects the process itself, which in turn benefits the organization. Organizational benefits detail the benefits to process outcomes rather than the processes themselves.

Several authors note the organizational benefits of RPA. Benefits of note include increased efficiency, productivity, and cost savings. Durao & dos Reis (2024, p. 13), in their analysis of RPA, found that in every company they examined, employees expressed the usefulness of RPA in reducing errors, costs, and routine work while increasing quality and employee motivation. Within a sales department surveyed, Durao & dos Reis (2024, p. 13) found that RPA acts as a "virtual assistant," providing better visibility to customer needs and allowing salespeople to solve problems faster. To this end, One manager within the Durao & dos Reis study (2024, p. 13) said that RPA "works as a process cycle time accelerator, this is where we see a great advantage, it is accelerating our time to market, that is, between the customer's order and what we deliver." In a similar vein, Ylä-Kujala et al. (2023, p. 172) and Flechsig et al. (2022, p. 6) both discuss the full-time equivalent (FTE) savings of RPA utilization. Both authors found that RPA implementation saved multiple FTEs (Flechsig et al., 2022, p. 6; Ylä-Kujala et al., 2023, p. 172). Additionally, Hofmann et al. (2020, p. 101) report that RPA integration can increase Key Performance Indicators (KPI).

Other research made light of the increases in customer satisfaction and service quality associated with RPA. Based on expert comments, Durao & dos Reis (2024, p. 113) concluded that better customer service, improved communication, greater customer satisfaction, and convenience are positive organizational impacts of RPA. Herm et al. (2023, p. 14) also noted that RPA allowed organizations to offer new services to customers that they were unable to before. These findings are similar to the "virtual assistant" that RPA provided to the sales department in the research of Durao & dos Reis (2024, p. 113).

Another critical benefit of RPA to businesses at the organizational level is the financial and ROI benefits. Ylä-Kujala et al. (2023) found that a significant driver of RPA adoption was the desire to reduce expenditures on the processes to be automated. Durao & dos Reis (2024, p. 15) find a link between RPA adoption and an "increase in the organization's profits." Researchers also found another financial benefit

to organizations of the ROI of RPA implementations. Flechsig et al. (2022, p. 5) find that RPA costs typically pay off within the first project, which takes a few months, and subsequent projects pay off even more quickly, sometimes within a few weeks. In like manner, Durao & dos Reis (2024, p. 14) find that RPA ROI is high and that most pay for themselves within the first year. Researchers van Hoek et al. (2022, p. 294) note that this ROI can come in two phases: short-term productivity improvements and the longer-term ability for employees to focus on higher-level strategic tasks.

The aforementioned longer-term freedom to focus on higher-level tasks is repeated several times throughout the RPA literature. Bogoevici (2024, p. 3171) writes that the goal of many organizations utilizing RPA is "end-to-end automation", where low-level tasks are handled independently. By handling these tasks in the background with RPA, businesses can release employees from the boring parts of their jobs (Ylä-Kujala et al., 2023, p. 171). Herm et al. (2023, p. 14) echo this sentiment as well, finding that one organization, SBH, uses RPA to free up human resources so they can focus on higher-complexity tasks. Durao & dos Reis (2024, p. 13) add that this freedom motivates employees and also impacts whole organizations and the services they provide to customers. Flechsig et al. (2022, p. 6) add that RPA "frees up human capital due to noticeable effort reductions of up to 60 percent of working time." Perdana et al. (2023, p. 15) likewise state that RPA can help increase key performance indicators (KPI). This extra time can be used for all types of value-adding tasks. Businesses report being able to focus on activities like handling exceptional cases and sophisticated communication (Flechsig et al. (2022, p. 6), allowing auditors to address issues important to their clients (Perdana et al. 2023, p. 11), focus on strategic priorities (van Hoek et al. 2022, p. 293) and collaborate with suppliers towards carbon-neutrality by 2050 (van Hoek et al. 2022, p. 288).

Yet another organizational benefit of RPA in the literature is increased flexibility and agility. This flexibility and agility manifests itself in several forms. Flechsig et al. (2022, p. 5) find that RPA allows businesses to be better prepared for supplier and customer issues, while both Flechsig et al. (2022, p. 6) and Herm et al. (2023, p. 16) note that businesses use RPA to combat cases of employee absence or turnover. Herm et al. (2023, p. 16) provide an example where a process needs to be completed within

three days at the end of every month. Without RPA, managers need to scramble to complete work in the event of employee vacation or illness (Herm et al., 2023, p. 16). These seasonal work peaks are also mentioned by Durao & dos Reis (2024, p. 14), who find that respondents utilize RPA to increase flexibility, capability, and ability to deal with work peaks and seasonality. Multiple authors, including Ylä-Kujala et al. (2023, p. 172) and Flechsig et al. (2022, p. 6), also point out that RPA is not subjective but outputs consistent results without the interpersonal conflicts or underperformance that is sometimes seen in people.

In tandem with the organizational benefits of RPA, RPA also benefits the processes themselves. These benefits present themselves in two main categories. The first category is the fast implementation speed of RPA. The second is process improvement of RPA, which details the increased efficiency, standardization, and error reduction of processes.

Many researchers found that RPA implementation speed benefitted the processes receiving RPA. Hartley & Sawaya (2019, p. 3) report that businesses choose RPA partially because it is relatively simple to implement compared to other automation solutions. They also note that rather than encompassing a start-to-finish process, RPA can target a single point (Hartley & Sawaya, 2019, p. 3). In conjunction with Hartley & Sawaya, Turcu & Turcu (2021, p. 71) find that RPA's swift implementation speed comes partly from how non-invasive the software is to existing systems. They continue by saying that RPA operates "above the organization's applications and cloud services" (Turcu & Turcu, 2021, p. 71). Hofmann et al. (2020, p. 102) add that, depending on the task, specialized programming knowledge is not a requirement beyond knowledge of basic programming concepts (Hofmann et al., 2020, p. 102). All of these components contribute to the benefit of implementation speed provided by RPA.

Next, researchers also determined that in the studied businesses, RPA enhanced the processes themselves. Hyun et al. (2021, p. 14), Lam & Tang (2023, p. 9), Perdana et al. (2023, p. 19), and Ylä-Kujala et al. (2023, p. 172), among many others, determined that RPA performed processes more quickly and accurately than manual processing. While addressed previously, Perdana et al. (2023) note that organizations can redeploy time saved by RPA to generate revenue. This increased efficiency has an

ancillary benefit. As inputs standardize because of the RPA, data quality for all downstream processes increases (Flechsig et al., 2022, p. 6; Ylä-Kujala et al., 2023, p. 172). As these inputs and outputs standardize, the processes become optimized, and redundant workflows and unnecessary steps are eliminated (Flechsig et al., 2022, p. 6). Flechsig et al. (2022, p. 8) note that companies should optimize processes before RPA implementation for reasons discussed in the drawbacks section. In combination with increased process speeds, researchers also find the processes are less error-prone than manual processing (Flechsig et al., 2022, p. 6; Radke et al., 2020, p. 6; Herm et al., 2023, p. 14; Lam et al., 2024, p. 11). Ultimately, the benefits of RPA can help companies operate better and lead to process improvements.

Drawbacks

Next, the drawbacks of RPA will be discussed. Like the benefits, the drawbacks of RPA can be categorized into two main categories: organizational drawbacks and process drawbacks. Organizational drawbacks include detriments that RPA can cause to an organization and organizational factors that can preclude RPA's success in an organization. The implementation failure of any software, including RPA, wastes time, effort, and capital. Process drawbacks refer to process incompatibilities with RPA adoption and the development and maintenance needs of RPA.

Several organizational drawbacks are present in RPA literature. First, high process expectations are an organizational drawback of RPA. The body of RPA research, though quick to point out the benefits of RPA, often, according to Flechsig et al. (2022, pp. 8, 13), “is hyped by practitioner literature with delusive promises that could encourage rash management decisions.” This overhyping, also addressed by Herm et al. (2023, p. 2) and (Asatiani et al., 2023, p. 110) leads to high process expectations, which if not managed and explained, can lead to disillusionment with RPA technology (Flechsig et al., 2022, p. 18). Part of this disillusionment stems from the report that “up to 50% of robotic process automation projects fail.” (Herm et al., 2023, p. 1). Even if projects do not fail, according to Wilcocks, “only about a quarter

of organizations reap the full benefits of their automation" (as cited in Asatiani et al., 2023, p. 110). As is the case with many things, to that which people have entrusted much, they will expect more.

The next drawback of RPA is the need for employees to embrace the software for it to bear fruit. As found by several researchers, this buy-in is not always present. Some employees take an "if it ain't broke, don't fix it" stance and refuse to utilize the software (Flechsig et al., 2022, p. 8). This occurrence was also found by Lam & Tang (2023, p. 9), who found that people are "entrenched in the manual approach." Others fear that RPA will make them redundant and they will lose their job (Flechsig et al., 2022, p. 8). Even if employees are on board with the change, they still need training on the new software. In what could be considered a good problem, they must also be trained for more strategic tasks (Flechsig et al., 2022, p. 8). Successful RPA implementation also requires management buy-in. Hsing-Hua Hsiung & Wang (2022, p. 16) find that information illiteracy among leadership is a massive roadblock for RPA and other digital transformation. From another point of view, Flechsig et al. (2022, p. 8) point out that favoritism of departments by upper management can block full RPA benefits and digitization efforts within less-favored departments.

Lastly, RPA implementation can complicate governance for businesses. As businesses attempt to comply with changing data governance, RPA can be a complicating factor. Hofmann et al. (2020, p. 103) discuss the trade-off between better processes and challenging and complex governance structures. To further complicate matters, businesses in sensitive industries, like the pharmaceutical company examined by Herm et al. (2023, p. 16), have stringent rules for even introducing software, let alone passing potentially sensitive information through it. Perdana et al. (2023, p. 12) add that this complexity only grows as RPA for larger-scale deployments and that effective governance is needed to manage the software. The literature is not in perfect harmony on this front, with researchers like Ylä-Kujala et al. (2023, p. 172) concluding that due to enhanced traceability and other factors, RPA simplifies governance. While organizational drawbacks are a component of RPA, the process drawbacks identified in the literature must also be addressed.

RPA researchers and the organizations they study acknowledge that RPA does not suit every situation. Though the benefits section details the swift time for implementation of RPA, several authors find that inefficient processes can erase this benefit. Lam et al. (2024, p. 8) note that despite potential efficiency gains, to utilize RPA correctly, organizations may need to re-engineer workflows so that RPA and manual processes connect smoothly. Van Hoek et al. (2022, p. 289) identify a similar pattern, saying that for some processes, improving the process before automation is a better investment than automating right away. Other processes, such as those that run infrequently, do not benefit from automation (Van Hoek et al., 2022, p. 289). Because software executes what it is programmed to, inefficient processes will remain inefficient, resulting in extra costs and resource usage (Hofmann et al., 2020, p. 101). In agreement with Lam et al. and Van Hoek et al., Hofmann et al. (2020, p. 101) note that pre-RPA process improvement and optimization are crucial. In addition to RPA's inapplicability for inefficient processes, RPA is also unsuitable for complex processes or those that require human interaction.

RPA technology, as stated by Bogoevici (2024, p. 3171), is designed for rule-based tasks. When RPA applications are outside this scope, researchers find suboptimal results. Dynamic processes that require creativity, behave unexpectedly, or require case-specific decision-making are frequently unsuitable for RPA (Turcu & Turcu, 2021, p. 72; Hofmann et al., 2020, p. 101). Such unsuitability was found by Flechsig et al. (2022, p. 8) when participants mentioned that several processes required personal communication and could only convert into rule-based tasks to a small extent. Others surveyed who did not adopt RPA “raised concerns about the reliability of RPA to process the numerous exceptions in PSM efficiently” (Flechsig et al., 2022, p. 8).

In research by van Hoek et al. (2022, p. 289), RPA is best used in processes with defined inputs and output. These known inputs and outputs allow for good-quality results because there are good-quality inputs (Ylä-Kujala et al., 2023, p. 172). When input quality degrades or unknowns enter into the process, problems arise. Průcha (2024, p. 14) finds that bad inputs and niche exceptions not considered during development can cause RPA to fail. Herm et al. (2023, p. 16) and Radke et al. (2020, p. 6) found similar cases where poor data quality caused RPA to become unreliable, not be suitable for full automation, and

require a human to stand by for assistance. In the case Radke et al. (2020, p. 6) examined, the RPA functioned as designed, but a misalignment between the ERP system and another company system caused the error, underscoring that a process is only as reliable as the input data. A different issue was observed by Lam & Tang (2023, p. 9), where a change in the format of a website rendered the RPA inoperable and required RPA maintenance to fix. To this end, Herm et al. (2023, p. 4) write that lightweight integrations like RPA are less robust.

Maintenance, as pointed out in the literature, is another drawback of RPA implementation. Organizations have to organize the development and maintenance of the RPA implementations. Flechsig et al. (2022, p. 6) reported that companies that adopted RPA created positions to develop, maintain, and optimize RPA within the organization. Despite these new positions, Flechsig et al. (2022, p. 7) do note that many respondents struggled with the capacity to develop and maintain RPA. They also note that understaffing, daily business, and many high-priority projects contributed to capacity struggles. (Flechsig et al., 2022, p. 7). Unsurprisingly, Průcha (2024, p. 1) found that companies often encounter difficulties maintaining their RPA. In all, the drawbacks of RPA can complicate and derail RPA effectiveness in an organization.

Job Loss

As with automation in general, a human once did the automated processes. That person must find a new task within an organization or be let go as their position no longer exists for a human to do. When determining the effect of RPA on a business, one must consider the effect software has on employees. As is shown in the literature, RPA, because it reduces how long arduous tasks take to complete, can impact how many employees are needed to perform those tasks. Hyun et al. (2021, p. 2) write that digital labor, like RPA, is already replacing employees in firms across the board. Similarly, Bogoevici (2024, p. 3182) explains that businesses target low-value jobs for digitization because these roles create problems that RPA can solve. Unlike Hyun et al., Bogoevici (2024, p. 3182) discusses other aspects of this shift to automation, including job creation for those developing and maintaining RPA.

Businesses are also under pressure to continue reducing costs, monetary or otherwise. Flechsig et al. (2022, p. 6) write that purchasing department managers face cost pressures and desire to keep their teams lean. To alleviate these pressures, managers focus on RPA to limit headcount and find full-time equivalent (FTE) savings (Flechsig et al., 2022, p. 6). Ylä-Kujala et al. (2023, p. 172) also point out that RPA is simpler to manage than a person. There are no attrition rates, stronger endurance to crises (transaction picks or drops), no emotionally justified underperformance, no interpersonal competition or conflicts between employees, and simplified governance (Ylä-Kujala et al., 2023, p. 172). These aspects could be attractive for managers looking to cut headaches while potentially cutting headcount.

Other literature points out that the cost savings from RPA do not always need to come from a headcount cut. Radke et al. (2020, p. 6) note that RPA can reduce poor production adherence, loss of customer satisfaction, and extra salary by doing existing work more quickly and with fewer errors. Herm et al. (2023, p. 16) note that one cosmetics business surveyed utilized RPA to assist in a CRM task for customer registration. While not fully automated, RPA allowed employees to handle errors rather than manually process most requests. Similarly, van Hoek et al. (2022, p. 294) write that at Maersk, a global supply chain company, RPA mostly augments staff, not replaces them. Despite this augmentation, both possible headcount reduction and productivity gains were factored into the enterprise value of RPA at Maersk, according to van Hoek et al. (2022, p. 288).

While van Hoek et al. (2022, p. 288) say that Maersk cites potential headcount reduction in its enterprise value calculation, other researchers found that this "potential" may be more sure as technology develops. In an interview with a private company (designated as Priv.A), a manager says, "In theory, the entire procurement workflow could be automated. There's no need to involve a purchaser in carrying out dull activities anymore" (Flechsig et al., 2022, p. 6). The manager continues by saying there is far more potential for automation than the current applications and that RPA could be used even in tasks like supplier negotiations. In line with this, van Hoek, Šimek & Šperka (2019, p. 215) write that robots will execute workflows and assign tasks to other robots and humans as technology develops. Lam and Tang (2023, p. 8) echo this sentiment, saying that the freight-forwarding industry will ultimately achieve full

automation with the help of RPA. In opposition, Perdana et. al. (2023, p. 15) note that full automation is the exception, not the norm. Even with full automation of tasks, employees are not let go but, are freed to work on value-adding tasks instead of the dull tasks done by the RPA (Perdana et al., 2023, p. 15) Additionally, Hsing-Hua Hsiung & Wang (2022, p. 16) write that RPA can manage tight labor markets. In such a case, employers are reducing future headcount (which they cannot fill anyway) rather than eliminating current positions.

The assessment by Perdana et al. was not shared by all, notably not by employees who had RPA implemented in their departments. Even Perdana et al. (2023, p. 15) note that they found a "misconstrued notion that automation means a machine or robot taking over what is typically done by humans" as opposed to automation being a resource for humans. Van Hoek et al. (2022, p. 289) note that there was animosity from teams where the potential automation impact was significant and that management saw instances of attempted sabotage. Van Hoek et al. (2022) cite another issue where a message about a "theoretical automation potential of 50%" was released to the organization (van Hoek et al., 2022, p. 295). Employees interpreted this as a desire to cut headcount by 50%, which, according to the company, was never the case. Regardless, employees were fearful and required multiple meetings to alleviate concerns (van Hoek et al., 2022, p. 295). Flechsig et al. (2022, p. 8) found comparable animosity in their paper, finding that elderly employees feared RPA making them obsolete or getting new work assigned to them because of RPA. Though RPA can result in job loss, researchers also note that it can increase employee satisfaction.

Employee Satisfaction

As technological advancements impact a process, that process frequently becomes easier to do, in addition to becoming more efficient. Hand sewing a garment is harder and time-consuming than using a sewing machine, the advent of which allowed easier work for sewers and increased their productivity. On the flip side of the discussion about job loss, RPA, which reduces how long arduous tasks take to complete, increases employee job satisfaction compared to doing arduous tasks manually.

Though the prospect of job loss from automation has a long track record of coming to fruition, the literature demonstrates RPA's ability to improve the satisfaction of employees. RPA excels in dull work, taking that burden from employees. (Lam et al., 2024, p. 8; Lam & Tang, 2023, p. 8). In agreement, van Hoek et al. (2022, p. 289) say long and dull tasks can be disinteresting and make employees less satisfied. This lack of satisfaction and the desire to change is found in the research of Ylä-Kujala et al. (2023) as well. Ylä-Kujala et al. (2023, p. 171) report that while Estate Blend, a real estate developer, initially pursued RPA as a cost-saving method, they also desired to "transform the employees' jobs" by removing arduous and dull tasks. These tasks can be transformed into a simple press of a button, which starts an RPA (Lam et al. 2024, p. 8).

On top of the dull work burden being shifted to RPA, as shown previously, employees can conduct more stimulating and value-adding tasks. These stimulating activities are not only a boon for businesses but also a boon for the satisfaction of employees. Several researchers noted the increased morale and job satisfaction of employees with RPA integrated into their work. (Flechsig et al. 2022, p. 6, Perdana et al. 2023, p. 21; Radke et al. p. 6; van Hoek et al. 2022, p. 293; Šimek & Šperka, 2019, pp. 214-215). Additionally, Flechsig et al. (2022, p. 6) also note that multiple companies they examined said RPA would help to increase salary groupings for departments using the software. Šimek & Šperka (2019, p. 214) also add that RPA can help by alleviating burnout and increasing work-life balance. Overall, RPA can increase employee satisfaction by reducing the burden of dull work on employees.

The applications, benefits, and drawbacks of RPA are addressed in the current literature. These authors do their assessments, except in a few cases, like Hsing-Hua Hsiung & Wang (2022), on larger firms. While some researchers addressed manufacturing specifically (Chirvase & Zamfir, 2023; Radke et al., 2020), little research, if any, has been done on the effect of RPA in small manufacturing environments. Do the benefits of RPA seen in the literature occur within small manufacturing firms when RPA is implemented? Are the same drawbacks seen in smaller firms, and are they to the same extent? The major gap in the literature is the absence of small manufacturing firms from the chorus of RPA research. This

paper intends to address this literature gap using a case study of the RPA implemented within Acutec Precision Aerospace.

CHAPTER 3: Empirical Analysis

While the literature largely attests to RPA's use in businesses, the value of these applications is not as clear for small manufacturing firms. Following the strategy of Lam and Tang (2023), Perdana et al. (2023), and Hyun et al. (2021), this chapter explores the benefits of RPA to small firms by comparing manual processes to RPA processes designed to, as Turcu & Turcu (2021, p. 71) say, "mimic human behavior." Turcu & Turcu (2021, p. 71). First, the manual and RPA processes will be described in detail and graphically represented using process diagrams. Next, data from manual and RPA processes will be converted into equations and graphs to demonstrate how long each process takes. Finally, these results will be compared and discussed to illustrate the benefits of RPA implementation within a small manufacturing context. For this research, RPA time savings compared to manual processes and a cost-benefit analysis will be quantitative assessments for RPA. More quantitative metrics, like job satisfaction and process optimization, will also be discussed to assess RPA. Four RPAs are analysed to determine RPA's impact on Acutec:

1. **Acknowledgement Reconciliation** Automates purchase order acknowledgment matching.
2. **Order Processor** – Automates purchase order entry and processing.
3. **Email Workflow** – Automates supplier email generation.
4. **Scorecard Creation** – Automates supplier performance evaluation.

I chose these RPAs from among the RPAs I developed at Acutec for several reasons. These were the most impactful and used most frequently. They also had a sufficient run history for data collection and were fully developed and stable, making them well-suited for analysis. Other RPAs had more fringe-use cases or lacked consistent enough use to warrant study.

Acknowledgement Reconciliation

Manual Process Description

To conduct business, Acutec uses purchase orders (POs) as a binding document where items, quantities, prices, lead times, and other terms are established and agreed upon by Acutec and the outside supplier. This agreement comes in the form of an electronic acknowledgment, signifying that the supplier received the purchase order, agrees to the terms within the purchase order, and has started processing the request based on the content of the purchase order. In the case of orders that require revisions, supply chain personnel make changes, then the augmented purchase order is sent to the supplier,

This system clarifies expectations for Acutec and suppliers but functions correctly only when vendors receive and begin processing orders. Acutec utilizes a series of folders to track the acknowledgment status of purchase orders acknowledged by suppliers.

After purchase orders are created through the Acutec ERP software, employees save purchase orders to Acutec's universal drive. Employees save these files to a folder containing purchase orders that have not been acknowledged by the supplier, called POs Not Acknowledged. These files contain a 6-digit PO number at the start of the file name for tracking purposes, which will be detailed later. Files within this folder have an unknown status with the supplier and are subject to scrutiny if they are not acknowledged within a reasonable timeframe.

Once saved, employees send purchase orders through email with a request for an acknowledgment from the supplier. This request could be a sales order or a short message from the supplier indicating they have received the order (with the understanding they will be processing it). When suppliers acknowledge a PO, employees save the acknowledgment within the company's universal drive. It is saved to a folder containing supplier acknowledgments called POs Acknowledged. These acknowledgments contain a 6-digit PO number at the start of the file name for tracking purposes, which will be detailed later.

Employees reconcile these two folders several times throughout the day, meaning purchase orders in the POs Not Acknowledged folder are checked to see if a supplier acknowledgment exists in the POs Acknowledged folder. This is done by seeing if the purchase order number, present at the beginning of the purchase order and acknowledgment files, is present in both folders. If the purchase order number exists in both folders, the supplier has acknowledged the purchase order. If the purchase order number only exists in the POs Not Acknowledged folder, the supplier has not acknowledged the purchase order. Employees re-prompt suppliers for acknowledgement for unacknowledged orders, ensuring prompt processing and eliminating delays.

The issues with this manual process are manifold. Firstly, the process is time-consuming, requiring a manager to open the two folders simultaneously and manually check if the purchase order numbers exist in both folders. Secondly, this manual checking can lead to errors that result in wasted time re-prompting suppliers that have already acknowledged the order, or worse, orders not being processed by the supplier, causing production delays due to late products. Thirdly, managers conduct this process multiple times daily, multiplying the time wasted and the potential for errors. All these issues contribute to inefficiency and errors in the process. This manual process was automated using RPA.

RPA Process Description

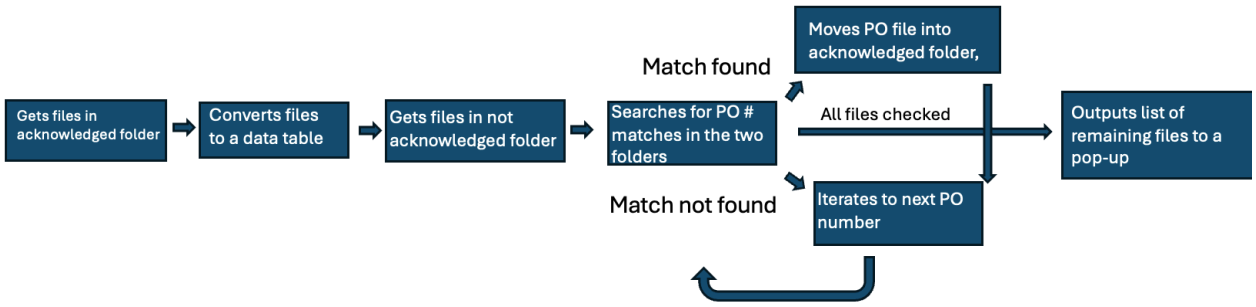
In a mirror of the manual process, this automation reconciles the POs Acknowledged and POs Not Acknowledged folders. It does this by pulling the files from the POs not acknowledged folder and searching for the 6-digit PO number within the POs acknowledged folder. If the automation locates the number in the PO number in the POs Acknowledged folder, it moves the purchase order from the PO not acknowledged folder into the PO Acknowledged folder. If the automation does not find the PO number, the automation leaves the file in the PO Not Acknowledged folder.

The automation also includes a dialogue box that displays when the automation completes. This dialogue box shows the files remaining in the PO Not Acknowledged folder, along with their creation

dates. This allows a manager to effectively determine which POs need to be resent to ensure timely processing and which POs are recent enough not to warrant scrutiny. The technical breakdown of the automation into its parts can be found in the Visual Process Diagram below.

RPA Visual Process Diagram

Figure 3.1 Acknowledgement Reconciliation Visual Process Diagram



Source: Author

Comparison of Manual and RPA Process Times

Executing the processes described above, the RPA completes reconciliations significantly faster than the manual process. Specifically, the RPA processes 73 purchase orders in the time it takes the manual process to complete just one. Hundreds of orders are processed weekly, with supplier acknowledgments constantly being received and reconciliations being performed. The chart below shows the average setup and per-item processing times for the manual and RPA processes.

Table 3.1: Acknowledgement Reconciliation Comparison

	Manual	RPA	RPA Time savings
Set-up duration (seconds)	11.4	3	73.7%
Per item duration (seconds)	3.3	0.16	96.15%

Source: Author

Order Processor

Manual Process Description

To conduct business, Acutec uses purchase orders to track items, quantities, prices, lead times, and other terms established and agreed upon by Acutec and the outside supplier. These purchase orders enter data from item quotations, supplier websites, and other sources into the Acutec ERP system. Once entered into the ERP system, delivery date tracking, item receiving, and item distribution are done based on the data within the ERP system.

Purchase order entry consists of four portions: general information, item details, shipping location information, and document exporting. First, employees enter general information. General information includes selecting the supplier, shipment method, FOB[7], and payment terms, among other general options. In the second step, item detail entry, employees enter information (Material ID, Description, quantity, price, due date, general ledger (GL) code, etc.) about individual items in the order. Employees enter each item separately to allow for tracking and receiving. Thirdly, employees enter the shipping location. The shipping location entry involves selecting which Acutec location the supplier will ship the order to and the department and end-user for distribution upon receipt. Lastly, employees export the file as a PDF and save it to the company's universal drive. This step allows the purchase order to be sent and monitored (see manual acknowledgment process).

The purchase order creation process can be divided into fixed and dynamic time portions. Fixed-time portions include the general information, shipping location, and file export portions. These parts do not depend on the number of items in the purchase order. These parts may vary slightly for different suppliers, but this extra time is negligible. For the dynamic time portion, the entry of item details depends directly on the number of items.

[7] Free on Board (FOB) is a shipment term that defines the point in the supply chain when a buyer or seller becomes liable for the goods transported

To complete the fixed and dynamic tasks, employees fill out fields within the ERP system with the correct information for the order. Most, if not all, of this information is located within the supplier quotation or comes from the end-user. Employees then transfer this information, usually by copy/paste, but in some cases by manually typing it into the ERP system. Once complete, employees export the purchase order document and save it into the universal drive.

Certain items are one-off purchases, called spot buys. These are typically items bought to meet an immediate need and are not expected to be purchased again in the future—or if they are, it happens infrequently and without any regular pattern. Other items, like packaging and janitorial supplies, are frequently reordered. Acutec utilizes vendor-managed inventory (VMI) for these products, ensuring that orders reflect actual usage, which reduces over-ordering and out-of-stock items. However, this approach requires new purchase orders each week. These weekly orders contain similar items but need to be manually processed like spot-buy orders. While both order types take time, frequently reordered items can be painful to process manually. In addition to frequent ordering, these items make up large orders, further increasing processing time.

To eliminate this problem for frequently reordered items, Acutec developed an internal purchase request system (PRS). PRS allows purchasing personnel to add items to a database. Once an item is entered into PRS, it remains in the database for future ordering. Once purchasing personnel add the items they wish into the database, they can add items to an order and submit the order. PRS creates a purchase order within the ERP system, saving time by reducing manual data entry. While this system is better than purely manual data entry, manual data entry is still required to select items and input quantities.

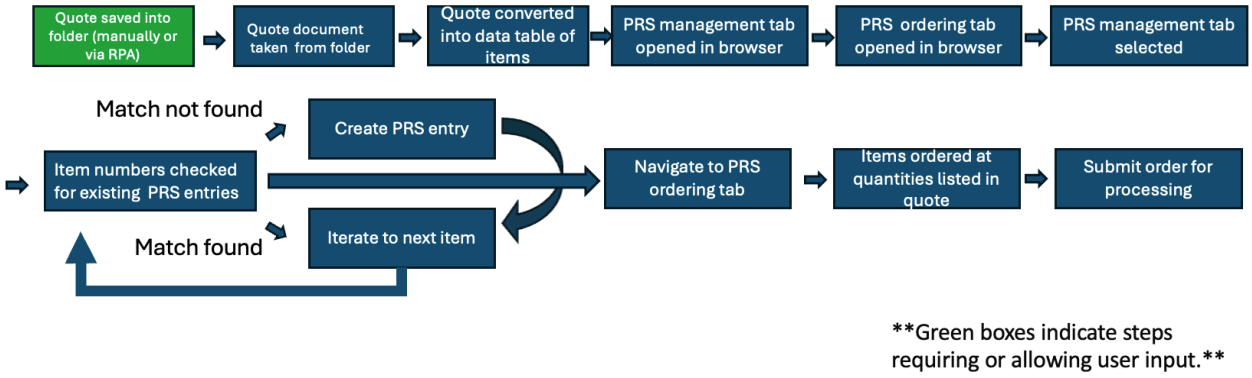
RPA Process Description

As shown in the diagram, the high-level process remains essentially the same, but instead of a human doing the data entry in PRS, the RPA conducts it. First, the RPA converts an order document into a data table. From this data table, the RPA checks if item numbers for every item in the order already exist

within PRS. If the items do not exist in PRS already, the RPA adds them. Once all items in the order are within PRS (either from being added or existing previously), the RPA orders the items at the quantities in the order document. After the RPA submits the completed order, supply chain personnel can edit the order if needed before delivering the PO to the vendor.

RPA Visual Process Diagram

Figure 3.2: Order Processor Visual Process Diagram



Source: Author

Comparison of Manual and RPA Process Times

For the Order Processor, manual and RPA processing times are made up of two components. The first component is the setup time. For the manual process, this involves all of the set-up steps addressed in the manual process description. For the RPA, this is the time spent opening the windows through which orders are processed. The second component is the time to process one item by entering it into a system. The chart below shows both the setup and item processing times.

Table 3.2 Order Processor Comparison

	Manual	RPA	RPA Time Reduction
Setup duration (seconds)	53	23	56.6%
Item processing time (seconds)	23	15	34.8%

Source: Author

Compared to other RPA processes, the Order Processor achieves significantly lower time savings. This difference is primarily due to how it operates. Unlike other RPAs, which perform most of their work in the background—bypassing the presentation layer and focusing on calculations and data processing—the Order Processor relies on direct interaction with the user interface. As a result, it must run at a slower pace. When working within the PRS system, wait commands can delay execution by up to 10 seconds when switching windows, with brief delays between most typing and clicking actions. These pauses are necessary to prevent errors but come at the cost of increased run duration.

Email Workflow

Manual Process Description:

After PO creation, Employees must send POs so processing can begin. Acutec primarily utilizes emails to accomplish this goal. This email typically contains four critical components but may have other optional components based on the order. The four main components of these emails are the supplier email address, the subject containing the Acutec PO number, the purchase order PDF, and a standard text that instructs suppliers regarding the PO. Other components include the quote document or additional miscellaneous documents.

The first three components, supplier email address, PO number for the subject, and the PO itself are all contained within (or are) the purchase order document. Vendor email addresses are stored within the ERP system and tied directly to the vendor. While employees can find these emails within the ERP

system, they are present on the purchase order for convenience. Supply chain personnel copy this information from the purchase order into the email and attach the document from the file system. The standard text placed in the body of the email is stored as a signature, which employees select from the email message options within Outlook and add to the email body. Any optional components are either attached from the original request or manually added to the email.

POs sent to suppliers typically fall into one of two types. Either they contain only the critical components mentioned above (which we will call “no attachment”), or they contain the critical components and the quote document provided by the supplier (which we will call “with attachment”). Employees forward components along with the original request to the supplier.

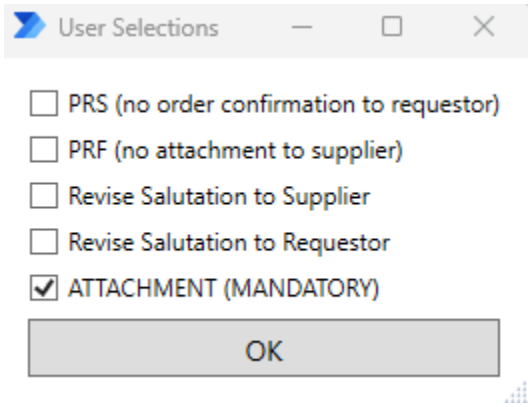
After an email is sent to the supplier, supply chain personnel respond to the requestor within Acutec, providing the PO number on which the item is ordered and instructions to reply to the email with any questions. Requestor emails are typically taken from the initial request, but the requestor's name can be manually searched within the Acutec address book to get their email address. Besides communicating necessary information, these purchase orders also provide a reference point for any future communication about the order.

RPA Process Description:

The RPA process automates the most common types of emails processed each day: the “no attachment” and “with attachment” types mentioned above. Emails outside these two types are often more complicated and should not be handled by a rule-based system like an RPA.

To use the RPA, supply chain personnel save the generated purchase order in a specific folder (RPA POs) in the universal drive. If processing a “with attachment” email, employees save the supplier quote in a different folder (RPA Attachment); otherwise, no file is put into the RPA Attachment folder. Supply chain personnel then start the automation and are prompted to select the email type they are processing. A screenshot of the pop-up that personnel see is shown below.

Figure 3.3: Email Workflow Graphic



Source: Author

Selecting nothing (besides the last checkbox, selected by default) processes the “with attachment” type. The PRS checkbox processes the “no attachment” type. The PRF checkbox processes an augmented “with attachment” type, in which the supplier gets no attachment, but the requester gets their request sent back to them. The Revise Salutation boxes allow minor changes to be made to the email. This could include calling out something in the purchase order for further attention or editing a portion of the default signature that would confuse recipients but not warrant sending the order manually. After selecting options and pressing the “OK” button, the RPA constructs and sends the email(s).

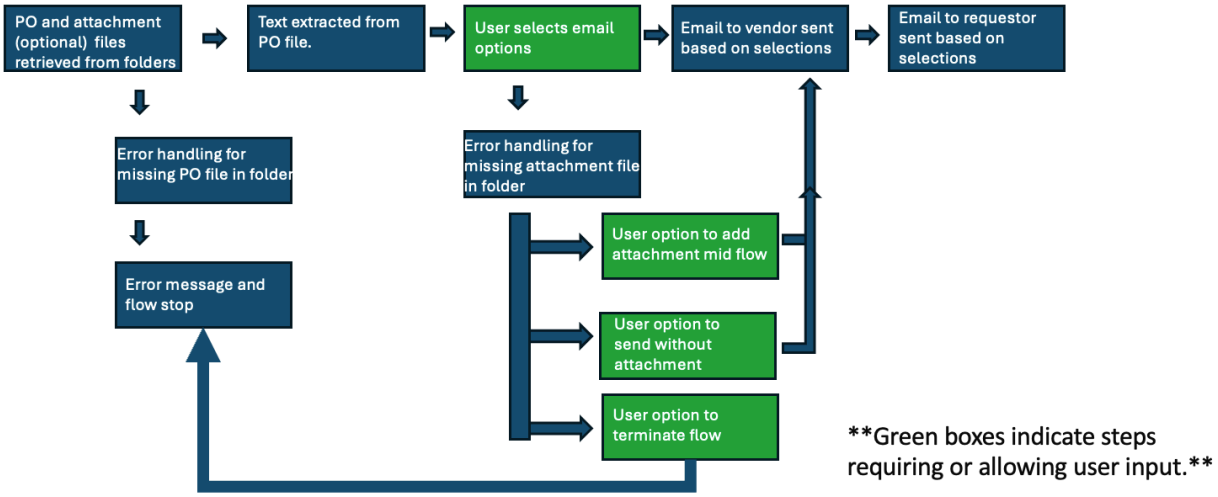
The RPA process works similarly in concept to the manual process but eliminates several of the email creation steps present in the manual process. Rather than relying on manual copy/pasting or searching through systems, the RPA gathers information directly from purchase orders.. While the RPA is not error-proof, it reduces human error by removing humans from the process. While human error is hard to prevent, RPA errors can be tracked and corrected because the RPA acts only as programmed. The RPA extracts this information directly from the purchase order and formats it as though a manual email is being sent.

When sending POs to suppliers, the RPA takes the PO number and vendor email address directly from the PO file. While the requestor's email is not present directly in the PO file, the purchase order

contains the first and last name of the requestor. The RPA constructs the first and last name into an Acutec email address, following the Acutec email address format (first initial, last name @acutecprecision.com). Below is a diagram of the RPA process.

RPA Visual Process Diagram

Figure 3.4: Email Workflow Visual Process Diagram



Source: Author

Comparison of Manual and RPA Process Times

The Email Workflow duration shown below averages the processing times to send one email. The chart below shows the average times for manual and RPA processing.

Table 3.3: Email Workflow Comparison

	Manual Process	RPA PROCESS	RPA Time Reduction (%)
Duration (seconds)	38.52	10.92*	71.7%

Source: Author

*The actual software portion of the RPA process takes 1.58 seconds on average. The remaining time results from the time it takes to complete the user selection steps.

Scorecard Creation

Manual Process Description

As part of AS9100[8] accreditation, Acutec must maintain quarterly communication with all suppliers regarding quality and on-time delivery (OTD) performance. This communication addresses how suppliers are performing in these categories and provides an opportunity for feedback and corrective action on issues. While Acutec already tracks the requisite information for this communication, this information must be synthesized into a standard format that can be sent to vendors.

Acutec utilizes an Excel document with multiple tabs to organize this information. Tab one of the document contains vendor information and quality and OTD performance. Tab two contains any disappointment(s) that Acutec had with the supplier during the quarter, as well as a place for the vendor to submit a corrective action. The third tab provides the internal data that was used to generate the quality performance score. The fourth tab provides the internal data that was used to generate the OTD performance score.

Supply chain personnel extract this information from various documents, internal dashboards, and other systems to fill out the data within a supplier scorecard document template. Once the template is complete, supply chain personnel save the document and distribute it to the supplier. Once the scorecard is sent to the supplier, an internal approved supplier list (ASL) is updated with the quality and OTD scores. For vendors not used during the quarter, quality and OTD are updated to "No Activity", indicating that the supplier was not used during the quarter. The scorecard creation process is repeated for each supplier used during the quarter, while the ASL updating process is done for each supplier in the ASL.

[8] AS9100 is a set of standards that define quality management system (QMS) requirements for the aerospace industry

RPA Process Description:

While other RPA applications have similar processes to their manual counterpart, the RPA for the scorecard is essentially the same. The RPA process takes the same inputs as the manual process, conducts calculations the same way supply chain personnel do manually, and outputs the information into the same places on the scorecard document.

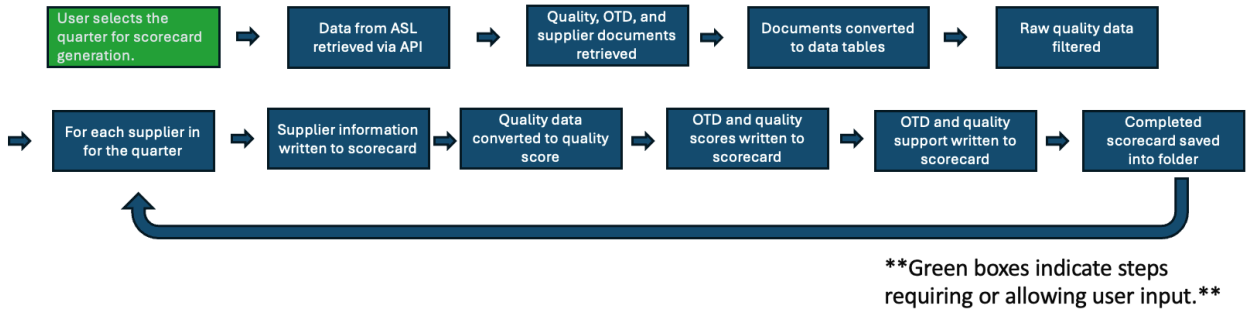
What differs materially from the manual process is the way that ASL updating is completed. Rather than entering data on the web application that stores the ASL, as is done in the manual process, the RPA utilizes an API[9] to make the changes automatically. The RPA locates the existing supplier entry within the ASL and updates the quality and OTD scores within that entry. This is done by sending an HTTP POST request with the requisite instructions. While RPA excels at interacting with systems that do not have an API by utilizing the presentation layer of a system, RPAs can also take advantage of applications with APIs, further increasing the usefulness of RPA.

Once the RPA processes all suppliers, its final action is to output a list of suppliers that were used within the quarter but are not found on the approved supplier list. Vendors can be added to the ASL at the discretion of the supply chain personnel utilizing the automation.

[9] An API (Application Programming Interface) is a structured set of rules and protocols that allows different software applications to communicate and interact, enabling one system to request data or functionality from another without needing to understand its internal workings, much like a translator facilitates interactions between two languages.

RPA Visual Process Diagram

Figure 3.5: Scorecard Visual Process Diagram



Source: Author

Comparison of Manual and RPA Process Times

For context, Acutec utilized 328 vendors in quarter three of 2024 and has 571 vendors within the ASL. This represents 571 active vendors, of which 328 were used in quarter three of 2024. Below are the manual and RPA processing times for the Scorecard Creation workflow for quarter three. These times include both the scorecard creation and the ASL updating process.

Table 3.4: Scorecard Comparison

	Manual Process	RPA Process	RPA Time Reduction (%)
Duration (hours)	18.72	1.03	94.49

Source: Author

As shown by the descriptions and process time comparisons above, in all four processes, the RPA considerably reduces process duration compared to conducting the process manually. For the Reconciliation process and the Scorecard process, non-setup processing times were decreased by nearly 95%. Even for the Order Processor, which saw the smallest process time percentage decrease, the RPA still decreased non-setup duration by nearly 35%. While process duration improvements show RPA's capabilities in a small firm context, quantifying these benefits to Acutec is a critical component of

whether the benefits seen from process duration improvement are worth the investment given for software and development.

Quantification of RPA Costs and Benefits

As found in the literature, the analysis of the four RPAs discussed above affirms the process duration improvements of RPA while also showing that these process duration improvements are found when RPA is applied to business practices conducted within a small manufacturing company. Existing literature suggests that large firms experience process duration improvements similar to those observed in this research. However, RPA may provide even greater overall benefits for large firms. If both large and small firms automate similar processes, the percentage reduction in processing time should be comparable, but larger firms would achieve greater total time savings due to their higher workload volume. This would lead to an outsized ROI of RPA for large firms for the same percentage reduction in processing time. While nominal process duration improvements cannot be ignored, the cost-effectiveness of such improvements must also be considered. Small businesses cannot afford to spend resources on process duration improvements that do not provide a return on investment.

To quantify the costs and benefits of RPA, several factors must be considered. For RPA costs, the time it takes to develop the RPA must be considered in tandem with the wage at which the developer(s) are paid for their time. In the case of Acutec, development was conducted by me in my capacity as a supply chain intern. As an intern, I made $15.50 per hour, which is used as the cost per hour of development for these calculations.

To determine development time, the initial creation date was compared to the date of the first successful production run. This does not include successful runs as part of development and testing, as those are still within the development window. In the tables below, these values are found in the “Time” column.

I split my time as an intern between RPA development and other intern tasks. Though the exact split is difficult to ascertain, several potential ranges are considered that cover multiple possible time splits. The splits will be a percentage of the full business days (8 hours) between creation and the first successful production run. These percentages are 25%, representing a minimal percentage of time spent on RPA development; 50%, an even split of the time on RPA development; and 75%, indicating a high percentage of time spent on RPA development. While the exact split is unknown, I estimate that somewhere between 50% and 75% of my time was spent doing RPA development.

The final cost associated with the RPA is the cost of the licenses themselves. A license costs $15 per user per month or $180 per year. Acutec purchases a total of 10 licenses at an annual cost of $1800 per year. The licenses allow unlimited RPA usage and development for a flat monthly fee. Software updates are released periodically and do not result in increased licensing costs. The license costs are assessed in the "Overall" column (indicated by a *), located at the bottom of the tables. This decision was made because the net effects are calculated as a yearly amount, so the full license cost can be applied there without complicating the costs of the individual automations, which all share the $1800 cost, along with other RPAs not addressed in this paper.

For the quantification of RPA benefits to Acutec, the time savings in conjunction with the dollar value of those time savings are used. Time savings are made up of two portions. The first portion is the manual time, which, without the RPA, would need to be spent doing whichever task the RPA is responsible for. These are direct savings, time which would otherwise be spent manually doing the tasks. The second portion is the time employees can use to do other tasks. As rote work shifts to the RPA, employees can work on higher-value tasks that have a more meaningful impact on firm development and financial performance. For example, an RPA that offloads one hour of rote work from an employee results in a total benefit of two hours (one hour saved and one hour gained to do more productive work).

To calculate the dollar value of the time savings, the average wage of the employees using the RPA is used. To calculate the average wage, I received the managerial levels of the employees who utilize

the RPA from the Acutec HR department. Using the Acutec pay scale for managerial levels, which provides base, mid, and high salaries for each level, I determined the average wage of the employees utilizing the RPA to be $33.23/hr. While these individuals are salaried, the hourly wage equivalent is used to calculate time savings, which have units of hours. Acutec values these employees' work at their wage from a cost perspective but expects profit generation from these wages, meaning the dollar value of the time is likely higher. Below is the cost-benefit analysis of the automations at the 25%, 50%, and 75% development time usage splits. Software costs are subtracted from the overall impact only in the last two columns of the bottom row, indicated by a (*)

Table 3.5: 25% Development time

Automation	Time (hrs)	Time Split (%)	Dev. Cost ($/hr)	Total Costs ($)	Time savings (hrs)	Avg. Employee Wage ($)	Year 1 Net Impact ($)	Year 2 Net Impact ($)
Reconciliation	8	0.25	15.5	31	20	33.23	633.6	664.6
Email	88	0.25	15.5	341	40	33.23	988.2	1329.2
Order Processor	248	0.25	15.5	961	80	33.23	1697.4	2658.4
Scorecard	184	0.25	15.5	713	160	33.23	4603.8	5316.8
Overall	528	0.25	15.5	2046	300	33.23	6123*	8169*

Source: Author

Table 3.6: 50% Development Time

Automation	Time (hrs)	Time Split (%)	Dev. Cost ($/hr)	Total Costs ($)	Time savings (hrs)	Avg. Employee Wage ($)	Year 1 Net Impact ($)	Year 2 Net Impact ($)
Reconciliation	8	0.5	15.5	62	20	33.23	602.6	664.6
Email	88	0.5	15.5	682	40	33.23	647.2	1329.2
Order Processor	248	0.5	15.5	1922	80	33.23	736.4	2658.4
Scorecard	184	0.5	15.5	1426	160	33.23	3890.8	5316.8
Overall	528	0.5	15.5	4092	300	33.23	4077*	8169*

Source: Author

Table 3.7: 75% Development Time

Automation	Time (hrs)	Time Split (%)	Dev. Cost ($/hr)	Total Costs ($)	Time savings (hrs)	Avg. Employee Wage ($)	Year 1 Net Impact ($)	Year 2 Net Impact ($)
Reconciliation	8	75	15.5	93	20	33.23	571.6	664.6
Email	88	75	15.5	1023	40	33.23	306.2	1329.2
Order Processor	248	75	15.5	2883	80	33.23	-224.6	2658.4
Scorecard	184	75	15.5	2139	160	33.23	3177.8	5316.8
Overall	528	75	15.5	6138	300	33.23	2031*	8169*

Source: Author

To analyze the investment further, I conducted a Net Present Value (NPV) analysis. Since the estimated development time ranges from 50% to 75%, I will assume 75% as a worst-case scenario. If the NPV remains positive even under these higher initial development costs, it will be even more favorable in lower-cost scenarios.

For this analysis, I will define the key inputs as follows:

- Initial investment **(I0)** = Initial development costs: $6,138
- Annual savings **(Bt)** = Time savings × Average employee wage: $9,969
- Maintenance costs **(Ct)** = License costs: $1,800 (assuming 0 ongoing development costs)
- Discount rate **(r)** = 7% (the rate that Acutec uses according to the CFO)
- Time horizons **(n)** = 3, 5, 10, and 20 years

The equation and results are shown below.

$$NPV = \sum_{t=1}^{n} \frac{(Bt - Ct)}{(1+r)^{t}} - IO$$

Table 3.8 NPV By Time Horizon

Time Horizon (Years)	NPV
3	$15,300
5	$27,357
10	$51,238
20	$80,405

Even at high development costs, NPV remains positive in the short and long term. While zero development costs are likely unrealistic over 20 years, this model also assumes no growth in the amount of time being saved, and hence, the dollar value of the annual savings.

Before conclusions are drawn, some columns warrant further explanation. The “Total Cost” column is a multiplication of the Time, Time Split, and Dev. Cost columns. This provides development costs, discounted by the percentage of the time spent developing the RPA. The 1 and 2-year Net Impact columns represent the benefits minus the costs for each RPA and all of the RPAs combined in the overall row. The variance between the 1 and 2-year net Impact columns results from development costs being incurred solely in the first year, making them a past expense that does not repeat. Although it would be possible to amortize these costs, presenting them this way highlights the long-term value of the RPA. Specifically, it emphasizes that after the initial investment, future years benefit from the RPA’s effective rate of approximately $0.86 per hour, compared to paying an employee ~$33.23 per hour for the same tasks.

It should also be noted that the future costs assume no continuing development or maintenance. These assumptions are made for two reasons. First, accurately calculating the future development/maintenance costs would be difficult, if not impossible. Second, these RPA applications underwent significant in-production testing, making the RPAs themselves highly reliable. To this end, in

my time at Acutec in a full-time position outside of the supply chain office, I have received several requests to add functionality while receiving only a few requests to fix broken elements.

Several conclusions can be drawn from the results of this analysis. First, save for the first year of the Order Processor, which is only -$224, at any percentage development time, every RPA is a net benefit to Acutec, as well as the overall net benefit being positive in every case. Second, because development costs fall off after year one, net benefits increase as time goes on, leading to a greater long-term value of the RPA to Acutec. Thirdly, the year one to year two net benefits assume no growth in the underlying time savings. As Acutec grows, the number of purchase orders being reconciled, emails being sent, orders being processed, and scorecards being created will increase, meaning that these benefits will grow as time goes on. In short, the process improvements demonstrated by the RPA applications are accompanied by quantified net benefits to Acutec. A positive NPV over short, medium, and long-term timeframes further indicate RPA's benefits to Acutec.

Process Optimization

One component of the literature on RPA is the need for process optimization. An inefficient process will remain inefficient even if it is done faster using an RPA due to the myriad problems inefficient processes cause in general and relating to RPA implementation.

These issues were no more prevalent than in the early iterations of the manual supplier scorecard process. Initially, this process was made up of multiple documents of different formats being sent to and requested from suppliers. On the manual processing side, this led to a bloated and confusing workflow with multiple steps for Acutec employees. If not followed correctly, this confusing process could result in an audit finding. On the RPA side, while the RPA can complete a bloated and confusing process, multiple issues arise from attempting to do so.

Firstly, just as the process is difficult to follow for humans conducting the process manually, the process is also difficult to program. Whenever overly complex processes are converted into code, the code

also becomes complex. Whenever complexity is increased, so is the likelihood of unforeseen errors and other issues cropping up during and after development. Even well-optimized processes sometimes have special cases where deviations from the process might be needed. A poorly optimized process likely has several special cases, which all require handling. In the best-case scenario, this adds significant time to development, but in the worst case, it can cause issues for end users and potential audit findings. Process complexity can also cause RPA implementations to fail, not because of the software itself but because the process was too unoptimized for RPA implementation. Secondly, even if RPA completes an unoptimized process faster than a human can, the downstream issues from the process still exist. For example, a supplier may question their quality score for a quarter. With multiple documents and complex score calculations, effectively communicating answers to a supplier could involve opening several documents and pulling components from each one to give an answer, which the supplier might not understand because of the inherent complexity of the entire process.

By optimizing the process, Successful RPA implementation is more likely and requires less development time. Downstream inefficiencies are nipped in the bud at the process level, being designed out of the process instead of being handled afterward. In the case of the Scorecard Automation, Acutec examined the process and decided that an Excel document that contains all the elements was the most efficient option. This allowed for a straightforward automation process, minimizing development time and error occurrence and leading to a successful RPA implementation. When suppliers respond with questions about their scores, information can be analyzed at a glance by supply chain managers, who can answer questions.

Manual Challenges

While the manual completion time calculations provided are generally accurate in describing the processes above, they do not account for real-world challenges encountered during a typical business day. While a task may have an ideal process duration in a controlled setting, daily operations often introduce

unforeseen factors that extend duration. RPA, because it operates regardless of these distractions, allows for more consistent quality, processing times, and overall consistency compared to manual processes.

At Acutec, these "unforeseen factors" mentioned above take many forms. While all manual tasks are susceptible to unforeseen challenges, longer tasks are particularly vulnerable, as their extended duration increases the likelihood of disruptions that can hinder execution. Each of the manual processes above is at risk from such disruptions, but as the most time-consuming process on a per-unit basis, the scorecard automation has the most risk when done manually and sees the most benefit from RPA implementation. While the rate of these disruptions in the manual process is difficult to quantify, it certainly exists. Utilizing an RPA insulates the processes from these disruptions by taking the human out of the process (save for starting the RPA and providing any input).

For context, RPA setup for a user consists of pressing a single button within the Power Automate application, while the manual process involves the opening and manipulation of multiple windows. In like manner, the RPA process runs in the background, while the manual process requires the user's full attention. If a user's full attention is broken by a phone call, a visit from another employee, or other expected day-to-day work, several sources of error can crop up. Transposition of numbers, inadvertently providing incorrect contact information for a vendor, or other issues associated with a lack of focus are eliminated. For the scorecard creation process in particular, one observed issue was employees accidentally editing the template scorecard instead of creating a copy and filling out the copy. Not only does this require extra work to correct, but it can also complicate the process for other employees attempting to utilize the template for their department. The RPA, having specific instructions on what to do with the template document, does not experience such errors.

Even without interruptions, humans are prone to inconsistent task execution. Rote and draining tasks increase the likelihood of typos, skipped entries, or pasting information into the wrong field. In the best case, this will be noticed and corrected with minimal time wasted, but in the worst case scenario, this can lead to incomplete and/or inaccurate information being presented as fact, with a host of associated

issues to follow. In the case of the scorecard information, a vendor who is wrongly penalized because of human error may be less likely to address actual concerns. They may view any concerns as just as likely to be founded on error as the wrongly penalized case. Because the RPA has a defined set of steps that it executes as it is programmed to, errors like these are eliminated. Additionally, RPA does not become burdened by burdensome tasks, it simply executes according to its programming.

Opportunity Cost

The decision for any company, especially a small firm like Acutec, to pursue RPA is not without opportunity costs. While opportunity costs could take many forms, several present themselves specifically to Acutec. To begin, the license cost of RPA for Acutec, approximately $1800 per year, is capital that Acutec cannot spend on any number of other business needs. While a company like Acutec with $100 million in annual revenue can take a flier on $1800 per year software, other smaller firms may have further considerations to make, especially if they want to make RPA a central component of their organization. The $1800 yearly cost serves many business functions, including running the Scorecard Automation, which assists Acutec in maintaining AS9100 certifications, which are required for Acutec to continue doing business.

Another consideration is the opportunity costs of the developer. As is discussed in the quantification of RPA costs and benefits section below, I split my time as a supply chain intern between RPA development and other intern tasks. Every hour spent developing RPA is an hour that could have been spent doing other intern tasks. In a more general sense, any RPA development resources, time, and effort could be spent somewhere else. While investing in high-ROI activities can lead to a long-term benefit for firms, that decision becomes more difficult when the ROI of an activity, like investing in RPA, is not as clear from a benefits perspective.

Even within the context of RPA, opportunity costs abound. By choosing a particular RPA provider, an organization forgoes the potential benefits of offerings from other RPA providers. Microsoft

PowerAutomate, the RPA software that Acutec utilizes, is a low-cost RPA provider, but things like development support and other services are lacking compared to higher-cost offerings. By choosing to develop in-house, Acutec saves money but also forgoes the expertise of a third-party developer. By having a locally run RPA instead of a cloud-based solution, Acutec maintains more control over the information processed by the RPA but forgoes functionalities that are only available with cloud-based systems.

CHAPTER 4: Conclusion

This research sought to evaluate the benefits of Robotic Process Automation (RPA) in a small manufacturing context. To accomplish this goal, RPA implementation at Acutec Precision Aerospace was used as a case study. Existing literature on the subject primarily examined large companies, leaving a gap in the analysis of RPA implementation in small firms. To address this question, the key research questions were:

(1) *Does RPA increase productivity in small manufacturing firms?*

(2) *Do RPA implementations have a positive ROI in small manufacturing firms?*

Based on existing research and my experience designing and implementing RPA at Acutec, I hypothesized that RPA would improve efficiency within a small manufacturing context.

Much of the literature on RPA focuses on its implementation and benefits within large enterprises, often overlooking small businesses' unique constraints and opportunities. Studies confirm RPA's ability to automate repetitive, rule-based tasks, leading to efficiency gains (Bogoevici, 2024; Herm et al., 2023). However, small firms face distinct challenges, such as limited financial and technical resources, which may hinder successful RPA adoption. In conjunction with these issues, RPA providers frequently cite large and well-funded firms as examples of successful RPA implementations, leaving small firms to wonder if they can see similar results without spending millions of dollars and whether a smaller-scale implementation would see similar efficiency benefits or cost savings and whether they can see similar results without spending millions of dollars.

A key gap in the literature is the lack of empirical studies examining RPA in small manufacturing firms. Even some research on larger firms was light on cost-benefit analysis, relying on surveys and interviews to determine RPA's value. This research also highlighted concerns regarding the cost-effectiveness of RPA investments for smaller firms and potential employee resistance due to job security fears and entrenched manual workflows. This project aimed to fill these gaps by providing empirical data from an actual small manufacturing firm's RPA implementation.

The empirical chapter of this project addressed these gaps by systematically comparing manual and automated processes within Acutec's supply chain department. Four RPA implementations were analyzed:

5. **Acknowledgement Reconciliation** Automates purchase order acknowledgment matching.
6. **Order Processor** – Automates purchase order entry and processing.
7. **Email Workflow** – Automates supplier email generation.
8. **Scorecard Creation** – Automates supplier performance evaluation.

For each process, the manual process was mapped out, explaining the process and associated context. Next, a description of the RPA implementation was provided, showing how the RPA accomplishes the task. Finally, the processing times for the manual and RPA processes were compared, quantifying the process's productivity increases from RPA at Acutec. Once all four processes were examined, a quantification of the costs and benefits from RPAs for each process was presented, with several potential scenarios for different development times.

This research utilized a case study and data visualization methodology to assess RPA in a small firm context. Acutec Precision Aerospace was the subject of this case study, with data visualization used to explain RPA processes and assist with cost-benefit analysis. While Acutec may not perfectly reflect the average small firm, it offers empirical evidence of RPA implementation in a smaller-scale setting than the large companies that dominate existing research. At Acutec, RPA was developed by a single individual to support a five-person department, mirroring the limited team sizes and development resources typical of small firms. Unlike larger businesses, there was no access to extensive internal knowledge bases or professional software engineers, further distinguishing this implementation from those in large-scale enterprises.

Three steps were involved in the gathering of quantitative data for this research. First, RPA processes were designed and implemented at Acutec Precision Aerospace. Next, the processing times for manual and RPA processes were tabulated and compared. Finally, a net-benefit analysis was conducted for

each RPA individually and for all RPAs combined, offering detailed and overall quantification of RPA return on investment (ROI) at Acutec.

Time savings were calculated by measuring setup duration and per-item processing time before and after automation. Financial benefits were estimated by calculating labor cost savings based on the average wage of employees using the RPAs. The return on investment (ROI) was assessed by comparing these savings to development costs. A net present value (NPV) analysis was performed to determine the present value of future benefits from the RPA.

The empirical analysis confirmed that RPA significantly reduced processing times across all four implementations. The most substantial time savings were observed in the **Scorecard Creation** process, where automation reduced processing time by 94.49%, saving Acutec approximately 20 hours per quarter. Similarly, the **Acknowledgement Reconciliation** resulted in 73 times faster processing compared to the manual process. Meanwhile, the **Email Workflow** automation reduced the average time required to send supplier emails by 71.7%. Overall, the four processes analysed within this paper eliminated approximately 150 hours of manual processing time for Acutec. When done by the RPAs, these tasks took approximately 51 hours (a 76% reduction), with 30 of those hours coming from the less-efficient Order Processor Automation. For non-Order Processor RPAs, 130 hours of manual processing were eliminated, taking the RPAs approximately 21 hours, or an 84% reduction in processing time.

The **Order Processor** saw a smaller but still meaningful reduction in processing time, with automation decreasing setup duration by 56.6% and per-item processing time by 34.8%. The order processor resulted in a smaller reduction because the other RPAs worked primarily behind the scenes, while the order processor interfaces with the purchase request system (PRS) on the presentation layer of a computer.

The cost-benefit analysis revealed that despite initial development costs, RPA implementations provided a strong return on investment. Even under conservative estimates, each automation yielded a net positive financial impact within the first two years. For example, the Scorecard Creation automation, developed at an estimated cost of $713-$2,139 (depending on development time allocation), resulted in

first-year savings of $3,177-$4,603. The NPV analysis showed that the RPA has a positive NPV in the short-term (3 years), medium-term (5, 10 years), and long-term (20 years), indicating that it has a positive return for Acutec.

In addition to quantitative benefits, RPA also provided qualitative benefits to Acutec, such as human error reduction, employee productivity gains, and process standardization. While difficult to quantify accurately, these qualitative benefits reinforce and add to the quantitative benefits of productivity gains and the ROI of RPA at Acutec.

The findings strongly support the hypothesis that RPA improves productivity and results in significant cost savings in small manufacturing firms with the capability to integrate them. The study demonstrated that even with more limited resources than their larger counterparts, small firms can leverage RPA to streamline operations and reallocate employee time to more strategic functions. This aligns with the broader literature on RPA's efficiency gains, but crucially, it extends these findings to the small business context, addressing the existing gap in the literature. This paper contributes to the literature in several ways. First, the paper provides empirical data on RPA implementation in a small manufacturing firm, showing that RPA software benefits extend to small firms, as they have been previously shown to do in large firms. Second, the research demonstrates RPA cost-effectiveness in small firms, even at a smaller scale than examined in most existing literature. Lastly, the research provides insight into challenges faced by small firms, such as processes that need to be optimized before RPA implementation can take place. By bridging the gap between theoretical RPA benefits and real-world small business applications, this research offers practical insights for small manufacturers considering automation.

While this research addressed a gap regarding small firms, there are many future research opportunities. As is the case with RPA research in general, further research needs to be done on the long-term impacts of RPA, especially for small firms. Research could also be done on how small firms scale RPA to meet more needs in different departments. Further research could also be conducted on RPA use in conjunction with AI or on AI as a substitute or replacement for RPA. Additional research could focus on the relative value of RPA in different industries, seeing if some industries have higher RPA ROI

than others due to their processes. While this study provided valuable findings, several areas remain open for future research.

This study shows that while RPA is often marketed toward large enterprises, it can also be a valuable tool for small manufacturing firms looking to streamline operations—especially for tasks that are rule-based, rote, and disproportionately time-consuming relative to their value. Small firms looking to implement RPA should optimize their existing manual processes and find someone with general software development skills to spearhead development and implementation. By reducing process duration, minimizing errors, and freeing employees for higher-value tasks, RPA allows small businesses to better utilize their human capital while still conducting day-to-day operations. By harnessing RPA's potential to drive efficiency and growth, small firms, like their larger counterparts, can contribute to a more technologically advanced and resilient manufacturing sector.

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