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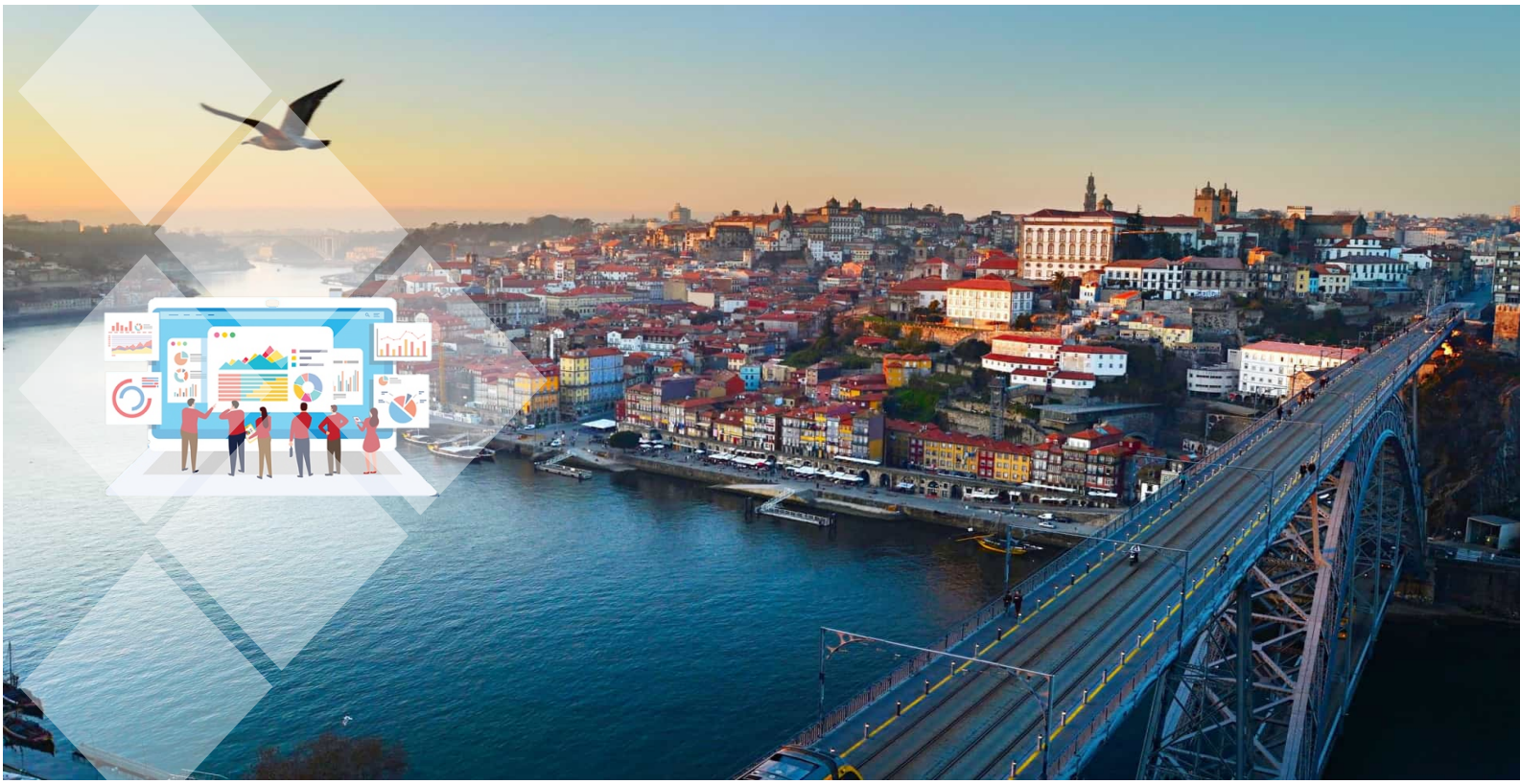

IEMS' 20

11th Industrial Engineering and Management Symposium

3rd January 2020

Biblioteca Almeida Garrett

Abstracts Booklet of IEMS'20

11th Industrial Engineering and Management Symposium:

The Impact of DEGI Research on Society

Editor: José Fernando Oliveira

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Biblioteca Almeida Garrett, Porto, January 3rd, 2020

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Organizing Committee:

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Acknowledgment of Reviewers:

Extended abstracts have been reviewed in draft form by individuals with diverse perspectives and technical expertise. The purpose of this independent review was to provide critical comments to assist the authors in making their published abstracts and their presentations as sound as possible. We wish to thank the following individuals for their reviews:

Alcibíades Guedes, Américo Azevedo, Ana Camanho, Ana Simões, António Carvalho Brito, António Galrão Ramos, António Miguel Gomes, Armando Leitão, Beatriz Oliveira, Bernardo Almada Lobo, Carlos Bragança de Oliveira, Eduardo Curcio, Elsa Silva, Flávia Barbosa, Gonçalo Figueira, Henriqueta Sampaio da Nóvoa, João Claro, João José Pinto Ferreira, Jorge Teixeira, José Barros Basto, José Coelho Rodrigues, José Faria, José Soeiro Ferreira, José Fernando Oliveira, José Luis Borges, Lia Patrício, LuÃs GuimarÃ£es, Manuel Pina Marques, Maria Antónia Carravilla, Maria Gabriela Beirão, Maria Pires, Mário Amorim Lopes, Nuno Soares, Pedro Amorim, Sara Martins, Teresa Galvão Dias, Thiago Sobral, Vera Lucia Miguéis Oliveira e Silva.

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Although the reviewers provided many constructive comments and suggestions, they did not see the final draft of the extended abstracts before their release. Responsibility for the final content of the abstracts rests entirely with the respective authors.

Organised by:

DEGI – Department of Industrial Engineering and Management

Faculty of Engineering, University of Porto

Welcome!

We welcome all the participants of IEMS'20, the XI Symposium of Engineering and Industrial Management, a joint organisation of DEGI and PRODEGI of the Faculty of Engineering of the University of Porto (FEUP). This symposium, in line with previous editions, aims to focus on the contribution to society of the research in our Department, mainly through PRODEGI.

To reach a wider audience, the papers presented during the day and the abstracts of this document do not include very in-depth details of the scientific work performed, and are organised around: the challenge, the methodology and the value for society. A visual "elevator pitch" of the research work precedes each abstract in this booklet. We will all be called, during the symposium, to vote for the best "elevator pitch" and the winner is announced at the end of the day.

As usually, in this symposium we will have presentations from our students along the day. Right after lunch, we will have the "End to End" session with two presentations of research works that involved DEGI researchers and organisations. The title "End to End" refers to the path followed by the research from the practical need (one end) through the research idea to its practical implementation (the other end). Right before lunch, we will have a presentation on the hot topic "Preparing our economy for real-world AI evidence" by Eduardo Pereira from Delloite.

We would like to welcome our colleagues from other universities in Portugal. It is a pleasure for us to be able to share this day with you. We are also happy to have among us several representatives of companies, some of whom have already accepted the challenge of hosting doctoral research work. We hope that their experiences can lead other companies to be our partners in joint research projects in the future.

We thank you all for being here and for your contributions. Still, we must thank especially the team that organised this symposium, this year almost with a majority of foreign students. Thank you, Cristiane Ferreira, Eduardo Oliveira, Luís Dias, Maria João Santos, Masoud Golalikhani and Sara Ali. Without your enthusiasm and dedication, this event would not have been possible.

José Fernando Oliveira â Director of the Department of Industrial Engineering and Management (DEGI)
Maria Antónia Carravilla â Director of the Doctoral Program in Engineering and Industrial Management (PRODEGI)

Biblioteca Almeida Garrett, Porto, January 3rd, 2020

Information for Participants

Symposium Venue

The symposium will take place at Biblioteca Almeida Garrett.

The venue information is detailed below:

- Address: Jardins do Palácio de Cristal - R. de Dom Manuel II 4050-239 Porto, Portugal $41°08'54.4"N\ 8°37'31.6"W$
- Tel.: +351 226081000
- Email: bib.agarrett@cm-porto.pt

Figure 1: *Entrance.*

Figure 2: *Auditorium.*

Figure 3: *Library.*

There is a private parking lot right beside Biblioteca Almeida Garret. However, it is paid. In terms of public transportation, there are two options: metro and bus. The nearest metro stations (Aliados and Casa da Música) are located 1.5km from the Venue. The nearest bus stops (204, 300 and 301) are located 600m from the Venue.

The event will occur in Biblioteca Almeida Garrett's auditorium and foyer. The entrance is inside Jardins do Palácio de Cristal and can be seen in figure 1. The reception will happen in the foyer near the auditorium. The auditorium (figure 2), where the presentations will happen, is located in the lowest floor of the library (figure 3).

Internet

There is Wi-Fi access in the building, with no password required.

Guidelines for Voting for the Best Elevator Pitch Award

The elevator pitches are available in this Book of Abstracts, at the beginning of each extended abstract, and at the IEMS'20 website: `http://www.fe.up.pt/~degi/iems20`. During the breaks, the elevator pitches will also be displayed at the Foyer. A bulletin containing thumbnails of the elevator pitches will be distributed to all participants. Each participant has **three votes**.

Biblioteca Almeida Garrett, Porto, January 3rd, 2020

Program Schedule

Friday, January 3rd

Reception of the Participants: 9:00 – 9:25 (*Foyer*)

Opening Session: 9:25 – 9:30 (*Auditorium*)

Morning Chair: Xenia Klimentova

PhD Projects: 09:30 – 10:30 (*Auditorium*)

A.1 Understanding carsharing: a business review towards relevant research insights. Masoud Golalikhani, Beatriz B. Oliveira, Maria Antónia Carravilla, José Fernando Oliveira

A.2 Applying Data Mining to Root Cause Analysis in Manufacturing: A Comparative Study on Logistical data. Eduardo Oliveira, Vera L. Miguéis, José L. Borges

A.3 The Risks of Data-Driven Models as Challenges for Societys. Sónia Teixeira, José Coelho Rodrigues, João Gama

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Coffee-Break: 10:30 – 11:00 (*Foyer*)

Elevator Pitches: 11:00 – 11:50 (*Auditorium*)

Sara Ali, Cristiano Flores, Alexandra Oliveira, Daniel Pereira, Cristiane Ferreira, Maria João Santos, Luísa Gonçalves, Carlos Martins Ferreira, Ricardo Soares, Luís Dias, Thomy Saputro

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Break: 11:50 – 12:00 (*Auditorium*)

Plenary Session - 12:00 – 13:00 (*Auditorium*)

PS Preparing our economy for real-world AI evidence.

Eduardo Pereira (Deloitte)

Lunch: 13:00 – 15:00 (*Foyer*)

Afternoon Chair: Abílio Pacheco

End to End: 15:00 – 16:00 (*Auditorium*)

B.1 Implementing a clinical digital repository in a hospital centre. José Coelho Rodrigues

B.2 POCITYF: A positive energy transformation framework. Luísa Gonçalves, Nilufar Neyestani, Ricardo Poeta

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Coffee-Break: 16:00 – 16:30 (*Auditorium*)

PhD Projects: 16:30 – 17:30 (*Auditorium*)

C.1 Machine Learning to advance clinical decision-making in oncology: a systematic review. Catarina Santos, Mário Amorim-Lopes

C.2 Product line selection in fast-moving consumer goods industries. Xavier Andrade, Luís Guimarães, Gonçalo Figueira

C.3 Stepping from real-world sample analysis to fostering efficiency improvements of problematic samples: a motivational case within the wastewater industry. Alda Henriques, Milton Fontes, Ana Camanho, Pedro Amorim, J. Gabriel Silva, Giovanna D'Inverno

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Break: 17:30 – 17:40 (*Auditorium*)

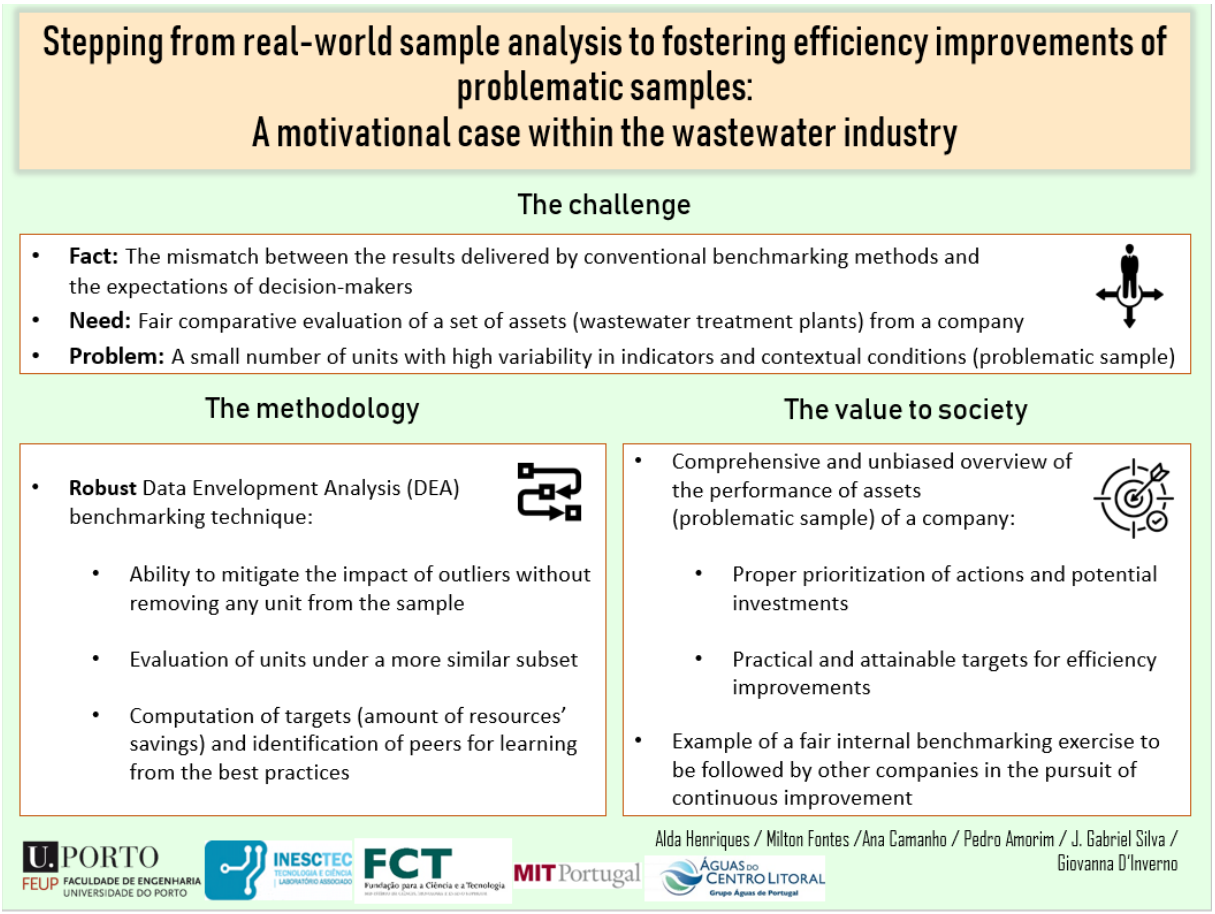
Award for the best elevator pitch and Closing Session: 17:40 (*Auditorium*)

Abstracts

Stepping from real-world sample analysis to fostering efficiency improvements of problematic samples: a motivational case within the wastewater industry

Alda Henriques [*], *Milton Fontes* [†], *Ana Camanho* [*], *Pedro Amorim* [*], *J. Gabriel Silva* [‡], *Giovanna D'Inverno* [♣]

[*] INESC TEC and Faculty of Engineering, University of Porto, [†] Ãguas do Centro Litoral (AdP Group), [‡] AdP Energias and Instituto Superior de Engenharia do Porto, [♣] Faculty of Economics and Business, KU Leuven



1 The Challenge

The efficiency assessment of real-world case studies can occasionaly deliver results with limited face validity for decision makers. The reason for this mismatch can be rooted in the large variability in data of inputs and outputs of small samples. This research describes a framework that was used in the context of the efficiency evaluation of a sample composed of 41 wastewater treatment plants (WWTPs) managed by the Portuguese water company Ãguas do Centro Litoral (AdCL). AdCL was willing to improve its

knowledge upon the relative performance of its assets to fostering efficiency improvements. However, the WWTPs analysed had notable differences in the magnitude of the indicators selected. Several factors could explain the variability encountered, namely the vast spectrum of dimensions of the WWTPs and the diversity in environmental factors, both structural and operational. Moreover, the small number of WWTPs (only 41) made it impossible to split the sample into smaller groups of more homogeneous WWTPs that could enable a fair comparative evaluation.

In the context of a benchmarking assessment, a set of decision making units (DMUs) is comparatively evaluated to search for improvements in efficiency. To guarantee a fair assessment, the set of DMUs should be homogeneous, i.e., the DMUs should be similar in their characteristics and should conduct the same productive process, corresponding to the conversion of inputs into outputs. However, in real-world cases, such as our case study, the homogeneity assumption may not be completely fulfilled due to the presence of atypical observations (outliers) and differences in the environmental context affecting the DMU's operation. Furthermore, the sample under assessment may be quite small, which invalidates clustering into smaller homogeneous groups prior to conducting the benchmarking exercise, or the removal of atypical DMUs. We call this type of samples âproblematic samplesâ, i.e., samples with a small number of DMUs and that present high variability in the indicators' setting or in the environmental conditions.

Conventional benchmarking techniques, such as Data Envelopment Analysis (DEA) may lead to biased results when applied to problematic samples. To obtain valuable information to foster practical efficiency improvements within a problematic sample, it is therefore necessary to have a framework that accounts fairly for existent variability without removing any DMU from the assessment.

In this study, we consider the application of a robust DEA approach both in its conditional and unconditional versions, namely including or not the contextual factors directly in the efficiency assessment. The suggested toolbox addresses two aspects simultaneously. First, it allows a fair efficiency assessment, delivering reliable information that can be used to prioritize actions and select potential investments. Second, it provides information about peers and targets for each indicator, to guide improvements based on the observation of best practices and information sharing.

2 The Methodology

DEA is a nonparametric linear programming technique that allows the comparative evaluation of a set of identical DMUs. This technique derives a single efficiency score for each DMU under assessment, based on the distance each DMU is from the efficient frontier, i.e., the set of DMUs that are using the best input-output combinations. In this study, we consider a robust DEA estimator following insights from the order-m frontiers to measure the efficiency of each DMU under assessment. This method is based on the concept of order-m frontiers, or partial frontiers, in opposition to the full frontier determined under the conventional DEA method. The use of order-m frontiers allows to mitigate the impact of outliers without removing any DMU from the sample. This is achieved by evaluating each DMU against a subset of DMUs rather than against the total set of DMUs. Two features contribute to define each subset and deserve to be highlighted. First, in the case of an input-orientation (as it is required in the present context of WWTP efficiency measurement due to the specificities of the production activity), each DMU is only compared with units that produce at least the same amount of output. Second, m units are randomly drawn with replacement to make the final subset of DMUs that can be potential peers for the DMU under assessment. The m-random drawing is repeated B times according to a Monte-Carlo procedure, where B is a large number. In each iteration, an efficiency score is obtained using an input-oriented DEA model. The robust efficiency score is computed as the average of the efficiency scores obtained in the B iterations. Since the benchmarks considered under this method are less extreme than in the conventional DEA approach, the efficiency scores obtained for each DMU are equal or higher than those obtained in the conventional DEA approach. This ensures a fairer efficiency assessment than using the conventional DEA approach.

Both the unconditional and the conditional versions of the robust DEA approach are used in this study to tackle the role of the environmental context faced by the DMUs, which affects their operation. In the unconditional case, m units are randomly drawn with replacement and with uniform probability, so that each unit is equally likely to be drawn. In the conditional case instead, m units are randomly drawn with

replacement, but with a probability determined by an estimated kernel function. Accordingly, units that operate in a more similar environment will have a higher probability of being drawn and included in the reference subset.

A piece of relevant information is the identification of the peers and the number of times they are used as benchmarks across the iterations. In addition to this, the intensity values for each peer are obtained as the average of the intensity values computed in each of the B iterations. Accordingly, this allows for the computation of targets for each under-performing DMU and the identification of the amount of resources that can be saved or reallocated.

For the empirical application, we selected two inputs (energy and labor), two outputs (the effort of removal of chemical oxygen demand (COD) and the effort of removal of suspended solids (SS)), and six environmental variables, by stemming from the literature, from discussions with the decision-makers of AdCL and also by taking into account data availability. The environmental variables were tested one at a time using the conditional version (plant age, plant capacity, percentage of utilization of installed capacity, disinfection treatment, sludge dehydration and pumping facilities inside of the WWTP).

3 The value to Society

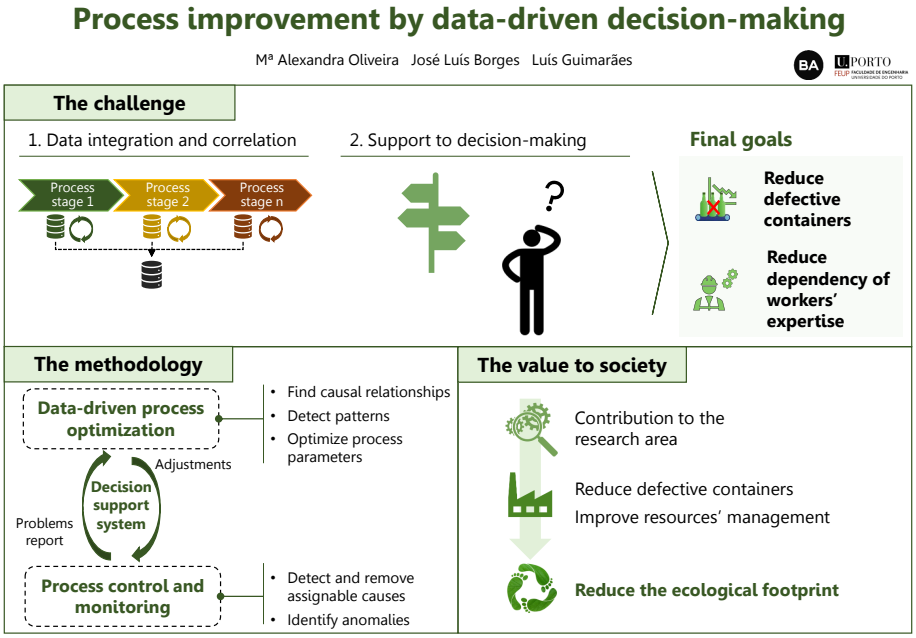
The application of the toolbox for performance measurement allowed to find a potential energy savings of 8% of the total energy consumed by the 41 WWTPs. This result is substantially more conservative than the value identified in the conventional approach (28%), which reflects the role of the robust method in mitigating the impact of outliers and in providing a fairer evaluation of units that leads to practical and attainable efficiency improvements. It was also found a potential reduction of 6.6 full time equivalent workers. This staff could be used in other activities within the company to improve the overall functioning of the system. The conditional robust DEA approach further revealed that the installed capacity, the disinfection treatment, the sludge dehydration and the pumping facilities have a significant association with the performance of the plants. Also, it was possible to identify the more relevant peers for each underperforming WWTP to facilitate the learning from best practices observations and information sharing. This study constitutes an example of an internal benchmarking exercise that can be followed by other water companies and industries, specifically when the samples to be analyzed are problematic. The proposed framework allows a comprehensive and unbiased overview of the performance of assets to guide the design of management practices and strategies leading to continuous improvement.

Moreover, this study has a twofold contribution for the scientific literature. Firstly, we contribute to the Management Science literature by proposing a framework for the analysis of problematic samples, based on robust conditional DEA, combined with a detailed analysis of peers and targets, typically reported only for traditional DEA assessments. Secondly, we contribute to the literature focusing on water utilities management by proposing an innovative specification of inputs and outputs reflecting plants effort in the treatment of wastewater, and by assessing the plants of a Portuguese company from an internal managerial perspective.

Process improvement by data-driven decision-making

Maria Alexandra Oliveira *, José Luís Borges *, Luís Guimarães*

* *Faculty of Engineering, University of Porto*



1 The Challenge

The current global market is marked by an extremely high competitiveness, caused mainly by the increase in supply and customer's expectations. Faced by this scenario, companies must strive to be more efficient and effective, in doing so quality and productivity play a major role. The capability to improve both quality and productivity of the delivered products or processes, will dictate the company's relevance in the market. Such effort can be measured by the enterprise's capacity to keep up with the evolution of the industry. With the rise of Industry 4.0, it became clear for organizations the importance of analysing the vast amount of data generated over the years by their core processes. The analysis of these large-size collections, known as Big Data, will enable enterprises to create knowledge from these collections and thus, gain insights to improve the quality of their products/services.

Motivated by a real-world case, our main goal is to improve the productivity of a glass container manufacturer, by reducing the amount of defective products. At this company, data has been collected and stored over the years, resulting in large amounts of data sets containing valuable information about the processes and products. Yet, these data are kept in silos corresponding to the different production stages. Up to now, no attempt has been made to either integrate all parts, or to correlate the information within an integrated approach. Hence, to succeed, our approach must be able to i) integrate the data from several production stages into the analysis and thus, providing conditions to ii) extract actionable insights from such data. This will enable the iii) creation of data-driven models to support and optimize decision-making on processes, which strongly impacts the quality of final products, and also results in a reduction on the dependence of the worker's knowledge.

2 The Methodology

The glass container manufacturing process encompasses several stages, some more critical to the quality of the final product than others. For this reason, we need to have a deeper understanding of the whole process, to be able to correlate all factors and understand their impact on our goal: minimize the percentage of defectives. The manufacturing process begins with the mixing of raw materials in the batch house. The mixture is then transported into the furnace where is melted up to 1500°C. After leaving the furnace, the liquefied glass goes through a conditioning process in order to assure the thermal homogeneity of the paste. Then, this glass paste ends its path in the feeders, where it is cut into gobs and distributed to a set of parallel independent section (IS) machines. Here, the container is formed by a molding process. After being given a shape, the container receives a heat treatment to reduce glass stress, followed by a coating treatment. The containers are then subjected to a strict quality control, performed by automated inspection machines capable of rejecting defective containers. Once they have been approved in the quality control process, the containers are packed on pallets at the end of the production lines. Figure 1 illustrates the manufacturing process stages.

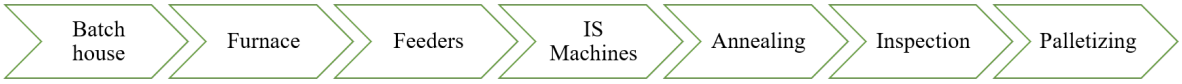


Figure 1: Glass manufacturing process.

From the production process stages, valuable information can be retrieved in order to be integrated into a root-cause analysis, where we aim to identify the factors with the most significant impact on the quality of containers. Information on the temperatures at different stages, on pressure values and closing/opening timings of the IS machines, on the cooling processes, are examples of the type of data we can collect from the process and we must include into the study.

One of the most critical stages of the whole process, and our main challenge, is in the IS machines phase. A great part of the manufacturing process is automated, but this particular stage is highly dependent on workers experience. The operators are responsible for setting adjustments in the production process, such as defining the machine speeds and temperatures. The adjustments, besides having a decisive influence on the final quality, are often a reaction to long feedback loops, meaning that the adjustments are not performed in real-time. This situation triggers the need of conducting a correlation analysis with a purpose of creating insights into the production parameters settings causing defects in the final product. Conducting this analysis will enable to conceive a support decision making system, intended to reduce the dependence of the worker's process knowledge, by recommending in real-time settings' adjustments which optimize operators' decisions.

Our proposed methodology is depicted in Figure 2. All collected data concerning both the process and products are essential inputs to the two main blocks of our approach, that work together as a dynamic system. In the data-driven process optimization block, we intend to develop a model that:

- Describes the quality of products and process: such task includes determining the factors which affect quality significantly, find correlations between them and identify the most probable causative(s) factor(s) that discriminates between defective and non-defective products.
- Classifies quality: for a given set of input parameters, predict the quality of the correspondent products.
- Optimizes parameters: based on the learned characteristics of the days reporting highest throughput rates, finding the optimal process parameters that consistently meet the target quality.

With the knowledge we can obtain from this model, it will be possible to conceive a system capable of providing recommendations on how tackle the problems reported from the process control and monitoring block. Every time a variable of the process is out of its boundaries, which means that may be jeopardizing

the quality of the product, the event is reported to the decision support system, so an action can take place as soon as possible. This feedback is also an important input to the data-driven model, since the more data on this kind of events it receives, the better will perform on future occasions. The combined action of these two main blocks aims to reduce the process variability, by compensating, detecting and removing assignable causes.

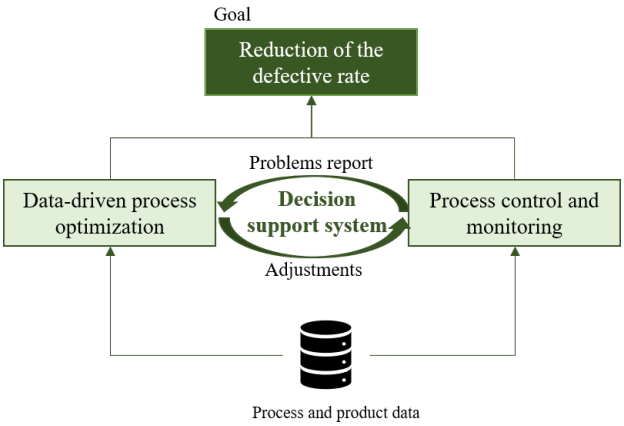


Figure 2: Conceptual methodology.

3 The value to Society

Our contribution to the society is threefold. This work adds value to research, since it proposes an approach that combines the optimization of the process and the process control. This allow us to conceive a system capable of providing improvement suggestions. Little research has been done when considering this combination to improve products quality in manufacturing industries.

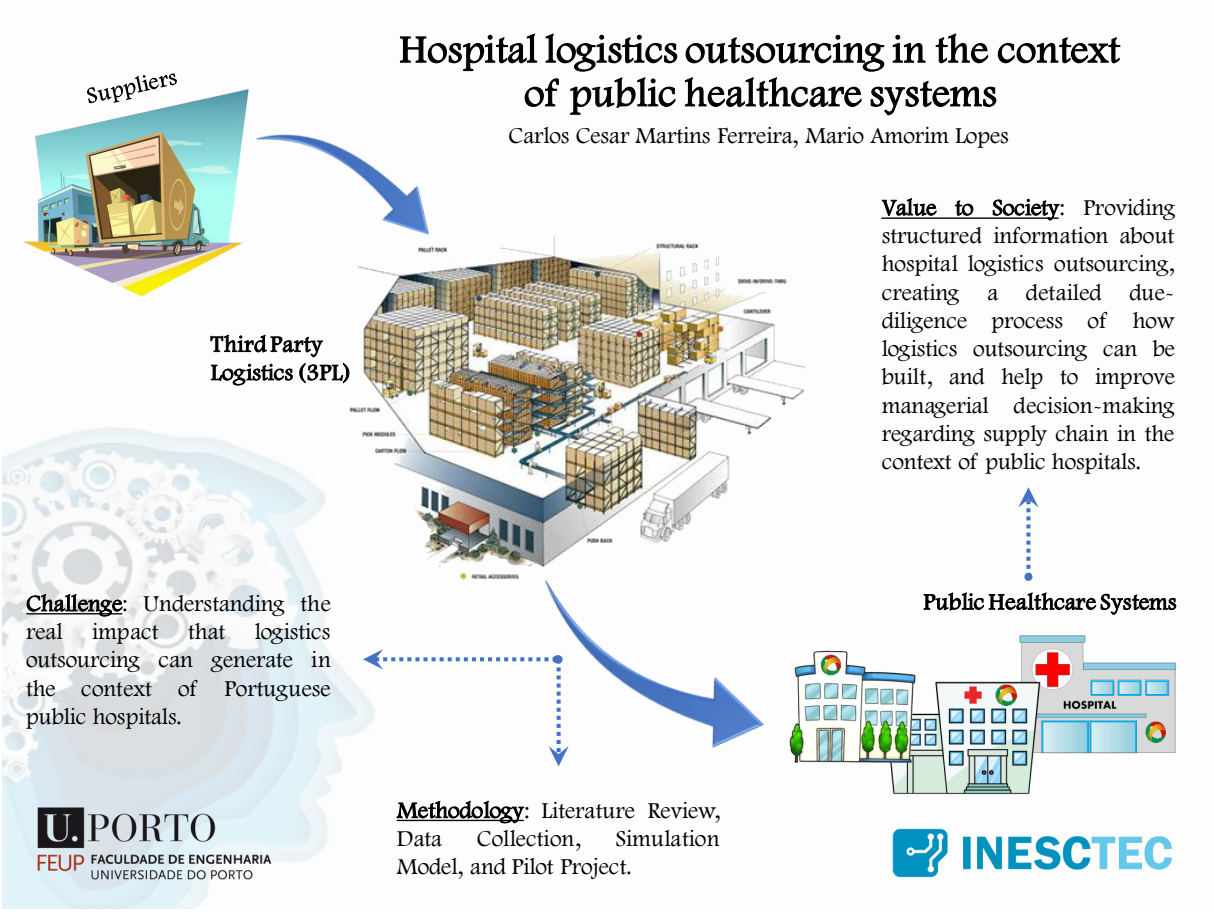
Additionally, it brings value to manufacturing companies. With this approach we not only aim to increase effectiveness, but also create knowledge of factors influencing the behaviour of the production system and disseminate the know-how in the prescriptive methods. Consequently, companies will be able to better dominate their processes and acquire dexterity in their decision-making. As a result, they will be placed in more favorable market positioning.

The work contributes to society in general, since companies will manage their resources more efficiently reducing the environmental impact.

Hospital logistics outsourcing in the context of public healthcare systems

Carlos Cesar Martins Ferreira*, Mário Amorim Lopes*

* *INESC TEC and Faculty of Engineering, University of Porto*



1 The Challenge

In 2016, the world spent US$ 7.5 trillion on healthcare, representing close to 10% of global Gross Domestic Product (GDP). Healthcare's share of GDP has ranged from 6.3% (low and middle-income countries) to 8.2% (high-income countries) on average. Between 2000 and 2016, global spending on healthcare increased every year, growing in real terms at an average annual rate of 4.0%, faster than the 2.8% annual growth of the global economy. Healthcare spending has increased most rapidly in low and middle-income countries, at around 6.0% or more annually on average.

Human resources and supply chain represent the largest share of the costs in healthcare systems, and estimates account that hospital logistics costs and supply expenses (per total expense) ranged from 15 to 45% of these costs, and increasingly bring the need for logistics efficiency within healthcare systems.

Public systems, in particular, are prone to bureaucracy, and restrictions regarding human resources and budgets. Furthermore, logistics processes are also prone to specific factors, such as lack of specialization,

inadequate physical structure, procurement processes with high costs and increased lead-time, inefficient deliveries, and reduced inventory management. When these aspects affect the hospital's logistics, besides generating waste of financial resources, patient care is also impacted since failing in the inventory management, forecast, and procurement can lead to several problems, including high prices, low-quality materials, and stock-outs of materials and medicines.

Considering all these limitations, healthcare systems need to find ways to overcome them. The paramount goal has been to improve the management and to become increasingly cost-efficient while, at the same time, retaining the current level of quality or even improving it. To achieve these goals, hospital logistics outsourcing through Third-Party Logistics Providers (3PL) has been suggested as a means to improve supply chain management, and at the same time to improve patient care in some public healthcare systems increasing the availability of goods and medicines, use of newer technologies, and equipment, among other aspects

An example of outsourcing through 3PL in hospital logistics is the arrangement between the United Kingdom's National Health Service (NHS) and DHL Supply Chain (DHL). Since 2009, NHS has started a large process of logistics outsourcing and has been achieving satisfactory results in terms of savings (around £826 million until 2018) and patient care improvement. Since February 2019, NHS has changed the 3PL provider from DHL to Unipart. Unipart was tasked with delivering medical devices and hospital consumables (other than medicine) to NHS trusts, warehousing, inventory management, order processing and delivery, and a subcontracted home delivery service, which makes up 10 percent of the contract. It is the biggest of 13 new national contracts forming the new NHS Supply Chain, which the government claims will generate savings of £2.4 billion over five years.

In this context, several benefits such as focusing on core competencies, improvement of logistics processes skills, adoption of more modern technologies in inventory management, decreasing of service delivery time, and cost reduction are expected from a 3PL arrangement. However, despite all these expected benefits, only a few studies have focused their efforts on producing knowledge about hospital logistics outsourcing in the public healthcare systems environment, and there is a profound gap of models and publications in this field.

The challenge is to understand the real impact that can generate logistics outsourcing in the context of Portuguese public hospitals, and to achieve this challenge; we will develop a simulation model. The primary expected use for the model will be to simulate both outsourced and self-managed scenarios according to the particularities of each hospital, allowing managers and decision-makers to make their decisions based on technical parameters, and filling the gap of the models in this field, since, although these types of models have been widely applied in both the healthcare and logistics sectors, in the best of our knowledge, they have never been used in this specific context.

2 The Methodology

We have designed four steps to achieve the objective of this work: **Literature Review**, **Data Collecting and Evaluation**, **Simulation Model Development**, and **Pilot-Project**.

- **Literature Review** - We will carry an extensive literature review to gather the state-of-art on hospital logistics outsourcing in the context of public healthcare systems, in which we will systematically search for papers and other documents (such as technical reports, and thesis) that have their main focus on hospital logistics outsourcing.

  From the literature review, we expect to answer essential questions such as in what situations have been made sense to implement logistics outsourcing, what have been the implementation's steps, what types of 3PL providers exist on the market, and what is the expected impact (i.e., what is the cost-benefit) of logistics outsourcing.

  Besides, we will summarize and systematize through tables and flowcharts information such as motivations, risks, benefits, decision factors, applied models, and obtained results regarding hospital logistics outsourcing in other healthcare systems that will fill a gap of publications in terms of classified information.

- **Data Collecting and Evaluation** - We will collect data from the physical and administrative structure of the Portuguese public hospitals in two ways, by referring to public information and from legal documents available on government databases.

  We will also need to understand the routines and procedures of workers who are directly involved in the supply chain operation as well as to understand the political, strategical, financial, and budgetary positions of the hospitals. To understand these factors, we will apply questionnaires addressed to two different groups, being the first one formed of administrative, nurses, and physicians, and the second one formed of managers.

  In order to complete or verify some information collected from the government databases, we will make in loco observations. Moreover, according to the nature of each questionnaire, we will use the more appropriated assessment methodology to create statistical measures.

- **Simulation Model Development** - Simulation models in logistics, represent an attempt to replicate the functional relationships between the logistical activities of facility location, transportation, inventory, order processing, and material movement mathematically. These types of models allow the managers to study the effects of different managerial policies and environmental conditions upon the logistics system without any manipulation of actual logistical operations.

  We will design a framework considering the structural and administrative data collected, and to establish the relationship among the considered variables. From this framework, we will develop the simulation model.

- **Pilot-Project** - We will develop a pilot project in at least one Portuguese public hospital that will serve as a case study. Real data from this hospital will be applied in our model and evaluated in order to test its outcomes and determine how the model could be improved.

3 The value to Society

The study aims to contribute to the scientific community, mainly in three ways. First, we will provide structured information about hospital logistics outsourcing in the public context, and fill a gap of publications in this field. Second, the structured information will also allow us to create a detailed due-diligence process of how the logistics outsourcing can be built into a public hospital. Finally, it is expected that the developed model, as well as the structured information and the due-diligence process, help to improve managerial decision-making about the supply chain in the context of public hospitals.

Also, since scientific knowledge and better decisions have a positive impact in the human, material and financial resources management, this study aims to increase the material quality and variety, to increase the investment of financial resources in new technologies (diagnosis equipment and medicines), improving the population's quality of life.

Machine learning to advance clinical decision-making in oncology: a systematic review

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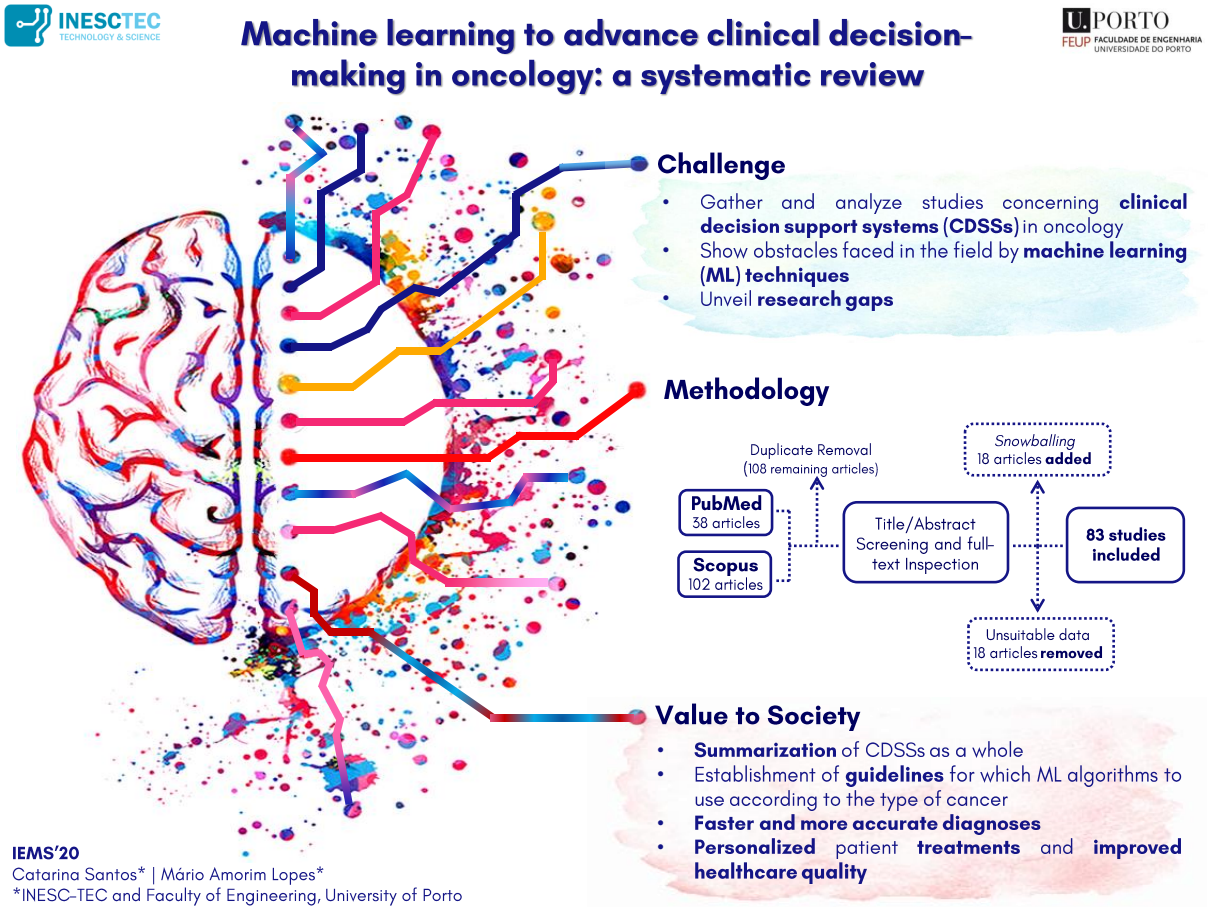

1 The Challenge

Despite continuous advances in understanding cancer's biological foundation and the constant emergence of new treatment possibilities, this disease is still one of the leading causes of death in developed countries, and the complexity of finding a cure for cancer, in its many forms, is still a very complex problem.

As part of the clinical procedures to diagnose and treat patients with cancer, clinicians collect massive amounts of data, including health status indicators of the patient, biological (and genomic) information, previous conditions, exams and diagnoses, follow-ups, among others. In recent years, this information has been increasingly collected and stored in electronic health records (EHRs), and has subsequently led to the development of the concept of personalized medicine, aiming at providing tailored treatment options according to each patient's biological traits and individual cancer characteristics. In spite of possible ethical and privacy concerns, the potential benefits of making this information publicly available

are endless: when paired with the current literature, it could be useful in variant reporting; in molecular profiling and/or tumor phenotyping; in enforcing the standardization of structured data (and imaging) collection; in determining optimal treatment therapies according to patients' individual characteristics; and in implementing sharing practices and transparency in general.

This exponential expansion in knowledge has, however, shortened the time for learning and keeping up with new guidelines and treatments. Indeed, with the data of a single patient occupying approximately 7Gb (and 70% of it being solely raw genomic data), the demand was created for automated support methods to incorporate and interpret data. Clinical decision support systems are characterized as computerized aiding tools based on artificial intelligence and/or machine learning. These have shown promising results in assisting in or confirming diagnoses and increasing confidence for new, inexperienced practitioners, as they are capable of sweeping and processing the literature and clinical records for relevance to patients with specific factors, and providing reference results/accuracy on similar previous studies.

In the particular case of oncology, which is the core focus of this work, an increasing number of Machine Learning Based Algorithms (MLBAs) – such as support vector machines (SVMs), random forests (RF), gradient boosting (GB), neural networks (NN) and k-nearest neighbors (kNN) – have been developed to create clinical decision support tools for a plethora of purposes. These aims include, but are not excluded to: imaging analysis, predicting patient outcome according to multiple constraints, analyzing gene expression and predicting the need for additional measures along with or after the main treatment. In gene expression analysis, MLBAs can be employed for the identification of new transcription genes linked to illnesses, thus being useful in targeted gene therapy. Furthermore, in imaging ML methods have even resulted in the emergence of a new field, named radiomics, aimed at being a supporting tool to, for example, deplete the complexity of cancer imaging protocols and increase the reproducibility and standardization in clinical imaging.

Throughout this review, several papers employing MLBAs to create clinical decision-support tools were found, and regardless of the chosen method, all confirmed those approaches to return higher accuracy than the traditional supporting protocols. These findings are however not without limitations. The first weakness, shared by all papers, is that the studies were retrospective, which does not have the same rigor of a prospective study and has the potential of reducing the quality of the data collected. The second is that most data were retrieved from a single institution, which can encompass small sample sizes with missing values and insufficient diversity to learn from. The last concern is related to the medical staff's reluctance to completely trust a machine, even if it results in less workload and considerably lower costs. However, the use of machine learning in the clinical environment should not be considered as a replacement for the medical staff, but rather as a tool to assist them in many tasks and lighten their work load.

Finally, three important research gaps still exist: (i) although common cancers, such as melanoma and glioblastoma, are extensively studied, rare cancers are seldom investigated, which is mostly due to the lack of enough publicly available data and information collected from single institutes, and reveals a lack of interaction between search centers; (ii) most studies are focused on diagnosing tools, and especially imaging analysis and radiomics, while papers focusing on optimal treatment options are still lacking; (iii) a single global mesh network of oncological data to train networks still does not exist.

2 The Methodology

Clinical decision support systems have unleashed the potential to revolutionize standard clinical practices. By applying machine learning algorithms, accurate and fast interpretation of complex data becomes possible. Furthermore, by analyzing data in bulk and comparing it to previous records and the current literature, these tools may be key in assisting medical personnel in developing targeted gene therapy, stratifying patients according to risk factors, and reducing the need for invasive, exploratory procedures, among many other purposes.

Hence, the systematic review here proposed was conducted to gather and analyze studies concerning clinical decision support systems in the field of oncology. It aimed at providing a detailed and thorough synthesis of the existing clinical decision health support systems and the machine learning algorithms

used in each specialty, as well as presenting the obstacles machine learning techniques still face in oncology and unveiling any existing gaps in these areas.

This systematic review was organized in accordance with the guidelines proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The PubMed and Scopus databases were searched for articles with the title, abstract and/or keywords containing the terms "oncology", "decision making" or "decision support" and "ML" or "Machine Learning" or "AI" or "Artificial Intelligence", and limited to English papers from the last five years. Duplicates were then removed, and titles and abstracts were screened for suitability. Exclusion criteria encompassed articles not available in full, letters to the editor, studies not using machine learning algorithms and papers not concerning oncology. Upon inspection of the reference list of the remaining full-text articles, a few studies were manually added due to their relevance (snowballing approach).

3 The value to Society

The value of this review is that it is not focused on specific applications of clinical decision support systems, but rather summarizing them as a whole, and it is intended to further ameliorate the understanding the use of machine learning algorithms in the field of oncology, as well as contribute with guidelines for which algorithms to use according to the type of cancer, which, to our knowledge, has not yet been provided.

By knowing which machine learning algorithms to apply, accurate and fast interpretation of complex data becomes possible. Furthermore, by analyzing data in bulk and comparing it to previous records and the current literature, these tools may be key in assisting medical personnel in developing targeted gene therapy, stratifying patients according to risk factors, and reducing the need for invasive, exploratory procedures, among many other purposes. In turn, for the patient (and the population as a whole), this would translate in faster and more accurate diagnoses, personalized treatments according to particular biological traits and individual cancer features, and improved healthcare quality in general.

Scheduling Human-Robot Teams in Collaborative Working Cells

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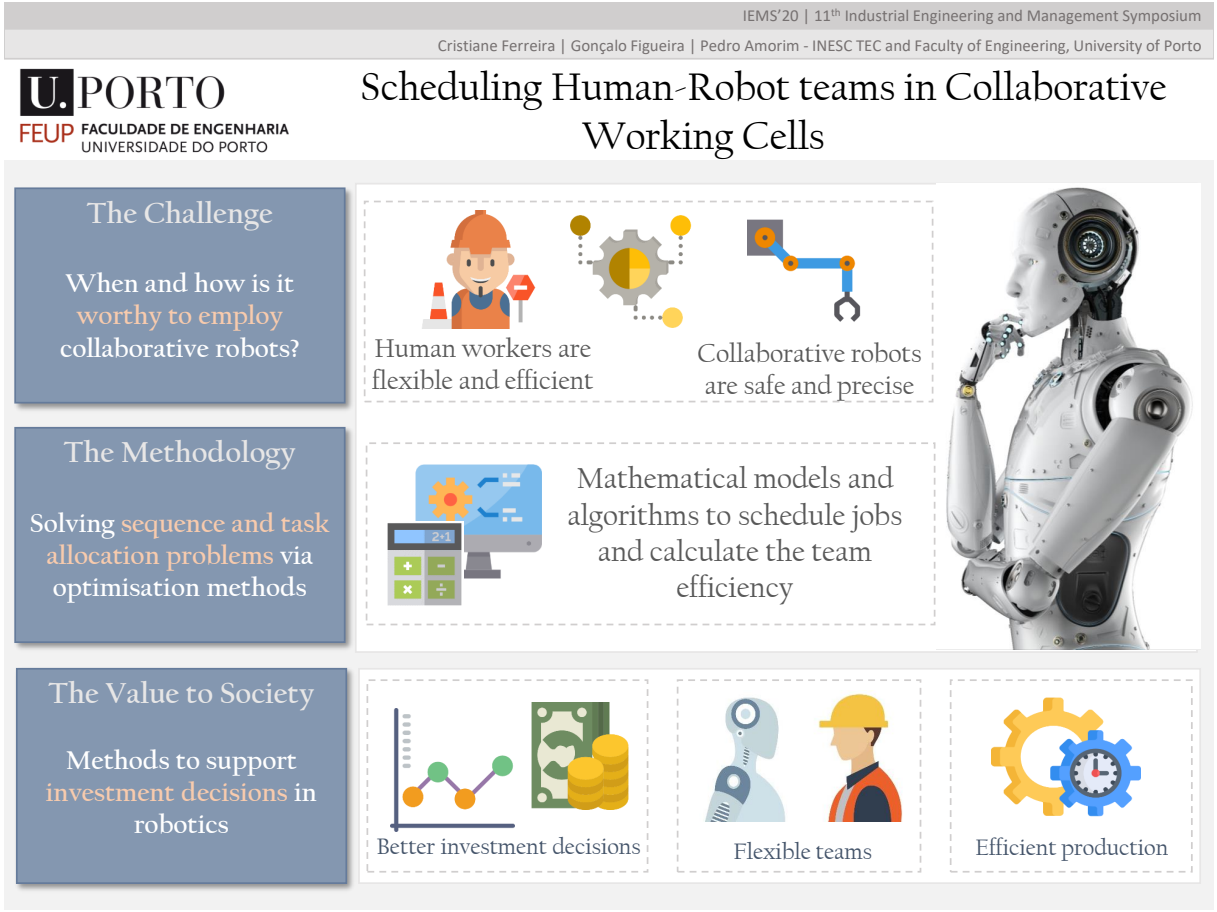

1 The Challenge

Since 2013, demand for industrial robots has risen by 19% on average per year, due to the ongoing trend towards automation and continued technical innovations. This growth is expected to continue, particularly with the explosion of collaborative robots (cobots). These belong to a new generation, designed with inherent safety features for what they may share the workplace with humans, embodying human-robot teams (HRTs).

However, the existence of cobots is forcing manufacturers to redesign their processes to achieve higher levels of efficiency. There are multiple trade-offs to consider, between the high performance of traditional robots, the great flexibility of human operators, and the compromise solution of HRTs. Important questions such as when and how to implement cobots are not trivial, given that tasks may be executed by only one resource (human or robot) or by both in collaboration. Depending on the number of tasks that each resource executes, their relative performance and several other aspects (e.g., as precedence

constraints), it might be worth, or not, to employ two resources instead of just a human or a robot alone. Determining how to do it involves solving task allocation and scheduling problems.

This work comprises the development of optimisation methods to support decision-making in HRTs. We analyse and extend problems described by the robotics literature, and study the Multimode Multiprocessor Task Scheduling Problem (MMTSP), which may be used to estimate the performance of collaborative teams. We also derive a variety of managerial insights, which are critical to companies that want to invest in cobots and evaluate the improvements provided by them.

2 The Methodology

The MMTSP is defined on a set of non-identical machines and set of jobs that may be executed in different execution modes. An execution mode is a subset of machines and results in a specific job processing time. We must assign modes to jobs and schedule them in such a way that each machine only processes one job at a time. The objective is to minimise the maximum completion time, i.e., the makespan. We also consider precedence constraints, as they are important in real production environments.

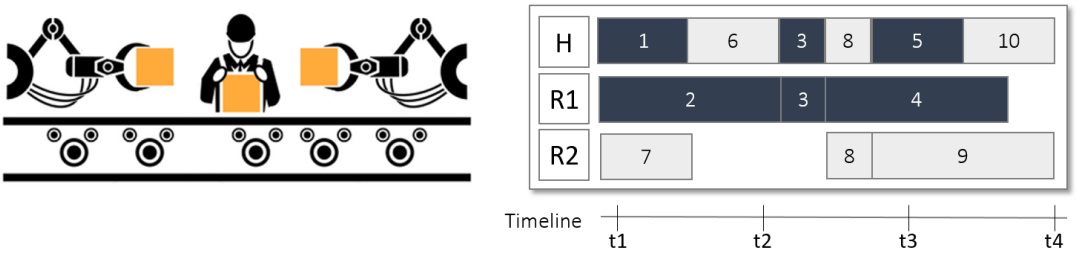

Figure 1: An hybrid working cell and a solution to the MMTSP

In a collaborative working cell, the set of machines is composed of humans and robots. The execution modes may be human or robots (working alone) or an HRT (in collaboration). Figure 1 illustrates an example of a working cell composed of two robots and one human. A feasible solution is presented in the Gantt Chart, given that there are ten jobs to be executed. Note that jobs 1, 6, 8 and 10 are executed by the human alone; the robots execute jobs 2, 4, 7 and 9; and jobs 3 and 8 are both executed by an HRT.

We propose a Mixed Integer Linear Programming Model (MILP), based on a disjunctive programming formulation. Moreover, we provide a Constraint Programming (CP) model, as CP has been producing favourable results for similar scheduling problems. A Genetic Algorithm is developed to generate good quality solutions for the set of larger instances.

A Linear Programming Model (LP), which is more than a linear relaxation of the MILP, is also devised to provide lowerbounds, enabling the evaluation of the methods on instances without known optimal solutions. Furthermore, all methods are submitted to pre-processing algorithms that identify redundancies and reduce the problem size.

The instance generation aims to reproduce the most common characteristics found in collaborative working cells. Thus, in addition to varying the problem size and precedence graph, we varied the average relative performance of resources, their performance when working in collaboration, robot eligibity (i.e., the percentage of jobs that can be executed by robots) and multimode eligibity (the percentage of jobs with the option to be executed in collaboration).

All methods considerably outperform both the robotics and the scheduling literature on their respective related problems. The CP model was able to prove optimality for 39% of the instances, against 4% for the proposed MILP model. In the instance set with known optimal solutions, the GA found solutions that are, on average, 1.6% distant from optimal. In the set of unsolved instances, the CP results were 3.2% distant from the lowerbound and the GA, 12% (this performance is affected by the instance settings, primarily robot eligibility).

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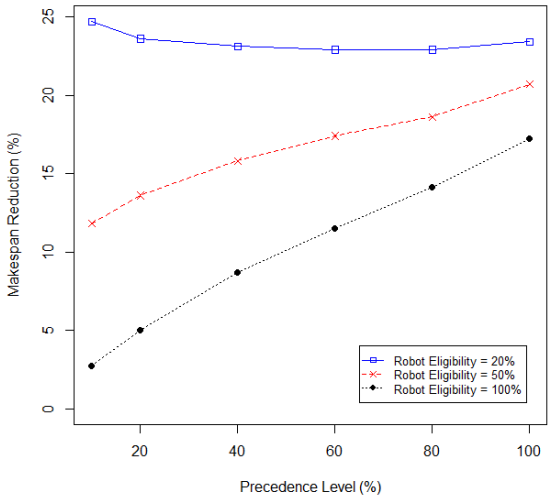

Figure 2: Makespan reduction over precedence level and different values for robot eligibility.

By running these methods, particularly CP, we are able to derive managerial insights on the advantage of HRTs. We first compared the optimal makespan in instances composed of humans versus instances composed of HRTs. The results motivate the use of cobots even if they are suitable for a small number of jobs, e.g. 20% of makespan reduction in instances with 20% of robot eligibility. With increased robot eligibility, these gains depends on the robot's performance.

Then we compared the makespan on instances with the same resources, differing on the existence of collaborative tasks, in order to analyse the improvements provided by collaboration. Figure 2 presents the relative makespan reduction over the precedence levels (a relation between the number of jobs and precedence constraints). Results show more significant gains in scenarios with lower values of robot eligibility. This is explained by the fact that settings with lower robot eligibility tend to have higher idleness of robots, favouring the simultaneous use of two resources. Moreover, note that for higher values of robot eligibility (when robots may execute 50%/100% of the jobs), the higher number of precedence constraints, the most significant improvements. Otherwise, if robots are suitable to operate on a limited set of jobs (robot eligibility = 20%), the potential gains seem to be independent on the precedence level.

3 The Value to Society

In this work, we developed optimisation methods to support decision-making in collaborative working cells. These methods will help managers make better investment decisions in robots and understand how they could implement them in practice. This will allow a smoother and quicker technological transition in the shop floor, and hence make industrial companies more competitive on a global scale.

Further studies may also extend this work to consider ergonomic aspects in task allocation, contributing to the well-being of their workers. The improvement of working conditions and proper introduction of robots in the operators' environment will make manufacturers more attractive and socially responsible, as well as improve their productivity.

Retail Distribution in Urban Slums: Empirical Studies for Inclusive Growth

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Retail Distribution in Urban Slums: Empirical Studies for Inclusive Growth

INESCTEC

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The Challenge

- **Motivation:** The demand for goods transportation in urban slums in emerging markets has increased in recent years. Particularly in Brazil, in 2019, the ten largest slums (favelas) are projected to surpass BRL 7 billion in consumption.
- **Problem:** The complexities and obstacles are huge within these low-income communities hinder the logistical operations of last-mile delivery.
- **Background**: Solutions to overcome the unconventional logistic conditions to reach end consumers in slums is scarcely reported in the literature.

Research Questions

Study 1 - *What are the customer's attributes that drive sales in the traditional retail channel in Brazilian slums? How do nanostores owner's tradeoff among attributes based on their perceptions of what consumers prefer in Brazilian slums?*

Study 2 - *What is the last-mile distribution cost structure to reach the nanostores in Brazilian slums and surrounding areas?*

Study 3 - *Is there a way to integrate the growing e-commerce channel into the nanostores delivery channel?*

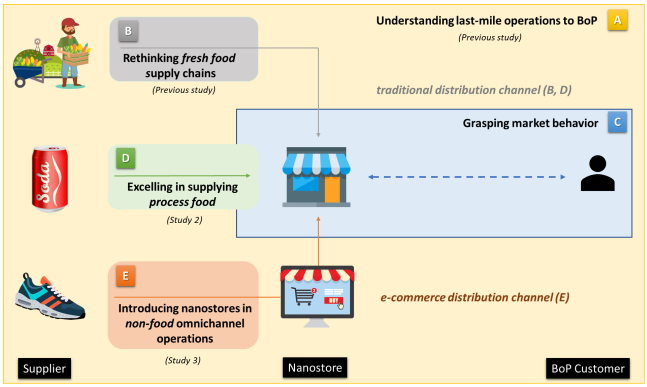
The value to Society

First, from the market demand side, it is mostly concerned with **base of the pyramid (BoP) behavior of consumers and nanostores** targeting BoP market preference to overcome delivery barriers in low-income urban communities.

Second, it intends to tackle the operational and tactical **supply chain planning to distribute products efficiently** into the Brazilian slums, focusing on the last-mile distribution process.

Finally, by combining BoP operational logistics complexity and BoP consumer market characteristics, **the research project intends to improve the cost of living and consumer welfare in slums** and hence **have an extremely positive impact of the livelihood of the favelas`s citizens** given the growth opportunities in digital commerce.

The Research Design and Methodology



Work project positioning in the last-mile distribution network

- **C -** The methodology strategy relies on a **choice-based conjoint (CBC),** allowing us to simultaneously uncover actual consumer preferences for traditional retail channel dimensions (e.g, price, and proximity) and the nature and degree of the biases that nanostores owners' have towards the preferences of these low-income communities
- **D -** The methodology relies on using data collected from a single CPG manufacturer partner to grasp in detail its operations. These data will have to reveal the difference in logistics drivers between different favelas and between favelas and other neighborhoods. Through this data, we will derive a **structural estimation model** for analyzing the cost structure of last-mile distribution
- **E -** The proposal in this third study is to **integrate the growing e-commerce channel into the nanostore delivery channel** as home-deliveries to favelas are not feasible due to lack of addresses, infrastructure, and security concerns.

1 The Challenge

The demand for goods transportation in urban slums in emerging markets has increased in recent years. Particularly in Brazil, low-income families have experienced rapid income growth with a high density of increasingly connected consumers to the Internet. Consequently, in 2019, the ten largest slums in Brazil are projected to surpass BRL 7 billion in consumption. However, the complexities and obstacles within these low-income communities hinder the logistical operations of last-mile delivery. Solutions to overcome the unconventional logistic conditions to reach end consumers in slums is scarcely reported in the literature. This research aims to allow companies to excel in their last-mile operations strategies, trough small traditional retailers (nanostores). We will keep an omnichannel perspective by combining offline and online channels to achieve a holistic distribution process to urban slums. Throughout a series of studies with complementary objectives, a new state-of-the-art last-mile distribution model to slums is to be developed. Our project also intends to improve the cost of living and consumer welfare in slums. Thus, we look at consumer preference choice focus on nanostore owners perceptions making able to have

a profound understanding of the trade-offs favela consumers make when evaluating their offering in the traditional retail channel.

2 The Methodology

This research project is composed of three studies that have complementary objectives. Another two previous studies were previously performed, providing us a grounded knowledge to investigate the dilemma of retail operations in urban slums.

In the first study, entitled 'Grasping market behavior: customers preferences and nanostores ownerâs perception', we seek to understand the choice behavior of consumers in Favelas. Our primary research challenge is the relationship between favela inhabitants and nanostores. Traditional retailers face hard choices when they decide how to improve the way they serve their customers in low-income markets, because it is difficult for nanostores to excel on all dimensions simultaneously. Thus, they must have a profound understanding of the trade-offs consumers make when evaluating their offering. Hence, our methodology strategy relies on a choice-based conjoint (CBC) design, which has become the dominant choice for conjoint analysis (Rao et al., 2014). In CBC, respondents repeatedly are presented with a menu of different attribute bundles and are asked to select their most preferred option. Each option is a combination of values (levels) for a limited set of characteristics (attributes). This methodology will allow us to simultaneously uncover actual consumer preferences for traditional retail channel dimensions (e.g, price, and proximity) and the nature and degree of the biases that nanostores ownersâ have towards the preferences of these low-income communities.

In the second study, entitled 'Excelling in supplying process food for nanostores', builds an empirical understanding of the operational logistics cost in the nanostores supply chain for process food as Consumer Packaged Goods (CPG) suppliers are the ones with more expertise in delivery to the base of pyramid (BoP) markets. In this study, our methodology relies on using data collected from a single CPG manufacturer partner to grasp in detail its operations. These data will have to reveal the difference in logistics drivers between different favelas and between favelas and other neighborhoods. Through this data, we will derive a structural estimation model for analyzing the cost structure of last-mile distribution based on characteristics such as street width, lack of addresses, and security profile to estimate logistics cost. The developed model intends to demonstrate the impact of the most important cost drivers for delivering efficiency. Moreover, the regression model will reveal the impact of the most important drivers for last-mile efficiency, and based on the obtained results and insights, current last-mile operational processes can be adjusted to achieve better supply chain performance in slum communities.

In the third study, entitled 'Introducing nanostores in non-food omnichannel operations', is derived from the study 1 and study 2 focusing the attention on the impact of the distribution costs to favelas but for the e-commerce channel. Increasingly, online retailers have to deal with home-deliveries in the favelas and the myriad of obstacles to reach final customers there. So, the growing e-commerce channel into the Favelas brings another perspective to last-mile retail operations as the fragmentation and informality in favelas highlight social development problems, which are even more boosted by online delivery barriers. Within this context, our proposal in this third study is to integrate the growing e-commerce channel into the nanostore delivery channel as home-deliveries to favelas are not feasible due to lack of addresses, infrastructure, and security concerns.

3 The value to Society

The scope of this research project may be seen through a double perspective. First, from the market demand side, it is mostly concerned with BoP behavior of consumers and nanostores targeting BoP market preference to overcome delivery barriers in low-income urban communities. Second, it intends to tackle the operational and tactical supply chain planning to distribute products efficiently into the Brazilian slums, focusing on the last-mile distribution process. In doing so, we address the BoP consumer attribute importance, tapping into the nanostore owners' knowledge and supplierâ optimal operations strategies.

Finally, these perspectives are glued by the innovative marketing-operational interface framework used to solve and understand the dynamics of these problems with an omnichannel drive.

In conclusion, the population of slums is a sizeable economic force and hence of high relevance for the economic growth of countries and the markets of CPG manufacturers. Moreover, more efficient economic activity, in particular in logistics, will dramatically improve the cost of living and consumer welfare in slums and hence have an extremely positive impact of the livelihood of the citizens of these slums. So, the importance of the research project proposal is clear from multiple perspectives.

Tactical Sales and Operations Planning: a holistic framework and a literature review of decision-making models

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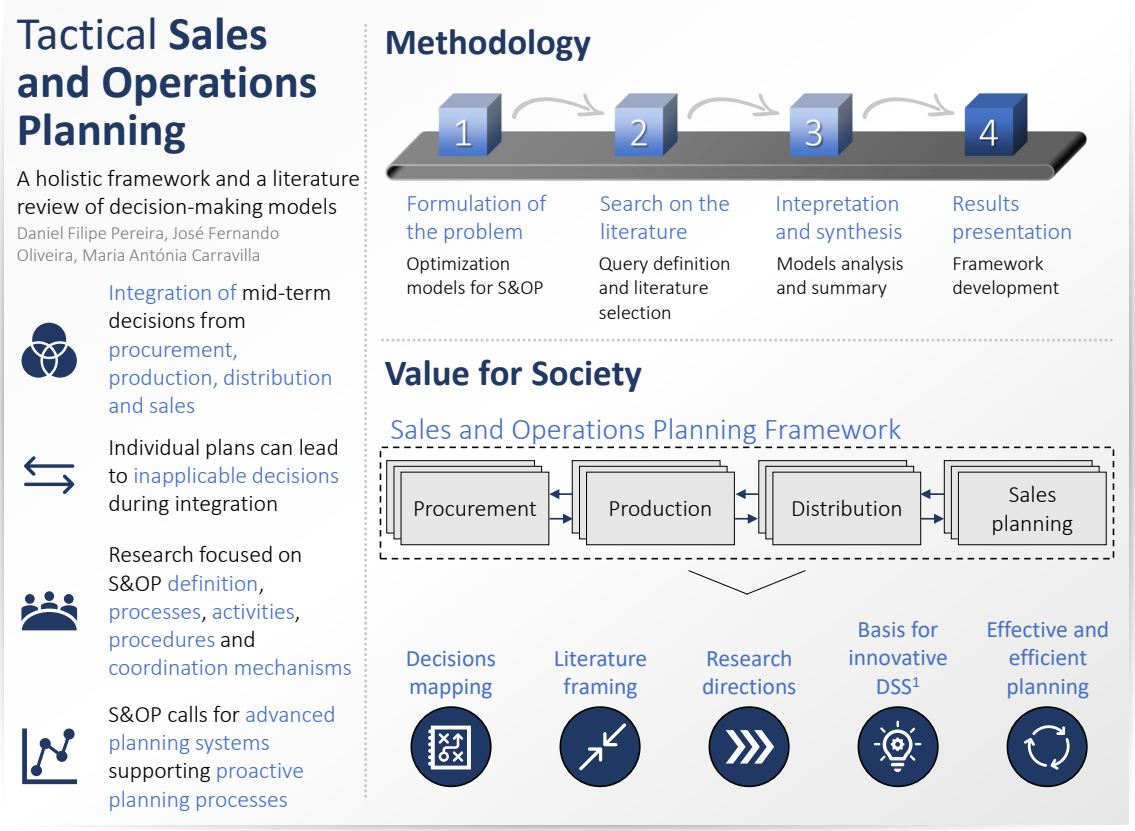

1 Decision Support Systems

1 The Challenge

Sales and Operations Planning (S&OP) has emerged as an extension of the aggregate production planning, integrating mid-term decisions from procurement, production, distribution, and sales in a single plan. Traditionally, these four essential functions of a supply chain were managed independently and linked through stocks. This strategy reduces the managing complexity but ignores the dependencies among functional areas. In the worst case, individual plans can lead to inapplicable decisions in the moment of integration. Thus, S&OP emerged as a strategy to cope with this problem. Furthermore, from an external perspective, globalization, market uncertainty, and growing supply chain complexity have also been supporting the need for integrated planning, especially when past research evidenced that cross-functional planning can boost the performance of an organization and maximize its global value.

The relevance of S&OP for organizational performance justifies the growing interest in the subject. Publications have been increasing both from practitioners and researchers. However, research has focused

more on S&OP definition, processes, activities, procedures, coordination mechanisms, and case studies depicting the benefits of the implementation rather than decision-making (or mathematical modeling) approaches to address the problem. The need for a more analytical perspective on the topic is also justified as the future of S&OP calls for advanced planning systems supporting more proactive planning processes, given the increasingly complex contexts of modern supply chains.

2 The Methodology

We conducted a literature review of the existing analytical models supporting S&OP with a focus on the identification of the decisions taken in the context of integrated and coordinated mid-term planning of procurement, production, distribution, and sales. Therefore, our search strategy was based upon the analysis of scientific contributions (i.e., papers and conference proceeding) explicitly containing optimization models.

Figure 1 presents the query used, whose primary goal is to return S&OP models. We combined the keywords "sales and operations planning" and "S&OP" with keywords related to optimization models. As a result, we were able to filter from the literature on S&OP only the papers pertaining to mathematical approaches to the problem. However, as S&OP emerged as an extension of aggregate production planning, our query was also adjusted to include papers related to mathematical approaches to aggregate production planning that jointly consider decisions from other functional areas (i.e., procurement, distribution, sales). There is a risk that these papers are not related to a context of S&OP program. However, studies depicting mere programs or systems used in internal supply chain planning may unveil tactical decisions that have not been considered by past research on S&OP models.

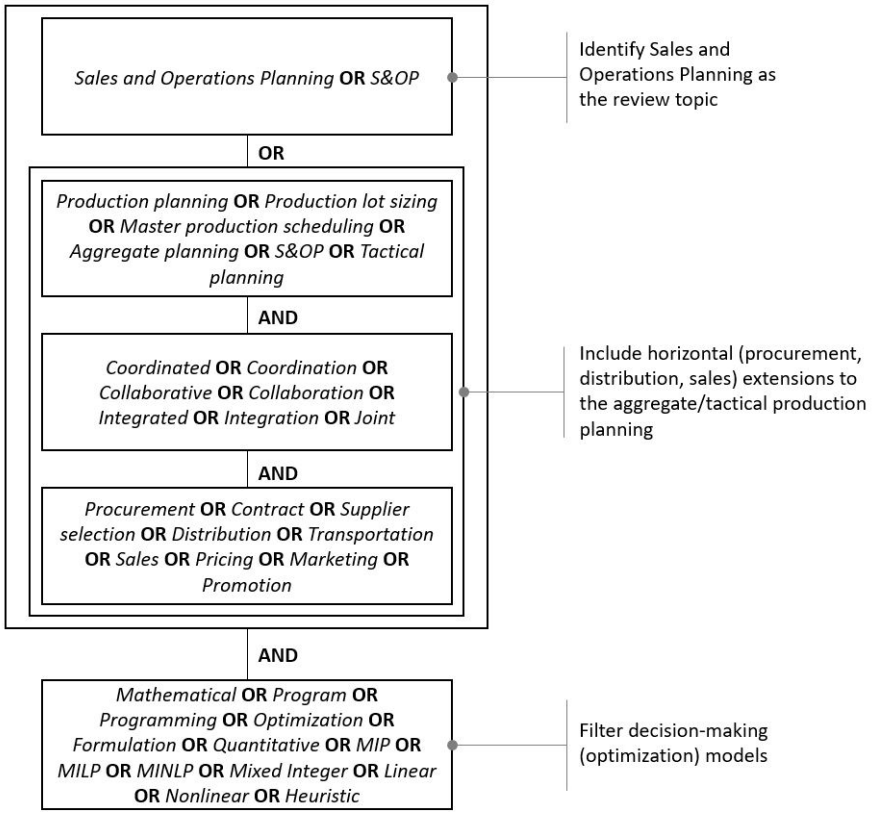

Figure 1: Literature review query

The body of literature was obtained using Elsevier SCOPUS and Web of Science citation databases in September 2019 (without limitation on the publication year in the search criteria). The search returned 688 papers. After abstract analysis, 141 papers were retained for a full reading. In the end, a total of 103 mathematical models and the inherent decisions were thoroughly analyzed from several perspectives. This

process allowed to group the papers in typologies regarding their level of integration of the different business functions in a company (e.g., procurement-production-distribution-sales *versus* production-sales). The interpretation of the overall matrix containing all the typologies of models enables the identification of the main decisions included in the models as well as the main gaps.

3 The value to Society

The main contribution of this review was the development of a holistic framework depicting the overall S&OP (Figure 2). This model contains all the decisions that can be potentially tackled in the mid-term supply chain planning. The relationship between all the decisions is addressed: not only the lateral relationships between procurement, production, distribution, and sales are explained, but also the connection of these decisions with the strategic function of the company, the operational execution, and other external factors.

Past literature is organized according to the framework, with the identification of the streams of the literature which have been extending the tactical production planning. From the reviewed papers, there are 27 S&OP models, that is, formulations that include, at least, one decision from each business function (procurement, production, distribution, sales). In addition there are 32 formulations that model decisions from three business functions (partially integrated models) and 44 formulations modeling dyadic relationships between production and another department.

Our review indicates that there is still a gap between the current practice and the vision of a fully integrated model proclaimed by past researchers. Moreover, the absence of a review of the current state-of-the-art modeling approaches to tackle the mid-term supply chain planning complicates the development of structured approaches. As a result, most of the past models on the field have either been developments for specific cases or non-integrated approaches to the problem. Our goal is to help strengthening and structuring a field of research with highly practical relevance. The proposed framework and the resulting research directions can contribute to the society by guiding future research that can be the basis for innovative S&OP decision support systems. We do believe that companies that resort to such systems will be more efficient and effective while taking their decision-making processes to the next level.

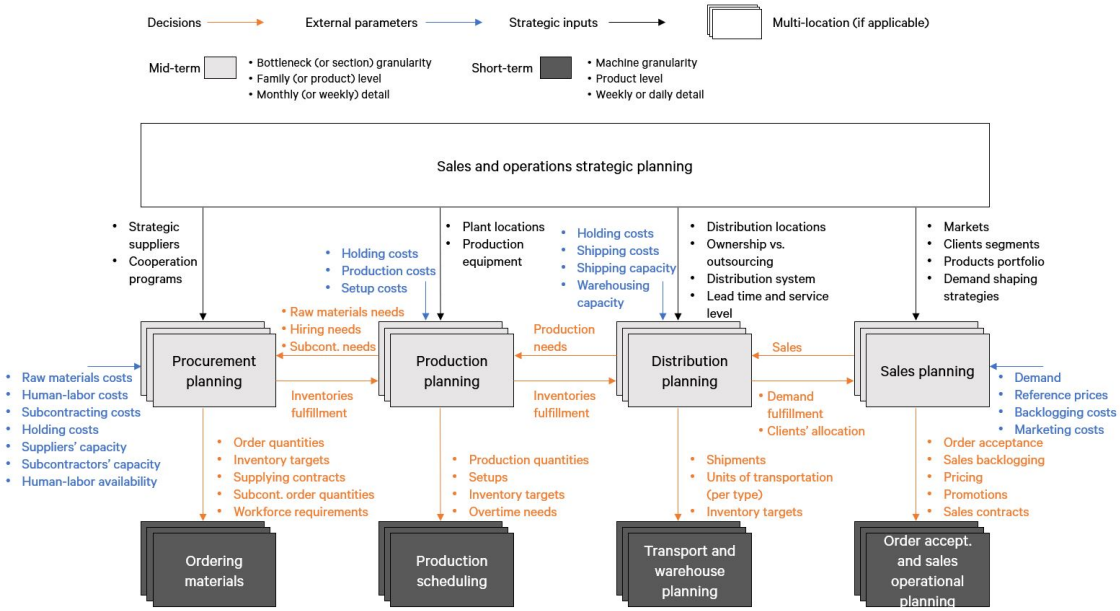

Figure 2: Proposed framework to represent Tactical Sales and Operations Planning

Applying Data Mining to Root Cause Analysis in Manufacturing: A Comparative Study on Logistical data

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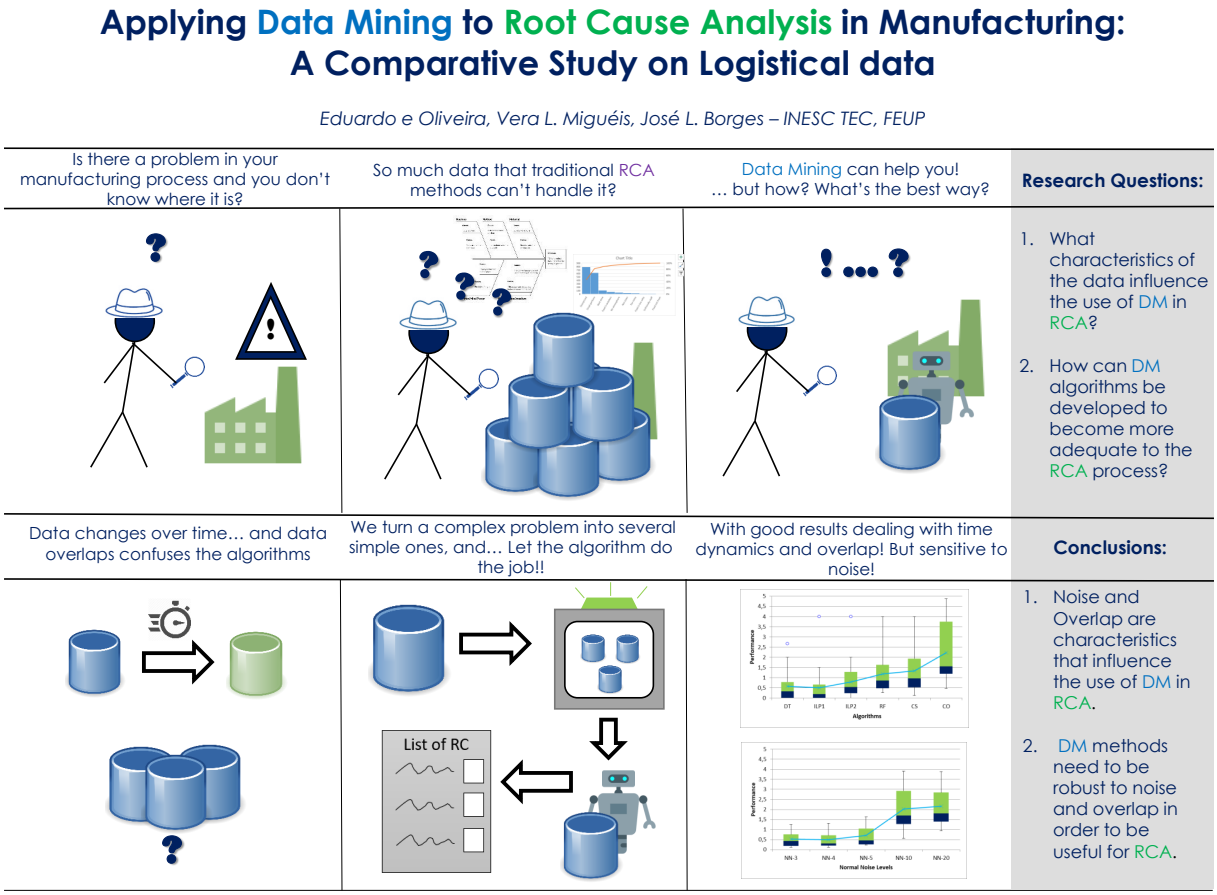

1 The Challenge

Root Cause Analysis (RCA) is the process of trying to find the real reason why a system went from a desirable state to an undesirable one. It is a critical process in manufacturing, as it is necessary for continuous improvement. If it is not possible to find the root cause of a problem, it is not possible to solve it permanently, being only possible to stop the symptoms.

RCA is quite demanding in terms of analysts' time when using traditional techniques. This situation is especially true if there is a considerable amount of data involved. As such, the application of Data Mining (DM) techniques to RCA is seen as a necessary step to improve the efficiency of the method.

Therefore, the aim of this research is to answer the following questions:

1. What characteristics of the data and the manufacturing process (specifically noise and overlap) influence the use of DM in RCA?
2. How can DM algorithms be developed to become more adequate to the RCA process?

To answer the questions above, it is required to consider the data existing in a RCA in manufacturing, and linking it to the DM methods. We can conceptualize the following three types of data:

1. **Location-time** - data of where (which machines) and when a product has gone through during its manufacturing process. This type of data consists of a mixture of nominal data (equipment and step identifiers) and timestamp data (when a product has gone through a machine performing a given step)
2. **Physical** - data of the physical properties (e.g., temperature, pressure) of the process a product has gone through. This type of data consists of numerical data of the different parameters at different steps.
3. **Action-log** - data of the actions that were performed on the equipment (e.g. maintenance). This type of data consists of a list with: the actions performed, the respective timestamp and equipment, a description of the action.

This study, focuses on the first type of data, which represents the internal logistics of a factory. This type of data is more accessible and requires the least level of sensorization. However, it presents some challenges of its own. The main challenges when processing this type of data are the following two:

1. **Time Dynamics** - during normal operation of a factory, operators may notice a problem and try to fix the symptoms. This creates a situation where products that have gone through a root cause have a different label (problem/no problem) depending on the time they passed through the root cause. This increases the complexity of the problem, and it is necessary to consider how the root causes change with time. Otherwise, DM algorithms will not be able to detect root causes, or they will detect spurious correlations.
2. **Logistical Overlap** - when a Lot of products travels through a factory during its manufacturing process, it happens that some products share a portion of their route. If a root cause happens to belong to that joint portion of the route, all the equipment belonging to that joint portion become as likely to be considered root causes as the equipment that is truly the root cause. Traditional DM classifiers usually select a single or a few variables, based on a criterion, to classify as main predictors or, in this particular context, the root causes. This criterion obviously influences the choice of the main predictors and needs to be tackled.

2 The Methodology

To tackle the issue of time dynamics, we propose a methodology with two phases: the first identifies moments with a high level of problematic products (problematic moments); the second uses a DM algorithm to find the equipment that is the root cause. This way, the proposed approach converts a dynamic problem into several static problems. The problematic moments are identified using a double sliding-window. In each window, the proportion of labels (problem/no problem) is modeled as a binomial distribution, with the proportion being the number of problematic products in the window divided the total number of products in the window. Differences between the proportion of labels are detected using a confidence interval.

For the issue of the logistical overlap, the main concern is that the classifiers could ignore equally important variables that could be root causes. Using only logistical data, it is not possible to distinguish between equipment that share a joint portion of the route. Thus, we developed three algorithms to overcome this difficulty. These algorithms are used in the second phase of the proposed methodology, and they provide a ranking of the importance of the predictors instead of rules. This way, the equipment

that is the root cause, but part of the joint portion, may appear on top of the ranking, with the same importance.

In the second phase of the proposed methodology, we tested six DM algorithms (one at a time): three classifiers - Decision Trees (DT - C4.5), two models of Inductive Logic Programming (ILP 1 and 2); and three algorithms for dealing with overlap - based on Random Forests (RF), Chi-Square (CS) test, and Co-Occurrences (CO).

Another characteristic of the data we want to study was noise. Data coming from a manufacturing factory is often noisy, and it is necessary to investigate how that noise impacts the application of DM techniques to RCA. Noise can be divided into two sources:

1. **Normal Noise** - noise that does not have any definable cause.
2. **Root Cause Noise** - noise that occurs due to mislabeling products that went through the root cause. We want to test how resilient the developed methods are to scenarios where not all the products that went through the root cause (in a problematic moment) are labeled as a problem.

To conduct a proper experimental study, it was necessary the development of a simulator based on a case study in semiconductor manufacturing. With it, it is possible to control, among other things, the level of noise and the root causes.

We performed a simulation study with 25 datasets, each one with different levels of noise. Each dataset is processed by the six algorithms mentioned, using two different confidence levels for the confidence intervals in the problematic moment detection. The most relevant results are summarized in Figures 1 (performance of each algorithm) and 2 (performance depending on the level of normal noise).

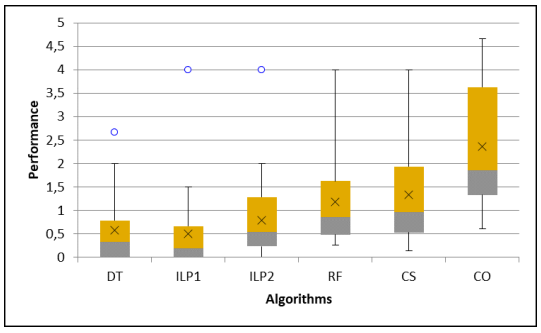

Figure 1: Boxplot with the performances of each algorithm. Higher values of performance is better. Each point represents a dataset.

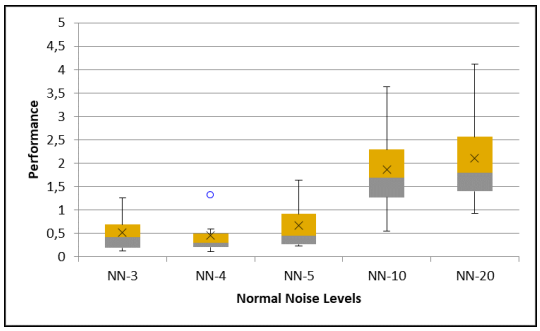

Figure 2: Boxplot with the performances for each level of normal noise. A higher number in the horizontal axis indicates less noise. Higher values of performance is better. Each point represents a dataset.

Overlap methods perform better than classifier-based methods, which is confirmed by a Kruskal-Wallis test. Normal noise has a considerable impact on the performance of the algorithms. In addition, Friedman tests and Scheirer-Ray-Hare tests reveal that it is not possible to discern any significant impact of root cause noise on performance. Also, no significant impact of the confidence level on performance is found (based on a paired samples T-test).

3 The Value to Society

Previous works on applying DM to RCA in manufacturing focused on finding root causes in a specific, static period of time. This work develops a methodology that can search through the data, find the problematic moments, and then analyze them to find the root causes.

In addition to this methodology, this work contributes to society and scientific community by developing a conceptualization and experimental study that allows us to identify the characteristics of the data that influence the application of DM to RCA, and what should be the focus when developing new algorithms. Hence, the answers to our research questions are:

1. Normal noise and Overlap are characteristics of the data and the manufacturing process that influence the use of DM in RCA.
2. To develop DM algorithms more adequate to RCA, they need to have a robust problematic moment detection, and the use variables' ranking algorithms instead of classifiers to overcome overlap.

These findings will allow for the development of DM techniques more adequate to RCA, creating tools that will make the analysts' job more efficient.

Understanding the Customer Engagement with the Smart Energy Services

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Understanding the Customer Engagement with the Smart Energy Services

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The Challenge

The service sector is witnessing a paradigm shift where traditional boundaries and roles are being redefined.

However, firms are facing difficulties in engaging customers with smart services.

As such, an in-depth understanding of customer engagement with smart services is lacking.

The Methodology

Applied to the energy sector, the qualitative study involved semi-structured interviews with 31 customers from 3 relevant groups in the energy service context:

- *Customers of home energy management systems (N=11)*
- *Customers of electric vehicles (N=10)*
- *Customers with high-consumption of electricity (N=10)*

The Value to Society

In the last five years, interest has been growing due to the imposition to understand the reasons customers adopt or reject smart energy services.

In this context, the study brings a deep understanding of customer engagement that could enable designers to develop competitive services with innovative value propositions and new ways of co-creating value.

1 The Challenge

In recent years, the service sector is witnessing a paradigm shift where traditional boundaries and provider roles are being redefined, as services are becoming highly interconnected. Consequently, new interactions emerge, and customers are increasingly engaged in shaping firms' offerings. The smart service sector is a good example of this paradigm shift. In an emerging industry, the technology-based services are delivered through smart objects. They are built on intelligence, awareness, and connectivity, enabling new interactions and new experiences that go beyond the dyadic relationship between the firm and the customer. Its invisible nature can dramatically affect the way customers perceive services, impacting customer engagement, and technology adoption. Therefore, a deep understanding of how the customer engages with services in this new context is required. Customer engagement is defined as a psychological process that involves the intensity of an individual's participation and connection with the organization offerings and activities, initiated by either the customer or the organization. Within the smart service context, the energy sector is undergoing a structural change, with the widespread use of smart technologies such as sensors, smart devices, and applications based on the implementation of smart grids. As such, this

sector is considered a rich context for the study, as an in-depth understanding of customer engagement with smart energy services is lacking. Part of the challenges is represented by the urgency to minimize the damages caused by global warming. To this end, solutions must be implemented to reduce emissions while maintaining the global economy on the growth track. As a feasible solution, smart technologies allied to renewable sources of energy must be implemented worldwide in the next few years. To address this challenge, the study aims to understand customer engagement with smart energy services, gaining a deeper comprehension of the customer engagement drivers that emerge in the smart service context.

2 The Methodology

In a qualitative approach, the study involved focus groups and in-depth interviews with a total of 31 participants covering energy customers. The empirical study was divided into two phases. First, based on preliminary semi-structured interviews, three relevant groups were identified according to their goals and experiences with energy services: Home Energy Management Systems (HEMS) customers, electric vehicle (EV) customers and residential customers with high consumption of electricity. Second, two focus groups and further semi-structured interviews were administrated to gain an in-depth understanding of customer engagement with smart energy services. Interviews were recorded and transcribed verbatim, and data analysis followed a process of data coding and categorization in order to systematize customer goals, activities, and related context, including smart objects, and the interaction with multiple actors.

3 The value to Society

In the last five years, interest has been growing due to the imposition to understand the reasons customers adopt or reject the smart energy services, as they are changing completely the way people use and take benefits from technology in daily life. In this context, the study brings a deep understanding of customer engagement that could enable designers to develop competitive services with innovative value propositions and new ways of co-creating value.

Condition-based model for a heterogeneous multi-unit system with resource dependency

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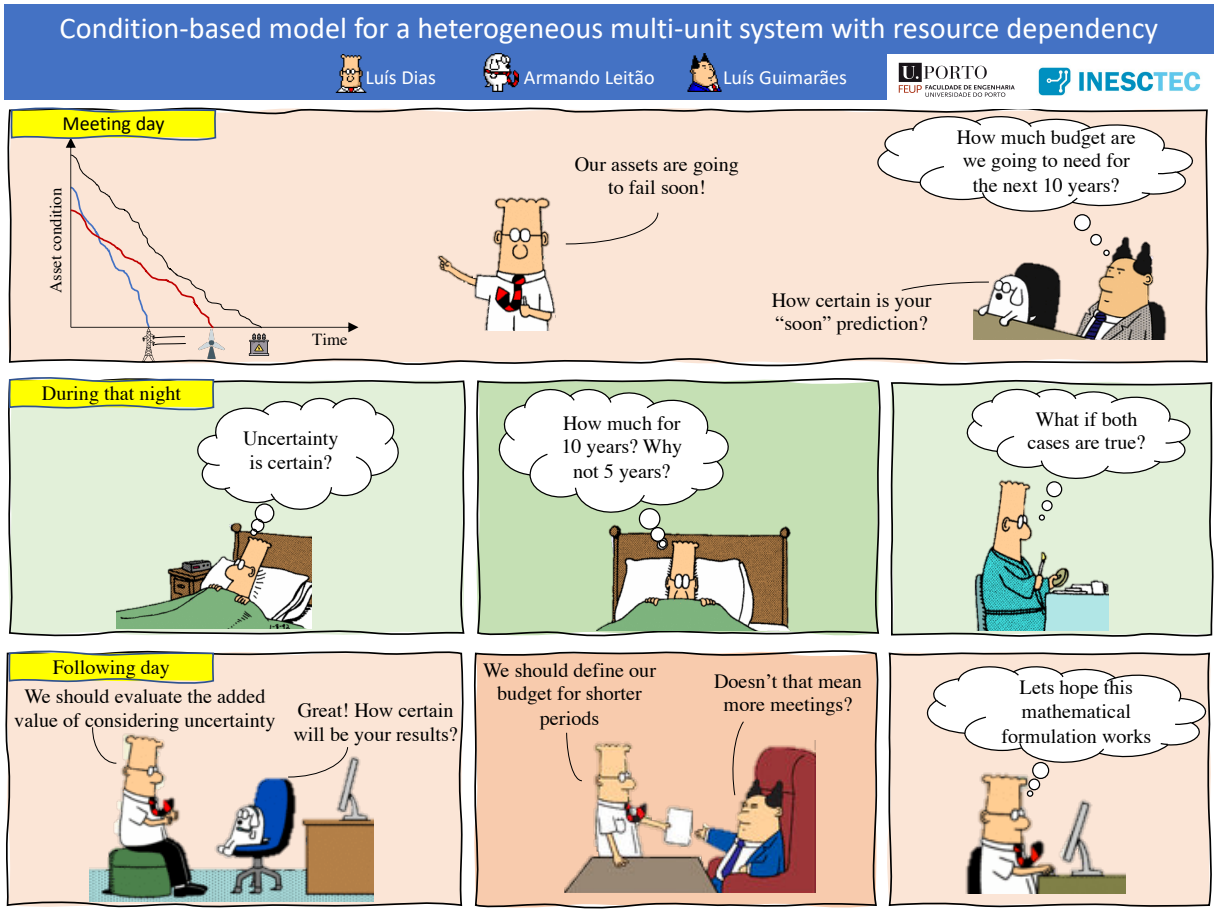

1 The Challenge

Recent advances in asset condition monitoring technology and equipment allowed many industries to start improving their operation and management decisions (O&M). Due to the increasing market competitiveness, industries focus is changing to reduce maintenance costs while maintaining or improving the throughput of their service or products. Moreover, the stream of data collected daily enables the monitoring and prediction of each asset condition. By capitalizing on this kind of information, industries can carry out suitable and effective management decisions, which are vital for the growth and sustainability of any company. Knowing this, a multitude of studies in this field has been conducted, and the scope of most works has rapidly shifted from managing simple repair operations to optimizing complex systems of multiple units based on the actual and future asset condition.

Motivated by a case study in the electric power industry, the problem to tackle is the definition of the maintenance budget, in a fixed planning horizon, for O&M activities performed in a heterogeneous multi-unit system. In this problem, the decision-maker (DM) manages several units which perform the

same activity but have different physical characteristics. Consequently, this leads to different condition degradation paths for each unit as well as different impacts on the condition for the same maintenance intervention and maintenance costs. Furthermore, all units share the same maintenance budget.

To tackle this kind of problem, the researcher's focus is on developing new condition-based approaches to provide optimal solutions for multi-unit systems. Condition-based optimization is a well-established field with advanced models which are well documented in the literature and capable of achieving an optimal solution under reasonable computational time. However, the vast majority of these models were developed for single-unit systems and are difficult to extend to multi-unit systems. This is because single-unit optimization models do not account for the interaction and dependencies between units in a system. Moreover, including these interactions significantly increases the problem complexity. To avoid this, researchers tend to rely on oversimplifying assumptions: i) assets having the same condition degradation rate, ii) maintenance intervention impact on asset condition is neglected or considered perfect, and iii) inter-dependencies between assets are usually considered separately. These limiting assumptions most likely generate sub-optimal solutions which are not applicable in practice. Knowing this, we aim to propose a novel mathematical model without relying on these assumptions and capable of being generalized to different industries with a similar problem. Hence, it is essential to study the problem characteristics to understand the added value of incorporating them into the model.

2 The Methodology

To achieve our goal, we divided the methodology into two parts. The first part focuses on developing a condition-based mathematical model to optimize budget allocation for any heterogeneous multi-unit system. To do so, we developed a novel condition-based mixed-integer optimization model. This formulation integrates asset replacement decisions with maintenance policies definition. In this work, the maintenance policy defines which and when a maintenance intervention should be performed, and the replacement strategy identifies when and how assets should be replaced or refurbished. An example of a possible solution for this type of problem is depicted in Figure 1. For the planning horizon, each unit can only be replaced once with a lead-time of one period, maintenance intervention cannot overlap with asset replacement, and it can only be performed once per period. Furthermore, a unit is always replaced whenever a failure occurs at a higher cost when compared with a planned replacement.

Since this is a condition-based approach, each unit condition will define the timing of these decisions. The main inputs of the model are the unit present and future condition, as well as the average condition improvement for each type of maintenance intervention. The model is developed in this manner to add some flexibility concerning the predictive technique to use. On the other hand, the definition of these decisions allows us to estimate the maintenance budget for each period. Hence, the available budget constrains the amount of unit replacement and maintenance intervention that can be performed.

Nevertheless, we allow for solutions that surpass the defined budget for a given period or multiple periods. Note that taking this assumption is reasonable, since the defined budget does not represent the entirety of the company resources. Notwithstanding, these kind of solutions are penalized and should be avoided. The objective is to minimize the net present value of the allocated budget for each period.

To understand and improve the proposed approach potential, in the second part, we study the added value of increasing the complexity regarding condition degradation and the end of horizon effect mitigation, known to exist in other mathematical approaches considering a finite planning horizon. Concerning condition degradation, we study the value of considering uncertain condition degradation. We achieve this using a Wienner process, which allows to simulate the degradation path of each unit until it reaches the failure threshold. To include uncertainty, we improve the formulation using a two-stage stochastic model. Also, to integrate risk and increase the solution robustness, we apply the CVAR objective function and the respective constraints. In this study, we consider two possibilities for this approach, which differ in the decision variables fixed in the second stage (scenario dependent). In short, we want to study the advantage of fixing budget and asset replacement compared with only fixing the budget. In total, we compare three approaches to conclude if a deterministic approach is enough for this kind of problems, and if not, what decision variables should be fixed. After defining which model to use, we study the planning horizon impact on the solution. Although the obtained solution is optimal for the planning

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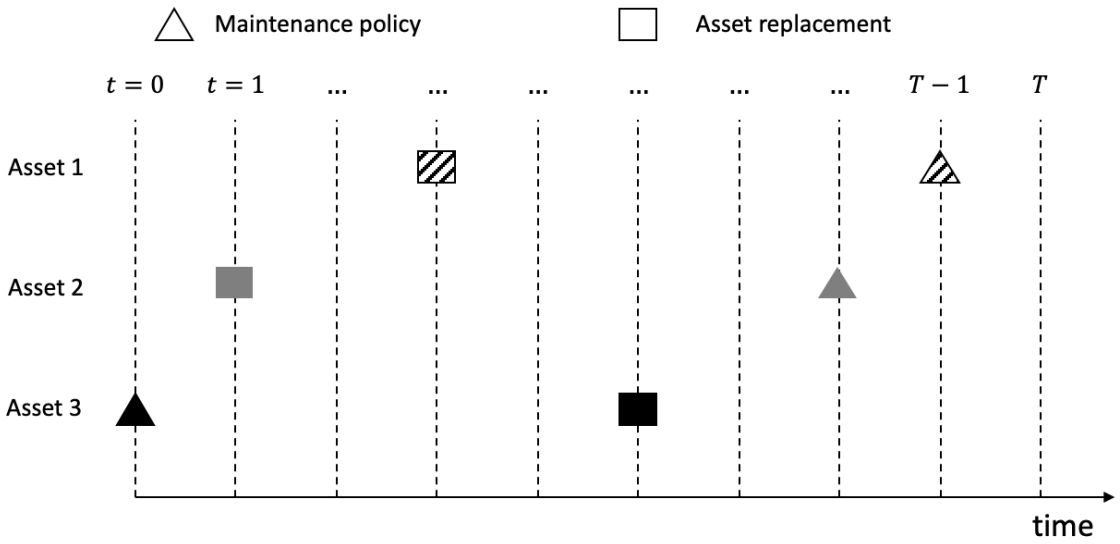

Figure 1: Example of a possible solution for a planning horizon with T periods and three assets

horizon, there is a possibility that the defined decisions could lead to a significant increase in costs in the following periods. To that end, we incorporate a rolling horizon approach into our model to update the solution dynamically. Then, we evaluate if the obtained solutions are better or worse than the ones provided by the standard approach. The resulting conclusions from this study will not only potentially improve the proposed formulation, but it will also provide valuable insights into the literature.

3 The value to Society

This work presents a novel mixed-integer model suited to multi-unit systems. This type of approach is different from the "status quo" in the field not only because it tackles the gaps found in the literature, but mostly because it is a business-oriented perspective of the problem. The aim is not only to present an approach encompassing the interconnected sub-problems for a heterogeneous multi-unit system, but it is also to provide a valuable tool to support decision-making.

The value to society can be seen from two perspectives: i) the company and ii) the customer. Companies adopting this approach will be able to increase operational efficiency and effectiveness, leading to increased profitability and an improved market position. From the customer perspective, it will enable access to lower-priced services/products and higher service level, which are the two most important benefits. This contributes to the growth of society by facilitating the accessibility of these services.

In the future, we aim to implement the presented approach to real case studies in the electric power industry. Furthermore, this approach is to be integrated with predictive models into an advanced analytical tool to obtain suitable solutions.

A collaborative transportation problem for players with different objectives

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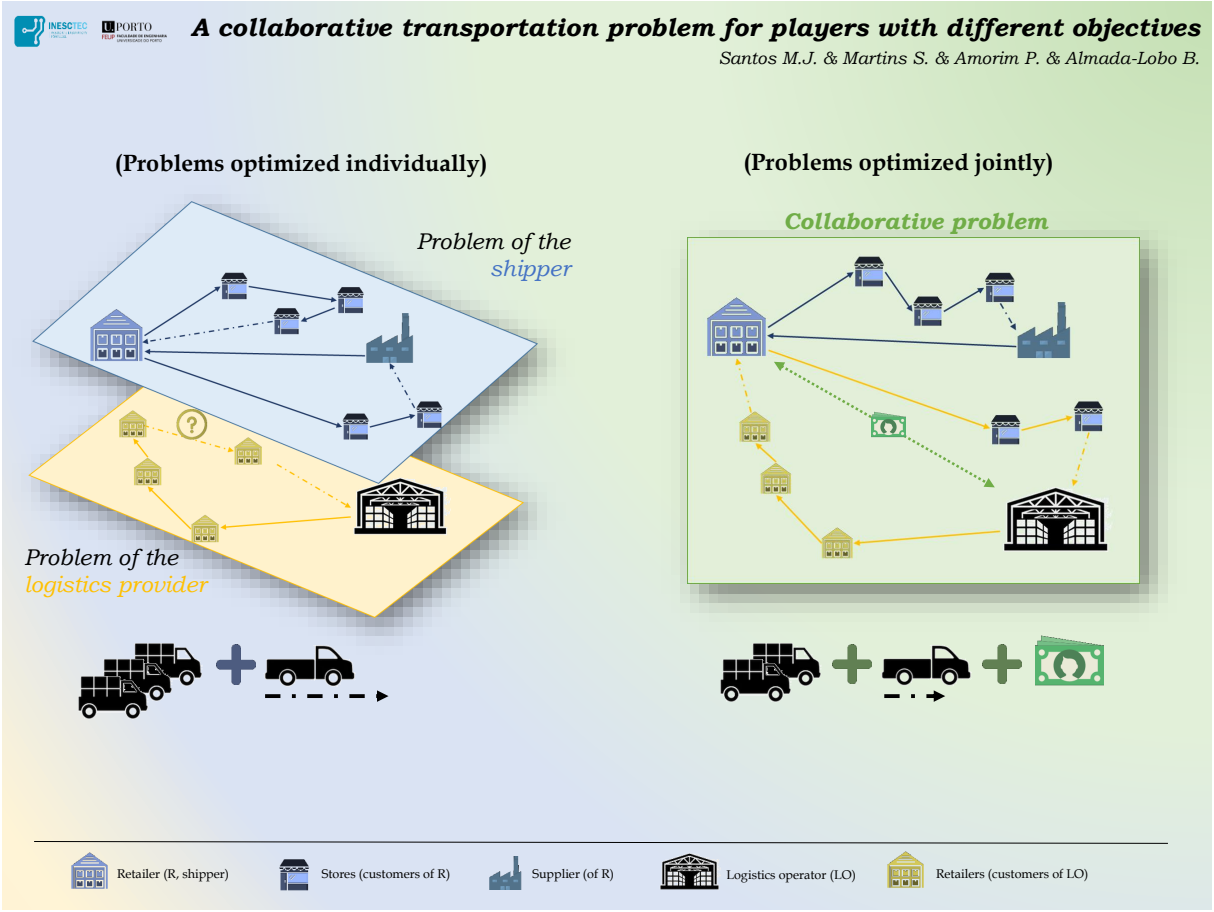

1 The Challenge

The development of strategies to increase the efficiency of transport operations has always been a hot topic in both practice and theory. In practice, companies (industry, retailers, logistics providers) search for solutions that maximize the usage capacity of their fleet of vehicles, reduce the empty distances and minimize the associated environmental impact. They usually focus on reducing costs and increasing the service level (e.g., consistency of routes/drivers, customers orders received within the specified time-windows). In theory, the research on new methodologies to handle the vehicle routing problem (VRP) is one of the main domains of Operations Research, for which the development of strong formulations of the problems and efficient solution methods to solve them is the primary motivation.

In the last years, much attention has been channeled to the topic of collaborative VRP, where similar or different companies make an effort to optimize their problems together, such as joint route planning. In summary, the joint route planning formulates the different VRP of each player as a single and global VRP, which is then optimized in order to reduce the costs (or increase the gains) of the coalition (the

group of players in collaboration). Afterwards, the gains are distributed by all players in the coalition. However, recently, it has been recognized that the joint route planning may neglect the individual goals of each player. For instance, one player may be more interested in reducing costs, while the other favours the consistency of its routes.

Thus, the challenge of this work is to develop an optimization model for the collaborative transportation problem between two players that have different problems to solve. This problem is motivated by a real case where a shipper (retailer) has a private fleet of vehicles to serve its customers (stores) and a logistics operator that serves independent customers (retailers or manufacturers). Today, the players do not collaborate, but since they operate in the same geographical region, the potential of collaboration may be high. In particular, one player (the shipper) faces a Vehicle Routing Problem with Backhauls (VRPB), where the goal is to minimize the total routing costs of deliveries at customers and pickups at suppliers, in the returning trip to the depot (backhaul). Alternatively, the shipper may use its fleet for the deliveries only, while paying for the suppliers to bring its requests to the depot. The other player (logistics provider) needs to solve a VRP with Profits that selects only the most profitable customers to visit, while also minimizing the number of vehicles required. By collaborating, the shipper may use only the vehicles of the logistics provider, guaranteeing profits for the latter and avoiding the environmental and economic costs that result from the use of an additional vehicle.

2 The Methodology

The collaborative problem tackled in this work describes the interaction of a shipper and a logistics provider. In such cases, the collaboration is said to be vertical, as the players are at different levels of the supply chain. However, since the shipper owns a fleet of vehicles and can perform its deliveries and pickups, the problem is formulated from the perspective of horizontal collaboration (i.e., both players are considered logistics providers). The individual problems of each player are as follows. The shipper optimizes the routes of its fleet such that each vehicle departs from the depot, delivers all the requests to the assigned customers, and then collects material from the suppliers in the return trip to the depot. The logistics provider also optimizes the routes of its vehicles, which depart from the depot and delivers all the requests to its customers. In returning to the depot, the logistics provider searches for profitable services to perform, in order to minimize the empty backhaul distances.

The collaboration takes place when the logistics provider is outsourced to pickup some load at the shipper's depot, and to deliver it to the shipper's customers, in its backhaul trip. Therefore, the shipper must decide when it should perform a delivery and pickup route with its fleet and when it should outsource the logistics provider to satisfy the demand of some of its customers. The logistics provider must decide which services may be accepted to reduce the empty backhauls, if the service is offered by the shipper, and if another service is offered by another company. Since the delivery routes of the logistics provider are predefined, the collaboration may only occurs in its backhaul trips. The collaborative transportation problem will be modeled as a Rich VRP, designation attributed to traditional routing problems that include several practical constraints. The Rich VRP includes capacity limitation of vehicles, heterogeneous fleet, multi-depot (each player has a distinct depot from which their vehicles start and ends their routes), time-windows that are necessary to satisfy at the delivery customers, and consistency of vehicles (customers have to be served by the same player). To assess the pollutant emissions generated, a simplification of the relation between distance and emissions will be used.

The problem will be formulated as a bilevel Rich VRP, which considers the problems of shipper and logistics provider at two different levels. The upper level, which is the dominant one, covers the problem of the shipper. The lower level is embedded in the former and copes with the problem of the logistics provider. Bilevel optimization models can optimize simultaneously two distinct problems, with different objectives and constraints, and where the decisions at one level influence the decisions at the other level, and vice-versa. Bilevel optimization problems may seem contradictory to collaborative problems. However, recently, the literature has been showing that bilevel optimization can be used as an alternative to model collaboration between different participants, particularly when there is limited information.

To solve the Bilevel Rich VRP, two different solutions methods will be developed. The first method is an exact reformulation that reduces the bilevel model to a single-level, incorporating the rational response

(decisions) of the lower level into the upper level problem. The second method is a heuristic, which does not prove the optimality of solutions, but is much more efficient in terms of computational performance, compared to exact solution methods.

3 The value to Society

The value of this work focuses primarily on the environmental impact of collaborative transportation. It has been proved in many scientific works, as well as in practice, that reducing empty distances of vehicles leads to a decrease in the negative impact of transportation. If a vehicle performs a delivery and pickup services simultaneously, instead of two different vehicles for each service, the total distance traveled can be reduced and, consequently, all the pollutants emitted by the vehicles while driving are also reduced. It is certain that if a vehicle travels full loaded generates more emissions than a vehicle travelling lighter. However, if one vehicle can attend the same number of customers instead of two vehicles, then it is almost certain that less emissions are generated. Besides, empty traveling does not add value to any company since it only increases fuel consumption and pollutant emission. Therefore, besides the economic aspect of collaboration, the problem investigated in this work promotes a more friendly-environment strategy than traditional non-collaborative routing problems.

Furthermore, the model developed here is intended to give support for decision-making of companies under the context of collaboration. The benefits of such model are the easy usability and easy implementation, which contrasts with the many collaborative models proposed in the literature, that are often hard to replicate and implement in practice.

Understanding carsharing: a business review towards relevant research insights

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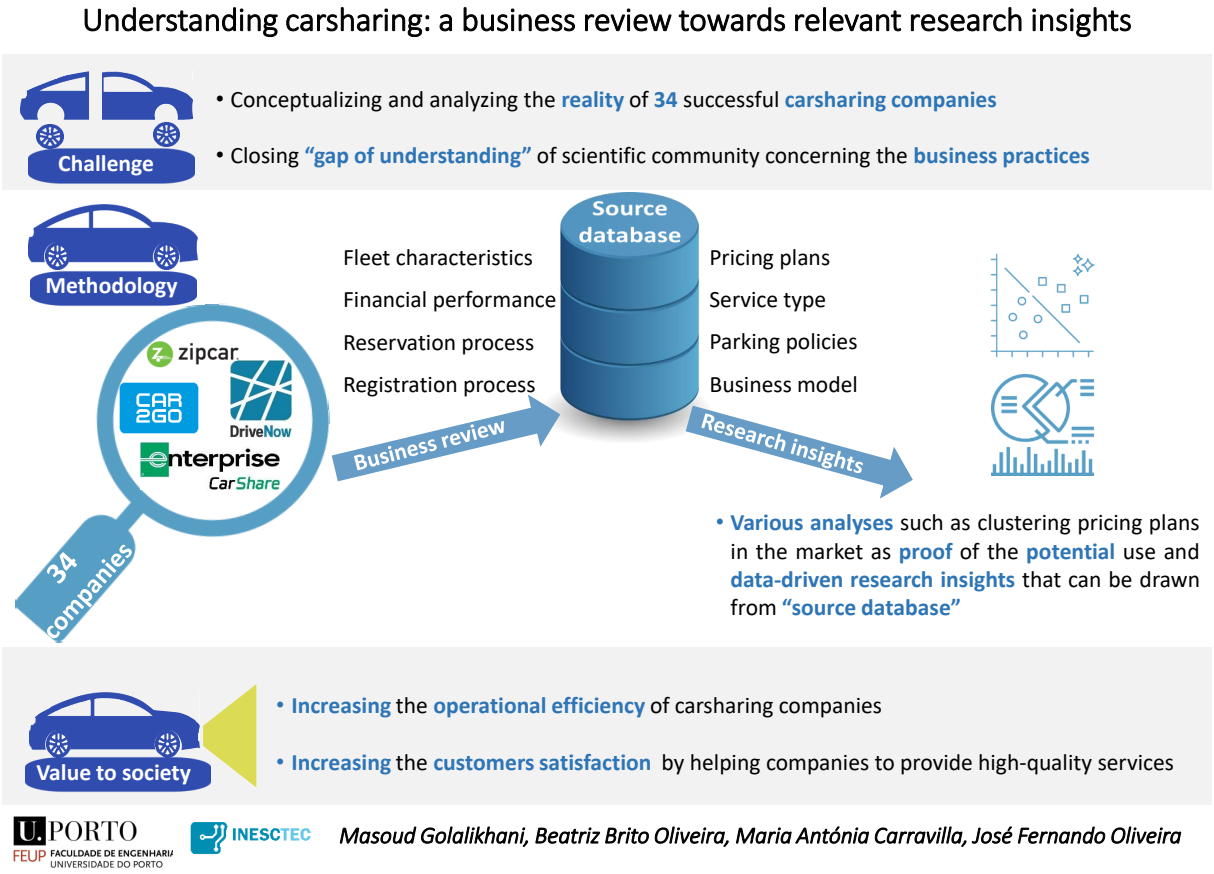

1 The Challenge

During the last decades, carsharing emerged as a flexible and sustainable mode of transportation. This new model of mobility allows customers to rent a car for short periods (minutes or hours) and offers them a convenient service since all the processes are usually self-service, and shared vehicles are distributed around the city close to the customers' needs.

The potential benefits of carsharing for the customers and companies, as well as its connection with more environmentally-friendly mobility choices, has led to a boom in the number of carsharing organizations (CSOs) throughout the world, and this market has never been as competitive as it is now. Thus, designing a viable carsharing system is challenging, as well as often dependent on a myriad of operational decisions that need to be supported by the adequate decision-support system. Therefore, carsharing is being increasingly studied in the Operations Management (OM) literature. Even though extensive research has been carried out regarding customers' and CSOs' characteristics, it has not yet considered relevant

operations and strategies of different companies to capture the main features of this market. As a consequence, there is still a "gap of understanding" of the scientific community concerning the business practices and contexts, often resulting in over-simplifications and relevant problems being overlooked.

In this work, we propose a first step in closing the "gap of understanding" by describing, conceptualizing, and analyzing the reality of some successful business-to-consumer CSOs operating throughout the world. Building on this, we highlight relevant "research insights" and structure all collected data organized by different OM topics, enabling knowledge to be further developed in this field. Therefore, the main contributions of this study are twofold. First, this study provides a global database that aggregates the main features of 34 successful CSOs, which may work as the primary source of real carsharing data for future academic works. This "source database" delivers an in-depth insight into the business practice that can be applied by researchers to develop more realistic models. Second, we concentrate on some of the most critical operations and processes, such as pricing schemes and fleet management, and the conceptualization of these operations. In order to better address these issues, and as proof of the potential use of this information and of the relevant insights that can be drawn for both researchers and practitioners, we conducted an in-depth analysis by applying data mining methods.

2 The Methodology

This study sets out to provide a "source database" about the main features of the carsharing market based on the reality of CSOs. To this aim, in the first step, three main sources of information were identified to provide adequate data sources for this study. We identified 34 successful business-to-consumer CSOs and 12 leading consultancy firms that provide services for CSOs, as well as some of the most popular customer review websites. On the one hand, analyzing consultancy firms allows us to understand the present and future needs of CSOs better; on the other hand, analyzing customer review websites helps us to understand customers' expectations and their evaluation of the CSOs.

In the second step, through an online process, all the relevant data were collected from the websites of main sources and aggregated in the "source database". Since not all relevant information was available in the main data sources, some other reliable references and websites were used to collect the required information. In this process, no categories were created beforehand; however, they emerged as the data was collected by organizing and synthesizing information. Ultimately, a total of 15 features based on different OM topics were identified. For each identified feature, research insights were derived from the data and its potential application in future studies was discussed.

Moreover, for some of the most critical operations in the market, data mining methods are applied. For instance, pricing plans of CSOs is one of the most critical and complex aspects of carsharing operations; however, it seems that it has been significantly neglected or over-simplified by carsharing researchers, and there has been a lack of research in this area. Therefore, we analyzed this feature in detail, and 173 different plans were identified based on the combination of 25 attributes in the structure of CSOs' pricing plans. These attributes represent different components of the plans and are based on different units, such as time, distance and currency. Furthermore, the monetary attributes are mainly divided into two types: fixed costs that do not depend on the use of vehicles (e.g., registration fee or monthly fee), and variable costs that depend on the use of vehicles (e.g., fee per minute). The K-means clustering technique was applied to find the similarities and differences between all the 173 plans. The clustering results showed that the average value of 14 attributes differentiated the clusters which are presented in Figure 1. Accordingly, the resulting clusters were characterized and named as follows.

The first cluster "which represents plans for rare use", is depicted in Figure 1 in red and has the lowest rate for fixed costs, such as registration, yearly, and monthly fees, and the highest rate for variable costs, such as price per minute and could be the best option for customers who rarely use carsharing services. The second cluster, "plans for occasional use", is shown in Figure 1 in blue and has an average rate for both fixed and variable costs and could be the best option for the customers who occasionally use carsharing services, and tend to use it for short-distance trips. The third cluster, "plans for commuting", is depicted in Figure 1 in green and has the highest rate for fixed costs and the cheapest rate for variable costs, and it thus can be the best option for the commuters. The fourth cluster, "plans for flexible use", is represented in Figure 1 in gray and named as for its flexibility since customers can pay "prepaid credit"

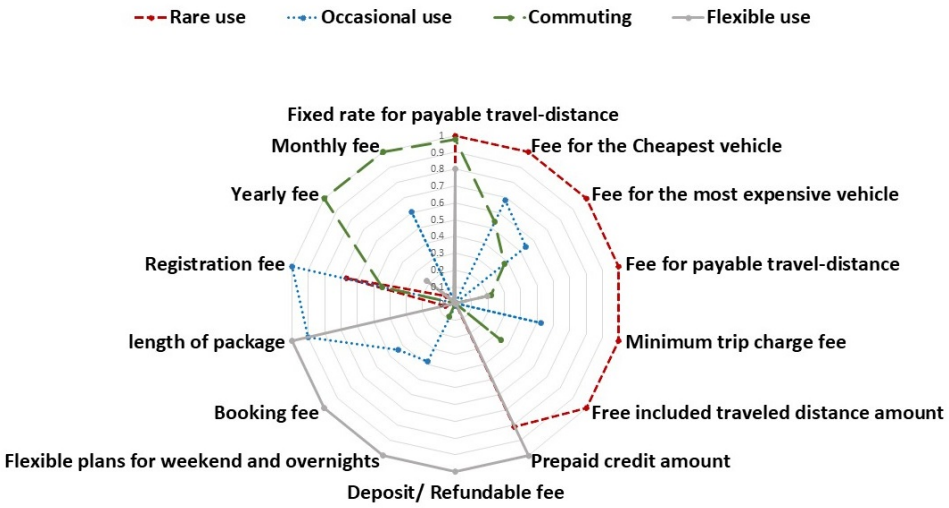

Figure 1: Visualization of clustering results based on 14 effective attributes

to benefit from the lowest prices during different periods of the day and days of the week.

Overall, three clusters allow customers to choose a pricing plan depending on the frequency of their usage, and one cluster aims to increase utilization of fleet in low demand periods.

3 The value to Society

The "source database" presented in this study not only can work as the primary source of real data in future research in this field but also deliver in-depth and relevant "research insights" to the scientific community that can be applied to develop future work. Apart from the scientific contribution, the collected data in the source database and the analyses of this study can have additional value to CSOs, since they can use the result of analyses to increase their operational efficiency and other metrics of performance. Moreover, from the customer's perspective, we expect that this research can help companies meet their needs and provide them with high-quality service, increasing customer satisfaction. Finally, numerous studies have documented the positive social and environmental effects that can be associated with carsharing, in specific situations, such as the reduction in car ownership. By providing comprehensive and detailed real-world data and insights, this work supports research in this field. In this way, it aims to help carsharing systems become more profitable, customer-centric, and environmentally conscious.

What can servitized manufacturers learn from their customers? An empirical investigation in the elevator industry

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1 The Challenge

An increasing number of manufacturing companies is competing through a portfolio of integrated products and services, breaking the boundaries between manufacturing and service firms worldwide. This is a service-led competitive strategy and the process through which it is achieved is commonly referred to as servitization.

Some authors argue that customer-centricity is essential in the development of product-service offerings. For a customer, service provision by the manufacturer may reduce both the risk and the maintenance and support costs that are incurred with the product operation (or at least stabilize and make them predictable.

Consequently, customers are demanding more services, such as contracting for capability, which means that the asset has to be available and working properly, and the provider of the asset only gets paid on

a per-use basis. Through services the customer may receive a greater diversity of options in the market with more customized offers. Customers also tend to demand more customization since they are better informed than ever and seem to demand their providers to offer service-based contracts. Therefore, manufacturing companies tend to add services to products, creating value for customers and ultimately for themselves. Nevertheless, only a limited number of empirical studies have investigated how customers promote or hinder servitization.

To address this gap, our study theoretically articulates and empirically tests an integrated model of factors that influence the predisposition of customers to purchase advanced services. In doing so, we answer the call for the evaluation of new service offerings from a viewpoint of customer acceptability and for the understanding of customers behaviour.

The study is based on a survey of customers in the elevator industry in Portugal. This industry was chosen because transition to services is still an open issue in the industry and it covers a broad spectrum of service offerings, from basic to advanced services, making it an interesting and rich setting to study. Some authors refer to the elevator industry as one that adopted servitization as a strategic response to the commoditization of the product and the corresponding limitation of revenue growth. Studying a single industry in one country, allows for the natural control of a number of contextual factors that may influence the customers predisposition to adopt increasing levels of advanced services.

2 The Methodology

In this paper, we analyze the factors that may influence customers predisposition to purchase advanced services. There may be a customer movement along the product-to-service continuum, that may be driven, not only by its financial performance improvement, but also for issues related to: 1. the transfer of risk from the operation to a competent provider; 2. the need to focus on the core processes of the business; 3. the reduction of capital investment costs in new equipment, preferring to abandon its ownership and instead pay for their use; 4. the will to increase its flexibility in relation to its installed capacity, by means of the acquisition of solutions to adapt its capacity continuously and rapidly. Customer organizations often want to focus on their core competences and outsource non-core functions, such as maintenance, to the provider of the equipment. Several authors argue that a servitized manufacturer not only provides value potential, but also co-creates value with the customer by adding services to products. These services affect the way by which customers create value and the manufacturer can influence the customers processes of value creation directly.

The co-creation of value with the customer through services is defined to a great extent by the types of services offered by the manufacturer. We can distinguish between basic services (BAS) and advanced services (ADS). In BAS, the focus is on product provision, and the activities are centred on and around production competences, as well as on the exploitation of production competences to assure the equipment state and condition. BAS include product/equipment provision, spare parts provision, warranty, preventive maintenance, repair and overhaul. In ADS, the focus is on outcome assurance, and its offering is a strategic decision. ADS are defined as a special case in servitization, meaning that the manufacturer delivers services that are critical to their customer core business processes (sometimes these ADS are also known as capability, availability or performance contracts). ADS include training in using the product, product upgrades, consulting, full maintenance contract, customer support agreement, risk and revenue sharing contract, revenue-through-use contract and rental agreement. ADS may extend the manufacturers operations into those of the customer for a lengthy term (5, 10, 15 years are typical), leading to a higher servitization intensity.

The factors were identified based on a survey of the customers of the elevator industry in Portugal. A total of 3,127 customers were contacted initially. These respondents were identified by means of the address lists of a major elevator firm. Our goal was to reach respondents which were responsible for the purchasing and management of services. A vast majority of respondents held senior positions in purchasing. The sample also contained a limited percentage of operations managers and, especially for smaller companies, general managers, owners and the residents themselves. The process of carrying out the survey led to 352 responses, implying a response rate of 11 per cent. Furthermore, surveys were only

validated when at least 75 per cent of the questions were answered. A validation rate of 65 per cent was obtained implying 230 valid responses. These customers represent over 5 per cent of the 140,000 installed elevators in Portugal. A number of hypotheses were developed and tested using the ordinary least squares regression method.

3 The value to Society

Much research has been dedicated to the design and benefits of integrated product and service offerings. But only a limited number of empirical studies have investigated how customers promote or hinder servitization.

Our model includes the following antecedents of the future purchase of advanced services: customer segment, size of customer equipment portfolio, current intensity of purchasing of basic and advanced services. This research extends the literature by providing new insights into the purchasing of basic and advanced services.

First, customers who already buy BAS have a predisposition to adopt ADS in the future. As the customer moves along the service offerings dimension, the product becomes just a part of the offering and is no longer intended to be the center of the value proposition. The customer benefits from the enhanced value proposition from the product-basic services bundle, and increases confidence on the manufacturers ability to provide quality services. Thus, the customer becomes more willing to contract ADS.

Second, customers who already show high intensity of contracted ADS in the present show a higher predisposition to buy ADS in the future. We argue that the customer will have an increased confidence in the manufacturers ability to provide services that are critical to its core business processes. Again, the trust in the service provider seems to be crucial. By trusting the provider, the customer becomes willing to contract for more ADS in the future.

Third, customers in the professional segment show a higher predisposition to hire ADS than the non-professional segment. The value added through ADS may have a significant influence on the customers processes of value creation. In this case, the nature of the service processes is professional, complex, with a high customer-provider contact and customized. Therefore, the existence of a purchasing function organisation, with technical and management skills may lead the customer to understand more properly the benefits of ADS and to contract for more of these services in the future.

Fourth, customers with larger portfolios of equipment under management have higher predisposition to adopt advanced services in the future. We argue that the complexity of managing larger portfolios leads the customers to focus its human, financial and technical resources on their main activities and reducing their operating costs by outsourcing services. Therefore, customers with a greater number of equipment under management seem to be more available for the formalization of long-term contracts and for the hiring of ADS in the future.

Finally, there seems to be a parallel adoption of basic and advanced services, using BAS as a platform rather than providing BAS first to a high extent, followed by ADS (since both variables BAS—A and ADS—A are significantly positive). Our findings are consistent with other findings, with servitization intensity building on product-basic services combinations, by adding ADS, but without ever giving up the supply of products and the provision of BAS.

Our findings also encompass important managerial implications by offering guidance for the design and deployment of servitization strategies. Our study makes two recommendations for manufacturing firms that are servitizing or considering it: (a) the adoption of a market segmentation is vital for the development of the service offering. This allows service providers to identify homogeneous purchasing behaviors against a particular offer and to develop appropriate service packages that provide adequate levels of customer satisfaction in these segments. (b) the development and provision of advanced services, mainly to the professional segments, in order to be successful in the adoption of servitization. Notwithstanding, the manufacturers entry into the service market requires offering BAS first to learn how individual customers create value through product usage, and this facilitates offering ADS.

Understanding How to Design Collaborative Economy Ecosystems Focusing on Well-being

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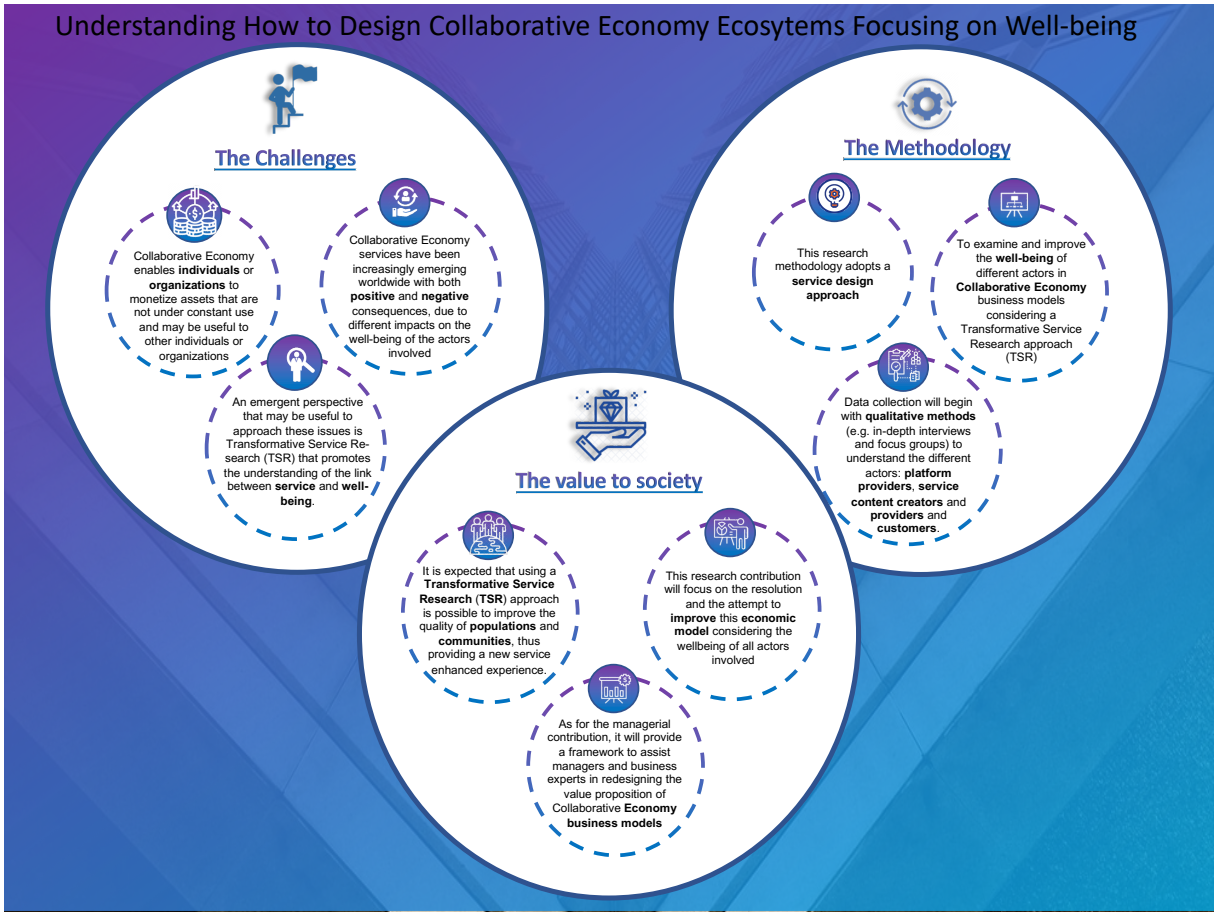

1 The Challenge

Collaborative Economy is the ability of an individual or an organization to lease or borrow goods, usually the under-utilized ones, rather than buy and own them (Frenken Koen, 2017). This concept enables individuals or organizations to monetize assets that are not under constant use and may be useful to other individuals or organizations. Usually, the sharing of these under-utilized assets is temporarily and is mainly in exchange for money or other services. Collaborative Economy prioritizes utilization and accessibility over ownership. The relationship between economic development and Collaborative Economy strengthened in the last decade. The service sector has undergone a vast digital transformation over the last 10 years in every corner of the world including the developed, developing, and underdeveloped countries (Dredge 2018). The digital revolution is responsible for the growth and development of students, employees and entrepreneurs, since it has uplifted the technical and analytical knowledge increasing the capability of people to interpret data, connect with others and carry out trade digitally. This has enabled

increasing the efficiency of Collaborative Economy business models (Mick 2012).

However, Collaborative Economy services have been increasingly emerging worldwide with both positive and negative consequences, due to different impacts on the well-being of the actors involved. Further research is indispensable for minimizing the negative consequences.

An emergent perspective that may be useful to approach these issues is Transformative Service Research (TSR) that promotes the understanding of the link between service and well-being. Transformative Service Research (TSR) has been currently labeled as a 'new area' in both service and consumer research. TSR is a combination of service and consumer research, which is mainly focused on improving the well-being of consumer entities i.e. the ecosystem and community in general. To explore how Transformative Service Research (TSR) and Collaborative Economy can jointly play a role in improving the quality of life of populations a systematic literature review was performed aiming at synthesising and integrating current knowledge and identify existing research gaps. The findings from the systematic literature review revealed that the models of Collaborative Economy may result in positive and/ or negative outcomes at the micro (individual), meso (organizational), and macro (global level). Some negative outcomes are, for example, unfair competion in unregulated markets, workers exploitation workers and, negative impacts on local neighbourhoods and quality of life in cities. Thus, further research is needed to understand how Collaborative Economy models should be designed to enhance actorsâ well-being and enabling new opportunities for innovation and promoting value co-creation among all actors in the service ecosystem.

2 The Methodology

The challenge is a better understanding of how to leverage technology to innovate digital services and improving well-being. These new services need to adopt a human-centered approach bringing together what is desirable from a human point of view and with what is technologically feasible and economically viable. Thus, both managerial and societal impacts need to be integrated. Service design has the potential for fostering service innovation because it enables bringing innovative ideas to life through a design thinking process (Ostrom et al. 2010). Also, it may transform the way organizations develop products, services, processes, and strategy.

This research methodology adopts a service design approach. Service design is currently emerging as one of the major themes of modern business and design education (Nisula 2012). Also, it builds upon contributions from multiple fields, including management, information technology, and interaction design (Grenha Teixeira et al. 2017). Service design can generate new service ideas by understanding customer experiences (Mahr et al., 2013). To examine and improve the well-being of different actors in Collaborative Economy business models considering a Transformative Service Research approach (TSR), it is essential to highlight customer experience as a central aspect of the study since it influences well-being (Anderson et al. 2013). A combination of different methods will be used in the different stages to obtain the necessary data and increase validation. Data collection will begin with qualitative methods (e.g. in-depth interviews and focus groups) to understand the different actors: platform providers, service content creators and providers and customers. Different examples of Collaborative Economy in different contexts, like Europe and Asia, will be used.

3 The value to Society

This research aims to better understand Collaborative Economy business models and provide insights to redesign them with a human-centered approach and focus on sustainability and well-being. It is expected that using a Transformative Service Research (TSR) approach is possible to improve the quality of populations and communities, thus providing a new service enhanced experience. Also, the results will enable to understand the impacts of those transformations on the actors within the service ecosystem.

This research contribution will focus on the resolution and the attempt to improve this economic model considering the well-being of all actors involved. As for the managerial contribution, it will provide a framework to assist managers and business experts in redesigning the value proposition of Collaborative Economy business models and thereby improving the well-being of their end-users enhancing the customer experience, and also improving the well-being of their employees and the service content creators and providers.

Synchronisation in vehicle routing: what it means and how can we tackle it

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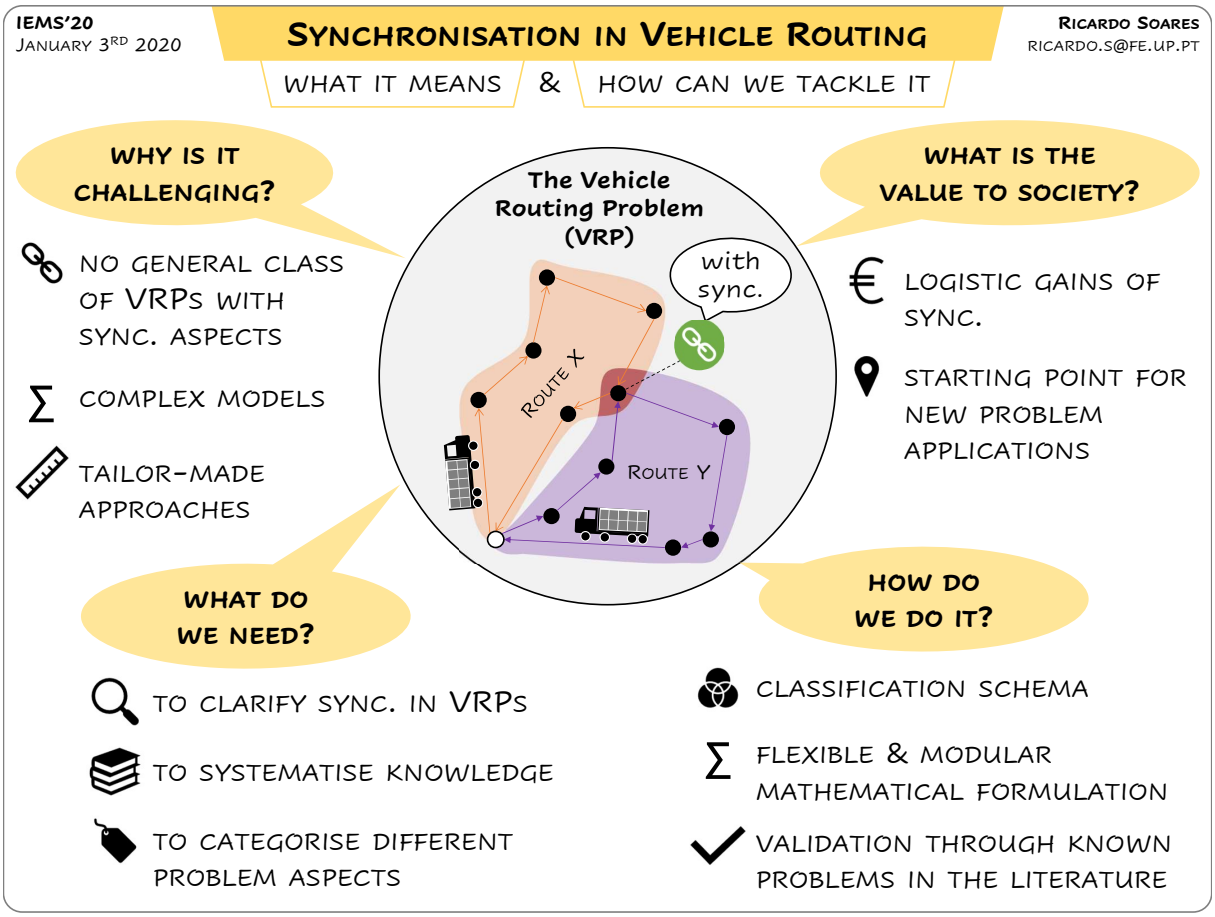

1 The Challenge

In supply chain management, transportation and logistics are at the core of research agendas, motivated by their impact on economic, social and ecological terms. Within this context, the practical relevance of the Vehicle Routing Problem (VRP) is indisputable and has been an effervescent field of research for the past 60 years. With the increasing developments in solution methods for solving hard routing problems and the ubiquitous access to real-time operational information, new opportunities emerge where synchronising operations and resources can potentiate significant logistic gains.

One of the VRP topics that has been gaining increasing momentum is the VRP with synchronisation aspects. It consists on a routing problem where a given set of routes is dependent on each other for the problem to become feasible. This problem usually translates into the need for different vehicles to meet in locations at the same time or within given time offsets or even travelling portions of a route simultaneously. The route interdependence present in the VRP with synchronisation is not present in

standard VRPs and constitutes a difficulty when developing solution methods for these types of problems, as a change in one vehicle's route may render all other routes infeasible.

Due to its low degree of maturity, the topic of VRPs with synchronisation is still underdeveloped. Synchronisation is still a broad concept in the literature, being frequently used for problem aspects that belong to any standard VRP. The concept of synchronisation needs to be clarified by stating its underlying differences to other problem aspects found in VRPs. Secondly, the fact that there is no common modelling framework for VRPs with synchronisation difficults the generalisation of these problems to a problem variant that is independent of the application.

2 The Methodology

In order to clarify the concept of synchronisation, a classification schema was envisaged, which takes on every problem aspect of the VRP and maps it into one of four categories. A visual representation of the schema is presented in Figure 1. The categories are linked with the direct scope of the interdependence that a problem aspect induces, which can be within the same route, between routes, among the whole routing problem or within different processes.

The four categories of the schema are:

- **Task Allocation** – concerns the problem aspects that, in the event a route is changed, only impact the feasibility of the route being changed;
- **Routes Synchronisation** – concerns the problem aspects that, besides potentially impacting the route being changed, may also impact other related routes;
- **Routing Coordination** – concerns the problem aspects that, although they do not impact the individual feasibility of any route, it affects the feasibility of the overall routing problem;
- **Process Integration** – concerns the problem aspects that can impact the feasibility of decisions beyond the scope of routing; in this category, we refer to problems where the interdependence is not established between the typical VRP entities, but between VRP entities and other external decisions, such as production or inventory decisions. The problem aspects that fit in this category are found in the general class of Integrated VRPs.

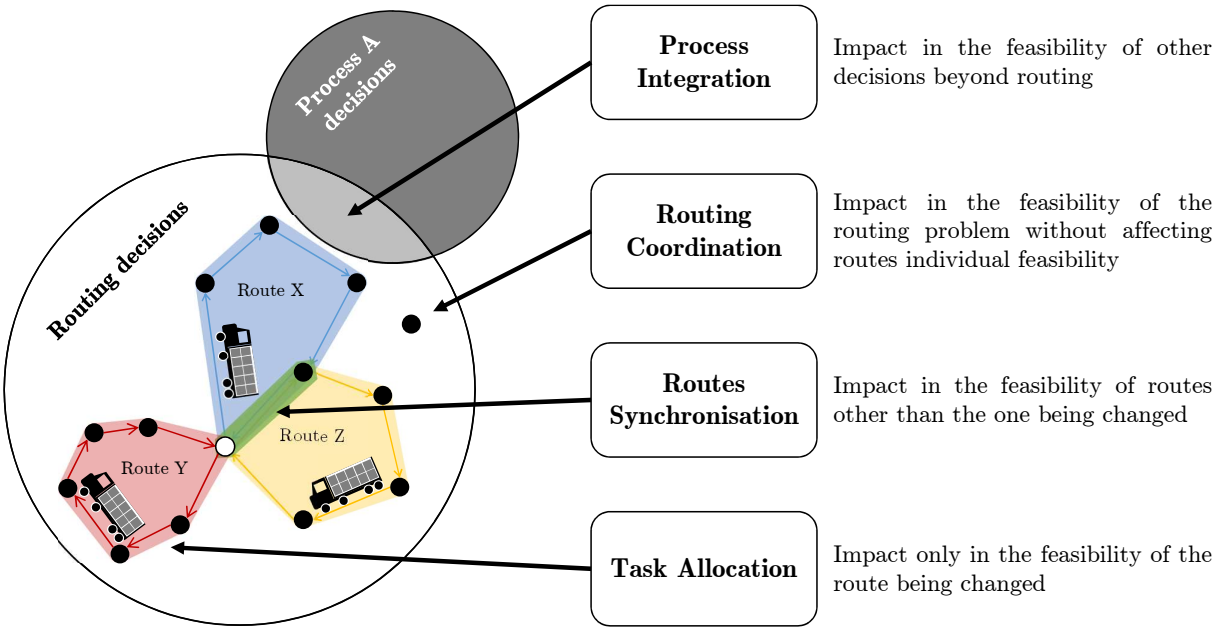

Figure 1: Visual representation of the proposed problem aspect classification framework

The development of this conceptual schema was grounded on a literature review, using progressively refined search queries for finding references of routing problems with synchronisation. The formal aspects of the selected publications were analysed, including the publication date, the journal type and the application scope, after which, through an iterative process, the authors converged to the presented classification schema.

We leverage this conceptual schema and convey it to a modelling framework for the VRP with Multiple Synchronisation Constraints that can be used in most real-world applications of this problem variant. We present a highly modular mathematical formulation that mingles synchronisation aspects with well-known problem aspects in the VRP literature, such as demand satisfaction, capacity constraints, time windows, among others.

3 The value to Society

Although it adds an additional source of complexity, synchronisation of vehicles constitutes a clear practical advantage for several operational realities, as it enables a better coordination of vehicles for certain routing tasks that are dependent on other vehicles, thus enhancing asset utilisation. In complex supply chains, where multiple vehicles, crews, materials and other resources are involved, synchronisation can be a catalyst for combining different operations that require different resources in a more efficient manner by decreasing unproductive times, which can eventually result in a decrease of the overall resources required.

The contribution of this work targets the Operations Research community by complementing previous work on routing with a modelling framework that can clarify and streamline these synchronisation aspects in terms of its modelling efforts, which can ultimately serve as a starting point for modelling new routing problems with synchronisation and potentially using it in solution approaches that resort to mathematical programming.

Furthermore, we build on existing literature on the classification of different VRP aspects and clearly define boundaries between what should be considered synchronisation and what should not, depending on the interdependencies that arise for given problem aspects.

Ultimately, this research work can be a starting point towards reaching a common class of routing problems with synchronisation that can be applicable to several real-world applications, thus triggering the adoption of synchronisation aspects by practitioners in their routing plans and taking advantage of its benefits.

Developing a well-trained algorithm for the on-line three-dimensional bin packing problems

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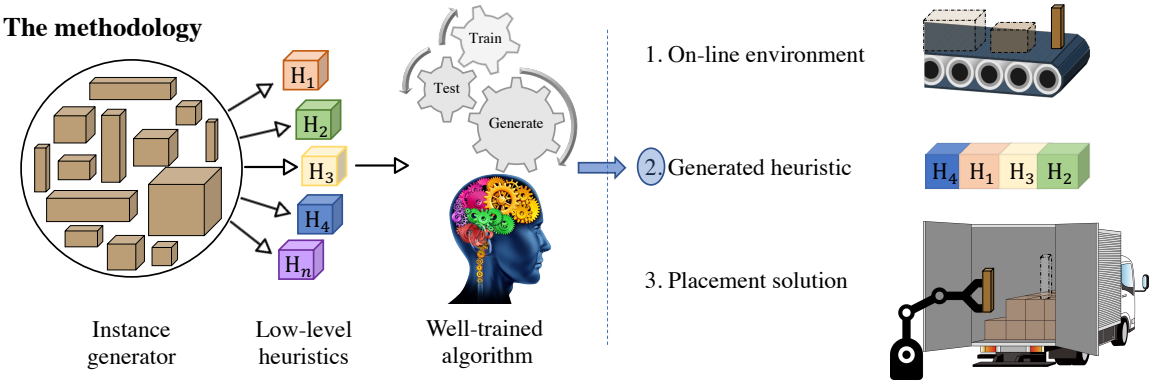
Developing a well-trained algorithm for the on-line three-dimensional bin packing problems

The challenge

- Packing a set of **boxes**, into a minimum number of **containers**, **without any information** about the unpacked boxes
- Considering all the relevant **practical constraints**
- Providing a **well-trained** and **efficient method** to solve **large-size instances** in a reasonable amount of time

The methodology



The value to society

Industry
- Reducing logistics costs
- Increasing operational efficiency

Society
- Reducing transportation and traffic congestion
- Increasing environmental sustainability

Scientific community
- Online 3D generator
- Well-trained algorithm

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO INESCTEC Sara Ali, José Fernando Oliveira, Maria Antónia Carravilla, António Ramos

1 The Challenge

During the last decades, effective utilization of transportation devices and transportation capacity received considerable attention by companies to achieve a competitive advantage. The classical three-dimensional Bin Packing Problem (3D-BPP) as an effective way to reduce logistics and transportation costs aims to pack a set of items into a minimum number of bins. An example of 3D-BPP can be found in Figure 1. In offline environments, full knowledge about the input items is available beforehand, which facilitates the packing process. However, situations in which items arrive one by one, and having to be packed into the bins when they arrive, are likely to arise in the real-world. In the literature, the situation described is named as the on-line/dynamic BPP. Therefore, in the on-line 3D-BPP, the objective is to

pack a set of cubic items (boxes), at their arrival, into a minimum number of cubic shaped bins (containers) without any information about the items to arrive in the future, neither their number nor their sizes. The on-line 3D-BPP has many applications in different areas, including robotic and automatic container loading in warehouse storage.

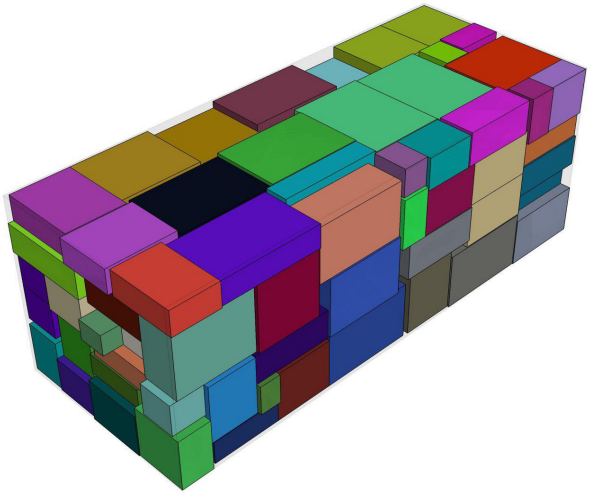


Figure 1: A general view of three-dimensional bin packing problem

The BPPs have been addressed in the literature with different solution approaches, such as exact methods and approximate methods, as heuristics and meta-heuristics. The exact algorithms can solve problems of limited size, and it usually takes a large amount of time to find an optimal solution, even for moderately sized instances. On the other hand, the heuristic algorithms are often developed to find fairly effective solutions in a reasonable time, when compared to exact algorithms. However, the existing heuristics are usually designed to solve a specific problem, and the quality of solutions highly depends on the features of problems. Therefore, meta-heuristic techniques have been applied to solve a broader class of problems, since, unlike the heuristics, their performance does not rely so heavily on the structure of particular problems. However, they are, in general, harder to implement and may yield poor results, when parameter fine-tuning is not carried out. Although extensive research has been carried out on the BPP, considering different solution approaches, there is still a lack of a general and efficient method to solve large-size instances in a reasonable amount of time. Moreover, most of the literature does not discuss the BPP in the on-line context. Therefore, to develop a more realistic approach that can be applied in practice, this research project aims to propose a well-trained algorithm that can take advantage of the strengths of several heuristics and do not require human intervention or parameter tuning. The well-trained algorithm will automatically generate good heuristics and find the best rules for the placement of the boxes inside the containers to operate over a wide variety of on-line 3D-BPP instances.

2 The Methodology

The on-line 3D-BPP is an NP-hard combinatorial optimization problem, which means that the problem cannot be solved in polynomial time. In the literature, heuristic algorithms have been extensively used since they are able to find fairly effective solutions, for large-size instances, in a reasonable amount of time. In order to achieve our objective and provide a well-trained algorithm that performs well on different sets of real-world instances, it is important to fully understand the different heuristics that were proposed in the literature. Therefore, in the first step, a thorough literature review will be conducted to identify the most important heuristics for solving packing problems. Moreover, although extensive research has been carried out on the BPP, there is still a gap in the literature concerning on-line 3D-BPP by taking into consideration a set of practical constraints. Therefore, in order to tackle an optimization problem for minimizing the total number of bins for on-line 3D-BPP, a comprehensive review of practical constraints that are frequently encountered in the logistic problems and industry will be conducted. Regarding the lack of on-line 3D problem instances in the literature, in the second step, an on-line 3D

problem generator will be developed to generate a large number of problem instances with specific desired properties, like the order by which boxes will be made available. The problem generator will be used to evaluate the performance of the identified heuristics, which will lead to the exclusion of the heuristics that do not have a good performance for on-line 3D-BPP. In the third step, the well-trained algorithm takes advantage of the strengths of the selected heuristics using some learning mechanism to solve on-line 3D problems, that may work well across instances with many different characteristics. The proposed well-trained algorithm can solve problems by on-line generating a new heuristic, building on the identified rules of previous heuristics, upon arrival of items of a particular problem instance. Finally, to ensure the adequate generalization level and the predictions accuracy of the proposed well-trained algorithm, some new problem instances from the literature will be used.

3 The value to Society

The main objective of this research is to provide a well-trained algorithm for 3D-BPP and can have three positive contributions to the companies, society, and the scientific community. The on-line 3D-BPPs have many applications in the real-world. Therefore, as the first contribution, the proposed algorithm can be used by companies in their packing process to increase operational efficiency and reduce the logistics and transportation costs. Secondly, in terms of society, effective BPP can minimize the number of required bins, which leads to a reduction in transportation, and consequently, a positive environmental impact. Finally, in terms of the value to the scientific community, the provided generator can be widely used by the researchers in this field for other on-line 3D packing problems, and also the proposed well-trained algorithm can be applied in other extensions of on-line cutting and packing problems in the literature.

The Risks of Data-Driven Models as Challenges for Society

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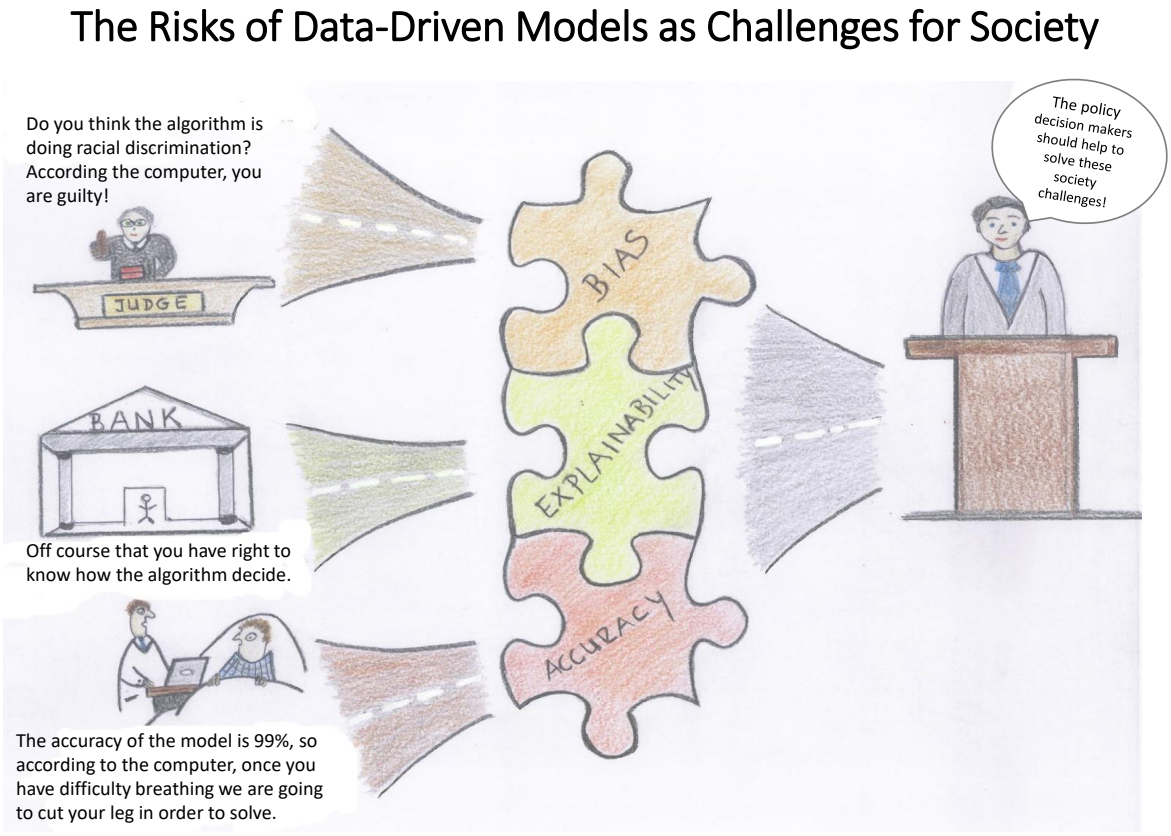

1 The Challenge

Data-driven Models have been used in the private sector, in areas such as retail, finance and telecommunications. More recently the data-driven models started to be applied in different areas of public interest, such as health, education, criminal justice, and public administration. Data-driven models are, therefore, becoming a disrupting and becoming an essential part of the operations of different companies and public services, on a daily basis, and are, therefore, creating new challenges for society. These adaptive models, due to their learning capability, reduce the intervention of humans, and support decision making. The use of such systems has benefits for society, for example bringing comfort or allowing faster problem solving, in many cases with better decisions than humans. However, this technology does not always decide correctly or without inaccuracies. Data-driven models can reproduce bias, eventually generating injustices and discrimination (for example, in court actions). This reinforces the need for explaining what happens in the system, namely the decisions made by the algorithms. The lack of transparency of systems does not always result from companies deliberately avoiding transparency, but rather from the complexity of

the algorithm. Another important dimension is the accuracy of the system. One of the phases of the data mining process is the evaluation of the model, which does not always really reveal how trustable the model is. These challenges are related to the risks of data-driven models, and can be organized in three dimensions: Bias, Explainability and Accuracy. The ethical problems that emerge from these risks, in particular on the public domain, make them a concern and a new challenge. With this background, and considering the importance of this topic to society, as well as its complexity, the purpose of this work is to understand the position where the three risk dimensions are addressed in the processes of developing Artificial Intelligence (AI) and Public Policy (PP).

2 The Methodology

The methodology proposed (Figure 1) answer the questions *Where are placed the Artificial Intelligence risks throughout the processes?*, i.e. to identify at which phases of the AI development process and at which phases of the Public Policy development process do these risks emerge and become a concern to the AI or PP development. To achieve this goal, we started by identifying the existing Public Policy and Data Mining (DM) reference processes, in order to position the AI risks. Subsequently, relevant documents were identified and selected from an appropriate data source, which on this case was the *Law and Policy Readings* list from *AI Now Institute*. The criteria for selection were to have an AI background, to address a topic of public interest and to be aligned with the risk dimensions, from which social and ethical problems may emerge. The following step focused on understanding the representativeness of the topics under study in the documents selected for analysis. For that, an analysis of the content of the selected documents was carried out, and the abstracts of these documents were considered using the word frequency count approach (Word Cloud), making possible to understand their representativeness. As mentioned earlier, we conducted this study to analyze three specific dimensions of risk in the data-driven models, which are concepts and ideas that we looked for in the text of the selected documents. The three dimensions were then identified and positioned along with processes. The work finish with a critical analysis of this distribution.

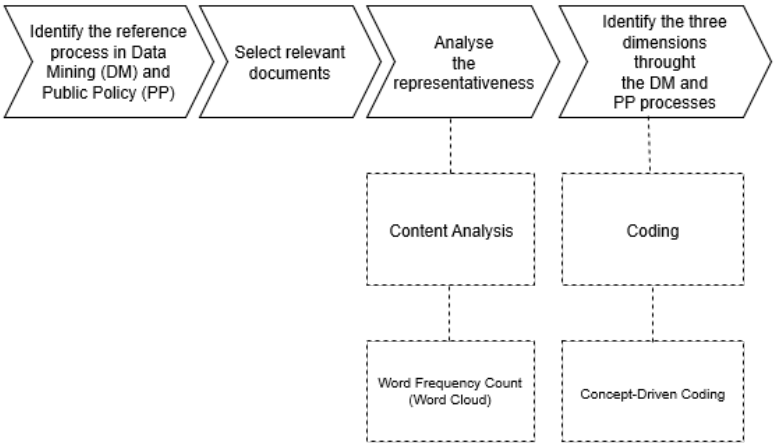

Figure 1: Methodology overview

3 The value to Society

The identification and positioning of the three dimensions along the Data Mining process (AI domain) and the Public Policy process allows us to contribute to the development of Artificial Intelligence algorithms and the Public Policies, as the positioning of the risks within the phases of those processes allows for more attention to those risk dimensions in the appropriate stage of development. In the case of Artificial Intelligence, this allocation of risks to development phases will allow developers and analysts to quickly identify where the problem occurs, what occurs, and what type of problem it is. The same happens

for the Public Policy process, the contribution of risk allocation to its process phases facilitates decision-making for policymakers involving decision-making about using AI tools. Moreover, there is an interaction between both areas, in the sense that when developing an AI algorithm, developers might be informed about the most relevant risks for the PP that might define the context of use of that algorithm, and when developing PPs, the decision-maker might also be better informed of the risks that emerge during AI development and the difficulties that might be faced during that process, which might be useful information to consider when defining the context of use of that algorithm or technology in general. Artificial Intelligence aim decisions of interest to society (use of the algorithm for PP) and that public policies contribute to overcoming risks and social challenges arising from Artificial Intelligence (context defined by PP).

An Integrated Supplier Selection & Inventory Management Under Supply Disruptions

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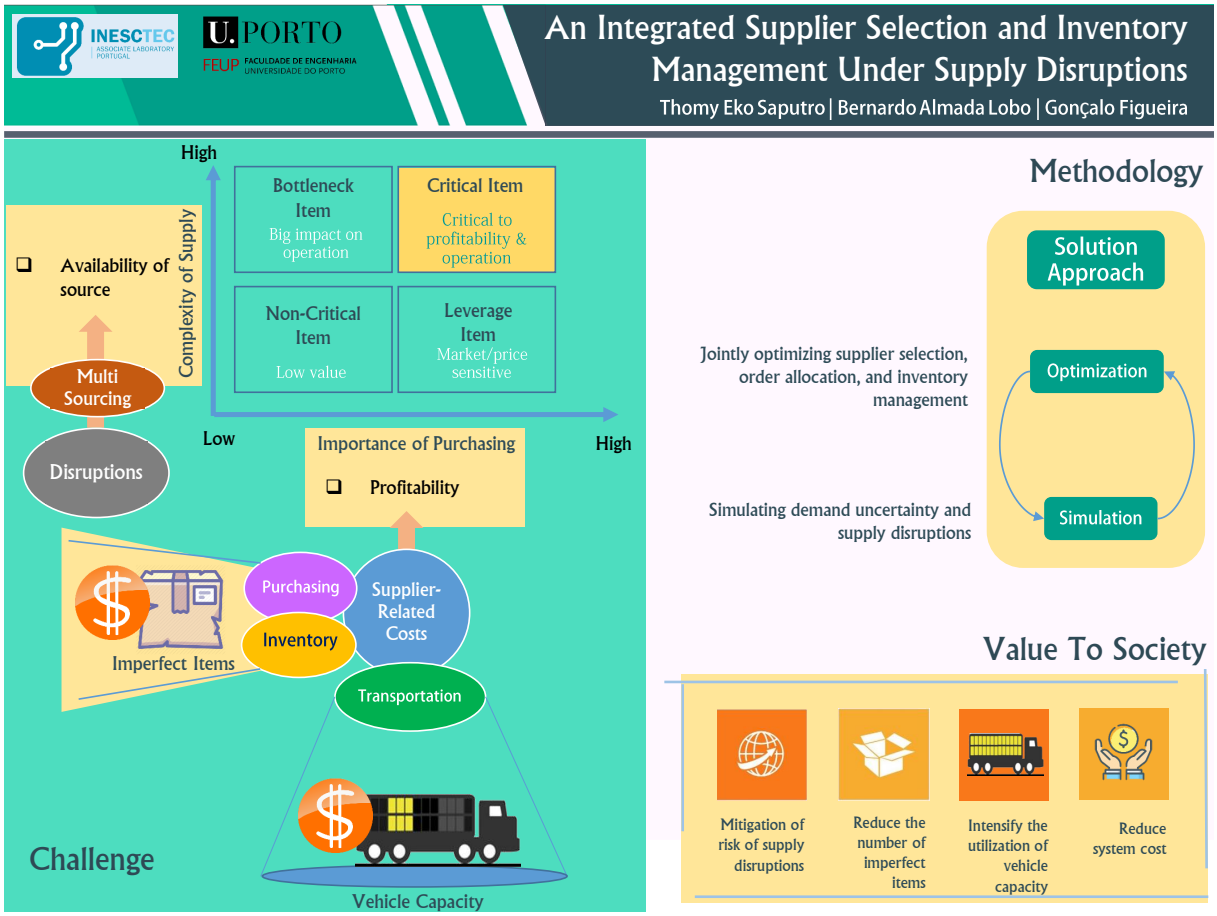

1 The Challenge

In competitive industries, cooperation with suppliers attracts manufacturing firms to gain long-term benefits since supplier performance has a significant impact on the firms' competitiveness, in terms of cost, quality, and on-time delivery. The success of the cooperation largely depends on a selective process in choosing appropriate suppliers. For items that represent a considerable value to the firm and a high supply risk, the so-called critical items, supplier selection becomes a strategic initiative that requires careful consideration within supply chain management.

In this context, it is important to integrate supplier selection with other activities, including order allocation, vehicle selection, and inventory management. These problems have received massive attention in the literature. However, some essential aspects related to suppliers have been disregarded, particularly dealing with imperfect quality and carrier capacity, which may affect the total cost incurred in the system.

Imperfect quality might additionally involve an opportunity cost. Indeed, the consequences of imperfect quality not only relate to the costs incurred in the shop floor as a result of defects or as additional costs for inspection, repair, material handling, but also to customer satisfaction. The transportation fares are generally charged according to the number of carriers. Utilizing carrier capacity (truckload) for shipping orders from suppliers may yield significant cost savings to the firm. Therefore, considering imperfect quality and carrier capacity when making the decisions, either strategic or tactical, provides an opportunity to further improve operational efficiency.

Despite a well-organized inventory management system, supply might suffer from disruptive events occurring at suppliers. Deliveries can be forced to delay due to disruptions. Therefore, mitigating the risk of supply disruptions is crucial to prevent a more significant impact on the entire supply chain. Selecting suppliers and managing inventory under supply disruptions is not straightforward. It requires an extensive model and sophisticated solving approach. Thus, the challenge of this study is to address the problem comprehensively and develop an effective solution approach considering the disruptions.

This study addresses the integration of supplier selection and inventory management under supply disruptions, incorporating imperfect quality and carrier capacity. A review system (Q, R) is adopted in the model. A simulation-optimization approach is developed to tackle the problem. In addition, the impact of supplier-related parameters is investigated to provide managerial insights.

2 The Methodology

A network supply under a multi-sourcing strategy, involving N suppliers and M plants is considered. Plants select two or more suppliers for material sourcing. This study attempts to determine a strategic decision, which is supplier selection, and tactical decisions, including order allocation and inventory. Figure 1 represents the network supply considered in this study. We assume that each order lot includes not only perfect but also imperfect quality items with a proportion of k_j. The holding costs of perfect and imperfect items are considered independent. Furthermore, imperfect items trigger consequences to the customer satisfaction and firm reputation. A cost incurred due to imperfect quality, such as external failure cost, is introduced in the model. Under full-truckload policy, suppliers charge the transportation cost based on the number of carriers. A single type of carrier with specific capacity of U_j is offered by a supplier. The objective function is to minimize the plants' total cost associated with supplier-related costs (fixed contractual and purchasing cost), inventory cost (holding, setup, shortage cost), transportation cost under a full-truckload policy, imperfect items related costs (external failure and imperfect holding cost).

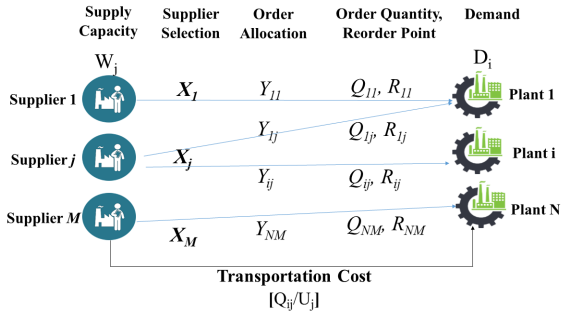

Figure 1: Network supply between plants and suppliers

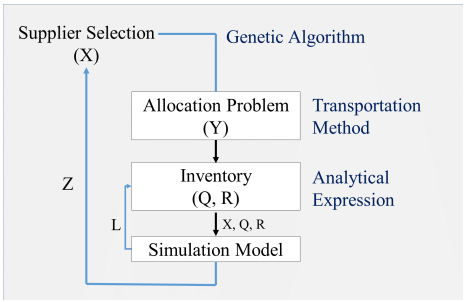

Figure 2: The solution procedures of analytic model enhancement (AME)

In order to solve the problem, we use the output of simulation to refine a parameter so that a given analytical model can be enhanced. In our model, instead of considering lead time in a steady condition (with no disruptions), suppliers' lead time is refined when disruptions occur. A simulation model runs as a stochastic evaluator of the solution. In the solution procedure, the GA evaluates binary decision variables of X (supplier selection) based on the total cost in the objective function. Given the value of X, order allocation (Y) is determined according to the transportation cost. Given the optimal order allocation, inventory decisions including order quantity (Q) and reorder point (R) are calculated by using analytical expressions. In each iteration, the refinement procedure begins such that, for every selected randomly X,

the lead time (L) derived from simulation incorporating disruptions is sent to the optimization. Reorder point *(R)* is enhanced according to the refined lead time (L). In our study, we iterate this refinement along k iterations. The solutions containing supplier selection (X) and inventory decisions (Q, R) are then passed to the simulation for objective function evaluation (Z). According to these variables, the performance measure (Z) based on the total cost incorporating stochastic demand and disruptions is returned to the optimization. The GA then uses this performance measure to optimize the solutions. Figure 2 illustrates the solution procedure in this approach.

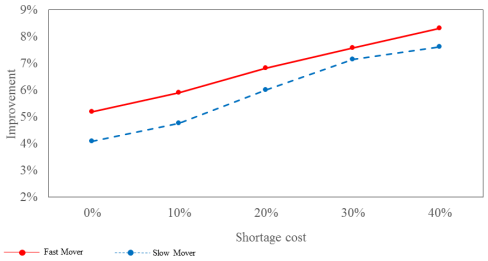

Figure 3: Improvement for different shortage cost

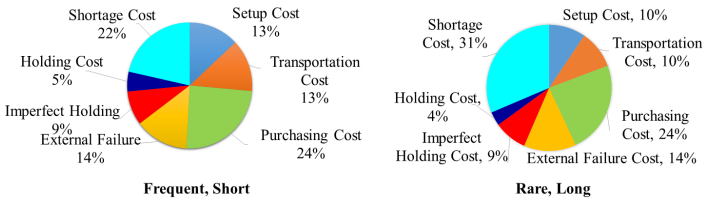

Figure 4: Impact of disruptions on the cost components

Two different problems are created, representing fast-moving and slow-moving items. Sensitivity analysis is performed to investigate the impact of disruptions, as well as supplier-related parameters and their interactions. The result shows that compared to the classical approach (without lead time refinement), the proposed simulation-optimization approach can improve the solution significantly as the shortage cost increases. Figure 3 shows the improvement in terms of the reduced total cost. The disruptions and their characteristics, including frequent with short and rare with long, have an impact on the total cost and trigger shortages. Figure 4 shows the impact of disruptions on the cost components. More specifically, rare with long disruptions incur total cost higher than frequent with short disruptions. According to the sensitivity analysis, contractual cost, vehicle capacity, imperfect quality, and lead time, as well as their interactions, are found to be the significant factor influencing supplier selection.

3 The value to Society

Incorporating imperfect quality and carrier capacity in the integration of supplier selection and inventory management, can help to enhance decision-making. According to the proposed model, the number of imperfect items can reduced and the utilization of carrier capacity can be intensified. The proposed approach shows the advantage of refining the lead time in the analytical model, particularly when shortages are costly. In other words, mitigating the risk of supply disruptions by considering a disruptive lead time when determining the reorder point could contribute not only to a better inventory performance but also improve supplier selection.

Product line selection in fast-moving consumer goods industries

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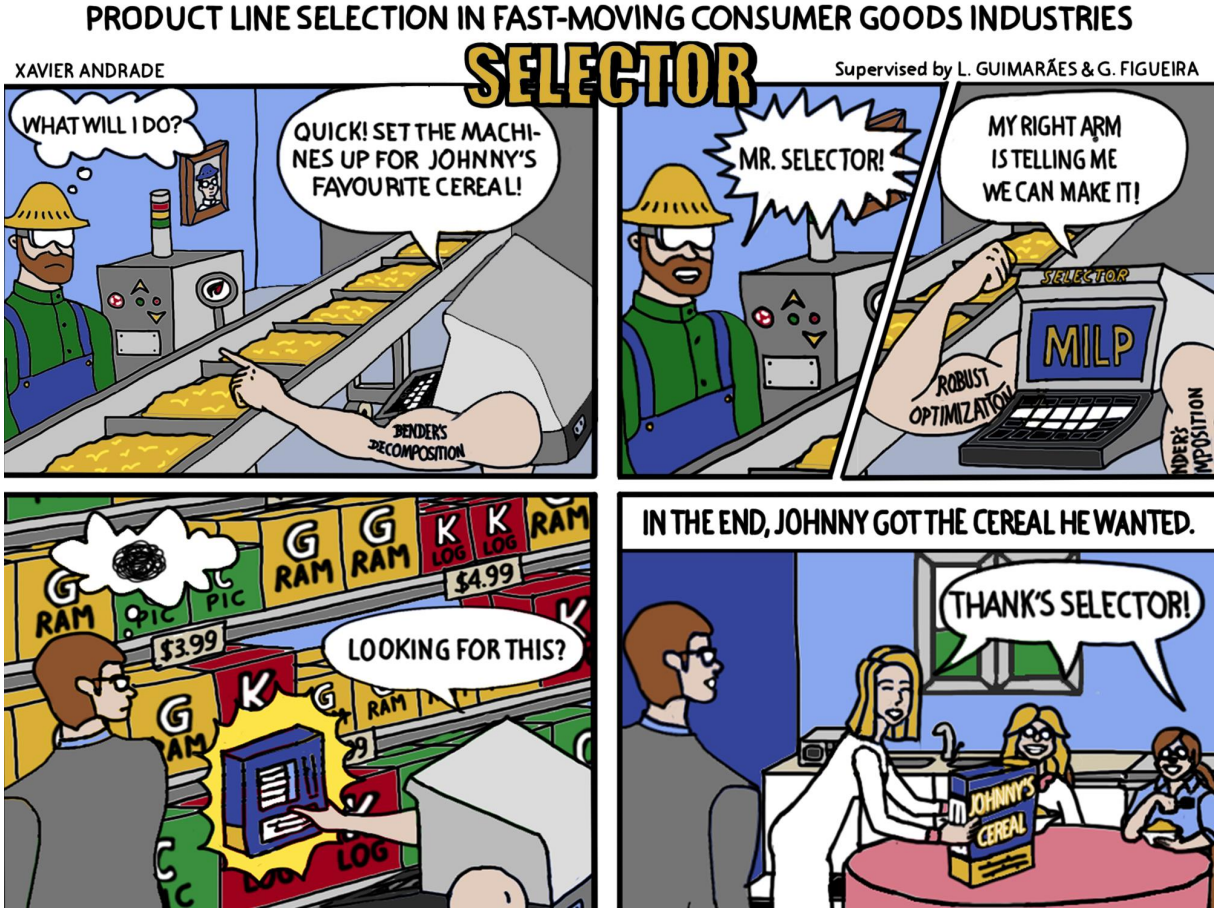

1 The Challenge

We want to provide fast-moving consumer goods (FMCG) producers means of managing their overextended product lines. A couple of decades ago, whenever a FMCG producer wanted to increase revenue, product introductions would ensue. This strategy increases the market share of the brand and the overall revenue generated by the product line. However, unless the new product complements others offered by the manufacturer, the average sales value of each of the product variants is expected to diminish. A dysergy occurs at the manufacturing plant where, without economies of scope, additional time must be spent setting up for the new product while, on average, production runs will be shorter across the line. Furthermore, each new product is either purposeful within the brand and cannibalizes the sales of what were previously core products, or it diverts from the core of the brand resulting on the dilution of its image and value. Introduction after introduction, the shortsighted chase for profit led manufacturers in many FMCG categories to a competitive trap where product lines are broad, brand power has dissolved, and the operational complexity chips away at the already thin margins of fast movers. Demand, in these categories, did not expand proportionally to the size of the product lines and is recently showing signs of

stagnation. Firms are aware of their current position, but their know-how on product removal is limited to trimming out those with the least share or that generates the least revenue. This can be shortsighted as it ignores both demand and production interactions between the products of the assortment. Also, product line selection (PLS) research lacks models for the fast-movers in the FMCG industry, as it fails to incorporate the appropriate modeling features and the development of the solution methods needed for practical use of the models. The research has been directed to durable goods, and neglects modeling recurring purchasing behavior appropriately and does not simultaneously account for the production costs, which play an important role in the decision, with a reasonable level of detail. Therefore, our challenge is threefold: (1) to build the optimization models needed for a general approach to PLS in this industry, (2) to earn the trust of firms in the approach by developing methods to obtain feasible plans for large scale problems and providing robust solutions, and (3) to apply our research to a real case, hence materializing its benefits and assessing its value.

2 The Methodology

Our challenge will be tackled quantitatively, with mathematical modelling and optimization as the methodological pillars of the approach. The general plan for this research is represented in Figure 1 and the work relative to the deterministic model is complete. We developed a general PLS model for the FMCG industry. It integrates the revenue-optimizing PLS problem with fixed costs using an attraction model for sales (where, inside each product category, the share of a product $S_j = a_j/A(W_0)$ with a_j being the attractiveness of product j and $A(W_0) = a_0 + \sum a_i$, with $i \in W$, being the attractiveness of the whole category) with a multi-period capacitated lot-sizing problem with shared setups. We account for the effects of safety stock without recurring to conventional uncertainty modelling by using piecewise linearization to include the nonlinear constraints associated with α service-level policies. To derive managerial insights general to the FMCG industry, we optimized selections among 12 potential products throughout a planning horizon of 6 periods and based the generation parameters on a real case (in real-world cases, the planning horizon comprises 12 periods and the selection is is made from anywhere between two and one hundred potential products). The results show that our way of optimizing the product line leads to sizeable benefits relative to other approaches (up to 4.2% higher profits relative to the single-period state of the art and 19.2% to the heuristics used in practice). Furthermore, we show that the benefits of this optimization are the greatest when capacity is tight, consumers seek quality over price, and the firm has a strong competitive position. With the use of a non-deterministic optimization approach we will ensure the solutions are deserving of the trust needed for such a high-stakes decision. Thus, we will provide a robust optimization model for PLS in this setting. First, we will perform a sensitivity analysis to measure the the impact of variations in each parameter. We model the uncertainty for the parameters that we identify as critical parameters and add it to the deterministic model. As getting solutions from the robust optimization model will be computationally expensive, we will be required to develop solution approaches using state-of-the-art mathematical programming techniques. We will make use of decomposition strategies to simplify the overall problem and procure valid inequalities to strengthen the formulation. Making the most out of our practical motivation, we will extend the robust optimization model with problem-driven constraints and extensions. This will ensure that the model is adequate for our beverages industry case study. The increased complexity stemming from these extensions will motivate the additional development of solution methods. As the main objective will be to solve the problem for the case of the manufacturer, the use of an approach that is tailored to the instance, incorporating knowledge about the specific case, is allowed.

3 The value to Society

Our work fills the gap in PLS research regarding FMCG. The topic has for long been directed at durable goods, such as cars and computers, rendering both demand and manufacturing parts of the previous optimization models inadequate for our target industries. Furthermore, current information sharing and direct-to-consumer trends have made possible for producers to have access to demand forecasts that are closer to the consumer, thus enabling the use of integrated PLS approaches. Nevertheless, marketing and operations are still two departments with conflicting objectives, and the use of optimization models to

interface them brings benefits to businesses besides those of simple cooperation, with significantly less labor required for operations a conflict resolution. Our ultimate objective is to disseminate the welfare enabled by these newfound conditions through real-world cases. While the objective throughout PLS research is clearly to optimize the profit of the firms, we believe that the benefits of such approaches can extend well beyond that. By reducing the amount of on-shelf options there is a reduction in the overchoice effect[1], thus enabling the everyday consumer to spend a little less effort in a menial inelastic activity such as grocery shopping. Furthermore, this is a reduction in the kind of value-destroying marketing that leads consumers to buy products they do not want, hence it reduces value waste. Less kinds of packaging results in less logistical complexity and costs. This extends the reduction of waste to the sourcing and distribution steps of the supply chain. Lastly, through the elaboration of this project we have been led to believe that an optimal selection is not just another profit improvement strategy, but that the benefits of efficient production will be shared with the consumers through a new competitive equilibrium.

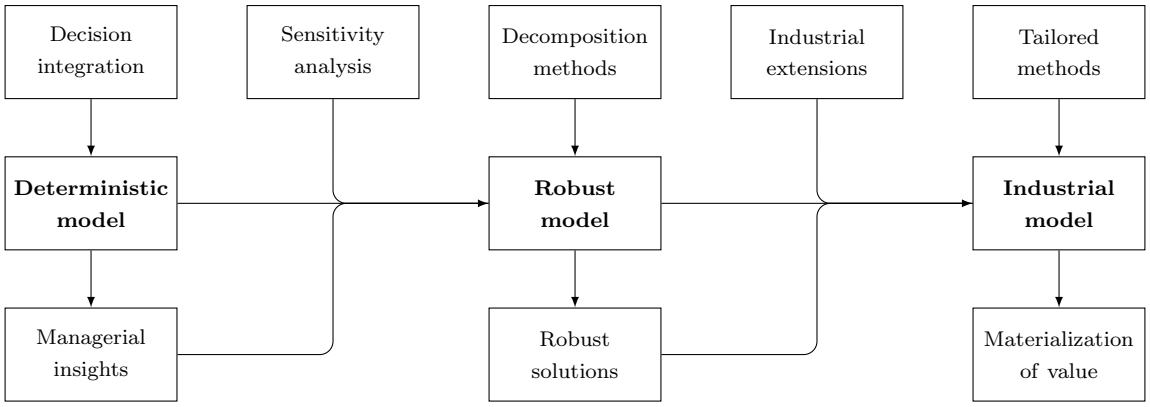

Figure 1: Strategy to tackle the PLS research gap.

[1] Decision avoidance and deferral due to an excessive number of options.

End to End & Special Sessions Abstracts

Biblioteca Almeida Garrett, Porto, January 3rd, 2020

Preparing our economy for real-world AI evidence

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** Deloitte*

As artificial intelligence (AI) becomes more sophisticated, its impact will transform business and society. These changes are inevitable, but how imminent is this transformation and what will be the economic effect of it? How do we actually will be able to tackle these changes and incorporate them for a new generation of purpose-driven strategic plans?

Implementing a clinical digital repository in a hospital centre

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Clinical Health Records used to be formed by a collection of paper records. Several information systems have been developed to substitute paper records, either developed by the information systems departments of hospitals or by private or public companies. Nowadays fewer paper records are produced in Hospitals. However, many kilometers of paper records are, and have to be, archived so that healthcare professionals have access to the complete health history of patients, and, therefore, lots of paper travels daily within hospitals. Furthermore, numerous records that come from other institutions, such as results of exams, arrive daily to hospitals to inform healthcare professionals to evaluate patientsâ conditions. Complex processes support paper flows within hospitals (that might even take a same record to several services in one same day), and create limitations for healthcare professionals to access data. Moreover, paper records are subject to be damaged or even lost. In order to overcome these challenges, Centro Hospitalar UniversitÃ¡rio de São João (CHUSJ), one of the biggest hospital centers in Portugal is implementing a clinical digital repository (CDR). A new digital archive is being acquired and implemented, where new clinical documents arriving to the hospital will be included (by being scanned to the repository) and clinical records stored in paper will gradually be digitized to become available online through the applications used by the hospitalsâ healthcare professionals. This project focuses on supporting the implementation of the CDR in CHUSJ, by applying managerial recommendations developed in recent research about implementation of new technologies in healthcare organizations. In this work we identified the implementation system, i.e., we characterized the adopter of the CDR (the CHUSJ), its users (technicians, assistants and healthcare professionals), the CDR itself, the CDR supplier, and the context where CHUSJ operates that influences this implementation. We then identified the indicators to measure the success of the implementation, and, based on these indicators and the previous characterizations, identified the needs of change and draw a strategy for the implementation that would address such needs while taking advantage of their positive impacts on the operations of the CHUSJ, namely of the archive department. Furthermore, recommendations concerning the implementation management have been developed to help guide the project management.

POCITYF: A positive energy transformation framework

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The initiative, which was funded by the European Union, aims at implementing the concept of Positive Energy Blocks (PEBs) â geographically defined areas with a renewable local production greater than the consumption, in annual average terms â in smart cities and communities with the aim of increasing the well-being of its citizens and improving the energy efficiency of buildings and infrastructures.

In the project, which involves 46 partners from 13 countries and eight cities, INESC TEC intervenes in multiple aspects. The Centre for Industrial Engineering and Management (CEGI) leads the work package in the development of activities of open innovation and for the participation of citizens, which will be applied across the two Lighthouse cities (Ãvora and Alkmaar) and in the follower cities (Granada, Bari, Celje, Ujpest, Ioannina and Hvidovre). The work of the Centre for Power and Energy Systems (CPES) will focus on the Portuguese Lighthouse city â Ãvora, in which it will develop several technological solutions, such as charging stations for electric vehicles, energy management systems, and will support technological integration.

With the implementation of these PEBs, POCITYF aims at transforming the urban fabric of these cities into more sustainable and citizen-oriented places. Ultimately, improving the quality of life of the cities involved through a sustainable and citizen-centred model. The POCITYF project, which will last for five years, is based on smart urban infrastructures and services in order to promote energy efficiency by substantially increasing the use of renewable energy combined with electric mobility solutions. European cities with protected cultural and historical heritage participate in the project, namely two Lighthouse cities, Évora (PT) and Alkmaar (Netherlands), and six follower cities: Granada (Spain), Bari (Italy), Celje (Slovenia), Ujpest (Hungary), Ioannina (Greece) and Hvidovre (Denmark).

The challenge is to create smarter cities whose locations would normally have limited possibilities for major infrastructural changes. For that, four energy transition tracks are defined, taking into account buildings, grid flexibility, decarbonisation of the transport sector, e-mobility and citizen engagement strategies. This will lead to a total of 10 integrated demonstration solutions, comprising 73 individual innovative elements (technologies, tools, methods). The demonstration will be held in 21 building complexes, covering a total floor area of 87 480 m2 with current energy needs of 13,25 GWh/year.

The project is financed by European funds of Horizon 2020. In Ãvora, besides INESC TEC, the partnership involves the City Council of Ãvora, EDP, Sonae, the University of Ãvora, the Science and Technology Park of Alentejo (PACT), DECSIS, Ubiwhere, Onyx Solar, Schneider Electric and the Faculty of Sciences and Technology of the Universidade Nova de Lisboa, among other European partners.