Development of analytical, evaluation and improvement tools, of distribution and pick-up processes within a courier logistic system

Bernardo Roque de Carvalho Freire de Abranches

Department of Engineering and Management, Instituto Superior Técnico

Abstract

The current economy context is highly competitive, competitiveness which is more significant if the focus turns to the parcel industry, with a very significant rise of supply from the emerging economies. Considering all these factors and taking into account the relevance of this industry to the other sectors of the economy, there is an enormous need of continuous improvement and optimization of the processes on this activity.

Rangel Expresso – company exclusively dedicated and responsible for the operation of FedEx in Portugal – acknowledges the potential of improvement on their processes of delivery and pick-up, and it is in this context that the motivation to develop the present work arises.

It was performed a characterization of the industry and of the company, the limitations and constraints imposed on the analyses have been identified, so that subsequently an evaluation of the actual process could be done, having as the only key performance indicator possible to calculate: distance. Afterwards, it was computationally implemented the different proposed methods and an analysis of the outcome was performed.

Finally, the conclusions regarding all the work were exposed, and some suggestions of future improvements were done, taking into consideration two different scenarios: respecting the constraints imposed by the company, and questioning these constraints.

Key-words: Rangel Expresso, FedEx, parcel industry, optimization, traveling salesman problem.

1. Introduction

The parcel industry is a key industry on the global economy. It plays a critical role on the reduction of asymmetries between countries in different stages of development, and promotes an increased integration from the most peripheral areas of the globe.

The continuous pursuit for an increase of processes efficiency is one of the main objectives of companies on the modern era, due to the general growing of the competitiveness on a global economy, this increase of the efficiency drives to a reduction of operational costs and creates the basis for a sustained increase of the profits.

According to the Global Express Association

(2015) this industry operates in more than 220 countries, and contributed with 140 billion dollars to the global GDP in 2013, generating 3 million jobs, directly and indirectly.

A report produced by Accenture (2015) refers that the number of volumes shipped grew 7%, in average, from 2010 to 2015, after some years of stagnation due to the 2008 financial crisis, the predictions state that the growth will continue on the coming years.

E-commerce has a significant impact in the success of the industry, and is a major driver of the future growth. A growth of 13% for e-commerce transactions were predicted to 2016, and in 2025 it might reach the 40% of the total of shipped volumes on the developed countries, and 30% on the remaining (Accenture, 2015).

Having all these facts under consideration, an increase of the operational efficiency is a key factor for the survival and success on this competitive environment. It is on this context that this work emerged: the present work aims to give a contribute on the development of tools to analyze, evaluate and improve the efficiency of the processes of delivery and pick-up on an industry with the specifications this has.

The Rangel Expresso operation (the Global Service Participant of FedEx in Portugal) - and its routes operating in Lisbon - will be the object of study. After a careful analyses of the quality of the present processes, alternative solutions will be proposed (respecting all the constraints imposed by the company), so that a subsequent comparison between the alternatives and the current method may proceed.

Finally, a conclusive analyses will be performed, with some future improvement suggestions.

2. Research Background

In order to reach the proposed objectives, there are three main topics that must be studied: Key Performance Indicators, Traveling Salesman Problem, Vehicle Routing Problem.

2.1 Key Performance Indicators

The main challenge on the definition of the performance indicators is to determine which are the indicators to be used, what is the best way to present them, and in which metrics should be expressed (Phillips et al., 1999). Halme (2010) refers the importance of making a careful selection, it is preferred to use few relevant indicators, instead of using many which can become difficult to interpret and inter-connect.

2.2 Traveling Salesman Problem

This is an Operational Research classic problem, in which the salesman has to visit *n* cities, one time only, and return to the origin, at the minimum cost. The objective is to determine which path will originate the minimum cost. The metrics used to do so, may be very diverse: distance, time, gas consumption (Matai et al., 2010). The problem is represented by a graph formed by nodes and edges, the nodes represent locations that must be visited and the edges represent the path and have an associated cost. According to Kumar & Li (1996) the cost between two points *i* and *j* is not always the same in both directions, when this occurs it is considered an asymmetric TSP.

Oliveira (2011) states that it is possible to solve this problem using exact methods, however this is the case in simple situations with a small dimension. Approximation methods are indicated to the majority of the problems, considering these methods there are different types of heuristics, such as construction heuristics (1), improvement heuristics (2) and metaheuristics (3):

1 – Algorithms constructed step by step, and stop whenever a solution is found, do not try to

improve it (Oliveira, 2011);

2 - These heuristics try to improve solutions generated by some construction heuristics, by removing, changing and introductions of nodes or edges (Oliveira, 2011);

3 – According to Hillier & Lieberman (2005), these heuristics are used to deal with problems that present a high level of complexity. The main difference, comparing to the previous heuristics, is the incorporation of procedures which avoid the stagnation in local optimal solutions (Oliveira, 2011).

Due to some constraints imposed by the company, the TSP was the chosen approach to optimize the routes under study. They are not interested in changing the zones in which the couriers operate, it is part of their culture and policy. The problem consists on a group of TSP's.

There is a relevant difference between the studies performed around this problem and our case of study: in this case we have a precedence constraint between two groups of nodes, first all the deliveries must be satisfied, and just then all the pick-ups must be dealt with. The origin of the deliveries is the last point to visit of the pick-ups stage. The last point to visit on the deliveries stage will be the origin of the pick-ups stage. It can be found several works around TSP's with precedence constraints, but generally it is regarding situations where a point must be visited just before another point. In the present situation we face a set of points that must be visited before another set of points, and this will originate a different challenge.

2.3 Vehicle Routing Problem

Although the TSP was the chosen approach, it is not possible to perform this work without any references to this problem, which theoretically would represent the ideal approach. Suthikarnnarunai N. (2008) states that the premises of the problem are similar to the TSP: the objective is to deliver goods, from an origin, to a set of clients, using a fleet of vehicles, within a time window, respecting all the constraints, at a minimum cost. Each vehicle has a limited capacity and an associated cost. It is possible to define other objectives, such as the reduction of the fleet or to minimize associated penalties to a poor service level (Suthikarnnarunai, 2008).

3. Implementation of the model

The first step is to evaluate the present method of deliver and pick-up, followed by a simulation of the results in case another method was applied. In this situation it was decided to use R, a programming language that makes it possible to generate the pretended results. The data requested to the company referred to the month of February, considered a typical month on this industry.

3.1 Limitations

Additionally to the limitation imposed on the analysis (there is no permission to change the zones where each courier operates), some others aroused such as a strong limitation of the data range of analysis. Some routes seemed incomplete (lack of information or lack of justification for atypical data), and only the distances were possible to calculate.

3.2 Evaluation of the present method

With the data provided (two Excel Spreadsheets, one for deliveries, another one for pick-ups) it was necessary to organize the visits chronologically and to search for missing coordinates, in order to create the appropriate conditions to calculate the distances.

3.2.1 API (Application Programming Interface)

It was necessary to develop an API to be able to calculate the distance between the different points, by road. This service is integrated on the

Google Maps JavaScript API, for that reason it was used the programming language JavaScript. It was also needed to generate a minimalist web application – using PHP (a server side programming language) – that would enable the calculation of the distances on a file and on a web page.

3.3 Implementation of the algorithms

After having all the distances calculated for the present method, it was necessary to generate the distances between all the points visited in each day, for each route, in order to build an asymmetric matrix to introduce on the script needed for the next step.

3.3.1 R

R consists on a programming language created on a free software also named R, and it can be extended by downloading packages. In the present case it was required to download the "TSP" package, which allows a comparison between the heuristics available:

- Nearest Neighbor;
- Repetitive Nearest Neighbor;
- Nearest Insertion;
- Farthest Insertion;
- Cheapest Insertion;
- Arbitrary Insertion;
- 2-Opt.

Afterwards, it is necessary to write a script (where the asymmetric matrix is included), that after inserted on the R environment will generate the pretended results.

3.4 Results

At this step, the distances - correspondent to the different methods and routes - were congregated and organized in order to perform the subsequent analysis. It was possible to consolidate it in Tables 1 to 3:

Table 1 – Comparative results (in absolute and relative terms) between the different routes and methods (Part 1)

Heuristics / Routes	Nearest Neighbor	Nearest Neighbor (r)	Nearest Insertion
LI100	870,8	790,6	752,2
	(-31%)	(-37%)	(-40%)
LI110	1088,9	987,7	924
	(-30%)	(-37%)	(-41%)
LI120	1080,3	933,5	880,7
	(-35%)	(-44%)	(-47%)
LI150	769,4	667,1	613,5
	(-27%)	(-36%)	(-42%)
LI190	1336,6	1187,4	1136
	(-30%)	(-38%)	(-40%)
LI193	663,1	583,6	562,7
	(-17%)	(-27%)	(-30%)
LI292	602,7	577,1	567,4
	(-8%)	(-11%)	(-13%)
TOTAL	6411,8	5727	5436,5
	(-28%)	(-36%)	(-39%)

Table 2 – Comparative results (in absolute and relative terms) between the different routes and methods (Part 2)

Heuristics / Routes	Farthest Insertion	Cheapest Insertion	Arbitrary Insertion
LI100	755,9	748,1	748,2
	(-40%)	(-41%)	(-41%)
LI110	954,5	944	950,6
	(-39%)	(-40%)	(-39%)
LI120	892,9	876,2	866,3
	(-46%)	(-47%)	(-48%)
LI150	623,5	600,2	620,5
	(-41%)	(-43%)	(-41%)
LI190	1151,6	1131,4	1143,3
	(-39%)	(-41%)	(-40%)
LI193	570,7	565	568,6
	(-29%)	(-29%)	(-29%)
LI292	573,3	568	569,5
	(-12%)	(-13%)	(-13%)
TOTAL	5522,4	5432,9	5467
	(-38%)	(-39%)	(-39%)

Table 3 – Comparative results (in absolute and relative terms) between the different routes and methods (Part 3)

Heuristics / Routes	2-Opt	Present method
LI100	972,7 (-23%)	1260,6
LI110	1174,1 (-25%)	1564,4
LI120	1132,5 (-32%)	1666,4
LI150	742 (-29%)	1050,5
LI190	1440,9 (-24%)	1903,2
LI193	638,5 (-20%)	801
LI292	599,2 (-8%)	651,7
TOTAL	6699,9 (-25%)	8897,8

3.5 Critical analysis of the results

It is clear, by reading Tables 1 to 3, that there is an enormous potential of efficiency increments. There are some reasons that justify these results:

The main reason is the disorganization of the processes, there is a limited control of the couriers and they have the responsibility to manage their own routes, without supervision. It is only required that they visit all the points they must visit (the deliveries and pick-ups are divided by postal codes correspondent to the zones of influence of each courier), however this originates some problems. This absolute independence may lead to highly inefficient paths that the couriers may take for personal reasons, for example. Moreover, there are some scans (which are connected to the FedEx and Rangel Expresso system) that are valid justifications for not being able to successfully deliver a volume, such as the absence of people on the destination address, this system can be easily corrupted by the couriers.

Another valid reason to these expressive results is the nature of the pick-up process, which has a partial dynamic nature. The majority of the pick-ups are previously scheduled, however there are a few pick-ups that are requested (within a certain time window) during the routes and this factor was not possible to replicate on this analysis. It is a small portion of the pick-ups (which represents 35% of the total distance between the two phases), but certainly it will affect the results.

It was also performed an analysis excluding atypical routes, as it was the case of LI193 and LI292. The author of this study believes that the data correspondent to these routes had some serious limitations, considering that some days (mainly on the LI292 route) there was just one point to visit, which is impossible to optimize and a waste of resources. After excluding these routes from the analysis, the results – expectedly – decreased, however not significantly enough to question any of the previous conclusions (3% on average for all the methods).

4. Conclusions

This work had the purpose of developing analytical, evaluation and improvement tools, for distribution and pick-ups processes, and despite having experienced several limitations (impossibility to redefine areas of influence, which limited the analysis to a set of TSP's, and incomplete data) it was possible to reach some strong evidences. There is an immense space to improvements, in the present reality the only defined process is the division of zones of influence by postal code, all the other processes are arbitrary. The operation runs on a survival day to day basis, instead of on a planned manner.

The first step to an improvement of the processes would be to start having updated and reliable data, this would enable the company to

increase the supervision over the couriers, to analyze properly some adequate key performance indicators (the distance is not the only important metric, the author of this work suggests the reading of the Kendal (2017) article - which refers to the “no turn left” policy adopted by UPS - as an example), and then to take decisions based on that.

It is recommended the adoption of a system that adopts one of the following heuristics:

- Nearest Insertion;
- Farthest Insertion;
- Cheapest Insertion;
- Arbitrary Insertion;

This measure would allow to increase the efficiency of the routes and, in addition to that, a very important increase of control over the all operation.

At a tactical level, and as a final recommendation, it would be advisable to study the hypothesis of reconfiguring the zones of influence.

5. References

Accenture. (2015). “Achieving High Performance in the Post and Parcel Industry”. *Accenture Research and Insights 2015.*

Global Express Association. (2015). “Express Delivery and Trade Facilitation: Impacts on the Global Economy”. *Frontier Economics*.

Halme, J. (2010). Global supply chain management and performance measurement. *Savonia University of Applied Sciences/ Tampere University of Technology.*

Hillier, F. S., & Lieberman, G. J. (2005). Non-linear programming and meta-heuristics. *Introduction to Operations Research, Chaps*, *12*(13), 547-616.

Kendall, G. (2017). *Why UPS drivers don’t turn left and you probably shouldn’t either*. [Online]. Disponível em: http://www.independent.co.uk/news/science/why-ups-drivers-don-t-turn-left-and-you-probably-shouldn-t-either-a7541241.html [acedido em Agosto de 2017]

Kumar, R., & Li, H. (1996). On asymmetric TSP: Transformation to symmetric TSP and performance bound. *Journal of Operations Research.*

Matai, R., Singh, S. P., & Mittal, M. L. (2010). Traveling salesman problem: An overview of applications, formulations, and solution approaches. *Traveling Salesman Problem, Theory and Applications*, 1-24.

Oliveira, R. (2011). Introdução ao problema do caixeiro viajante. *Investigação Operacional, Optimização em redes e grafos.* Instituto Superior Técnico.

Phillips, P., Davies, F., and Mountinho, L. (1999). The Interactive Effects of Strategic Planning on Hotel Performance: A Neural Network Analysis. *Management Decision*, 37(3), 279 – 288.