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Advisor: Dr. Gültekin Kuyzu

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Introduction

Welcome to the 2019 MIT-Zaragoza Masters of Engineering in Logistics and Supply Chain Management Research Journal!

The four papers included in this journal were chosen from the fifteen projects submitted by the class of 2019 at the Zaragoza Logistics Center. The articles are written as executive summaries and are intended for a business, rather than an academic audience.

The purpose of the executive summaries is to give the reader a sense of the business problem being addressed, the methods used to analyze the problem, and the relevant results, conclusions and insights gained. The complete projects are, of course, much more detailed. We have also included a complete list of this year’s projects with short descriptions at the end of this journal.

The articles in this publication cover a wide range of interests, approaches, and industries. This variety of topics illustrates one of the hallmarks of the MIT Zaragoza program: the students’ ability to focus their course work and research on topics that most interest them.

These projects are conducted in conjunction with the Zaragoza Academic Partner (ZAP) Program, an initiative to enhance applied research and closer industry-academia relationships in the field of supply chain management.

The ZAP Program gives MIT-Zaragoza program students the opportunity to work closely with industry professionals on actual supply chain problems, and gives companies an opportunity to interact with a student or student team along with a professor as expert thesis advisor who together bring new insights and approaches to a current supply chain project.

We hope you enjoy the articles. If you wish to discuss any other aspect of the program or wish to find out how your company can interact with our students, please do not hesitate to contact me directly.

Happy reading!

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# Bio-Inspired Algorithm for Optimization of Delivery Routes at Samsonite Chile S.A.

By Adriana Aragón and Sergio Correa  
Thesis Advisor: Gültekin Kuyzu, Ph.D.

**Summary:**  
In this thesis, we model a real-life case study of outbound distribution as a rich Vehicle Routing Problem (VRP). We develop an exact mathematical model and an Ant Colony Optimization (ACO) heuristic. The heuristic was successful in reducing transportation costs and number of trucks to near-optimal values and is projected to be used to guide future routing decisions at the company.

**KEY INSIGHTS**

1. Exact optimization yields solutions with a lower number of vehicles and total costs. However, it cannot be used in day to day operations where large instances of the problem are frequent.
2. An ACO heuristic achieves close to optimal results that reduce the number of trucks required by 24% compared to current company practices.
3. The heuristic requires minimal processing time, making it suitable for day to day use at Samsonite.

## Introduction

Samsonite International S.A. is the world’s largest travel luggage company. Their products are sold in over 100 countries in Asia, North America, Europe and Latin America through a variety of wholesale distribution channels, both in retail stores and through e-commerce. In Chile, Samsonite works under the name Samsonite Chile S.A., importing travel luggage and other accessories and managing four brands: The international Samsonite brand and three domestic brands, namely Saxoline, Xtrem and Secret. Samsonite owns fifty-four stores in Santiago and an e-commerce channel and distributes most of its products and brands to the largest retail stores in the area.

The Santiago region represents the largest operation and customer base for Samsonite Chile. Forty-two percent of the country’s population is located in this area, and the main players in the domestic retail store industry have their most significant operations in this city. With approximately 70 shopping centers, 54 Samsonite stores and other clients, this adds up to a total of 350 retailers located nearby. Contracts between Samsonite and most of these customers specify detailed delivery schedules with predetermined days of the week and specific time windows for shipments.
In order to manage the complexity of this network, Samsonite has two main facilities: a corporate office located in Las Condes, Santiago, that manages all the sales processes, and a warehouse located in Pudahuel, from where all shipments go out. For transportation of their products, Samsonite leverages a third-party delivery company. Although most of the shipments - especially within the Santiago area - are small in size, the third-party company has different types of trucks in order to be able to manage different sized shipments and customer requirements, and it charges a daily fee based on the number and type of trucks used on any given day. In total, twenty-seven trucks are available for Samsonite, with a total capacity of 529 cubic meters. Each day, the Operations Supervisor obtains information about orders for the next day and manually generates delivery routes based on the incoming orders and a weekly delivery calendar. Some retailers have predetermined days of the week when they receive orders, and some schedule deliveries on variable days depending on demand at each location. Meanwhile, per retailer’s contracts, deliveries must occur within predetermined time windows at each location. These time windows span on average 1 hour and 44 minutes. Delivery hours range from 07:30 to 17:00, with 85% of customers demanding delivery before 12:30. On average, unloading at each location takes one hour.

The current manual process has led to frequent late deliveries and unevenly loaded or underutilized trucks, which managers believe are undermining the company’s profitability.

Methodology

We followed a two staged approach to solve the Heterogeneous Fleet Capacitated Vehicle Routing Problem with Time Windows (HFCVRPTW): first, we developed a mathematical model and later an Ant Colony (ACO) heuristic.

We considered the following assumptions:

- The number and locations of customers are deterministic
- The number of vehicles of each size is predetermined.
- Driving and unloading times are deterministic and based on typical peak hour data

Problem formulation:

Let \( C = \{1, 2, 3 \ldots n\} \) a set of nodes which represent a set of customers and a distribution center represented as the node 0, which conform a set of nodes that have to be visited, \( N = \{0\} \cup C \). Hence, there is set of arcs \( A = \{(i, j) \in N^2 \setminus i \neq j \} \) that can be traversed. Let \( S \subseteq N \) be an arbitrary subset of nodes and for undirected graphs, the cut set \( \delta(s) = \{(i,j) \in A : i \in S, j \notin S \} \) is the set of edges with exactly one endpoint in \( S \). Therefore, for directed graphs the in-arcs are defined as \( \delta^-(s) = \{(i, j) \in A : i \in S, j \in S \} \) and the out-arcs are defined as \( \delta^+(s) = \{(i,j) \in A : i \in S, j \notin S \} \).

Each node has a demand \( q_i \), where \( i \in C \), which have to be satisfied by a heterogeneous fleet of \( k \) type of trucks, \( K = \{1, 2, 3 \ldots k\} \) with a capacity \( \lambda_k \) where \( k \in K \), and there are \( \varphi_k \) truck of each \( k \) type where \( k \in K \) with a cost of \( \gamma_k \) where \( k \in K \). Furthermore, each node has a service time of \( \phi_i \), where \( i \in N \), and a travel time of \( \tau_{ij} \) where \( (i,j) \in A \). The distance between node \( i \) and \( j \) is given by \( d_{ij} \) where \( (i,j) \in A \).

The mathematical formulation of the problem is as follows:

Decision variables:

Let \( x_{ijk} \) be a binary decision variable that is equal to 1 when de edge \( (i,j) \in A \) is covered by type vehicle \( k \in K \) and \( t_{ik} \) a continuous variable that accumulates time in node \( i \in C \) when it is visited by vehicle type \( k \in K \).
Model:

\[ \text{Min } f_1 = \sum_{i \in N} \sum_{k \in K} x_{ijk} d_{ij} \]  
\[ \text{Min } f_2 = \sum_{i \in N} \sum_{k \in K} x_{ijk} y_k \]  
\[ \sum_{j \in j \in C} x_{ijk} \leq \varphi_k \quad \forall k \in K \]  
\[ \sum_{i \in i \in C} x_{ijk} \leq \varphi_k \quad \forall k \in K \]  
\[ \sum_{i \in i \in C} x_{ijk} - \sum_{i \in i \in C} x_{ijk} = 0 \quad \forall j \in J, \forall k \in K \]  
\[ \sum_{i \in i \in C} \sum_{j \in j \in C} x_{ijk} = 1 \quad \forall i \in \mathcal{I} \]  
\[ \sum_{i \in i \in C} \sum_{j \in j \in C} x_{ijk} = \lambda_k \quad \forall k \in K \]  
\[ t_{ik} + \phi_i + \tau_{ij} = t_{kj} + M(1 - x_{ijk}) \quad \forall k \in K, \forall (i,j) \in \mathcal{I} \]  
\[ a_i \leq t_{ik} \leq b_i \quad \forall k \in K, \forall (i,j) \in \mathcal{I} \]

We have two objective functions: (1) minimizes distance while (2) minimizes the number of vehicles. Equations (3) and (4) restrict the total number of trucks to the available quantity of trucks according to their capacity. (5) is a flow conservation constraint that ensures that from each node only one node can be visited, and that each node can be reached from a single node, while (6) ensures all nodes are visited. (7) restricts the capacity of each tour to the available capacity in the vehicle performing the tour. Equation 8 follows the Miller, Tucker and Zemlin (MTZ) formulation for elimination of subtours and calculation of accumulated time. Lastly, (9) handles the time windows in which each node must be visited.

Because the VRP is an NP-hard problem and exact optimization is only applicable for small-scale instances, we developed a metaheuristic approach to solve the HFCVRPTW on both small and large-scale problems.

We selected an ACO algorithm based on evidence suggesting that it outperforms other metaheuristics in VRP problems using empirical data (Sri Asih et al., 2017). ACO algorithms are also adaptable to a broad range of VRP variations with significant potential for hybridization and integration with other systems (Gupta & Saini, 2017).

The ACO metaheuristic is one of the most frequently used in VRP research, and is inspired by the foraging behavior of ants, particularly their laying and following of pheromone trails to find the shortest path to food. ACO algorithms use artificial agents called ants, that communicate indirectly by the means of artificial pheromone trails. These trails, which change during execution based on paths followed by previous ants, contain numerical information which the ants use to probabilistically construct solutions by iteratively adding solution components to partial solutions, taking into account the dynamic pheromone trails that reflect search experience (Gendreau & Potvin, 2010).

We developed an Ant System (AS) ACO variant using five ants and with parameters of \( \alpha = 1.2 \) and \( \beta = 2.2 \).

We ran both the exact optimization and the ACO algorithm using real demand data for 10 days the company considers are representative of a typical two weeks of operations.

Results

The mathematical model results in a significant reduction in both total costs and required number of trucks, in an average processing time of 302 seconds. Daily average cost savings add up to 31%. Meanwhile, the ACO algorithm achieves on average a 24% cost reduction and requires an average processing time of 126 seconds, 42% of the time required by the exact optimization model. Results from the heuristic are on average 9% away from optimal in terms of number of trucks and 19% from optimal in terms of costs. On several occasions, the heuristic is able to converge to the best found solution.

We were also able to find one day in which the company was using a lower than optimal number of trucks, resulting in violation of time windows.
Results from sensitivity analysis suggest that the length of time windows has a significant impact on the required number of trucks and their utilization. As length increases, the algorithm is able to find better solutions with fewer trucks and higher load factors. This finding is expected to be used to guide better decisions regarding customer renegotiations at the sponsor company.

An initial trial was conducted by Samsonite using the ACO heuristic to guide routing decisions on a day with 13 demand locations. On similar days, their usual routes have typically involved the use of eight trucks, whereas the heuristic was able to find a solution using only four larger trucks (see Figure 1), at around 60% of the usual cost.

![Figure 1. ACO algorithm suggested routes](image)

Though managers decided to use five trucks instead, they achieved satisfactory results, as during the trial they were able to comply with delivery times using a much more efficient set of routes (see Figure 2).

![Figure 2. New routes used by the sponsor company](image)

**Conclusions**

In this thesis, we explored the Heterogeneous Fleet Capacitated Vehicle Routing Problem with Time Windows (HFCVRPTW) for the real-life distribution system of Samsonite Chile S.A. We implemented a mathematical optimization model and an Ant Colony Optimization (ACO) algorithm to find daily delivery routes that reduced overall number of trucks and transportation costs compared to the company's current practices. Our results show that ACO generates promising solutions that represent cost savings of around 24% and meet the service levels contracted with customers. ACO converges to solutions that are on average 19% away from the best found solutions obtained from the exact optimization, in less than half of the processing time. The sponsor company is in the process of piloting the use of our ACO algorithm in their daily distribution operations.

**Cited Sources**


Defining Strategies to Mitigate Supply Risks

By Nadja Gassner and Humberto Pardi
Thesis Advisor: Alejandro Serrano, Ph.D.

Summary:
This thesis tackles supply disruptions coming from second-tier suppliers by identifying the main drivers, measuring the monetary value at risk and defining tailored strategies to manage and mitigate the risk per production facility.

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KEY INSIGHTS
1. Dealing with suppliers that are vertically integrated is very efficient but comes at a risk.
2. Understanding the operational and business of second-tier suppliers is crucial to assess supply risk.
3. Measuring raw material risks leads to tailored mitigation strategies that can prevent a supply chain disruption.

Introduction
During the summer of 2018, the Food and Beverages Industry in Europe suffered from scarcity of carbon dioxide (CO₂) as a raw material for soft drinks production coming from a decrease in supplier production volumes. This was deteriorated by an under forecasted demand given the fact that the season reached higher sales than expected due to the high temperatures and the influence of the football World Cup. The lack of availability of CO₂ resulted in a threat to finished goods availability in the UK, France, Poland, Ukraine, and other countries, creating emergency supply chain costs for many companies (Davies & Butler, 2018). The sponsor of this thesis, a soft drinks manufacturer, was affected because of this situation. CO₂ is a cheap raw material that is purchased from industrial gas suppliers, who have a vertically integrated supply chain and guaranteed availability through long-term contracts and vendor managed inventory. Because of this, CO₂ was of no strategic importance for companies in recent years. The purchasing of industrial CO₂ for soft drinks production can be compared to water supply. People trust their water carriers to provide them when they need and pay the bill at the end of the month without controlling their spending, but what can be done if there is a disruption at the second-tier supplier?

Methodology
This thesis aims to help building a robust raw material supply chain by applying risk mitigation strategies. In order to do so, in a first step the main causes leading to a CO₂ disruption were identified using root-cause analysis techniques. Second, the risk level was analyzed at all production facilities and a risk segmentation derived to prioritize the effort of risk mitigation. The monetary risk for the location was calculated by a value-at-risk approach. Finally, risk management strategies were proposed as short-term solutions and tailored risk mitigation strategies as long-term solutions.
Analyzing root-causes and segmenting the risk

**Capacity**

The market risk is driven by the fact that CO₂ is largely a by-product of the ammonia industry, where the maintenance period is in summer when production of beverages is the highest. Consequently, the risk of the sponsors’ plants increases if their suppliers are sourcing from ammonia sources.

**Inventory**

CO₂ is stored in high-pressured tanks that have a size between 20 and 50 mt. In many cases these tanks belong to the supplier. Short-time inventory adaptations are constrained by this fact.

**Number of sources**

CO₂ prices are mainly driven by the transportation cost. Therefore, CO₂ is provided from local sources to the plants. Mapping the geographical location of the sources around the plants, regions with few sources can be identified.

**Flexibility**

The global market of industrial gases is an oligopoly with a few strong players. CO₂ volumes that are at risk in summer are small volumes for the main suppliers, and their willingness to serve these volumes is low. This leads to a non-existent spot-market and limits flexibility to supply CO₂. In addition, each source of CO₂ must be audited and be a certified to a standard purity level.

These root-causes can be clustered into internal factors and external factors. The external factors are conditioned by the market structure and define the risk. In this case, external drivers are the dependency on ammonia and the scarcity of sources. These risks were quantified for each plant to segment them according to their level of risk intensity.

In order to estimate the risk horizon of a facility with multiple sources, the monthly contracted volume of the suppliers and their dependency on ammonia were used to determine the expected monthly volume of non-ammonia CO₂. Then, taking the daily average of the highest monthly consumption in the last years, it is possible to determine the days of CO₂ inventory at risk.

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Dependency on Ammonia</th>
<th>Monthly Contracted Volume</th>
<th>Non-Ammonia CO₂ Volume/Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier 1</td>
<td>80%</td>
<td>200</td>
<td>40</td>
</tr>
<tr>
<td>Supplier 2</td>
<td>60%</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>Total Non-Ammonia Volume/Month</td>
<td></td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Max Daily Consumption</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Days of Inventory Secured</td>
<td></td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Days of Inventory at Risk</td>
<td></td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

The volume of CO₂ at risk is obtained by multiplying the days of inventory at risk by the expected maximum daily CO₂ consumption. Then, by dividing this raw material risk by the consumption per liter produced, the finished goods volume at risk is determined.

The net revenue per plant can be translated into net revenue per liter of finished goods produced by dividing between the yearly production volumes. Finally, the finished goods value at risk for any given plant can be calculated as the net revenue per liter multiplied by the amount of finished goods that are at risk for that plant.

The risk measurement has been conducted on all company plants, estimating a value of €24 million per year and distributed among 5 countries.

**Managing and mitigating supply risk**

Risk management strategies focus on short-term solutions and back-up the CO₂ supply in case of a disruption. A first measure is to engage with identified small suppliers on option contracts. These option contracts will be the right to purchase a certain amount of CO₂ but not an obligation in exchange for a relatively high purchase price. In order to ensure a response time for these suppliers, an internal benchmark of a minimum inventory of 5 days was established. With additional tanks and an increase of the order frequency this benchmark can be achieved at all plants. The CO₂ inventory held as a response time accounts for a value-at-risk of 2.4 million €.

Risk mitigation has the goal of building a robust supply chain unsusceptible to any risk coming from a supplier. Therefore, the risk mitigation measures should cover the total risk value calculated.
**Self-Generation**

In order to obtain more control over the supply chain, big companies try to invest to become vertically integrated. In the case of the CO₂ industry, on-site self-generation by natural gas combustion can be achieved in countries were electricity and natural gas prices are low enough to bring a return on an investment of 1.2 million €.

A self-generating unit has been proposed to be located in one plant in Ukraine and one in Russia, were its CO₂ production capacity has the capability of fulfilling the whole consumption of CO₂ during the summer, reducing the risk value in 10.7 million €.

**Raw material substitution**

Estimates gathered from the companies’ plants show that from 35% to 50% of the annual contracted volume of CO₂ was either waste or used in the production process. Some processes present the opportunity of substituting the CO₂ used with nitrogen (N₂). Given a substitution of 22.6% of the used CO₂ in Poland, 1 week of additional inventory can be secured during the summer, reducing the risk value by up to 6.3 million €.

**Strategic Inventory**

Strategic inventory is additional stock that is independent from the daily replenishment policies and will only be touched in case of a crisis. In order to decide a reasonable location, the remaining value-at-risk determines the volumes needed. To reduce the risk in the two plants in Poland, a strategic inventory would be needed there. As there are constraints in terms of space, an alternative location is Ukraine. This location allows to take advantage of the self-generation facility and will turn the location into a strategic hub for CO₂. With this measure, the 4.9 million € remaining risk will be mitigated.

These measures achieve to reduce the total value-at-risk and can be summarized in the figure below.

**Conclusions**

This thesis includes in a first step the risk mapping and value-at-risk measurement and in a second step the mitigation of the value-at-risk. This general concept can be applied by any company with an internal supply risk coming from first-tier or second-tier suppliers. The detailed risk management and risk mitigation measures that are mentioned can be adapted by companies facing a supply risk coming from an oligopoly market structure.

Internal supply chain risks can be controlled because the frequency and predictability of events is much higher than external risks and the impact is much lower. Because of this, once the bottlenecks are identified, it is possible to build strategies that account for the whole risk and not just on the expected risk value based on the low probability of an external risk occurring. To reduce raw material risks, scholars propose diversification of suppliers, but there are some industries like the industrial gases where suppliers share the same sources of raw material, and therefore, diversification of sources or second tier suppliers is of great importance. Dealing with raw materials where suppliers are vertically integrated and offer end to end supply chain solutions is very efficient, but it obviously comes at a risk.

**Cited Sources**

Applicability of Robotics Process Automation (RPA) in Global Procurement

By Lorena Callejas and Byulha Kim
Thesis Advisor: Gültekin Kuyzu, Ph.D

Summary:
This project tackles the questions of which operational activities are practically applicable to RPA in the Procure to Pay (P2P) process to ensure efficiency gains and the compliance in payments to suppliers, and thereby, support an overall digital transformation strategy within a company.

KEY INSIGHTS
1. Process should be well-designed and understood before implementing RPA, so bad practices don’t get automatized.
2. High manual transaction volumes, standardization and rule-based activities and level of human intervention are key elements to identify activities candidates for RPA.
3. RPA can bring economical or/and efficiency benefits to the company.

Introduction
The world is being transformed by technologies that are changing the way it works at a speed we have never experienced before. It is entering into a digital revolution that is leading companies to transform their operations to be more efficient and competitive.

Industry 4.0 is a disruptive trend within the companies because of its impact on value creation to the business, and in the recent years, production and logistics have being the main areas in which companies are focusing on transforming their operations. Nevertheless, the Procurement area is recently being considered as part of Industry 4.0.

One of the most popular technological advances within Industry 4.0 is the Robotic Process Automation (RPA). RPA is robotic software that relieves employees of doing tedious repetitive and operational tasks, allowing them to increase their competences and build value in other areas where is needed. (Kopec et al., 2018). The rapid and recent advances in RPA technology in the Procurement field and the increasing number of companies looking to adopt robots- offers strong motivation for Procurement Managers to seriously consider the deployment of robots for process automation in their companies.

For this, it’s important for companies to evaluate their current processes and identify the opportunities for automation by robotic techniques before implementing them.

Problem statement
A Company is on a continuous journey of optimizing its business through a digital transformation...
technology. The procurement area, wanting to get on board this journey, wants to analyze the possibility of implementing RPA in the operational part of the P2P process. The company is having delays in payments to its suppliers of indirect procurement, which represents €450M in purchases expense per year. The objective is to implement RPA in the process to increase efficiency so the relationship with suppliers is not compromised and payments can be made on time.

Our approach focused on understanding the current situation of the P2P process through interviews with process owners and evaluating activities in order to identify activities that could be potentially automated.

**Methodology**

To assess and design the P2P process we used the DMAIC methodology for process improvement. This methodology consists of five important steps:

- Define: develop a focused problem statement.
- Measure: document the current process and assess baseline performance.
- Analyze: collect input and evaluate.
- Improve: understand top causes and identify possible solutions.
- Control: sustain changes (DMAIC Tools).

After understanding the current situation, it was necessary to evaluate which activities were candidates for automation. RPA is a digital tool relatively simple to implement, is not as expensive as other technologies, and the return on investment is usually in the short term. Nevertheless, it cannot be implemented without a deep understanding and analysis of the scope of the process because not all activities are candidates for automation. For this evaluation, three elements were considered: volume transaction level, standardization and rule-based level, and human intervention level.

**Understanding the current situation**

In order to understand the current situation of the P2P process and to achieve the highest priority goals of this project, workshops with key users of the process were performed, in order to appreciate the detailed actions in each step and recognize potential activities that could be automatized. The actual P2P process flow is described as follows:

**Evaluating activities**

To identify candidate activities for automation, an evaluation for each one of them was performed, based in three elements.

The first element considered was high-volume manual transactions. These activities should be simple and repetitive and should not need any analysis or decision making (Lacity 2012).

The second element considered was the level of standardization and rule-based of the activity. “Exceptions are critical for robots because they are not intelligent. If there are exceptions in the process, robots don’t know what to do with them. In this case, robots need to skip these tasks and leave them to the humans” (Lintukangas, 2017). On the other hand, activities that are rule-based are candidates for RPA because the robot will act according to the rules provided without the need to analyze or make any decisions. There will be a factor that determines a specific result based on rules determined by the company.

The last element considered was the level of human intervention. This means that the task requires analytical and decision-making processes, which cannot be done without professional skills and cannot be taught to RPA (Lintukangas, 2017).

According to the evaluation, the first activity to automate is number 4 (create purchase order). Nevertheless, this activity is already performed automatically by the ERP; once the shopping cart is approved, the system automatically sends the purchase order to the supplier, so there is no need for an RPA implementation in this activity.

The next two activities that could potentially be automated, are number 2 (review shopping cart) and number 7 (receive invoice and perform 3WM). Although these activities have exceptions in the...
process and are not entirely rule-based activities, it is still possible to apply RPA, not for 100% of the cases but for the ones that are most common, in order to reduce the volume processed by the workforce.

Finding possible solutions

Activity #2: Review shopping cart

The shopping cart review consists of crossing information between the system and the quotation, such as price, quantity, product or service, supplier, or payment terms, among others. This is a manual validation that has to be performed by Operational Purchasers for every single Shopping Cart created in the system. According to the data delivered by the Company, from January to September of 2018 more than 20,000 Shopping Carts where created for indirect procurement.

Given that this activity is based on just reading information and validating that it is the same, there is no need for a person to do this for every Shopping Cart. The application of RPA for this activity consists of automatically crossing the information and generating a log with only the documents that have a discrepancy between them, which will be the Shopping Carts that are reviewed by a person.

For the RPA to be able to read the supplier’s quotation, it is important to create a general template in which the vendor will fill all the information regarding the good or service to be purchased and this document should be attached to the Shopping Cart.

Activity #7: Generate 3WM

The 3WM activity is performed by the Company’s ERP; nevertheless 90% of them are re-processed manually because of inconsistencies between the three documents (Purchase Order, Confirmation Receipt and Invoice) that are presented for several reasons. One of the most common one is that the Confirmation Receipt is missing (15% of Confirmation Receipts are done on time) so when the ERP systems runs the 3WM, it cannot validate the information correctly because the Line of Business never registered the reception of the product or service in the system. When this happens, the person in charge of re-processing the 3WM has to follow up with the person in charge in order to receive the product in the system.

If the company implements RPA for this activity, when the robot encounters a situation like this, it will automatically send an alert to the person that created the Shopping Cart in order for him/her to accept the product or the service in the system. This alert could be an email sent to the employee, which contains a link (to the ERP web system) or it could be sent through an application to the employee’s smartphone, making it really simple for the person to accept the good or service in the moment he/she gets the alert.

These solutions will reduce the volume of Shopping Carts and 3WM that humans have to review and follow up, allowing them to dedicate that time to other activities that can generate more value to their area and the business.

Conclusions and recommendations

During the project, we could identify that Company has been doing some of the tasks manually in the procurement department and data management has not been systematic, for this reason it was not easy to identify what were the root causes of problems that were presented in the process. For this reason, it would not be easy for the Company to introduce RPA directly into the whole business processes.

Therefore, the Company would be able to maximize the benefit of RPA application, by at first, introducing it partially to certain activities and then gradually expanding the application range.

In this case we analyzed the operational part of the procurement process (P2P) which is the right way to introduce RPA. After the analysis performed in this project, we could identify two potential activities that could be automated by RPA. These solutions will reduce the volume of Shopping Carts and 3WM that humans have to review and follow up, allowing them to dedicate that time to other activities that can generate more value to their area and the business. These activities are estimated to have a visible effect of improving work efficiency by 29%.

Additionally to this initial efficiency gains, the value that this implementation could bring to the Company is what it can do next with all the information that is going to be generated in the process. The Company will have the causes of all the discrepancies of information between documents in the two activities. Once it has enough information, after the first year, the Company will be able to identify other main root causes for mismatches and set additional rules for the robot to follow for those specific cases and reduce the volume of transactions processed by employees even more.
As a recommendation, the Company should prepare for the detailed strategy of management for external reputation and potential decline of morale for employees due to the RPA application, and advanced planning for employees whose job roles are changed or even terminated after application of RPA. The maximization of the effects derived from RPA could be achieved only when systematic preliminary planning and thoughtful action change are concurrently accompanied by efforts to minimize the possible negative effects of RPA application.

**Works Cited**

DMAIC Tools, https://www.dmaictools.com/


Network Optimization of Spare Parts Logistics Flows in a Global Scale

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Summary:
This study proposes a Supply Chain Network Design model for Spare Parts in the Personal Computer industry that goes beyond the company boundary to reach the supplier’s network. The goal is to unfold hidden synergies that may lead to cost reduction opportunities by facing third party assets as a possible extension of a company distribution network.

Introduction
The ever-increasing level of competition among companies in the consumer goods industry has forced players towards numerous cost reduction initiatives in order to sustain their value propositions.

In this sense, companies competing in the Personal Computer industry went into a process of outsourcing their production to China, setting up global HUBs to fulfill the demand in more developed countries. This phenomenon has led to lower total sourcing costs in exchange for increased need for coordination of international logistics to move products on a global scale.

During decades, the mechanics of the third parties’ operations were ignored by the companies that contracted their services since much optimization was still possible within their own operations. The company behind this case study is no different. A series of footprint review initiatives were conducted generating great supply chain savings.

Now, with the EMEA (Europe, Middle East and Asia) Spare Parts network at a mature state, supplying more than 100 countries through 22 local hubs and one Distribution Center, the organization saw an opportunity to extend the scope of the supply chain beyond the company boundaries. The goal was to include the 3PL facilities in an end-to-end mathematical model to reveal new network optimization opportunities.
The model was created using the Supply Chain Guru software from Llamasoft, a tool designed to deal with complex projects at a global scale. Several possible combinations of flows were analyzed to get to an optimal scenario that represents savings of €2.21 million per year.

**Setting up the scenarios**

The studied supply chain operates in five layers or echelons. The two first layers are owned by the 3PL (one in China and one in the Czech Republic), while the next three are managed and operated by the company (the DC in Netherlands, Country Hubs and Clients Locations).

![Figure 1: Representation of the multi-echelon network](image1)

This multi-echelon footprint is mostly linear, meaning that products flow from the supplier in China to a hub in the EMEA region to then reach the company DC that ships products to the Country Hubs and, finally, clients. Most orders go through all these 5 locations before being fulfilled (exceptions are urgent shipments and specific events or resale flows).

The scenarios to optimize the product flows tested how the 3PL network could be leveraged bypassing some of the current nodes that represent additional moves and consequently additional transportation, handling and inventory costs. These possible links were analyzed by first generating a Baseline that reflects the current operation showed in Figure 1 and then relaxing three specific flow constraints to identify the opportunities. The constraints relaxed are:

1) Ship to Country HUBs directly from China.
2) Ship to Country Hubs directly from Czech.
3) Ship to the DC directly from China.

![Figure 2: Scenarios tested on the model](image2)

**Building the optimization model**

Once the scenarios were structured, the most challenging part and the core of this study was building the optimization model. With workshops and deep dive sessions into planning, logistics and finance areas, 32 Key Design Decisions were made, data regarding Costs and Master Data was collected and cleaned to fill 14 tables in the system.

When dealing with a third party a lot of uncertainty is included. The lack of involvement and the confidentiality terms in the contracts with the 3PL make the input data less accurate increasing the need of extensive sensitivity analysis on the most uncertain assumptions.

After interactions and adjustments, the Baseline model had €42 million in annual costs with an adherence of 98% to the actual P&L, representing very well the operation. Still, costs for the new links had to be gathered, so a mix of rate cards from other business units and new assumptions were made.

![Figure 3: Baseline with linear model and €42 million in costs](image3)
Selecting the optimal model

By relaxing the Baseline constraints, new possibilities were analyzed. It turned out that all the changes resulted in savings being the flow from China to the DC in Netherlands the most relevant one.

The scenario selected represents the best alternative to supply each of the 22 Country Hubs. Four of them are supplied directly from the Chinese HUB, representing €0.69 million in annual savings. Three are supplied from the Czech Hub of the supplier representing €0.14 million in annual savings. This node also supplies 11 countries for direct client delivery of resale products and this change generates a cost reduction of €0.55 million per year. Finally, the remaining 15 Country Hubs maintain their supply in the Netherlands DC, which has the parts coming straight from China, and this new link represents €0.83 million in annual savings.

The majority of the savings come from inbound and outbound costs reduction. Transportation and taxes play a small role in the model and the same happens with inventory holding costs that go slightly up due to increased lead times on the new flows. The total reduction of €2.21 million per year represents 5.3% of the €42 million Baseline.

Conclusions and Recommendations

In this work, we expand the classic approach of Network Optimization to include the supplier network on the end-to-end model. By doing so, we faced new challenges such as access to the supplier data and the need to stress assumptions.

The results must be faced as a first step towards a higher integration among the two networks. Going forward the company will have the challenge of implementing the changes by negotiating the savings split with the 3PL and ensuring the new rates. The ordering process will need to be adapted to the Country Hubs, and inventory policies will need to be adapted.

The use of a leading-edge tool was an accelerator and allowed the team to focus on the scenario analysis. Additionally, it equipped the company team with a powerful analytical model that represents the end-to-end Supply Chain operation of Spare-Parts in the EMEA region allowing further enhancements and projects. Among these future initiatives we suggest a prioritization of the joint inventory planning that is estimated to generate at least €3 million per year.

Cited Sources


PROJECTS

Cost Estimation Modeling for Procurement of PCBA & Electronic Components
Team: Poornima Baba, Shantanu Patil, David Uherka
Advisor: Dr. Yasel Costa

This project investigates a cost estimation technique for Printed Circuit Board Assembly (PCBA) in electronic components. Statistically based non-parametric models were formulated to estimate PCBA prices for different development stages. Consequently, it will enable both the R&D and Procurement departments to make more informed and accurate decisions in costing and design.

Improving Productivity Measurement in Clinical Supply Chains
Team: Carlos Arto, Walter Soriano
Advisor: Dr. Spyridon Lekkakos

The main objective of this thesis is to evaluate and provide recommendations for improving the procedures currently in use to measure productivity in the supply chain dedicated to clinical trials in a pharmaceutical company, a leader in the sector. The key question to address is: How to improve the productivity measurement in clinical Supply Chains?

Airline Inflight Wine Distribution Capabilities for a Freight Forwarder, from Supplier to Caterer
Team: Miguel García, Valeria Paternó
Advisor: Dr. Susana Val

This thesis tackles the characterization of the inflight wine distribution and the research question on how to measure and improve the distribution network of in-flight beverages, by adopting a supply chain reference framework approach, implementing the applicable KPIs and monitor the processes that are most likely to cause performance gaps.

Saving lives while saving money: Forecasting and Planning Strategies for a new product launch in the Pharmaceutical Industry
Team: Gloria Corella, Richard Ward.
Advisor: Dr. Yasel Costa

This thesis faces the supply chain challenge of a new flu medication launch. High demand volatility, long lead times of pharmaceutical industry and short shelf life characterize the problem. The goal of this project is to provide inventory management and business recommendations in order to mitigate demand uncertainty.

Sellout Predictive Model for a Consumer Electronics Company
Team: Carlos Illades, Diego Maldonado, Ana Viann
Advisor: Dr. Mustafa Çagri Gürbüz

This thesis addresses the problem of determining the main factors that influence the sellout of consumer electronics devices and describes a process to incorporate those attributes into a predictive model applying novel automated learning techniques.
Distribution Cost Modeling and Forecast in Clinical Supply Chain
Team: Guillermo Nieva, Alejandro Sandoval
Advisor: Dr. Yasel Costa

The project is about forecasting the cost for a clinical trials supply chain. It is developed in a network that involves self-owned distribution centers and third-party logistics providers. Exhaustive data cleaning was performed to compare it with the activity reported in their Distribution System. Subsequently, modelling through several machine learning algorithms was executed to finally provide a prescriptive model that highlights the variables with more cost impact.

Fuel Truck Fleet Efficiency Study, DEA benchmark approach among different markets
Team: Isaac McCracken, Nathalie Outeiro
Advisor: Dr. Gültekin Kuyzu

This study examines twenty-six petroleum distribution fleets in three countries with the objective of identifying the efficiency frontier using Data Envelopment Analysis. Inefficient fleets are examined to determine possible action plans to improve performance with special focus on the Argentine fleets.

Supply Chain Segmentation in FMCG Industry
Team: Pablo Fernández, Pau Seres, Juan Toruño
Advisor: Dr. Spyridon Lekkakos

This thesis assesses the benefit of applying specific Supply Chain configurations adapted to the different customers’ behaviors, within the Fast Moving Consumer Goods industry. Additionally, a methodology to shift from a One-size-fits-all strategy towards a Segmentation strategy based on a Menu Of Services is proposed in order to boost the profitability of the company.

Supply Chain in Armed Conflict: Does it pay to save?
Team: Hani Alkhatib, Gilmar Centeno, Cándido Pérez
Advisor: Dr. Yasel Costa

This research models the main operations of goods delivery from an INGO helping during a protracted conflict in Syria. Our results via cost simulation support practitioners’ views which focus on efficacy (responsiveness or agility) instead of efficiency (minimal cost). Furthermore, the research suggests the convenience of including social costs in Humanitarian Supply Chain Network Design.

Prescriptive and Descriptive models for improving efficiency in Logistic Processes
Team: Nasir Khan, Francisco Suárez
Advisor: Dr. Gültekin Kuyzu

In this thesis, we build an interactive simulation model to evaluate different future scenarios and recommend improvements for the material management function of a mining company. After analyzing the current status, we studied a large amount of data, and finally, we modeled the operation as a dynamic system. In our study, we generated a proposal to improve the effectiveness of the function, not only to reduce the growing trend in the inventory levels, but also to improve the current levels of service.

Use of Advanced Digital Technologies in Integrating External Manufacturing Planning
Team: Santiago Cuadrado, Cavit Tosun
Advisor: Dr. Mustafa Çagri Gürbüz

We demonstrate how Robotic Process Automation (RPA) can be used as a temporary tool to handle an increased amount of information sharing processes in supply chain systems. By creating proof of concepts based on real business scenarios, we showcase how RPA’s fast development complement traditionally slow ERP implementations.
Bio-Inspired Algorithm for Optimization of Delivery Routes
Team: Adriana Aragón, Sergio Correa
Advisor: Dr. Gültekin Kuyzu

In this thesis, we model a real-life case study of outbound distribution as a rich Vehicle Routing Problem (VRP). We develop an exact mathematical model and an Ant Colony Optimization (ACO) heuristic. The heuristic was successful in reducing transportation costs and number of trucks to near-optimal values and is projected to be used to guide future routing decisions at the company.

Strategic Supply Risk Management of a Key Raw Material
Team: Nadja Gassner, Humberto Pardi
Advisor: Dr. Alejandro Serrano

This thesis tackles supply disruptions coming from second-tier suppliers by identifying the main drivers, measuring the monetary value at risk and defining tailored strategies to manage and mitigate the risk per production facility.

Applicability of Robotics Process Automation (RPA) in Global Procurement
Team: Lorena Callejas, Byulha Kim
Advisor: Dr. Gültekin Kuyzu

This project tackles the questions of which operational activities are practically applicable to RPA in the Procure to Pay (P2P) process to ensure efficiency gains and the compliance in payments to suppliers, and thereby, support an overall digital transformation strategy within a company.

Optimization of Spare Parts Logistics Flows in a Global Scale
Team: Jaime Aróstegui, Giuliano Babbini, Damián Diéguez
Advisor: Dr. Gültekin Kuyzu

This study proposes a Supply Chain Network Design model for Spare Parts in the Personal Computer industry that goes beyond the company boundary to reach the supplier’s network. The goal is to unfold hidden synergies that may lead to cost reduction opportunities by facing third party assets as a possible extension of a company distribution network.
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