IEMS'19
10th Industrial Engineering and Management Symposium

The Impact of DEGI Research on Society

Location: **TECMAIA**
Date: **3rd January 2019**

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

ESPAÇO MUNICIPAL

TECMAIA PARQUE DE CIÊNCIA E TECNOLOGIA DA MAIA

Abstracts Booklet of IEMS'19

10th Industrial Engineering and Management Symposium: The Impact of DEGI Research on Society

Editor: José Sarsfield Cabral

ISBN 978-972-752-242-2

TECMAIA, Maia, January 3rd, 2019

Table of Contents

Organizing Committee:

Cristiane Ferreira

Duarte Ferreira

Eduardo Oliveira

Luís Dias

Maria João Santos

Sara Martins

Sofia Cruz Gomes

Thiago Sobral

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, Flávia Barbosa, Gonçalo Figueira, Henriqueta Sampaio da Nóvoa, João Claro, João José Pinto Ferreira, Jorge Freire de Sousa, Jorge Manuel Pinho de Sousa, Jorge Teixeira, José Barros Basto, José Coelho Rodrigues, José Faria, José Soeiro Ferreira, José Fernando Oliveira, José Luis Borges, Lia Patrício, Luís Guimarães, Manuel Pina Marques, Maria Antónia Carravilla, Maria Gabriela Beirão, Mário Amorim Lopes, Nina Costa, Nuno Soares, Pedro Amorim, Sara Martins, Teresa Galvão Dias.

Additionally, we would like to acknowledge the authors that submitted to IEMS'19:

> Cristiane Ferreira, Dario Messina, Eduardo Oliveira, Gonçalo Monteiro, Luísa Gonçalves, Luís Dias, Maria João Santos, Masoud Goulalikhani, Mateus Martin, Miguel Leichsenring Franco, Nabila As'ad, Parisa Sadeghi, Paulo Azenha, Ricardo Soares, Sofia Cruz-Gomes, Thomy Eko Saputro, Xavier Andrade

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!

Ten years have passed since the first Industrial Engineering and Management Symposium (IEMS) was organized. The initial motivation was to stimulate the research activity at the Industrial Engineering and Management Department (DEGI) of the Faculty of Engineering of the University of Porto (FEUP), and to disclose its advancements and outcomes in companies and other higher education institutions. In particular, the IEMS was imagined as a unique opportunity for the PhD students and young researchers of the DEGI to share their work, discuss their ideas and gather feedback from colleagues, teachers, researchers and practitioners. IEMS should become a channel through which outside institutions and companies could contribute to the research topics and suggest areas for future cooperation.

I do not take any risks if I state that the initial challenge was totally successful! The program of the IEMS'19 proves what I am saying, and I do not exaggerate saying that, in the scope of Industrial Engineering and Management, the IEMS is the most relevant scientific event that takes place today in the country.

Over the years, the IEMS has always been conceived, organized and managed by a team of DEGIâs PhD students. I am deeply grateful for the generous and brilliant work done over the years by the students of the Doctoral Programme of Industrial Engineering and Management of FEUP. Today, my special thanks go to the team that set up this year's edition: the Organizing Committee of IEMS'19.

I could not find a better way to symbolize the spirit and culture we share at DEGI than this event. Accordingly, I am very happy that my time as Director of DEGI ends during the tenth edition of IEMS. It is precisely during this Symposium that my successor will officially take office. I ensure you that with Professor José Fernando Oliveira the progress, enhancement and future of IEMS are guaranteed. Enjoy the journey!

The Director of DEGI
José António Sarsfield Cabral

TECMAIA, Maia, January 3rd, 2019

Information for Participants

Symposium Venue

The symposium will take place at TECMAIA.

The venue information is detailed below:

- Address: Rua Eng. Frederico Ulrich, 1650 - Zona Industrial da Maia I 4470-605 Maia, Portugal 41°15′29.88"N 8°38′29.65"
- Tel.: +351 229408200
- Email: geral@tecmaia.com

Figure 1: *Entrance.*

Figure 2: *Auditorium.*

Figure 3: *Foyer.*

There will be free parking available inside TECMAIA.

The event will occur in TECMAIA's main building. The entrance is near the small lake that can be seen in figure 1. The reception will happen in the ground floor. In the first floor there is the auditorium (figure 2), where the presentations will happen, and the foyer (3), where the coffee-breaks and the lunch will take place.

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'19 website: `http://www.fe.up.pt/~degi/iems19`. 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**.

Program Schedule

Thursday, January 3rd

Reception of the Participants: 9:00 – 9:25 (*Entrance - Ground Floor*)

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

Morning Chair: Beatriz Oliveira

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

A.1 Designing Efficient Dispatching Rules for Stochastic Job Shop Scheduling with Setup Times. Cristiane Ferreira, Gonçalo Figueira, Pedro Amorim

A.2 Empowering asset management decision using advanced analytics. Luis Dias, Luis Guimarães, Armando Leitão

A.3 Designing Service Platform for Service Ecosystem. Nabila As'ad, Lia Patricio

---

Coffee-Break: 10:30 – 11:00 (*Foyer*)

Special Session: 11:00 – 11:40 (*Auditorium*)

MobFood Project - *Mobilization of Scientific and Technological Knowledge in Response to the Challenge of the Agrifood Market* .
Carla Teixeira (PortugalFoods), Mafalda Carvalho (IST), Sara Martins (FEUP)

Break: 11:40 – 11:50 (*Auditorium*)

Elevator Pitches: 11:50 – 12:30 (*Auditorium*)

Sofia Cruz-Gomes, Thomy Saputro, Eduardo Oliveira, Masoud Goulalikhani, Xavier Andrade, João Dias da Silva, Paulo Azenha, Mateus Martin, Gonçalo Monteiro, Ricardo Soares

---

Host Presentation - TECMAIA: 12:50 – 12:45 (*Auditorium*)

Lunch: 12:45 – 15:00 (*Foyer*)

Afternoon Chair: José Coelho Rodrigues

PhD Projects: 15:00 – 16:00 (*Auditorium*)

B.1 A mathematical formulation for the collaborative transportation planning problem. Maria João Santos, Eduardo Curcio, Pedro Amorim

B.2 How do external and internal factors promote or hinder servitization over time? An in-depth case-study in the elevator industry. Miguel Leichsenring Franco, Bernardo Almada-Lobo, Rui Soucasaux Sousa

B.3 Sequencing a Balanced Mixed-model Assembly Systems in a Footwear Industry. Parisa Sadeghi, Rui Rebelo, José Soeiro Ferreira

---

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

End to End: 16:30 – 17:30 (*Auditorium*)

C.1 Revenue management system for the car rental business.
From FEUP: Beatriz Brito Oliveira, Maria Antónia Carravilla, José Fernando Oliveira
From Guerin: Paula Raicar, Delfina Acácio

C.2 Power transformers health diagnostics and prognostics.
From FEUP: Luis Guimarães, Luis Dias, Miguel Ribeiro, Armando Leitão, Manuel Matos, Leonel Carvalho, Ricardo Bessa
From EDP Produção: Nuno Rocha, Paulo Mira, Rui Vilhena, Nuno Martins

---

End to End: 16:30 – 17:30 (*Auditorium*)

Special Session: 17:30 – 18:00 (*Auditorium*)

Blockchain: beyond the hype *- Use cases for SCM and other fields .*
Mário Amorim Lopes (FEUP)

Break: 18:00 – 18:10 (*Auditorium*)

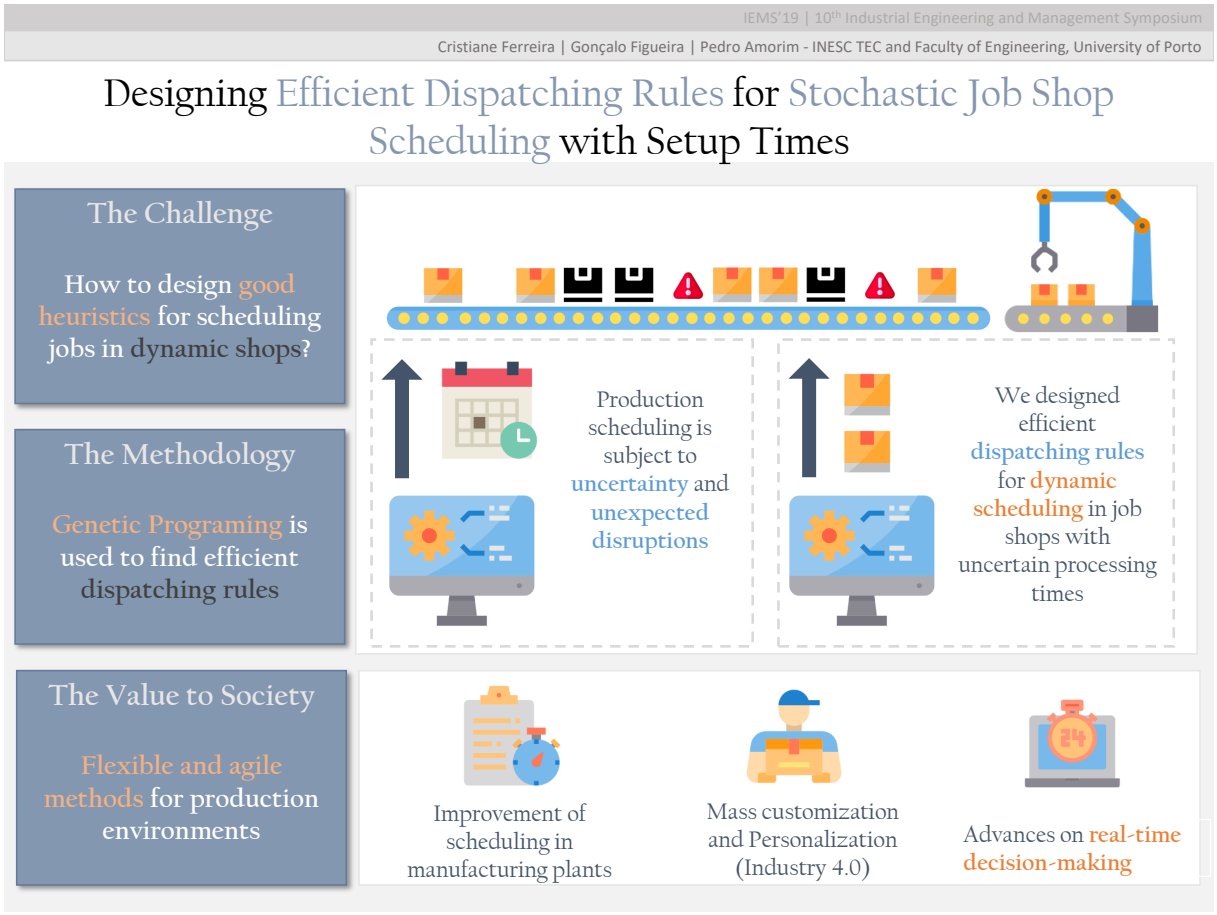
Award for the best elevator pitch and Closing Session: 18:10 (*Auditorium*)

Abstracts

Designing Efficient Dispatching Rules for Stochastic Job Shop Scheduling with Setup Times

Cristiane Ferreira*, Gonçalo Figueira*, Pedro Amorim*

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



1 The Challenge

Dynamic scheduling refers to environments where the schedule of jobs is subject to unexpected conditions. In dynamic job shops, the sequence of operations must be continuously re-optimized to adapt to the unexpected deviations. In this work we aim to design efficient heuristics for job shops that incorporate real-world characteristics such as uncertainty in the processing times and setup times.

Dispatching rules have been shown to be a promising approach for dynamic job shop scheduling. They are simple and fast sequencing methods, used to prioritize jobs waiting to be processed. Some works from the scheduling literature show that these rules outperform static optimum schedules even with moderate levels of uncertainty in processing times. This reinforces the use of simple scheduling methods in dynamic stochastic environments.

This work analyses the influence of two frequent aspects of real job shops, uncertainty in processing times

and the sequence-dependent setup times between operations in the same machine. We adapt the instance set used by Lawrence and Swell and extend their work by automating the rules design.

2 The Methodology

Genetic Programming (GP) has been widely used for designing efficient dispatching rules and heuristics for scheduling problems. In the last decade there has been an increasing attention to the use and improvement of this technique, but most of the works use deterministic processing times and do not consider important aspects found in real-world manufacturing environments.

GP is an evolutionary method in which the individuals are computer programs. The objective is to find individuals that can be interpreted or executed to produce a solution a specific problem. Thus, the fitness value of each individual corresponds to how well it is able to perform a specific computational task.

The individuals are commonly represented as symbolic expression trees, composed by *terminal* nodes and *functions*. The former include parameters of the problem, which are operated by the latter. Figure 1 illustrates an individual, represented by a parsing tree and the corresponding dispatching rule. In the example 2, a, b and c are terminals, possibly related to the attributes of the the operation. The function set is composed by the mathematical operators $*$, / and $-$.

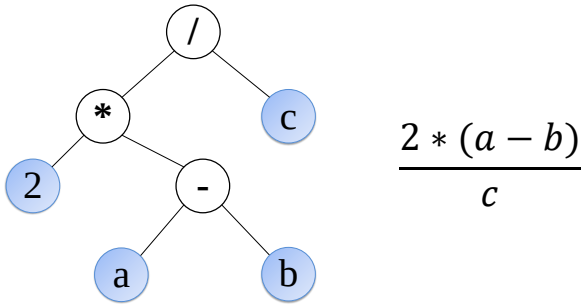


Figure 1: A GP individual tree example and its corresponding mathematical expression

In this work an individual represents a rule to prioritize awaiting operations. Each rule results in a sequence of operations which will define the schedule for the job shop. The fitness of an individual is the average performance measure of many schedules built by sorting operations according to the corresponding dispatching rule.

The function set is composed by the four basic arithmetic operations (+,-,/,×), the conditional *If* and the logical operators (or, and). The terminal set is based on rules found in the scheduling literature. We also incorporated relevant attributes such as setup times.

2.1 Fitness Function

The objective of the fitness function is to guide the evolution process through efficient dispatching rules. Therefore a dynamic job shop simulator was implemented for measuring their performance. The simulation builds the schedule by sequencing the operations on a machine's queue every time a new job arrives. Once an operation finishes processing, its actual processing time is used to update the schedule, the job moves to the next machine and the dispatching rule is called again. When all operations are executed, the final makespan is then returned.

2.2 Experimental Design

The basic problem set is composed by 53 deterministic job-shop benchmark instances. Uncertainty was introduced into these problems by generating stochastic versions of each instance. Given the processing time of an operation and a coefficient of variation, which determines the uncertainty level, the actual processing times were found by a gamma distribution. In this work we applied six different uncertainty levels. The setup times were also sampled from a gamma distribution. For each deterministic instance in the basic problem set there are four variants generated with different setup time levels.

In order to perform a fair evaluation of the resulting rule, we do not use the complete instance set in the GP training. The objective is to evaluate if training the GP with a fraction of the instances is sufficient for it to design good rules for the complete set. Thus when evaluating an individual the fitness function uses less than 1% of the instance set.

2.3 Computational Results

We performed three experiment sets with GP. The first one aimed to generate a combination of the best benchmark rules. In the subsequent experiment the objective was to verify if simple rules with a poor performance could help producing efficient schedules when combined with other terminals. The last experiment set also considered the setup time terminal.

The overall results show that in general the three evolved rules performed clearly better than the benchmark ones. The difference in performance becomes greater as the setup time increases. This was expected since the training set included setup times. Comparing the evolved rules, we notice that the results from the second and third experiments are always better than those produced by the first. We also observe that as the level of setup time increases, the performance of the third rule becomes better than the second.

3 The value to Society

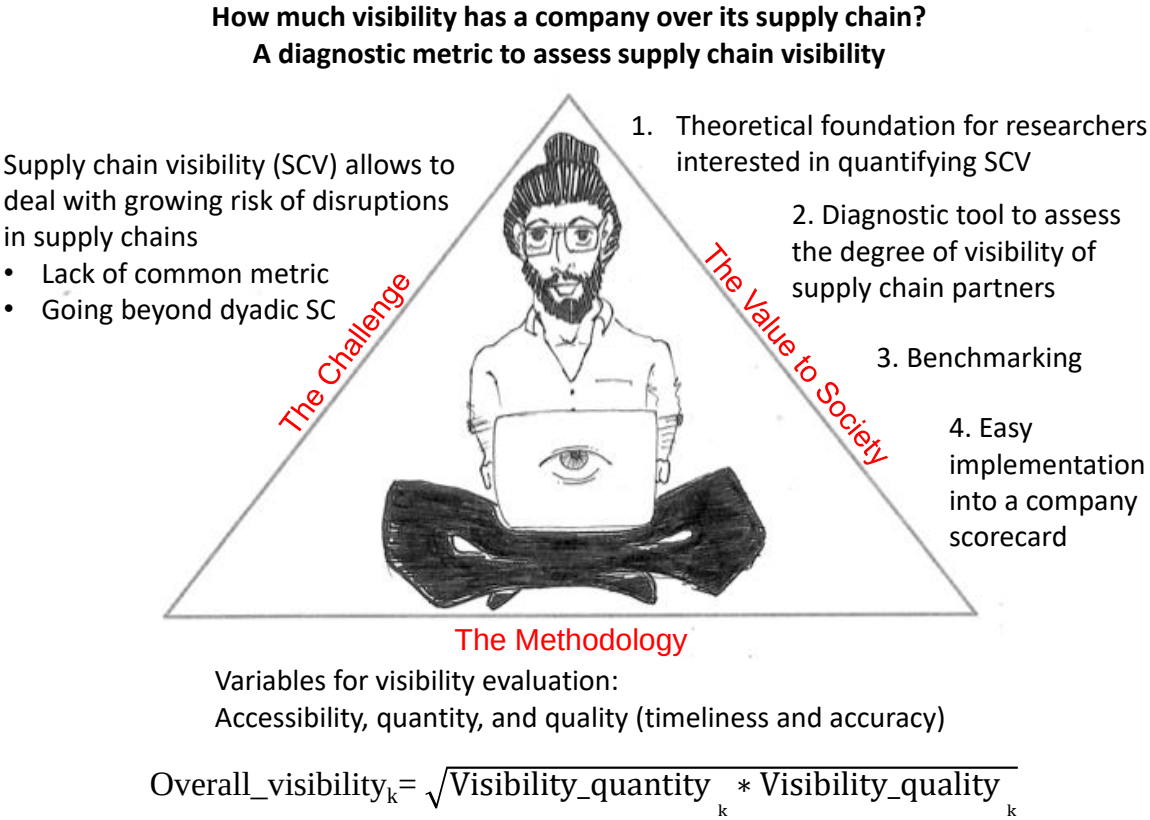
Mass customization and personalization are important trends in the arising Industry 4.0. These new paradigms require new processes and methods across the whole supply chain, especially in the design and management of manufacturing systems. Production scheduling, for instance, should become more flexible, adaptable, and agile to deal with customer changing requirements and product variety.

The value to society derives from the improvement of real-time scheduling by designing efficient dispatching rules. Agile decision-making has been receiving an increasing attention due to the market volatility and the unexpected disruptions found in real-world manufacturing. Therefore this work presents a relevant contribution in producing better methods to cope with these dynamic environments.

How much visibility has a company over its supply chain? A diagnostic metric to assess supply chain visibility

Dario Messina *, Ana Cristina Barros †, António Lucas Soares *

* *INESC TEC and Faculty of Engineering, University of Porto,*
† *INESC TEC - INESC Technology and Science*



1 The Challenge

Nowadays, companies are called to operate in a context characterised by increasing complexity, growing adoption of outsourcing, global dispersion of business partners, and continuous reduction of production costs. All these trends lead to growing uncertainty and consequently to a greater risk of disruptions of supply chains.

Supply chain visibility (SCV) contributes, according to many researchers and practitioners, to solve this problem. It is the capability of supply chain players to have access to or to provide the required timely information from/to relevant supply chain partners for better decision support.

Although highly recommended, SCV appears difficult to achieve and decision-makers believe that this

can be related to the lack of a common metric. In this regard, several authors have attempted to provide qualitative and quantitative methods to assess visibility but most of them have focused their attention on dyadic relationships or linear supply chains, and so failing to grasp the real complexity of modern supply chain networks.

Therefore, with this research we aim to describe a quantitative approach that, based on the types and properties of the shared information, allows managers to assess the degree of visibility of their supply chain partners. In particular, the resulting metric is intended to support decision-makers in benchmarking the visibility of different supply chain partners and in preparing for effective disruptions management in complex supply chains. This will enable us to answer the research question: "How to assess the visibility that a company has over its supply chain partners?"

2 The Methodology

To develop the visibility metric, we structured the research in two phases. Taking into account that this study is theoretical in nature, the first phase involved the definition of the dimensions of the metric, and the mathematical model to assess them. This phase was based both on the literature review about visibility assessment and on several brainstorming sessions with the leading research group.

To provide such global view of the supply chain, firms need to exchange different types of information across the supply chain. These types of information can be grouped into internal and external. Internal information is any information present at firm level or supply chain level gathered from companiesâ information systems, while external information refers to any information related to supply chain or the environment, and gathered from institutional reports, stock market, public institutions, and consultancy reports, among others. The types of information analysed are:

1. Available capacity: capacity of equipment and manpower to execute extra work;
2. Production process: sequence of processes needed to make a product;
3. Stock level: level of available inventory in-house, in transit, and backlog;
4. Order/supplier order/customer order: refer to both confirmed order and communication of changes from/to the interested parties. For supplier and firm, it includes also forecasts;
5. Geopolitical constrains: geographical and political conditions where the partners are based that can affect the manufacture of the final product;
6. Track and trace: capability of a firm to track and trace the position of goods starting from the production until the delivery to the end customer;
7. Logistics service provider contract: contractual conditions agreed linking the firm and logistics service provider, such as carriers;
8. Supplier/customer contract: contractual conditions agreed between the firm and its supply chain partners;
9. Alternative supplier: identification of the possibility of having multiple suppliers;
10. Market changes: changes in customerâs behaviour (for supplier and firm refer to forecasts).

Furthermore, the metric considers two properties of the accessible information, namely quantity and quality. Quantity refers to the amount of information available that is shared among partners while quality is obtained as a combination of the timeliness and accuracy, assessed using the four-point Likert scales in Figure 1.

After all the individual judgments have ended, it is possible to combine them adopting the geometric mean in order to obtain a node overall assessment. In particular, the overall visibility of the node k can be calculated as follows:

Score	Quantity
1	Unsatisfactory
2	Most of the time we ask for more information from our partner
3	In some case we ask for more information from our partners
4	Satisfactory

Score	Timeliness
1	Unsatisfactory
2	Information is updated only upon request
3	Information is updated most of the time without request
4	Real time

Score	Accuracy
1	Only in few occasions
2	Sometimes
3	Most of the time
4	Always

Figure 1: Likert scales for dimensions assessment

$$\text{Overall\_visibility}_k = \sqrt{\text{Visibility\_quantity}_k \cdot \text{Visibility\_quality}_k}$$

In the second phase, we carried out a focus group with a panel of expert practitioners. The goal of the focus group was to test the practical relevance of the metric and to improve its usability.

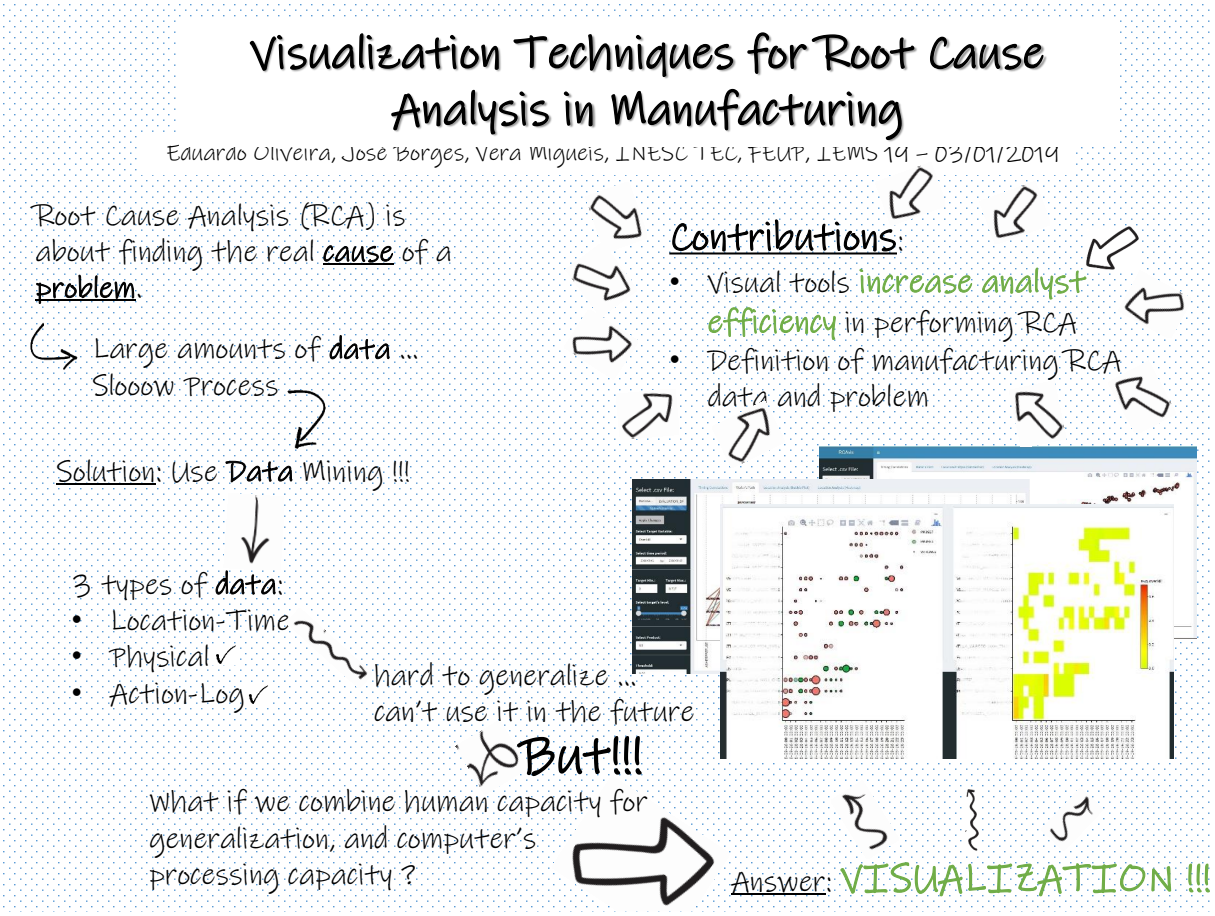
3 The value to Society

The quantitative approach presented in this study contributes to both research and practice by providing a better understanding of visibility in supply chains. The approach provides a theoretical foundation for researchers interested in quantifying the visibility of information in supply chains. This research has also several implications for practitioners. First of all, it provides a valuable diagnostic tool for decision-makers to assess the degree of visibility of supply chain partners. Also by intervening in the properties of the information shared, the tool allows to evaluate the impact of improvements in the current degree of visibility. Although the metric provides a global measure of supply chain visibility, an additional application could be to support decision- makers in the preparation of effective management of disruptions in complex supply chains. Secondly, the metric can be used for benchmarking purpose allowing to compare the visibility level of the firm with partners, with competitors or with companies belonging to similar sectors. Finally, the metric may be implemented into a company scorecard, in order to provide transparency of external and internal performance, and to translate performance into value creating actions. During the focus group, the managers involved in the study evaluate the results of the study accurate and conform to their perception. The metric resulted to be easy to use and not time consuming. However, the most useful aspect of the approach, according to managers, is that it is able to shows the weaknesses of the supply chain with different levels of detail.

Visualization Techniques for Root Cause Analysis in Manufacturing

Eduardo Oliveira*, José L. Borges*, Vera L. Miguéis*

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



1 The Challenge

Root Cause Analysis (RCA) is the process through which we aim to find the real cause of a problem in order to solve it permanently. It is a very important process in manufacturing, as it is indispensable for manufacturing companies which wish to achieve continuous improvement. Traditional RCA techniques (e.g., Pareto Charts, Fish-bone Diagrams, 5-Whys) are used by the analysts to select the relevant information. However, as the amount of information keeps increasing, these techniques are becoming insufficient, as they still require considerable human input and consume valuable human resources' time.

Data Mining (DM) techniques have appeared as the next step in terms of RCA techniques, and their adoption is still in the beginning. These techniques allow the detection of patterns in large amounts of data, presenting the most likely possibilities for a root cause, reducing the analysts' search space, and therefore the time spent to find a root cause. However, most techniques have the limitation of focusing on a single period of time. In fact, performing RCA on a continuous basis to find root causes and develop long-term knowledge (which leads to continuous improvement) is challenging.

When considering RCA in a manufacturing context, we can discern three types of data:

1. **Location-Time** - data of where (which machines) a product has gone through during its manufacturing process and when. This type of data consists on 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 on 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 in a list where the actions performed are registered with a timestamp and associated to an equipment, together with a description of the action.

Location-time data is the one most readily available, but also the one that does not allow for generalization of knowledge. As an example, "The root cause occurred in machine A at 18h00 27/04/2018" (based on Location-time data) is not generalizable, while "If the initial temperature of the oven was above 300°C, problem X occurs." (based on Physical data) is, and can be used in the future. Therefore it is very complex for DM techniques to be able to generalize using only Location-time data. The need for generalization is two-fold: first, it allows the knowledge generated to be used in future occasions; second, it allows us to search over a larger sample, without having to focus on a single period of time.

However, these advantages could be achieved by integrating the flexibility of human analysis with the computer capacity for processing large volumes of information. As such, we believe that visualization techniques are the most appropriate.

The purpose of this research is to use visualization to help the analysts performing RCA by focusing their attention on the most relevant patterns in the data, therefore increasing the efficiency of this process.

2 The Methodology

In the task of RCA, we are trying to discover the true root cause of a problem from a myriad of possible causes. Visualization can help in this kind of process with large volumes of information, by structuring and presenting said information in such a way that it highlights the true root causes.

In order to develop visualizations that helped the RCA process with Location-time data, we first define the manufacturing RCA problem as having the following elements: Products, Equipment, Steps, and Targets.

During the manufacturing process, products go trough several steps, which are performed on equipment. In the end, the product has to achieve certain quality targets. If it does not, it means there were problems.

Given this, we developed four interactive visualizations (the user can interact with these visualizations through filters and zooms that enable the user to adjust the density of information on the screen):

- **Product Path** - We can see the path a *product* has taken during the manufacturing process. Here path signifies the *equipment* in which the *product* has been processed in each *step*. This visualization allows us to see if there is an equipment or a sequence of equipment that have a higher rate of problems.
- **Location Analysis** - We can see for each *step* and *equipment*, which times had a higher concentration of problems. The concentration of problems can be seen in two different ways (size and color) which originates two different visualizations with the same purpose (example in Figure 1). This visualization allows us to see the moments an equipment produced a high volume of products with problems, which increases the likelihood it is a root cause.

- **Timing Correlations** - We can see if each *step* occurs at the same time relative to the other. In other words, we may detect delays between steps, and see if these delays lead to an increase in problems (i.e., if these delays are root causes).

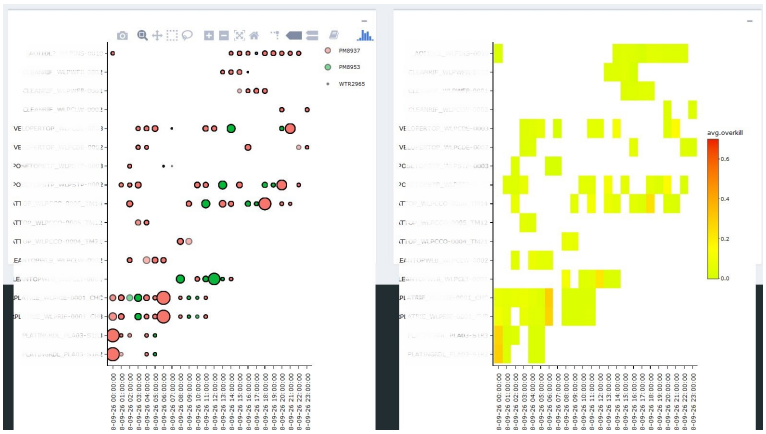


Figure 1: *Location Analysis* visualizations example. The y-axis shows the equipment, and the x-axis the timestamps. In the visualization on the left, the concentration of problems is represented by size (larger bubbles mean higher concentration). In the right visualization, the concentration is represented by color, where the one closer to red represent a higher concentration.

In order to validate the proposed visualizations, we organized a session with potential users of these visualizations, belonging to the semiconductor manufacturing company used as case study. Overall, the users emphasized that a visual tool could decrease the time they spent in RCA of problems, by focusing their attention on the most likely root causes. It was also possible to obtain some insights on perception, based on the constructive criticism the users provided during the session.

3 The value to Society

To summarize, the contributions of this study are:

- The identification of several types of data that can be present in manufacturing RCA problem.
- A general definition of the manufacturing RCA problem, which can be used as a basis for the development of other solution
- Visualizations that help the analysts reduce the time spent performing RCA
- Some considerations on perception that could guide the development of future visualizations

Upgrading Business Performance and Decision Making in Waste Management through a KPI-based Decision Support System

Gonçalo Monteiro *, Ricardo Simões †, Bernardo Almada-Lobo *

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

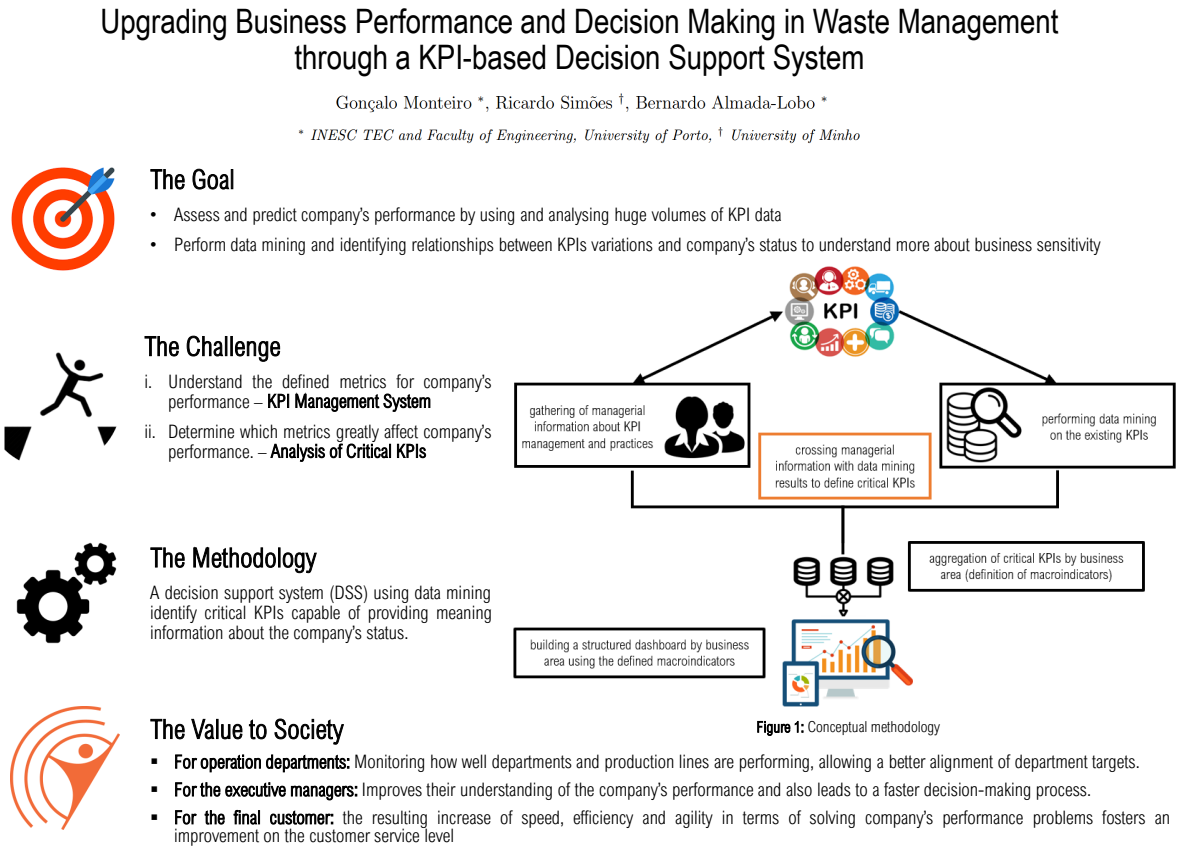


Figure 1: Conceptual methodology

1 The Challenge

Nowadays, industry, and society in general, have been dealing with a recent and challenging problem, huge volume of gathered data. Particularly, companies process a great volume of information expecting that it will positively impact their business competitiveness and market position. However, performance goes beyond the amount of data gathered towards which path and decisions companies can take from that information.

Motivated by a case study with a solid waste management company, the goal is to, correctly, assess and predict company's performance by using huge volumes of gathered data and by structuring data-enabled systems capable of analyzing these data and providing a robust strategic direction to companies. To do

so, we must face the following challenges: i) to understand the defined metrics for company's performance and ii) based on this, to determine which metrics greatly affect company's performance.

Key Performance Indicators (KPIs) are measurable metrics that demonstrate how effectively a company is achieving key business objectives. KPIs can be highly customized by managers to best fit their business and project needs. Business strategies fueled by KPIs and managerial information have been highly accepted across industry since they perform extremely well on assessing whether the business goals have been achieved or not. KPI-based strategies have been widely presented in the literature led by the "hot topic" Business Intelligence.

Notwithstanding companies are, everyday, looking for and implementing, supposedly, better and more meaningful KPIs leading to a reality where too many indicators are defined and no distinction is made between operational and managerial ones, as well as no hierarchy is built in terms of how each of these KPIs inform about the company's status. Furthermore, KPI assessment and analysis are still performed using spreadsheets and developing monthly static reports in an attempt to retrieve and present useful information for the decision-makers. However, it is clear that such approaches are far from being either efficient or capable of taking full advantage of the potential of a KPI-based strategy.

Data mining is the process of sorting through large data sets to identify patterns and establish relationships to solve problems through data analysis. By performing data mining and identifying relationships between KPIs variations and company's status, managers can understand more about business sensitivity and which metrics should be tracked more closely, as well as providing information about potentially new KPIs.

2 The Methodology

To reach our goals, we propose a new methodology consisting on a decision support system (DSS) using data mining to identify critical KPIs capable of providing meaningful information about the company's status. This system should be able to provide real-time information and predictive insights through the use of these critical metrics.

These methodology is structured in five stages: i) gathering of managerial information about KPI management and practices, ii) performing data mining on the existing KPIs, iii) crossing managerial information with data mining results to define critical KPIs, iv) aggregation of critical KPIs by business area (definition of macroindicators), v) building a structured dashboard by business area using the defined macroindicators.

As a starting point, several meetings and interviews should be performed in order to identify with operation and executive managers potential flaws in the KPI management. Here, the focus should be on understanding information availability and agility, as well as how hard decision making is performed. Also from these interviews, an initial list of potentially critical KPIs should be retrieved.

From this, we perform a data analysis of the existing KPIs with the purpose of identifying patterns between KPI variations and company's status. By crossing the results of the data mining process with the initial list, we can define a group of critical KPIs, as well as critical points on the company's operation that require further measurements. After identifying the critical KPIs, these are grouped and aggregated according to the field of activity/business area (e.g. financial, environmental, social) they belong.

The final output is a dashboard built and structured by business areas, where each area's performance is assessed using a broader macroindicator resulting from the aggregation of the previously defined critical KPIs and capable of providing meaningful information and predicting performance results for each of the company's business areas. The work is performed closely with both operation and executive managers to make sure there is a strict correlation between the DSS results and the company's reality.

In spite of arising from our case study with a solid waste management company, we intend to present a methodology capable of being extended to other industries.

3 The value to Society

These days, a successful company is much more than a great product or a process. In today's reality, insights and information, as well as a strategic planning and an alignment between information systems and business strategy can leverage the success of a company. With that in mind, this work presents a novel decision support strategy focused on providing a precise assessment of the company's performance, as well as predicting future scenarios and business evolution.

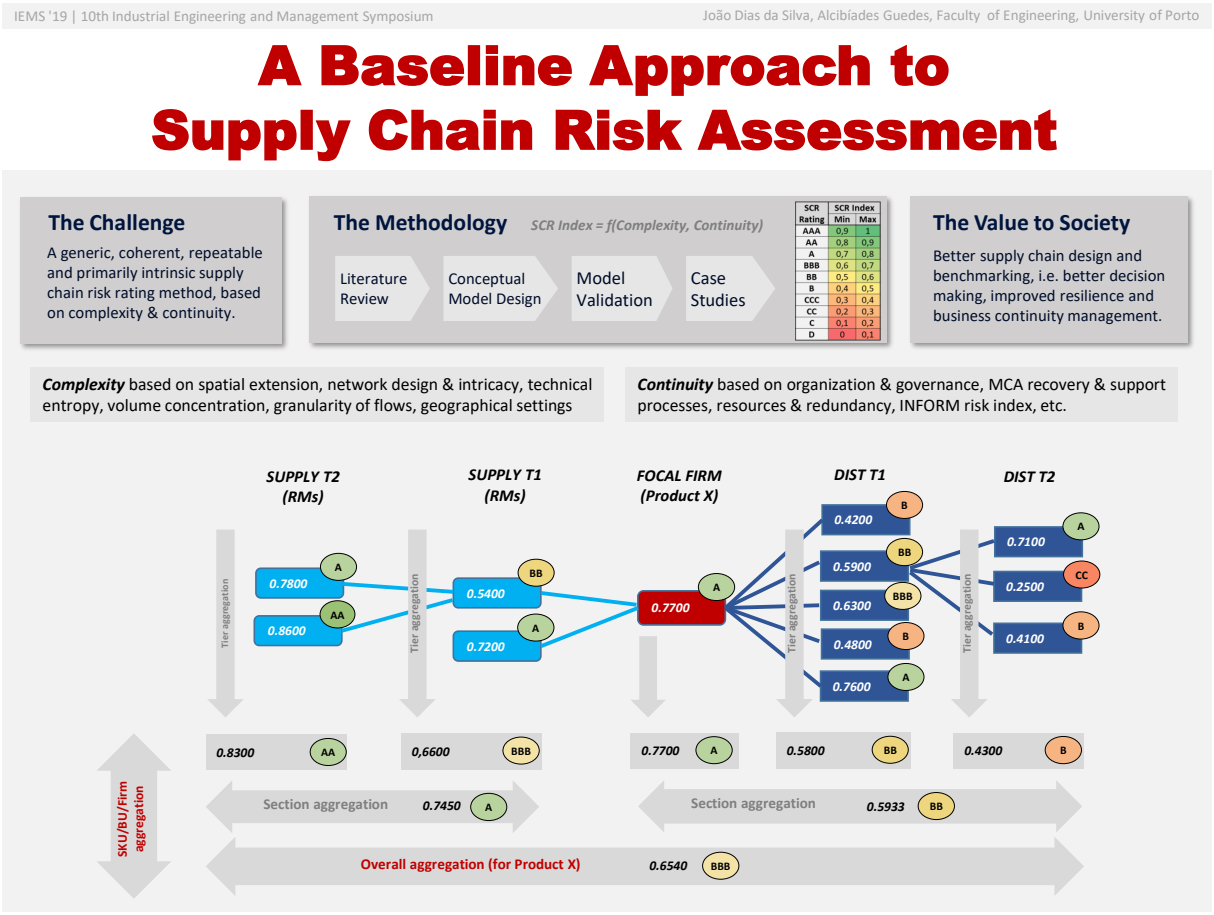
Currently, the task is quite hard, particularly due to the increased volume of data, as well as the lack of data organization and centralization. For that reason, the information and the metrics focused on the company's performance are diffused and unstructured.

Therefore, the value of this work to society can come from: i) the operation departments, ii) the executive managers and iii) the final customer. By having a defined list of critical KPIs, operation managers can better monitor how well their departments and production lines are performing and, as a result these metrics can allow them to better align department targets. From the executive managers perspective, having a dashboard capable of gathering and presenting how well all business areas are doing, not only improves their understanding of the company's performance, but it also leads to a faster decision-making process. Finally, for the final customer, the resulting increase of speed, efficiency and agility in terms of solving company's performance problems fosters an improvement on the customer service level, as well as a decrease on production costs which, consequently, can lead to a decrease on selling prices, or, as it happens in our case study, a decrease on tax values.

A Baseline Approach to Supply Chain Risk Assessment

João Dias da Silva*, Alcibíades Guedes*

* *Faculty of Engineering, University of Porto*



1 The Challenge

Over the past decades, global manufacturing and logistics networks have attained unprecedented levels of complexity, with supply chains becoming evermore prone to operational disruptions of unforeseen causes and consequences. Within this context, the design of resilient supply chains has become a challenge of the utmost importance, and so has the need for innovative methods and tools that can assist in assessing the risk of disruption. In particular, the demand for an end-to-end perspective about risk in supply chain systems has been dramatically increasing in recent years, thus driving the need for tools that are able to determine the overall risk of disruption based on specific network configurations and features. This "aggregate" approach has been extensively addressed and advocated by "enterprise risk management" models, and its importance and usefulness for managers have been confirmed by several behavioural risk analysis studies, as well as by a number of models developed in the corporate world. Recent research on supply chain risk (SCR) management has already tackled this challenge, but most "aggregate" approaches address one-off decisions based on supply-side risks alone, tend to use relative measurements and apply risk models that are mainly driven by financial metrics. In addition, current research is typically devoted

to specific industry/sector contexts, is sometimes based on subjective or doubtful data, and does not formally contemplate the assessment of supply chain subsets. This research project aims to address the need for an innovative and practical "aggregate" methodology to assess the propensity for disruptions in supply chains, thus the following research questions have been formulated: (RQ1) *Which common criteria and modelling procedures should be used to assess the risk of disruption in supply chains, so as to ensure consistency among different supply chain sections and aggregation levels, and throughout time?* (i.e. how to measure), and (RQ2) *What are the requirements and what is the most appropriate methodology to rate the overall risk of disruption of supply chain systems, regardless of industry and market characteristics?* (i.e. how to rate).

2 The Methodology

This research project is essentially exploratory and its goal is to create an effective, versatile, straightforward and evidence-based framework to assess and rate overall supply chain disruption risk. The research methodology, which basically follows the Design Science Research (DSR) framework, is summarized in Figure 1 and includes: (i) a thorough literature review of risk management theory and practice, SCR assessment frameworks, and rating methodologies, (ii) the development of an original conceptual model for SCR Rating, (iii) the formal validation of the model, regarding its fundamentals, procedures, criteria and output sensitivity (through simulation), and (iv) the application of the model to real cases (for illustration, feedback and improvement purposes). The project is currently on phase (iv).

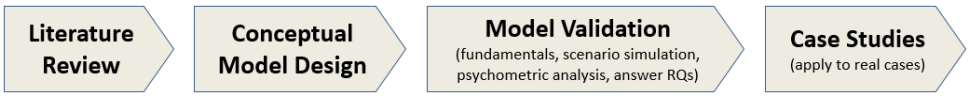
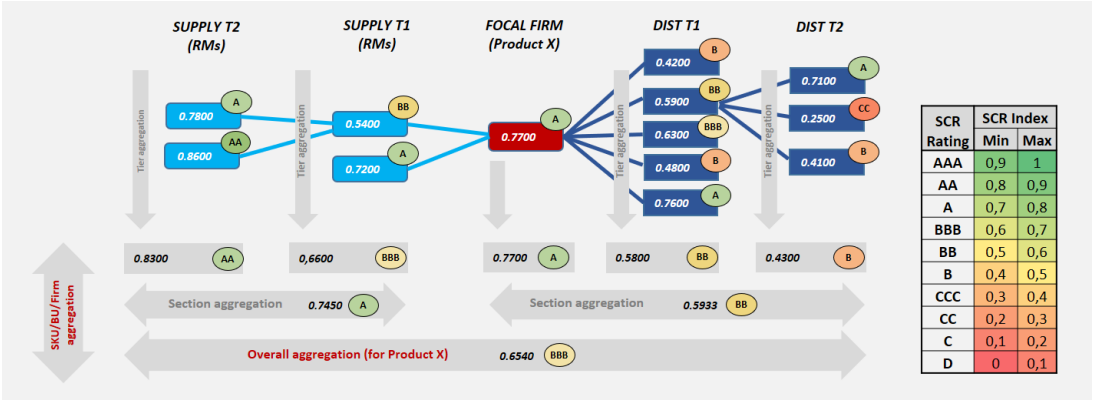


Figure 1: The research methodology

Our ultimate goal is to create a generic, coherent, repeatable and primarily intrinsic SCR rating method. By *generic* it is meant that the proposed framework is supposed to be applicable to a wide range of supply chain systems, regardless of industry, size or configuration. By *coherent*, it is meant that the proposed rating is expected to be consistently computed for broader and shorter extensions, as well as for more or less aggregated levels of supply chain systems. By *repeatable* it is meant that the proposed rating methodology should be stable and consistent throughout time, allowing current output to be compared with past or future results. Finally, by *primarily intrinsic* it is meant that the proposed methodology should be essentially based on observed features and objective measures obtained from within the system, rather than on perceptions, estimates or any other subjective measures. On the one hand, there is strong evidence that higher network complexity (e.g. higher operational granularity, larger product ranges, longer networks, larger number of connected nodes, etc.) generally drives up the propensity for supply chain disruption. On the other hand, no matter how thoroughly most corporations are able to identify, assess and treat their main risks, they will usually fail to foresee some relevant type of risky event or circumstance, and/or will often be surprised by the actual frequency or disruptive power of some known risks. Following this logic, our model infers the propensity for disruption of a certain supply chain system from both its *Complexity* and its *Continuity* features. *Complexity* reveals the structural and operational intricacies of the supply chain system, while *Continuity* reflects the preparedness and resources in place to cope with disruptions.

The model was designed for product and product-service supply chains only. For each product or product family (finished good) assigned to the focal firm, the supply chain is modelled as a process network that emerges upstream, according to the *bill of materials* structure, and downstream, following the distribution channels (see Figure 2). Each node corresponds to a certain production or storage facility with its inbound and outbound links. For each node in the network, we must collect observable data according to specific Complexity and Continuity assessment criteria, so as to derive local SCR indexes and ratings (i.e. at node level). Local SCR indexes can then be combined to compute network indexes and ratings at various levels of aggregation. The Complexity assessment criteria pertain to a number of structural and operational features: spatial extension criteria, network intricacy, manufacturing intricacy,

operational patterns, geographical setting. The Continuity assessment criteria are compiled from a set of BCM-related binary conditions (e.g. governance, legal and regulatory compliance, crisis management, business impact analysis, recovery of mission critical activities, alternative suppliers, etc.), as well as from the INFORM risk index for the respective geographical regions. At each node, we calculate: (i) the Complexity sub-index, and (ii) the Continuity sub-index. The SCR Index for this node is then calculated as the quadratic mean of both sub-indexes. The SCR Index is a decimal number between 0 and 1, and the corresponding "SCR Rating" (SCRR) is determined within a 10-level scale where "AAA" corresponds to the highest SCR index (i.e. lowest propensity for disruption, or highest resilience) and "D" corresponds to the lowest SCR index (i.e. highest propensity for disruption, or lowest resilience). After we have computed all the SCR Indexes at node level, we can vertically and horizontally aggregate them in order to determine higher level SCR Indexes and ratings. See Figure 2. By definition, an overall SCR Index results from a full vertical and horizontal aggregation process, be it for a single product, or for a family of products (ultimately, for a full business unit, or a even a full business corporation).



SCR Rating	SCR Index Min	Max
AAA	0,9	1
AA	0,8	0,9
A	0,7	0,8
BBB	0,6	0,7
BB	0,5	0,6
B	0,4	0,5
CCC	0,3	0,4
CC	0,2	0,3
C	0,1	0,2
D	0	0,1

Figure 2: Determining the SCR Rating (SCRR)

The validation of this construct supposes a thorough evaluation of its coherence and readability (discriminatory power), so as to give an answer to RQ1, and also requires a critical analysis of its fundamental logic as a SCR rating system, in order to respond to RQ2. A mass simulation of supply chain scenarios has been conducted for this purpose, and has produced good results so far, mainly regarding the *acceptability* and *internal consistency* metrics, yet it is still in progress concerning the *validity* and *responsiveness/sensitivity* metrics, as we need to test the behaviour of the rating with as many static and dynamic (transitional) instances as possible. In addition, the construct is currently being applied to four real cases (supply chains of different sizes and industries), which will provide important inputs regarding its usefulness and usability in real environments (interpretation and meaningfulness, ease of computation, potential for automation, other opportunities for improvement, etc.). The four cases are: (1) Home and DIY categories within a national retailer, (2) a global manufacturer of cork products, (3) a large food industry manufacturer, and (4) an international fashion retailer.

3 The Value to Society

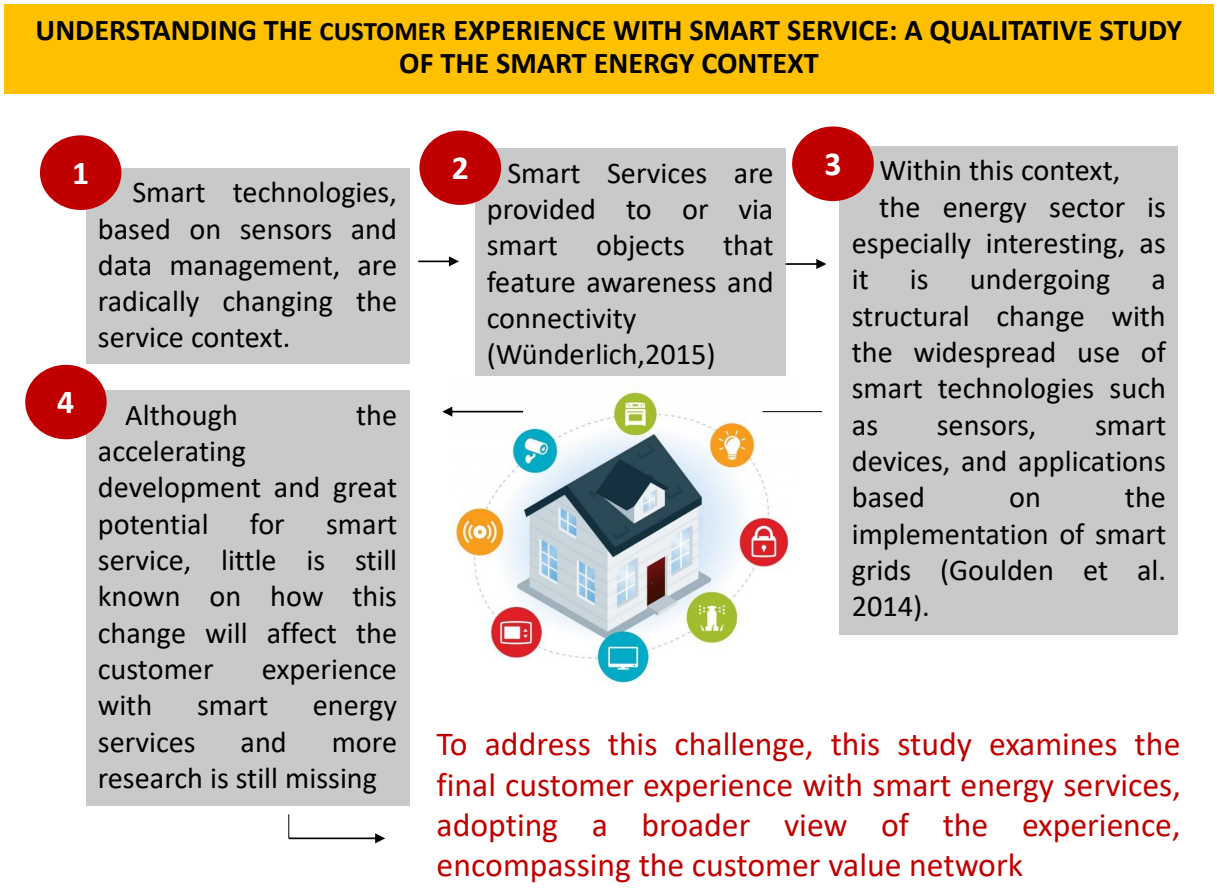
Supply chain risk assessment tends to be an increasingly relevant topic, not only as a complement to standard risk management implementations, but also due to its role in strategic and tactical management activities. The use of standardized methodologies and measures is an obvious advantage, not only at firm level, but also for markets in general. Being an absolute measure (rating) rather than a relative or comparative one (ranking), the proposed construct may be used to compare more or less related networks, which is certainly useful for supply chain design/redesign and benchmarking purposes (intra/inter-firm). Most measurements at node level can be easily computed from existing business and operational data/models, and some of these inputs simply have binary statuses (easier to maintain). Moreover, the emphasis on consequence-based risk analysis and preparedness/BCM raises awareness and provides valuable insights on how to deal with extreme scenarios or unknown events. The ultimate goal of this project is to build

a better perception of the propensity for disruptions in supply chains, thus helping strategic and tactical decisions, adding transparency and reliability to processes, while improving business continuity and fostering value creation.

Understanding the Customer Experience With Smart Service: A Qualitative study in the Smart Energy Service context

Luisa Goncalves *, Lia Patricio*

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



1 The Challenge

Understanding and enhancing the customer experience is a priority for service researchers and practitioners. Customer experience can be defined as a multidimensional construct focusing on a customer?s cognitive, emotional, behavioral, sensorial, and social responses to a service offering during the customer?s entire journey. Smart technologies, based on sensors and data management, are radically changing the service context. Smart Services are provided to or via smart objects that feature awareness and connectivity (Wuenderlich et al., 2015). The smart service context is more complex, as customers now interact with an ecosystem of service providers, involving multiple channels and devices, resulting in more complex customer journeys. Its invisible and interactive nature can deeply affect the way customers create their own experiences in the smart context, with lower levels of service provider control and higher levels of customer control (Chandrana 2018), resulting in more complex customer journeys (Lemon and Verhoef

2016). These customer journeys go beyond the dyadic relationship between customers and firms, encompassing experiences with a larger network (i.e. family, community, service providers, manufacturer, etc.) (Helkkula et al. 2012). This changes the nature of customer experience with technology-based services, as customers may play a more active role in different stages of service provision. Within this context, the energy sector is especially interesting, as it 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 (Goulden et al. 2014). These trends lead to a more open and complex service environment, where actions result from demand response, that refers to changes in electric usage by customers in response to changes in the price of electricity or to incentive lower electricity use at times of high wholesale prices or when a power system is unbalanced. To address this challenge, this study examines the final customer experience with smart services, adopting a broader view of the experience, encompassing the customer value network. Although the accelerating development and great potential for smart service, little is still known on how this change will affect the customer experience with smart energy services and more research is still missing.

2 The Methodology

In a qualitative approach, the study involved focus groups and in-depth interviews with a total of 31 participants covering energy consumers. 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: (a) Home Energy Management Systems (HEMS) customers, electric vehicle (EV) customers and residential customers with high consumption of electricity. Second, three focus groups and further semi-structured interviews were administrated, to gain an in-depth understanding of the customer experience with smart services. Overall, individual and group interviews involved 31 customers. Interviews were recorded and transcribed verbatim, and data analysis followed a process of data coding and categorization (Charmaz, 2006) in order to systematize customer goals, activities and related context, including smart objects, energy system, and other actors.

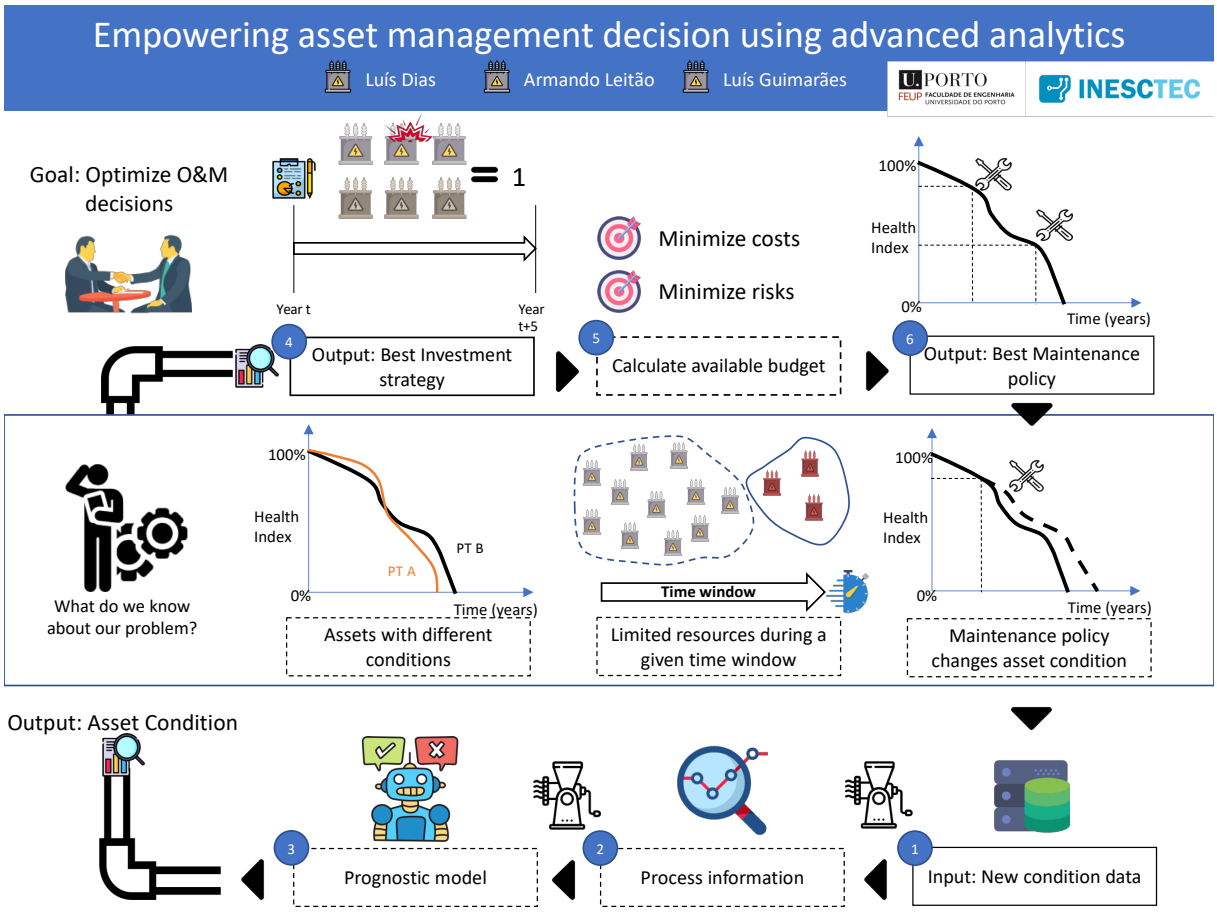
3 The Value to Society

The preliminary results brought the identification of customer experience elements, enabling to assess customers? experiences, including their goals, activities, interactions, and their willingness to explore the whole potentiality that smart services and technology offer. Despite progress in smart service offerings, potentialities and problems related to the customer immersed in the smart context remain largely unexplored. In the last five years, interest has been growing due to the imposition to understand the reasons customer adopt or reject the smart services, as they are changing completely the way people use and take benefits from technology in daily life. In this context, such study brings a deep understanding of customers? experiences, behaviors, and expectations in the smart service environments as experiences varies from contexts, activities, and interactions, enabling service designers to develop competitive services with innovative propositions and new ways of co-creating value.

Empowering asset management decision using advanced analytics

Luis Dias * , Luis Guimarães *, Armando Leitão *

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



1 The Challenge

Across several industries, the recent transition from a regulated to a competitive market has dramatically increased the companies' pressure to become more efficient. New consuming patterns have also resulted in more stressful operating conditions and in shorter and complex maintenance cycles. Thus, the diagnosis of potential failures in their early stage can not only increase the equipment reliability but also decrease the revenue loss due to service downtime. To this purpose, years of operation have generated an important amount of information ready to be analyzed and used to forecast O&M costs of current and future installations.

Motivated by a case study in the electricity industry, the goal is to tackle industry asset management problems with advanced analytical tools to support decision-making procedures. To do so, we must be able to answer to the following challenges: i) to correctly assess the equipment condition and ii) based on this condition devise a quantitative approach for the asset portfolio that is capable to integrate condition models with asset management decisions.

Due to the complexity of this type of problems, existing condition models only diagnose and predict the asset condition. These models fail to provide decision support to the company encompassing the whole asset portfolio and practical constraints (e.g. limited budget, spare parts scarcity, equipment location, etc). This contributes to higher inefficiency in the decision making process which leads to misplaced asset investments and inappropriate maintenance policies. Moreover, little research has been done when we consider both condition monitoring and asset management decisions together. To tackle these challenges we plan to develop a framework optimizing maintenance decisions, namely investment decisions and maintenance policies, which considers the present and future asset portfolio condition. The integration of both models into a single framework not only allows to generate efficient decisions suited to the company, but also provides a flexible analytical tool capable of improving overtime.

2 The Methodology

To achieve our goals we propose a new methodology for asset management depicted in Figure 1. The outputs of the proposed methodology are an "Investment plan" for the asset portfolio and the respective "Maintenance policies".

We intend to develop three analytical models in order to build the proposed methodology: i) diagnostic model, ii) predictive model and iii) a multi-objective optimization formulation integrating both models. Whenever new data is available, the first step in our methodology is to "Extract relevant information". Therefore, a diagnostic model is used for failure diagnosis and severity quantification. Rather than only focusing on the binary classification of failures, the model has to be capable of evaluating the severity of each failure. This allows to compare distinct failures in different equipment and help decide which maintenance action should be carried out.

On top of the diagnosis model, we will develop a predictive model that will empower the DM with information regarding potential failures in the future. This allows to take advantage of the aforementioned model in order to anticipate equipment downtime due to failure. Moreover, the predictive model will be dynamically updated with new data originated from different sources allowing to monitor the asset portfolio. The model will allow the quantification of the impact of certain failures on the equipment longevity, providing the literature with new insights regarding the deterioration process. In this model we approach the equipment condition into two perspectives: short-term condition and long-term condition. On the short-term we focus on repairable failure(s) that reduce the equipment performance. We plan to combine unsupervised algorithms with dimensionality reduction algorithms, such as anomaly detection algorithms and principal component analysis (PCA) respectively, due to the small number of failure records when compared to the number of non-failure records. This approach will allow to quantify the failure severity and the respective failure mode. On the long-term we focus on catastrophic failure(s) rendering the equipment end-of-life. This analysis will be done using remaining useful life models (RUL) which allow to incorporate different types of factors affecting equipment degradation.

In the second step "Optimize decisions", we use the asset portfolio condition to help the DM define the investment plan and the maintenance policies. The investment plan covers the equipment to be replaced and when they should be replaced based on the asset long-term condition. This plan is defined for a fixed-time window (e.g. 5 years) and it can not be modified during this period. Due to budget constraints the company can only replace certain assets. Limited by the short-term condition and the investment plan, maintenance policy decisions establish how we should allocate the available resources for each equipment and what maintenance interventions should be carried out. We want to define feasible maintenance policies avoiding catastrophic failures for equipment that were not selected for replacement in the fixed-time window. For this problem, the DM aims to minimize maintenance costs without subjecting the company to excessive risk. Thus, the asset management decisions are going to be established using a rolling horizon multi-objective formulation trading-off maintenance costs and the asset portfolio risk. The final output is the best asset management plan encompassing the portfolio condition and the DM preferences. Although inspired by our case study in the eletricity industry, we intend that the framework is as general as possible so it can be extended to other industries. The novelty of this work is threefold: i) new condition models to diagnose and predict equipment condition using unsupervised approaches; ii) novel multi-objective formulation using a rolling horizon approach and iii) a new analytical framework combining asset long-term and short-term condition with investment and maintenance policy decisions.

Figure 1: Conceptual methodology

We already addressed the diagnosis model in a submitted work for the journal "IEEE Transactions on Power Delivery", where we proposed an unsupervised approach for fault diagnosis of power transformers.

3 The value to Society

This work presents a novel asset management framework for the electricity industry to tackle the aformentioned gaps. This type of approach is different from the "status quo" in the field not only because it integrates the asset portfolio condition with multi-objective optimization, but mostly because it is a business-oriented perspective of the problem. We aim to present a framework considering the interconnected sub-problems for the portfolio size and mix using advanced analytics.

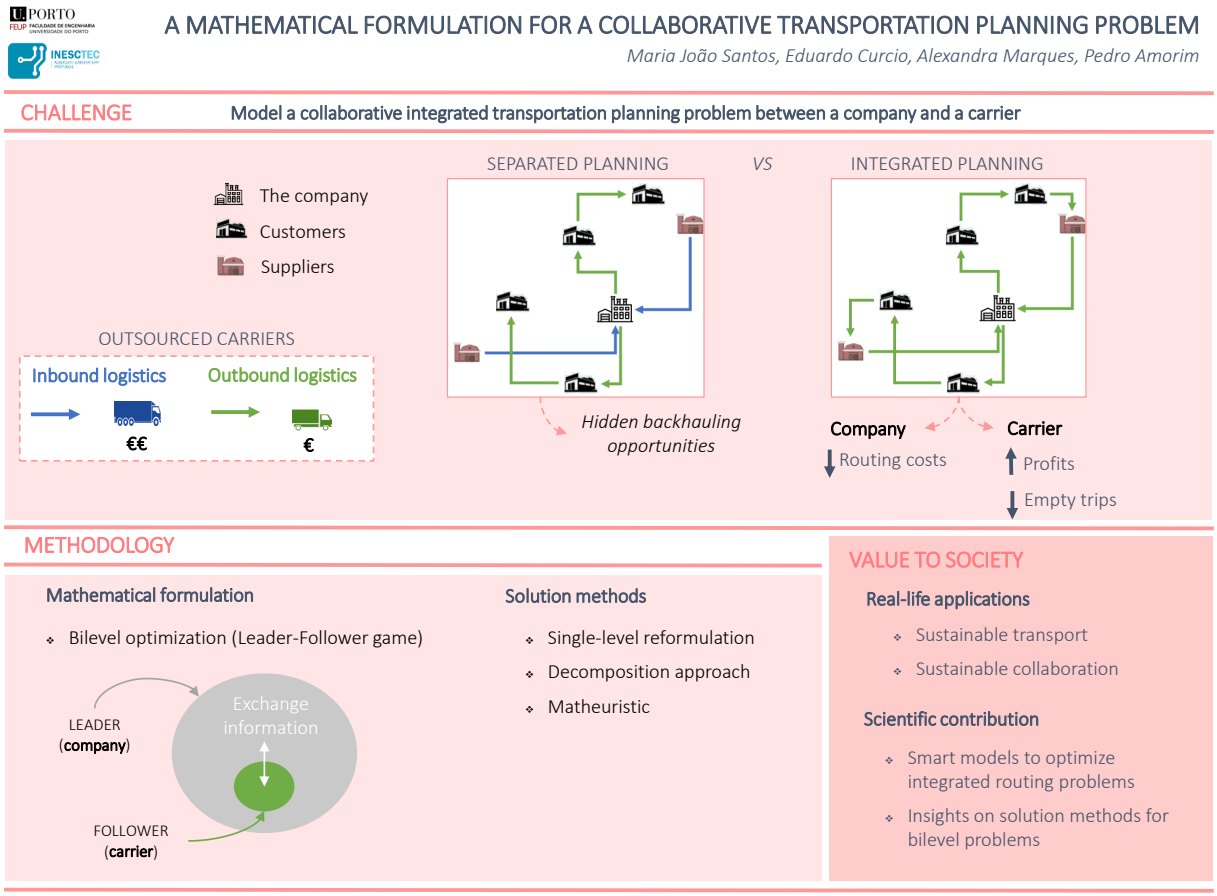
The value to society can be seen from two perspectives: i) the company and ii) the customer. Companies adopting this approach will be able to increase operational efficiency and effectiveness leading to increased profitability and an improved market position. From the customer perspective is the access to lower electricity prices and higher service level (e.g. grid downtime due to equipment malfunction) which are the two most relevant benefits. Additionally, low electricity prices enable the growth of smart cities contributing even further to an increased customer satisfaction.

In the future, the approach presented could be extended to other type of industries. Furthermore, the different building blocks presented in Figure 1 will be flexible enough to integrate different condition monitoring models and multi-objective optimization techniques in order to fine tune the methodology performance.

A mathematical formulation for the collaborative transportation planning problem

Maria João Santos*, Eduardo Curcio*, Pedro Amorim*

*INESC TEC, Faculty of Engineering, University of Porto



1 The Challenge

Outsourcing logistics operations to third party logistics (3PL) providers is becoming more common in several industry segments. 3PL providers have become specialized in different logistics operations, such as distribution and warehousing, and can considerably improve service level and customer satisfaction. For the company that outsources these services, time and resources can be released so the company may focus on its core business operations. Moreover, logistics management costs are substantially reduced, since the company avoids the need of its own fleet of vehicles and the associated costs, such as drivers and maintenance plans.

Another trend observed in the logistics sector is the collaboration between different 3PL providers (horizontal collaboration). With respect to transportation, the collaboration often implies the exchange of customers orders between vehicles of different owners, aiming to improve the vehicle's efficiency and to

reduce the no-load backhaul cost. The latter designates the cost of a vehicle traveling empty and impacts directly on the vehicle's efficiency, since empty trips may represent about one fourth of the total distance of a complete route. The collaboration between a 3PL provider and a manufacturer (vertical collaboration) usually relies on determining bid contracts that most benefit both parts. For this reason, the collaboration problem between a 3PL and a manufacturer is often modelled as a pricing problem in the literature. On the other hand, the literature lacks optimization models that effectively considers both the transportation and the pricing problems.

Having identified the trends, and a major gap, in the literature regarding transportation planning and collaboration, the challenge of this work is to formulate an efficient mathematical model for a collaborative integrated transportation planning problem and propose solution methods to solve it. The transportation planning is integrated in the sense that both inbound routes (to collect raw-materials at suppliers) and outbound routes (to deliver products to customers) are planned together. In many industries, the inbound and outbound planning processes are carried out separately by different planners. However, several real cases have already demonstrated the benefits of planning integrated inbound-outbound transportation, which results in reducing travelling costs, fuel consumption and CO_2 emissions. The collaboration in the transportation problem arises when the manufacturer outsources the service to the 3PL provider, aiming to reach a price that is fair for both parts.

The problem under research is formulated as a bilevel optimization problem, i.e. an optimization problem partitioned in two levels: the upper level problem is composed of an objective function, a set of upper decision variables and a set of upper constraints, while the lower level problem, with its own objectives, variables and constraints, is part of the constraints of the upper level problem. The bilevel problem relates with a Stackerlberg game, which was firstly introduced in economics to model a game between a Leader (upper level problem) and a Follower (lower level problem). Bilevel formulations have been investigated for distribution problems, such as network design, node interdiction and vehicle routing and scheduling, for which most of the literature is very recent.

Due to the complexity and NP-hardness of bilevel optimization problems, the majority of solution methods developed are metaheuristics, among which evolutionary algorithms are undoubtedly the most popular methods. Some exact approaches are also proposed in order to mathematically formulate and solve the problem, but many difficulties arise when the bilevel problem introduces real-life specifications, resulting in continuous and integer variables and nonlinear functions.

2 The Methodology

The collaborative integrated transportation planning problem is modelled as a Vehicle Routing Problem with Selective Backhauls (VRPSB). The VRPSB considers a transportation network composed of a depot (origin location), a set of customers that receive products from the depot (visited in outbound routes) and a set of suppliers that send raw-materials to the depot (visited in inbound routes, also known as backhauls). All customers demand must be satisfied in a single visit, by a single vehicle, whereas backhauls routes are optional. Thus an integrated route is created if it is more cost-effective than a dedicated inbound route. The selection of which suppliers to visit, if any, is determined by the 3PL, as it will only agree to perform an integrated route if the incentive offered by the manufacturer is sufficient to compensate the cost increase in distance (or other metric used by the 3PL provider).

The VRPSB is formulated as a bilevel mixed integer programming (MIP), where the upper level describes the problem of the manufacturer and the lower level describes the problem of the 3PL provider. The objective of the upper level is to minimize the total routing costs that include the variable cost (total distance), the total incentives offered to the 3PL and the additional outsourcing costs, which arise when dedicated inbound routes are required. The objective function of the 3PL is to maximize the total profits determined as the sum of incentives offered by the manufacturer (to perform integrated routes) and incentives offered by the manufacturer competitors.

The rationale behind bilevel programming follows. The upper level selects a strategy and passes this information to the lower level. Then, the lower level selects its own strategy, known as the rational response. The set of all rational responses is known as the rational set. Considering the rational set, the

upper level can thus anticipate the actions of the follower before taking its own decision. At the end, the upper level chooses the strategy that leads to its best objective function, reaching an equilibrium solution. This work proposes a reformulation technique and a matheuristic to solve the bilevel VRPSB. The reformulation allows to reduce the bilevel MIP to a single level MIP, which is recognized to be more tractable than bilevel programming. The reformulation technique also allows to investigate the complexity introduced by bilevel optimization, in comparison with single level models. Afterwards, an hybrid solution method that combines both exact and heuristic algorithms (matheuristic) is developed to tackle real life instances of the problem.

3 The value to Society

The contribution of this work covers two spheres of operations research: mathematical modelling and real life applications of optimization problems.

With respect to the mathematical model, this work investigates new formulations and solutions methods to tackle two different optimization problems simultaneously - the routing and the pricing problem. This work aims to define the properties of a bilevel MIP problem and design solution methods that are able to efficiently solve the problem for several instance sizes.

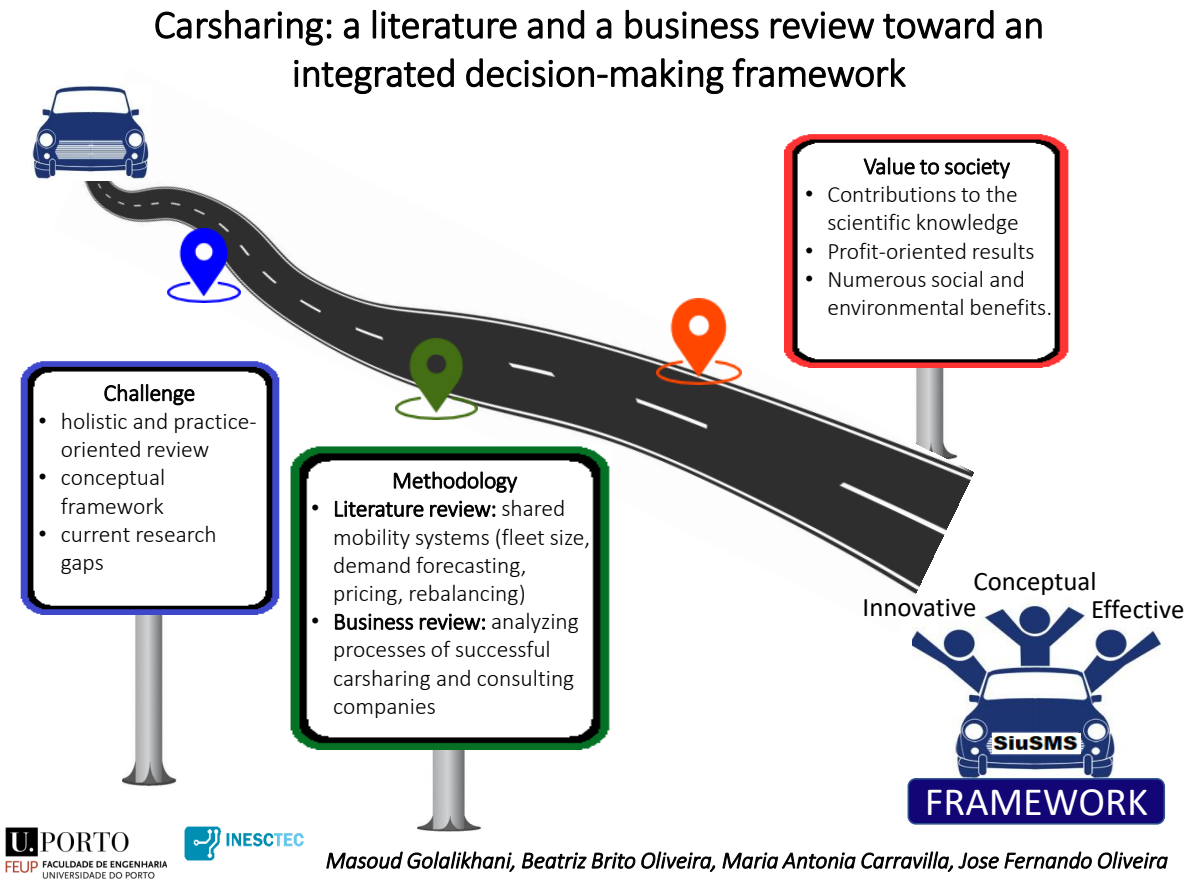
With respect to real-life applications, this work describes a methodology that promotes the collaboration between different players involved in the same planning process that pursuit different objectives. The routing problem is usually solved with a centralized perspective, i.e. the manufacturer only considers its owns needs. Notwithstanding, outsourcing a transportation service requires the definition of a contract, which is usually defined independently on the transportation planning. This work demonstrates the potential application of bilevel programming to tackle real logistics problems, where different players can interact with each other in order to reach to an agreement that best benefit both.

Finally, this work investigates and exposes the impact of collaboration and integrated planning in the sustainability of transport activities in supply chains.

Carsharing: a literature and a business review toward an integrated decision-making framework

Masoud Golalikhani *, Beatriz Brito Oliveira*, Maria Antónia Carravilla*, José Fernando Oliveira*

*INESC TEC and Faculty of Engineering, University of Porto



1 The Challenge

In recent years, shared mobility systems have started to integrate urban transportation systems. Consequently, there has been a significant rise of shared mobility modes, including carsharing services like car2go, ride-hailing services such as Uber, carpooling/ride-sharing services like BlaBlaCar, micro-mobility services like scooter sharing and bike sharing, and other modes.

Among these modes, carsharing represents a novel way of transportation by shifting private mobility from ownership to service use. Therefore, an individual has access to a fleet of vehicles on an as-needed basis. Carsharing companies allow consumers to rent a car for short periods by the hour or minute, which may make this mode of transportation attractive for short-distance daily-needs trip purposes. Also, carsharing offers consumers a time-saving and economical service since the processes of reservation,

pickup and return are usually self-service and shared cars are typically distributed around cities, close to the user's residence. Moreover, costs of fuel, insurance, vehicle maintenance and repairs are often included.

There are three major types of carsharing. The first is peer-to-peer (P2P), in which consumers may make their own car available for sharing with others to recover a portion of the vehicle costs, by using a technological platform. Secondly, in business-to-business (B2B) carsharing, an organisation owns a fleet of vehicles and supplies the required fleet for a corporation, namely for work-related trips. Thirdly, in business-to-consumer (B2C) carsharing, a company owns a fleet of vehicles that are shared among consumers. Throughout this work, we will focus on B2C carsharing. The existing carsharing systems within B2C are divided in round-trip services, where the user is required to drop-off the car in the same location it was picked-up from, and one-way trips, where the user can deliver the car in a different location than the one where he or she started the journey. The former service can be divided into two sub-types: station-based trips, where the pick-up and drop-off must occur in specific stations, and free-floating, which is a relatively new operational model in carsharing where the customer can pick-up a car anywhere and, at the end, leave it at any parking space within a given area. This is the most flexible form of carsharing and has been able to attract new customer groups. Due to the flexibility of one-way services, cars can be dropped-off in areas with lower demand while being needed in other areas of higher demand. Therefore, the company needs to apply different strategies to balance the system, satisfy customer demand and make the system more efficient and profitable.

The carsharing market has never been as competitive as it is now. Therefore, we have witnessed a proliferation of different research on various mobility topics. Existing works can be generally split into two groups. First, it is possible to identify several works that share an empirical perspective. These publications have collectively built a theoretical empirical-based knowledge system about shared mobility features, trend, impacts, and market potential, mainly obtained by surveys. Second, from a more quantitative perspective (often based on optimization approaches), the existing papers tackle various problems in strategical, tactical and operational levels. Nevertheless, there are still research gaps in this area since previous research is generally focused on a specific topic instead of considering the integration of relevant problems. Moreover, relevant and realistic system requirements that affect this business in practice, as verified in the previously mentioned empirical-based research, are often not considered.

Therefore, the first challenge of our work is to provide a holistic and practice-oriented review of carsharing for future research. Then, the main contribution of this study will be to introduce a conceptual framework, based on the review performed, and keeping a significant focus on business. With this framework, it will be possible to identify gaps and ways to bridge them in the future. The expected result will empower carsharing companies to meet their customer expectations and make their business more profitable and sustainable.

2 The Methodology

Despite the emerging importance of carsharing and the large number of papers published in this area, to the best of our knowledge no state-of-the-art practice-oriented literature review is available, addressing the realistic issues that affect this type of mobility. With this study, we aim to fill this gap by integrating a traditional literature review with a more practice-oriented review. Therefore, our review is divided into two main stages.

Firstly, we conducted a comprehensive literature review related to shared mobility systems. We considered empirical and evidence-based research papers that, for the most part, analysed the impact and features of shared mobility systems, the typology of customers, global market trends, as well as market potential. We also considered quantitative papers in this field, tackling problems faced by these mobility systems in different strategy levels. For example, in a strategical level, companies must decide where to locate stations and how many parking places are required, while on a tactical level they decide on the fleet size. As for the operational level, it is the most studied in the literature and includes demand modelling issues, rebalancing schemes, pricing problems, as well as performance measurement.

Secondly, to gain a better understanding of current real-world operations, processes, challenges and other

factors that are difficult to obtain from the literature review, a business review was carried out. In other words, we felt the need to go further than the existing literature review to generate knowledge that is relevant in practice. This was achieved through market research, based on the following directions:

- Identifying successful carsharing companies and analyzing their operational processes and characteristics, such as the geographical distribution that they cover, their service type (i.e. round-trip/one-way, station-based/free-floating, etc.), fleet type, membership procedure, pricing, bonus and promotions schemes, reservation procedures, as well as the features of their mobile app, among others.
- Identifying consulting companies that provide services to carsharing companies, exploring the operational solutions they offer, often not yet tackled by the literature.

Finally, we bring together all obtained information to establish an innovative and effective conceptual framework for decision-making in carsharing, identifying research gaps and providing fundamental future research opportunities to bridge these gaps.

3 The value to Society

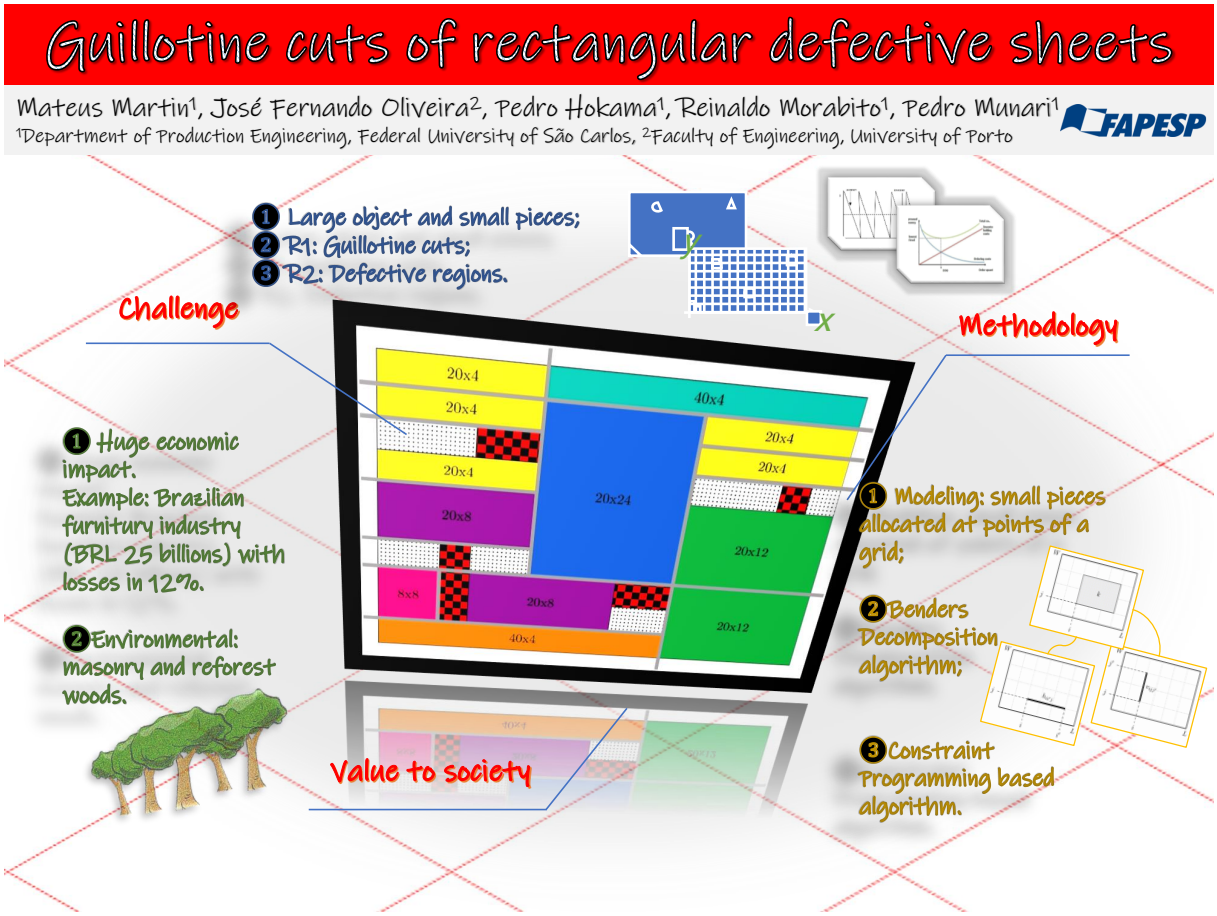
The first objective of the present research is to provide a comprehensive review and conceptual framework, by synthesising a literature and a business review. Regarding contributions to the scientific knowledge, this work will enable researchers to address the main factors that affect this business in practice, identifying gaps and research opportunities for future work in the proposed framework.

Apart from the scientific contribution, the proposed work also aims to have additional value to carsharing companies, customers and society. The benefit to carsharing companies is related to the expected profit-oriented results. On the one hand, it can support them in adjusting their pricing policies and reducing the operational costs, mainly through better car repositioning and demand forecasting. 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, especially considering the business review that focuses on the customer requirements to join and use this mode of mobility. Finally, numerous social and environmental benefits are commonly associated with carsharing, supported by an increasing body of empirical evidence. For example, a large number of car sharing companies include electric vehicles in their fleets and also shared mobility system can reduce the total travel mileage of automobiles. These can have a significant impact in addressing one of the most critical environmental issues, global warming since automobile usage is one of the most significant sources of air and noise pollution and also a substantial source of carbon dioxide.

Guillotine cutting of rectangular defective sheets

Mateus Martin*, José Fernando Oliveira†, Pedro Hokama*, Reinaldo Morabito*, Pedro Munari*

* *Department of Production Engineering, Federal University of São Carlos,* † *Faculty of Engineering, University of Porto*



1 The Challenge

The manufacturing industries often have some type of cutting operation, in which larger stocked objects are cut in order to produce small pieces, as intermediary parts or final products, to their supply chains. The cutting operations can be related to the cutting of jumbo reels in the paper industry, flat glass in the glass industry, rocks in the marble industry, foams in the mattress industry, etc.

These operations are a response to scenarios such as (i) uncertainty in demand for small pieces, which makes safer to store larger objects; (ii) possible economies of scale in the purchase and stock of raw material, or even risks of unavailability in future purchases; and, (iii) the costs of transportation and storage of the larger objects are generally lower than the corresponding costs for the small pieces, when taking into account the complete manufacturing process. However, it also introduces an additional stage of production, i.e., the cutting operation, which produces inevitable losses. Therefore, the problem of

determining how to cut the larger objects to produce the small pieces gains relevance when seeking to minimize the adverse effects of trim loss on production costs.

This work deals with two additional requirements when cutting rectangular sheets. The first is related to the cutting technology, which may require guillotine cuts, i.e., cuts that always generate two smaller rectangles when applied to a larger rectangle. The second requirement is related to quality constraints, which requires small pieces without any defects. For instance, during the production of a glass ribbon in the glass industry, it is common the appearance of tiny imperfections, which can not appear in the small pieces. Another example is the cutting of wood in the furniture industry, which has to avoid small pieces with knotholes, both for structural and aesthetic reasons. Fig. 1 depicts a cutting pattern for a rectangular sheet with defects, where the red checkboard rectangles are the defective regions. The goal of this work is to provide solutions for the rectangular two-dimensional cutting problem when guillotine technology and defective sheets are considered. The objective is to generate cutting patterns with minimal waste.

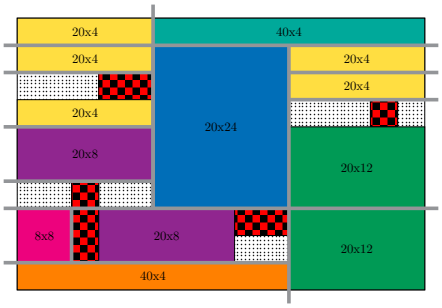


Figure 1: Example of a rectangular two-dimensional sheet with defects.

2 The Methodology

The methodology used is based on Integer Linear Programming (ILP) and Constraint Programming (CP), two techniques widely studied in the optimization field. Regarding the problem itself, we represent each defective region as a set of overlapping rectangles, regardless of its shape. In this way, a large object is discretized according to a two-dimensional grid, where each defective region is positioned in a Cartesian system. Over this geometric model, we developed an ILP formulation. The main decisions regard the allocation of the small pieces to points on the grid that represents the large object. Any allocation of small pieces that would overlap a defective region is avoided by the model, due to the requirement of quality constraints. The requirement of guillotine cuts is satisfied with additional decision variables and constraints.

We also proposed solution methods for this model, besides the straightforward resolution of the monolithic model by a commercial solver, by decomposing the problem decisions, in order to address more challenging instances. Firstly, we developed a Benders decomposition algorithm from the proposed ILP formulation. The Benders decomposition is a variable partition technique that divides a model between the hard decisions, which should be solved first, and the easy decisions of the problem, which should be analyzed next, in an iterative procedure. The proposed decomposition analyzes first the allocation decisions of the small pieces into the large object, and then in a second phase, the requirements of guillotine cuts are analyzed.

A CP based algorithm was also developed. The CP is a programming paradigm in which the constraints play the leading part by representing the relations among the variables, and guiding the search process that will lead to problem solutions. Our algorithm selects, in a first phase, a subset of small pieces to be allocated in the large object. Then, in a second phase, requirements of quality constraints and guillotine cuts are checked for the selected small pieces in a CP framework. Particularly, it is tested whether or not all selected small pieces can be allocated in the large object, avoiding overlaps with defective regions, being able to be cut with guillotine technology. Fig. 2 depicts two solutions obtained by the proposed solution methods with material utilization close to 90%, by considering the large object as a whole.

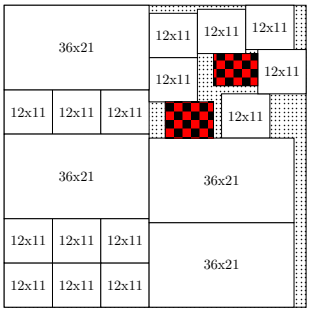


Figure 2: Solutions with material utilization close to 90%.

3 The value to Society

Despite its potentiality for practical applicability, the guillotine cutting problem of defective sheets has been barely studied. Actually, despite efforts to standardize production in the last decades, some materials intrinsically have imperfections, which need to be considered in the production planning.

To the best of our knowledge, the proposed ILP formulation is the first model of this kind for this problem. Therefore, this work presents some theoretical contributions, by proposing an ILP model, and also by applying decomposition techniques to a particular problem. It should be noticed that although the problem can be easily stated, hand-made solutions for the guillotine cutting problem with defective rectangular sheets tend to present low levels of material utilization, due to the intrinsic difficulty of the problem, which severely increases with the number of defective regions.

The development of analytical tools for decision makers facing cutting operations in industrial processes contributes directly to the reduction of costs regarding raw material consumptions, and indirectly by reducing energy and labor costs. Under a sustainability framework, it contributes to decrease the use of non-renewable resources, under the environmental pillar.

For future research, the model could be adapted to consider other kinds of quality constraints not addressed here. For instance, minimum distances between guillotine cuts, which is relevant in the glass industry to avoid cracks in the large object.

How do external and internal factors promote or hinder servitization over time? An in-depth case-study in the elevator industry

Miguel Leichsenring Franco*, Bernardo Almada-Lobo*, Rui Soucasaux Sousa†

* *INESC TEC and Faculty of Engineering, University of Porto,* † *Catholic University of Portugal (Porto)*

How do the external and internal factors promote or hinder servitization over time?
An in-depth case-study in the elevator industry.

The Challenge
Which factors may promote or hinder servitization in manufacturing firms?
How do they play out over time?

The Methodology
Single retrospective in-depth case study.
Analysis of one multinational elevator manufacturing firm with operations in Portugal.

The Value to Society
This research extends the literature by providing insights into how relevant external and internal factors may promote or hinder servitization of the manufacturing firm over time and under which circumstances:

- Three clear servitization implementation periods emerged: "the manufacturing period", "the service-led period" and "the advanced services period".
- Our findings suggest that the legal factor is a "hygiene" factor, in the sense that it was found to promote the implementation of servitization across the three periods.
- The strategic orientation towards services, resulting from a severe economic shift in the beginning of the third period, combined with a change in the competitive environment and on customers' demand, seem to promote servitization.
- The creation of a separate organization to handle the service offering by developing a dedicated sales force and a structure with dedicated service managers and technicians positively impacted the servitization intensity over time.
- Over time, there seems to be a balanced adoption of basic and advanced services, using basic services as a platform rather than providing basic services first to a high extent, followed by advanced services.

IEMS '19
10th Industrial Engineering and Management Symposium

Miguel Leichsenring Franco
Bernardo Almada-Lobo
Rui Soucasaux Sousa

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO DEPARTAMENTO DE ENGENHARIA E GESTÃO INDUSTRIAL

1 The Challenge

Today an increasing number of manufacturing companies is competing through a portfolio of integrated products and services. This is a service-led competitive strategy and the process through which it is achieved is commonly referred to as servitization. Integrated product-service offerings can be distinctive, long-lived, and easier to defend from competition of lower-cost economies, being a conscious and explicit strategy for market differentiation. Much research has been dedicated to the design and benefits of integrated product-service offerings from a manufacturer perspective, but mostly from an organisational level. More recently, some authors suggest that the organisational environment may also affect servitization of the manufacturing firm. Thus, servitization seems to be driven from both the outside and within the company. Notwithstanding, only a limited number of empirical studies have investigated in a holistic

manner how external and internal factors impact servitization. Given that servitization is considered a long-term, often incremental process, there is also a strong need for studies on the implementation process of servitization over time. In order to address these gaps, this study provides insights into which factors may promote or hinder servitization in manufacturing firms and how they play out over time. Specifically, we conduct an in-depth case study of a manufacturer in the elevator industry in an European country. The elevator industry was chosen because it was one of the first to initiate servitization and today is highly servitized, covering a broad spectrum of service offerings, from base to advanced ones. Elevators are long-lived, technically complex equipment that demand high safety requirements and therefore ongoing maintenance and inspection. This case allows for the examination of long-term dynamics of servitization over time, fulfilling the purpose of this research.

2 The Methodology

Case research is considered one of the most powerful research methods in operations management, in particular for examining how and why questions, as well as longitudinal issues. It is also suitable for developing new theory. The case method was adopted because it permitted the collection of rich qualitative data through participant observation. As a manager of the manufacturing firm analysed, the lead author was directly involved in managerial decisions, allowing him to leverage on his field experience and to contribute with new and unique insights to the subject matter. Due to the concerns over confidentiality, access to in-depth fieldwork is not easily granted to outsiders. The literature recognises the knowledge-yielding character of inquiry from the inside, and legitimises the contribution of industry practitioners to management research. Participant observation provides an opportunity to gain access to events and groups that otherwise would be inaccessible to the researcher. Furthermore, the researcher may also perceive reality from the viewpoint of someone inside the case study rather than external to it. Despite its advantages, this data collection technique may lead to some potential biases: the influence of the researcher over participants behaviours, the impact of the researchers own beliefs, and the potential lack of objectivity, for instance following a commonly known phenomenon and become a supporter of the group or organization being studied. Finally, the researcher may not have sufficient time to take notes or to raise questions about events from different perspectives, as a detached observer might. To mitigate these potential problems, interviews were conducted by two researchers, with one researcher handling the interview questions, while the other recorded notes and observations. Therefore, the interviewer has the perspective of personal interaction with the informant, while the note taker retains a different, more distant view. In order to enhance reliability and validity, a research protocol was developed, using the conceptual framework (Figure 1) as a lens for analysis. This protocol contains the procedures and general rules that should be followed during data collection and indicates from whom or where different sets of information are to be sought. The core of the protocol is the set of questions to be used in interviews. It outlines the subjects to be covered during an interview, states the questions to be asked and indicates the specific data required. This ensured that all areas of enquiry were covered. A single case was chosen, because it is an unusually revelatory, extreme opportunity for research access and may lead to deep insights that are unobtainable in quantitative studies. Thus, single-case research typically exploits opportunities on a significant phenomenon under rare or extreme circumstances. Up-Down Elevators was selected because of: i) in-depth access to the company (people and archival documents); ii) access to relevant information over 60 years (from 1955 until 2016); iii) the firm not only produces goods (elevators) but also provides all sort of services to the installed base. Following the triangulation principle, our data consists of a wide range of material: semi-structured interviews with senior managers, memos of workshops with the company key decision makers, the company internal documents and presentations, data on delivered goods and services, brochures about the historical development of the company, publicly available information and site visits and participant observation by the author on the company premises during the research period. Since interviews are a highly efficient way to gather rich, empirical data, we used numerous and highly knowledgeable informants who view the focal phenomena from diverse perspectives. These informants included organizational actors from different hierarchical levels, functional areas, groups and geographies. The interviews lasted 60-120 minutes and were conducted over a period of two months. Throughout the study, following each interview a thematically arranged outline describing the covered issues was written. Interviews were carried out until theoretical saturation was reached, that is, when no new information emerged. A total of 15 semi-structured interviews was carried out: 2

Co-CEOs, 2 senior service managers, 2 senior new installation managers and 7 service managers and 2 new installations managers. All of them were recorded. Detailed write-ups were prepared and sent to the interviewees to validate the data and maintain participant engagement in the research process. Data were collected, and then documented and coded, in order to reduce and map it into categories. From the literature review and the conceptual framework we created a provisional start list of codes prior to fieldwork. Thereafter a pattern analysis of the data was conducted in order to look for causality.

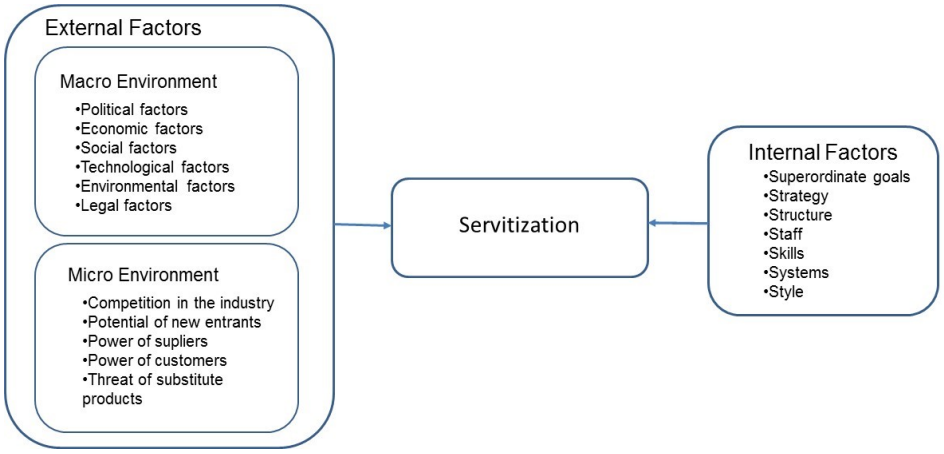


Figure 1: Conceptual Framework

3 The value to Society

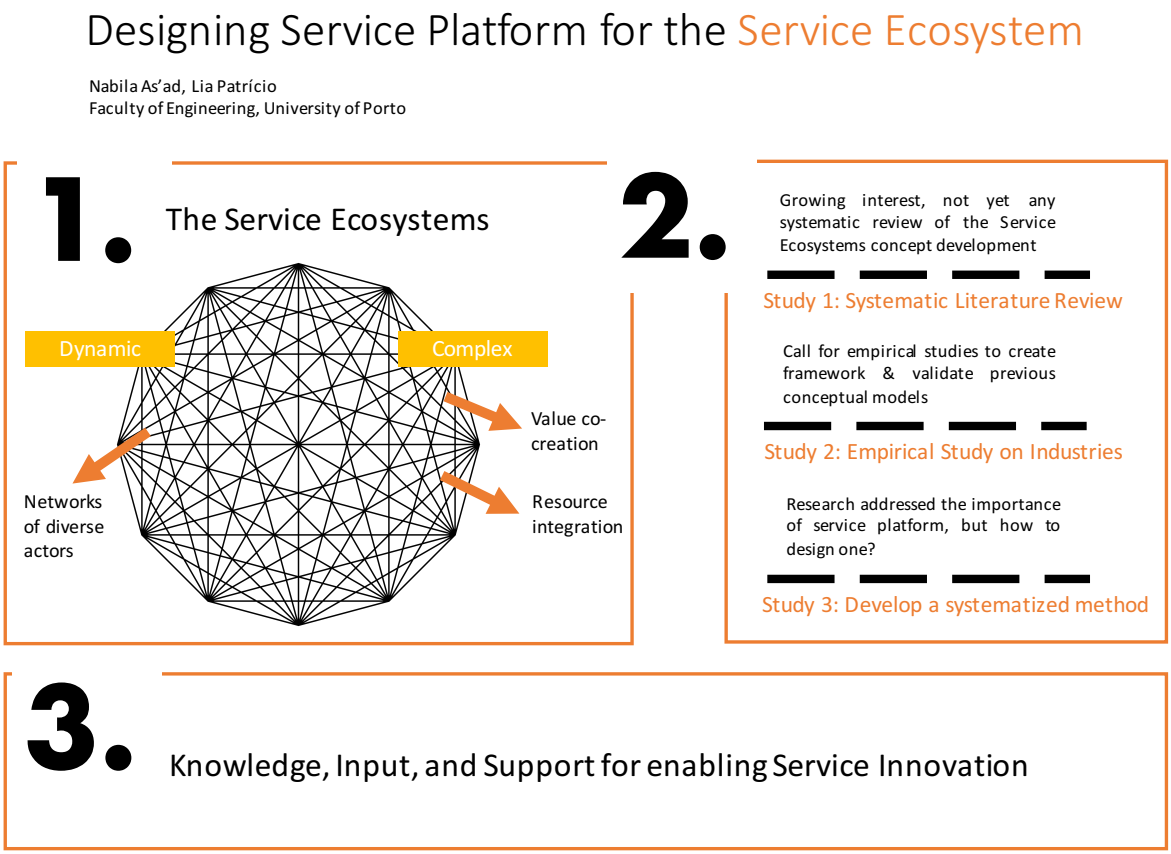
Much research has been dedicated to the design and benefits of integrated product-service offerings. However, only a limited number of empirical studies have considered the factors that impact servitization over time. This research extends the literature by providing insights into how external and internal factors promote or hinder servitization of the manufacturing firm over time and under which circumstances. From the analysis, three clear servitization implementation periods emerged: the manufacturing period, the service-led period and the advanced services period. Our findings suggest that the legal factor is a hygiene factor, in the sense that it was found to promote the implementation of servitization across the three periods. The strategic orientation towards services, resulting from a severe economic shift in the beginning of the third period, combined with a change in the competitive environment and on customers demand, seem to promote servitization. Furthermore, in the second period competition promotes servitization, leading the manufacturer to provide new services and existing services not only to the installed base but also to the captured base (elevators installed by other manufacturers). But this factor also seems to hinder servitization intensity, since competition may lead to a reduction of service prices. Furthermore our findings indicate that the creation of a separate organization to handle the service offering by developing a dedicated sales force and a structure with dedicated service managers and technicians positively impacted the servitization intensity over time. The change from a traditional to a servitized manufacturer required significant organizational changes in language, values, design process and organization design. A separate organization unit protected the emerging service culture with its metrics, control systems and incentives. It also seemed to be easier to initiate service orientation in the corporate culture and therefore improving direct service profitability, the quality of customer relationships and the selling of more services over time. Today it also helps the manufacturer to diffuse knowledge across the network and to better manage the service personnel.

First, our findings are consistent with other authors, with servitization intensity building on product-basic services combinations, by adding advanced services, but without ever giving up the supply of products and the provision of basic services. Second, our findings provide new insights into the provision of basic and advanced services. Over time, there seems to be a balanced adoption of basic and advanced services, using basic services as a platform rather than providing basic services first to a high extent, followed by advanced services.

Designing Service Platform for Service Ecosystem

Nabila As'ad *, Lia Patricio*

* *Faculty of Engineering, University of Porto*



1 The Challenge

The dynamic and complexity of the market have attracted service researchers to examine it on the ecosystem level. As a result, the concept of service ecosystems become the central concept in service research. Within Service-Dominant Logic (S-D Logic) perspective, service ecosystems is defined as a set of actors integrate resources to co-create value through service exchange and they are connected through institution and institutional arrangements.

There has been a growing interest and notable contributions from service research to the development of service ecosystems concept, however, we see three main challenges.

Firstly, there is not any systematic examination and review of the evolvement of service ecosystems concept. Furthermore, the ecosystem concept has also been adopted by different areas. For example, a set of actors connected through mutual purposes known as business ecosystems in the area of Business and Management and a set of web services developed and connected to support business processes called as

web service ecosystem in the area of Information Technology (IT). It is then important to explore the different interpretations of ecosystem concepts, emphasizing their key differences, which are currently blurred. Therefore, we adopts a systematic literature review approach to examine the evolvement of service ecosystemsâ key constructs, future researches, and to examine differences, overlaps and complementarities of its concept compared to the other perspectives in Business and IT.

Secondly, our systematic literature reviewâs preliminary results show that the majority of service ecosystems literature are conceptual studies. Furthermore, our analysis of the future research agenda shows the calls for developing empirical studies to create new framework and validate previous frameworks within different contexts. As a result, this study will conduct empirical study on real-life industries to understand the value co-creation processes amongst complex and dynamic service ecosystem. Two industries are being studied, namely utility and air transportation industry, to enrich the analysis by comparing the results between two different contexts. This study will adopt Service Design approaches to create innovative and cutting-edge service offerings. Service Design provides holistic approaches to design for the complex service systems. It doesnât not only focus on enhancing customersâ experience, but also enhancing the value co-creation within organizational and customers those lead to the overall service solutions.

Thirdly, the call to develop service platform has been emphasized within the study of complex service systems. Extant studies in service ecosystems literature have shown the importance of service platform to facilitate value co-creation to foster innovation in the ecosystem. However, there has not been a systematized approach to develop a service platform. Therefore, this study aims to develop a systematic design approach for designing service platform, by emphasizing the process of value co-creation and resource integration amongst actors.

2 The Methodology

Prior to achieve the research objectives, this projects adopts qualitative and quantitative approach to understand the value co-creation processes amongst actors in the ecosystem. Qualitative approach enables researchers to explore meanings behind activities within social contexts. Within this study, in depth interviews, participatory workshops, and survey are being conducted with the ecosystemsâ stakeholders being the participants of the study. In parallel, longitudinal study is conducted to study the evolvement of the service ecosystem.

Furthermore, to support the development of a systematized design approach, this study adopts Design Science Research methodology. Design Science Research combines behavioral and design perspectives in designing an IT-based solution, thus guiding researchers to build the solution based on the specific problem context (Hevner, March, Park, Ram, 2004) .

3 The value to Society

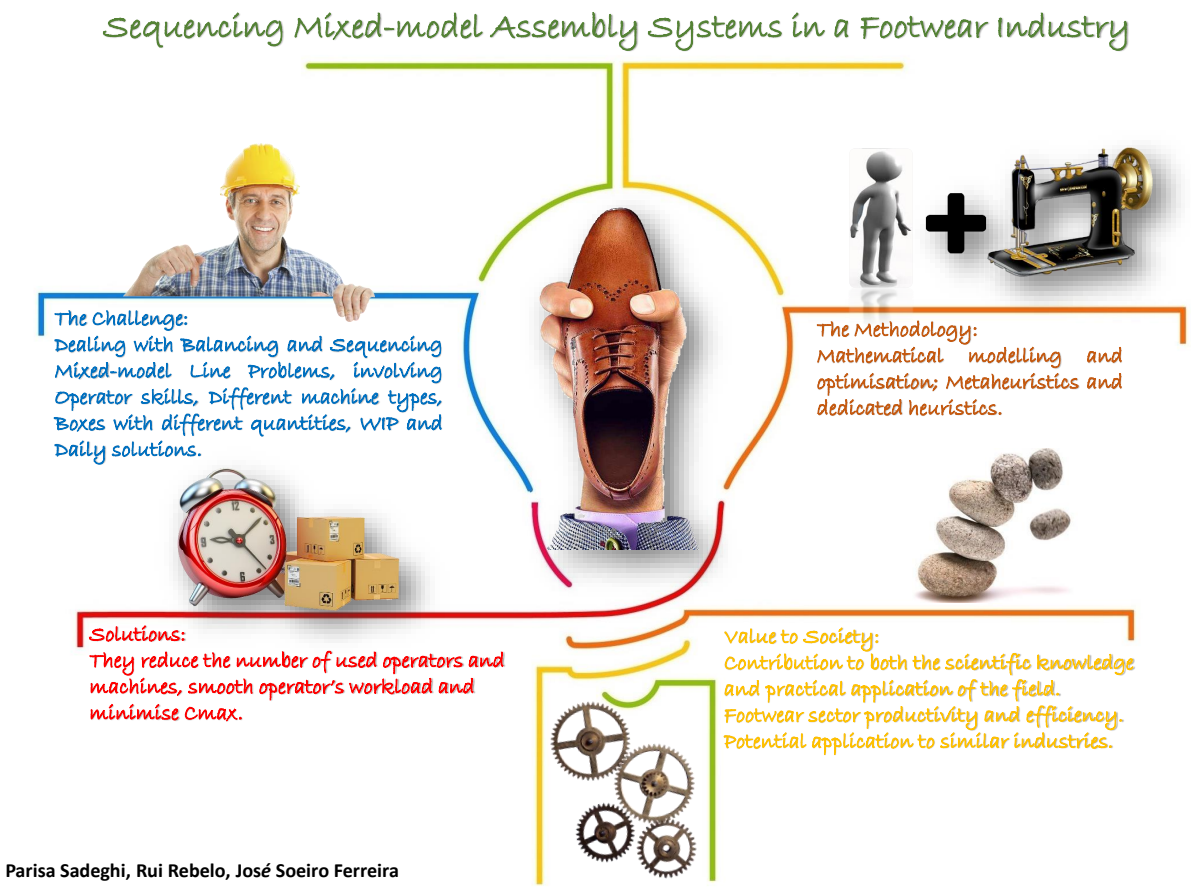
First, this research project starts with a systematic literature review on the Service Ecosystem notion. Second, empirical cases on real-life industries are analyzed. Third, a systematized design approach for designing service platform will be developed.

Consequently, this research project contributes to both research and managerial societies. In terms of research, it will contribute in the development of the S-D Logic Service Ecosystem literature. On the other hand, this project works as an input as well as a support and knowledge for organizations in fastening resources coordination and collaboration within their respective service ecosystem to foster innovation.

Sequencing Mixed-model Assembly Systems in a Footwear Industry

Parisa Sadeghi * †, Rui Rebelo†, José Soeiro Ferreira * †

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



1 The Challenge

Portugal is one of the major world players in the footwear industry. This is the case because the country has chosen to invest in technology innovation, research, manpower qualification, innovative design and internationalisation. Much has changed, from low-cost mass production to serving clients consisting of small retail chains, where orders are small and models are varied. Consequently, work plans vary frequently and traditional flow lines are steadily being replaced by more flexible and sophisticated systems. That is the case of the large footwear company considered in this work, Kyaia in Portugal, whose production is almost entirely for worldwide export. The company has invested in completely new flexible automated assembly lines (and participated in their design), which transport boxes with the components of different models, from and to warehouses, that can reach any workstation with specialised operators, in any order. These flexible assembly lines offer many possibilities but certainly they require the solution to complex balancing and sequencing problems, involving large dozens of boxes and workstations.

The footwear industry produces shoes for men, women and children. Each of these groups requires

distinct models, which also change according to the season. Clients' behaviour has also changed, which, in turn, has led to a decrease in the number of orders per model. As an effect, it is appropriate to have several models in the production lines simultaneously. The associated balancing problems are usually known as Mixed-model Assembly Line Balancing Problems ($MALBP$). Sequencing is also considered and if it is studied after balancing, then it is named as Mixed-model Assembly Line Sequencing Problems ($MALSP$).

It is presumed that the balancing problems are solved in advance, and the assignment of the tasks to difference operators and machines are known. In continue, the sequencing of the mixed-model systems will take into account by concerning that assignments. This work is MALSP but, with the particularities that parts of a model are inside boxes, moving along the transportation systems, and operators with different skill levels and machines from various types are also involved. The quantities in the boxes are considered fixed, at this stage, with a maximum of 10 pairs of shoes inside each one. Moreover, it deals with two different stitching lines of the company.

Sequencing is a decision-making process that plays a crucial role in most manufacturing industries. A proper allocation and sequence of tasks enables the company to improve its purposes. The objective of this work is the minimisation of makespan, that is, the minimisation of the last completion times of all the tasks (included in all boxes) of all operators and machines. However, the type and the dimensions of the problems involved suggest an approximate solution method. It will be described in the next section.

2 The Methodology

The solution method Variable Neighbourhood Descent Mixed-model Sequencing ($VND - MSeq$) is proposed. Via this method, we get the advantage of having diversification by testing different neighbourhood structures. This method is composed of two parts. The first one is a constructive heuristic, which is developed to generate initial solution; in the second part, VND is used to improve the solutions.

To construct possible initial solutions different dispatching rules are used. To the extent that VND-MSeq needs one initial solution then the one with the best objective function is chosen. The dispatching rules are used in this work are the following:

1. Largest Number of Successors (LNS);
2. Critical Path (CP);
3. Longest Processing Time (LPT);
4. Shortest Processing Time (SPT);

The first rule, which is the *Largest Number of Successors* is used in 3 distinctive ways and the *Critical Path* method is applied in 2 different manners. Therefore, 7 possible initial solutions are constructed and, the one with the best objective function will be chosen as the initial solution. By using the mentioned rules, different priorities are defined for the order of entry of the tasks in the lines and consequent assignment to the workstations. Changing the position of a task may result in a new solution. Therefore, the concept of neighbourhood structures may be utilised to change task positions.

In any incumbent solution. By changing the position of tasks, it is possible to make the table of tasks infeasible. Consequently, each neighbourhood structure should be applied in a way to prevent any infeasibility. The dimension of each neighbourhood structure is firstly based on the given problem and, secondly, related to the defined values of the number of search iterations and the number of neighbour solutions, which should be searched in each iteration. Five neighbourhood structures ($Ns1 - Ns5$) are used for this purpose. The key issue considered in each neighbourhood structure is related to the feasibility which should be satisfied in all $Ns1$ to $Ns5$. By randomly (or by any other rule) changing the sequence of a task, an infeasible table of tasks may be obtained. One possibility to avoid this situation is to change the position of the tasks in the table so that tasks that are prior to the task selected in the routing diagram

are considered first. This rule is called *Precedence Preserving*. Finally, the objective function will be calculated for the created sequence of tasks.

The VND-MSeq method starts with all the neighbourhood structures and applies them to the current solution. Then, the best solution is chosen as the incumbent one. The search process stays on the structure that gives the best answer and searches that neighbourhood until an improvement is obtained. Otherwise, all other structures are applied to the current solution and then, the search moves toward the best one. This process repeats until the number of defined iterations, which is 50, is attained. If an improvement is not attained, among all neighbourhood structures, then the VND-MSeq stops sooner.

Computational experiments were performed in some randomly generated instances and in real data. They were divided into small, medium and large-size instances. The small sizes are generated, but the medium and large sizes are based on real data from two different lines of the footwear company, WIP is involved, being treated as new models. The gaps of the VND-MSeq for the small instances, have the average of 1%. Considering the actual instances, significant gains were achieved compared with the company results.

3 The value to Society

In the context of new flexible stitching systems in a large footwear company, the practical problems considered and solved in this work are unique. Such problems simultaneously involve operators and machines, and the units moving in the lines are not pairs of shoes but boxes containing numerous quantities of product components. Let us emphasise that this work also has a clear practical scope, influenced by the need to contribute to overcoming the daily difficulties of a large company with new technologies to be managed. In fact, the company has handled the problem of balancing and sequencing fairly manually, so the methodology can clearly improve its procedures.

Moreover, in progressively competitive world, managers of the industrial environments, to succeed and survive, they need to gain operational efficiency and consumer satisfaction. The footwear industry has been remarkably improving over the last years. The high variety and quality of the products and the international competitiveness are an impressive reality. The assembly systems integrate new automatic transportation equipment that will only be effective if it is well managed. Given that production plans change rapidly, it is crucial to know and adapt the number of operators and machines required and the time table of the tasks. This study essentially focuses on sequencing the resources. The proposed solution approach could easily be adapted and used in other footwear companies or other similar industries.

A sustainable innovation model for Sharing Economy

Paulo Azenha*, Gabriela Beirão*

* *Faculty of Engineering, University of Porto*

1 The Challenge

Sharing economy (SE) businesses have emerged as a disruptive approach to the traditional way of doing business. Sharing Economy is also known as collaborative consumption or the collaborative economy or peer economy. It refers to a hybrid market model of a peer-to-peer exchange. Such transactions are often facilitated via community-based online services and holds the promise for a more sustainable world by giving access to underutilized resources at a fraction of the cost to some who canÂ≪t or do not want to buy new products and the chance of making an extra income for those who already own such underutilized resource. For example: Providing people with access to goods who can’t afford to buy them, reducing negative environmental impacts through decreasing the amount of goods needed to be produced, cutting down on industry pollution, accelerating and production patterns.

Research has pointed out the difficulty that businesses face in developing innovative products and services. For example, firms often struggle to retain customers on their platform, as customers, low switching costs between competitors. In sharing economy markets where transactions are not highly time and location

sensitive, customers often aim to bring transactions outside the platform. These firms have lower control over service quality as they are not involved in delivering the good or service. Some markets are less suited to achieve profitable growth when transactions occur on an infrequent basis.

The need for developing ways to ensure population well-being has been addressed in literature as transformative service research. This has been defined as "the integration of consumer and service research that centres on creating uplifting changes and improvements in the well-being of consumer entities: individuals (consumers and employees), communities and the ecosystem".

Our challenge is better to understand how to leverage technology to innovate digital services and improving well-being. need to adopt a human-centred approach bringing together what is desirable from a human point of view with what is technologically feasible and economically viable. both managerial and societal impact needs 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. it may transform the way organizations develop products, services, processes, and strategy. This approach brings together what is desirable from a human point of view with what is technologically feasible and economically viable.

2 The Methodology

The market successes of SE businesses, as well as the social futures of collaborative networks, are often tightly associated with the technologies on which they run. However, only a few recent studies have investigated the roles of mediating technologies. Research has studied this issue using different perspectives. For example, in some discussions, this technology is an 'algorithm', while in others it is a 'platform', and in many more, it is simply 'technology'. There is a need to reconcile these views and understand from a human-centred perspective on how to develop innovative services promoting well-being. The project will start with a systematic literature review covering the sharing economy and transformative service research literature. This aims to synthesize the current state of knowledge, identifying research gaps and developing a conceptual framework. Then service design methods are going to be used to better understanding customers and their context, and in this way envision future innovative digital service solutions aiming to improve.

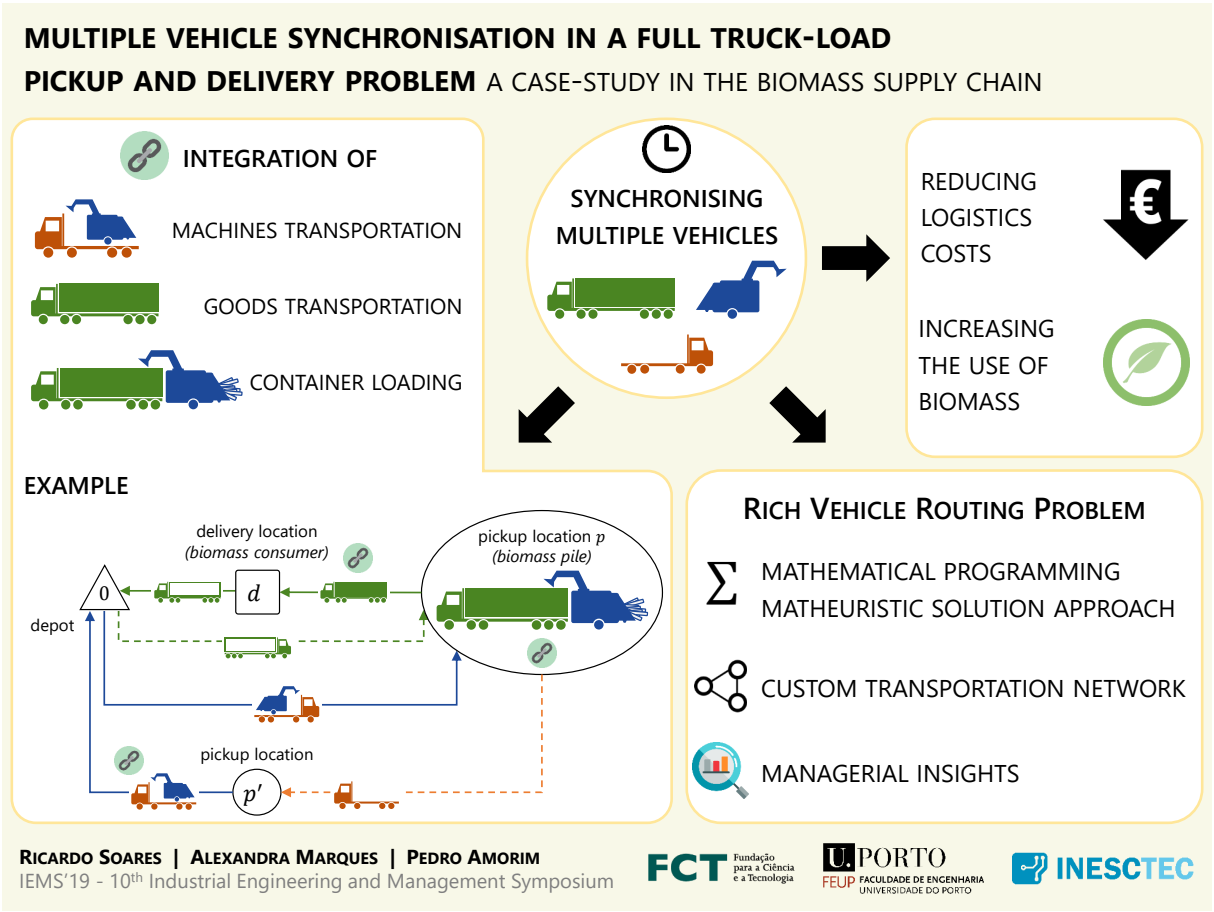
3 The Value for Society

The moral imperative for transforming consumers' lives through service is founded on the concept of human dignity, which advances the development of rights and responsibilities. Services dominate the lives of consumers today. However, to a large extent, transformative consumer not address the role of services in affecting consumer well-being. The sustainable service approach embedded in the Sharing Economy may have an important role in this transformation for communities. However, services have the challenge to understand customer's and populations needs in order to actively contribute in improving local well-being.

Multiple vehicle synchronisation in a full truck-load pickup and delivery problem: a case-study in the biomass supply chain

Ricardo Soares *, Alexandra Marques †, Pedro Amorim *

* *INESC TEC and Faculty of Engineering, University of Porto,*
† *INESC TEC - INESC Technology and Science*



1 The Challenge

Increasing efficiency of transportation planning processes in real life applications is a challenging task. Synchronisation of operations and vehicle routes can play a major role to increase cost efficiency. Moreover, when the vehicle service time is affected by the existence of other vehicles with similar schedules in the same location, there may be delays or unnecessary idle times that impact the plan flexibility and lead to an increase of the transportation costs. In some situations, there is a need for two or more vehicles (or crews) to meet at the same location and time to perform an interrelated operation in order to avoid unnecessary travel efforts, such as additional travel costs, waiting times or vehicles.

This work addresses the daily planning of integrated routes for three distinct types of vehicles that need to be synchronised to perform interrelated operations with minimum logistics costs, as shown in Figure 1.

This planning problem exists in the biomass supply chain and specifically relates to the synchronisation of vehicles involved in wood chipping and transportation when these operations are combined at the roadside of forest sites (called "hot systems").

(a) truck (b) loader (c) lorry

Figure 1: Types of vehicles

Trucks deliver the biomass residues from the pickup locations to the delivery locations. Loaders are vehicles that perform an operation on raw materials (i.e. chipping biomass residues) at pickup locations, prior to its transportation to delivery locations. They are trailer-mounted machines that are pulled by a lorry whenever it needs to be moved between pickup locations. Lorries are support vehicles that only carry out operations related with the loaders pickup and drop-off between pickup locations.

Figures 2 and 3 illustrate the synchronisation aspects addressed in this problem. Loaders and trucks must be present at the same time at pickup locations so that its loading operations can occur. Loaders can only serve one truck at a time until its container is full, so other trucks may need to wait for the loader to become available. The loader will remain idle if no truck is available at the pickup location. To the best of our knowledge, this combination of synchronisation aspects present in this real-world application is not found in the literature on vehicle routing problems.

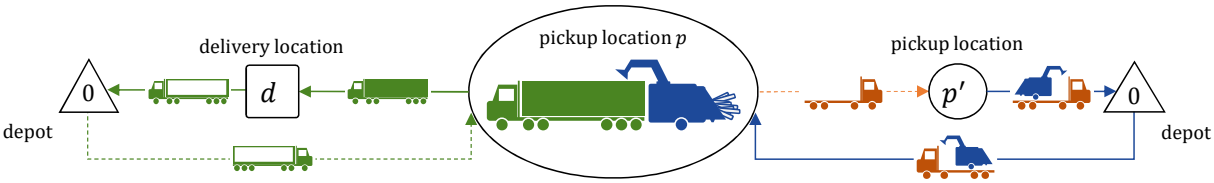


Figure 2: Chipping, transportation and hauling network

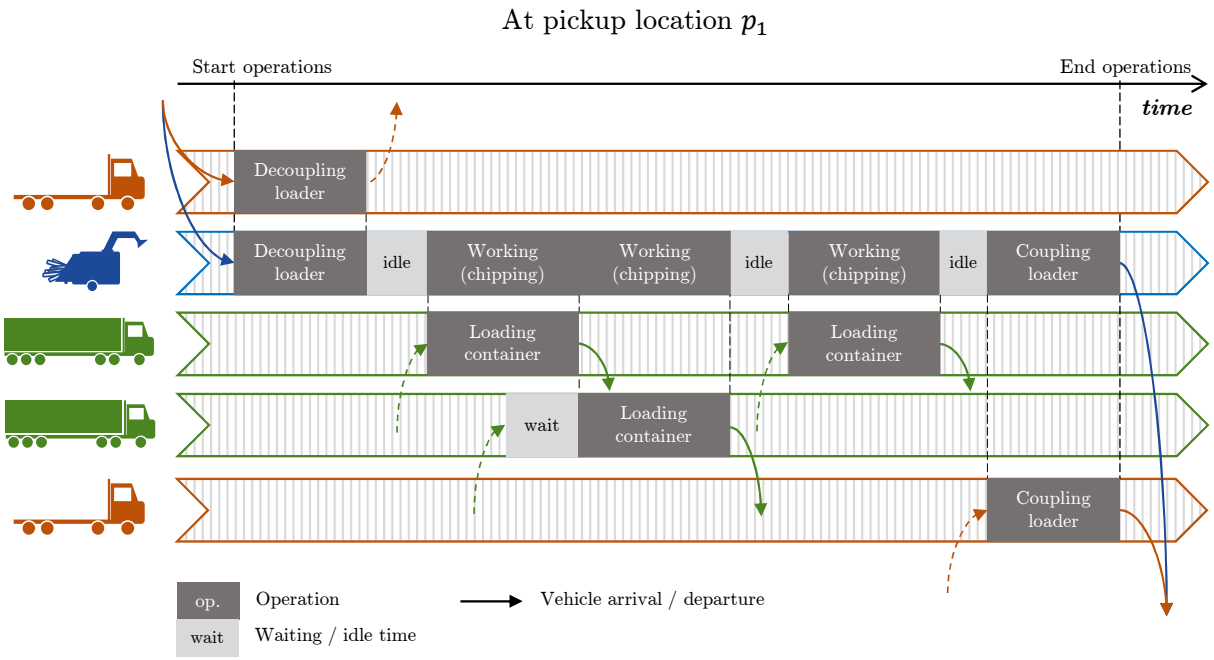


Figure 3: Timeline exemplifying the occurence of operations synchronisation at pickup locations

2 The Methodology

Vehicle routing problems with multiple synchronisation constraints typically demand additional modelling efforts, namely in the design of the transportation network. The modelling approach consists in a mixed integer programming model and encompasses three routing sub-problems (one for each type of vehicle), all of them intertwined with synchronisation constraints in order to ensure the problem requirements. For each one of these routing sub-problems, a custom transportation network is developed, where artificial nodes are considered, each one corresponding to a given task to be performed by vehicles. These tasks are then "connected" by means of a precedence graph, resulting in the generation of a transportation network where all its incoherent possibilities are eliminated beforehand in a pre-processing stage.

Due to the combinatorial nature of this problem and of VRPs in general, exact solution methods for this problem are only adequate for small scale instances. For large scale instances, based on a real-world case-study, a "fix-and-optimise" matheuristic was conceived, outperforming the results obtained by a commercial solver. Additional computational experiments were also devised, where different key operational parameters were tested with the purpose of assessing its impact in the obtained routing plan. Finally, we compare the obtained routing plan with the company's current planning approach and quantify the potential savings that may arise from the adoption of these synchronisation aspects.

3 The value to Society

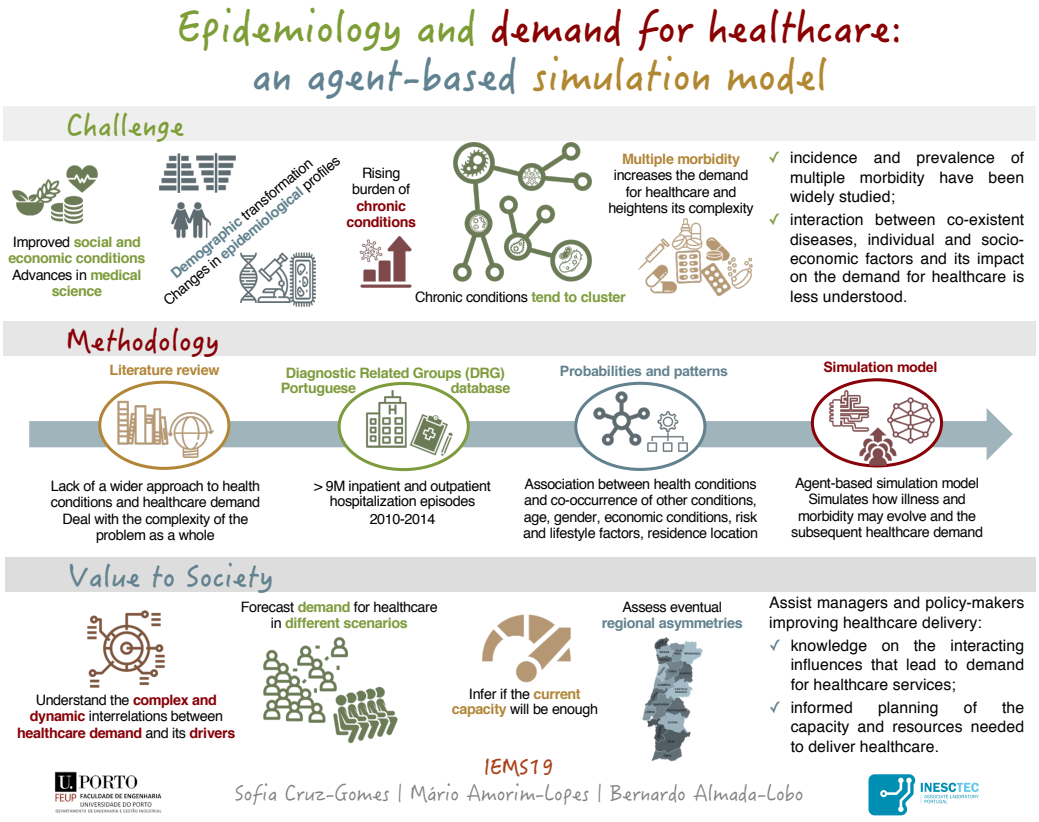
Design and planning of Biomass-for-Energy Supply Chains (BESC) has been widely studied, as society reinforces the major role of biomass as a global primary energy source. In the case of woody biomass (produced from branches and other by-products of forestry operations), as in other forms of biomass (e.g. residues from agriculture, forestry, fisheries and municipal waste), the availability is temporally and geographically fragmented, which makes it particularly relevant to find cost-effective solutions for biomass production, storage and transportation up to the consumption facility. One of the key challenges in forest-based supply chains is reducing its logistics costs, as they typically represent 30% to 50% of the cost of the finished products. This issue, along with the fact that products in the forest industry tend to have very low margins, leads to the constant need for efficiency in the supply chains' operations.

This research work frames itself in a doctoral programme and in ongoing research projects at INESC TEC: EasyFlow ("Collaborative and efficient logistics towards more sustainable forest supply chains"), BIOTECFOR ("Biobusiness and Technology for the efficient valorization of endogenous forest resources in the North of Portugal and Galicia") and GOTECFOR ("Technology for the mobilization and use of Forest Biomass in agro-industry").

Epidemiology and demand for healthcare: an agent-based simulation model

Sofia Cruz-Gomes*, Mário Amorim-Lopes* †, Bernardo Almada-Lobo*

* *INESC TEC and Faculty of Engineering, University of Porto,* † *Católica Porto Business School.*



1 The Challenge

In the last decades, the improved socio-economic conditions and the advances in medical science led to significant improvements in health and longevity, responsible for a significant demographic transformation and a subsequent drastic change in the epidemiological profiles and in the patterns of health and illness.

Chronic diseases are now the world's leading cause of death, and their burden is increasing rapidly. As the prevalence of chronic conditions continues to rise, several attempts to understand the main causes and consequences of these epidemiological changes have been made. The prevalence of the most common chronic diseases and the main factors on which they depend is now known. It has been shown that increases in the prevalence of chronic diseases rise the demand for healthcare and generate new challenges on ensuring the delivery and financing of healthcare services. Furthermore, it is known that chronic conditions tend to cluster, as people with one chronic condition are more likely to also have others.

Although the prevalence of multiple morbidity and its impact on healthcare demand have been widely studied, the complex interaction between multiple co-existent diseases, demographic and socioeconomic

factors and its impact on the demand for healthcare services is less understood. The methods used to understand and predict the epidemiological evolution evolved from simple state-transition and statistical methodologies to more complex epidemiological models. Typically, the former analyze and forecast the incidence and prevalence of specific diseases, while the latter aim to represent the complex epidemiology of disease occurrence and its association with a range of related factors and processes. Due to the complex nature of the interaction between epidemiology and several individual, social and demand-related factors, computational models and simulations are now seen as central research tools in epidemiology.

Through an empirical analysis for Portugal, we aim to develop an agent-based simulation model to explain and forecast the epidemiological conditions and subsequent healthcare demand, accounting with the evolution of several drivers. Our approach differs from previous studies by addressing five main limitations of the existent approaches. First, the analysis of multiple co-existent conditions is usually made considering only the chronic conditions, and a better understanding on the interaction between chronic and non-chronic disease is also of major interest. Second, most of the studies intended to provide knowledge for a specific disease (or group of diseases) and its association with other conditions that are previously known to be related, which can hide less obvious relations between conditions. Third, studies dedicated to the analysis of coexistent diseases and their evolution over time consider a simple count of conditions or, more succinctly, if the individual has or not two or more chronic diseases at the same time. Forth, studies analyzing longitudinal changes in morbidity over time and through the life course are limited, as well as analysis considering cohorts effects on the co-existence of health conditions. Finally, most of the research is only focused on the analysis of historical data and does not go further in assessing for the future healthcare services demanded to contribute to a more informed planning. To the best of our knowledge, no such application of a similar approach to epidemiology and healthcare demand exists.

2 The Methodology

In order to tackle this problem, we started by reviewing the key literature on the demand for healthcare and on epidemiologic models for a deeper understanding of the scope, advantages and limitations of the assorted theories and approaches. The literature reviewed pointed to several topics worthy of investigation, where it stood out the lack of a wider approach to health conditions and healthcare demand, capable of dealing with the complexity of the problem as a whole. Among the more advanced epidemiological models that may be able to deal with the intricacy of the problem, agent-based modeling is recognized as a promising approach to model the complex interactions and processes related to health conditions. Although this type of models has been applied to single chronic diseases, it is still underused among researchers and a broader use of agent-based modeling to provide insights on population health and consequent demand for healthcare services and resources is missing. Identifying the main research gaps enabled us to define the direction of our research and frame our contribution.

Using data from the Portuguese Diagnostic Related Groups database (Base de Dados Nacional de Grupo de Diagnóstico Homogéneo) we constructed a dataset with information on more than 9 million inpatient and outpatient hospitalization episodes in the period 2010-2014.

Historical data was used to infer about the probabilities and patterns on the evolution of health conditions through their association with the co-occurrence of other current or previous chronic and non-chronic conditions, as well as of other relevant factors, such as age, gender, economic conditions, risk and lifestyle factors and residence location.

These patterns were then used in the development of an agent-based simulation model (ABM) that simulates how illness and morbidity may evolve and the subsequent healthcare demand, using projections for some relevant variables (e.g., demographic) and considering specific 'what if' scenarios (e.g., change in the prevalence of a specific condition).

Furthermore, the results on the expected healthcare demand were used to infer whether the current physical capacity will be enough to provide the expected volume of healthcare services and for the assessment of eventual regional asymmetries.

3 The value to Society

There are many factors driving the demand for healthcare services. Nowadays, in a context of rising coexistence of multiple health conditions, it is recognized that epidemiological factors are extremely relevant on driving the decision to seek for care. Moreover, a higher prevalence of multiple conditions increases the demand for healthcare services and heightens its complexity. Thus, a deeper analysis of the interacting influences that lead to the complex pattern in the use of health services, addressing the evolution on morbidity patterns and planning for the needs of the different types of healthcare services is of most importance.

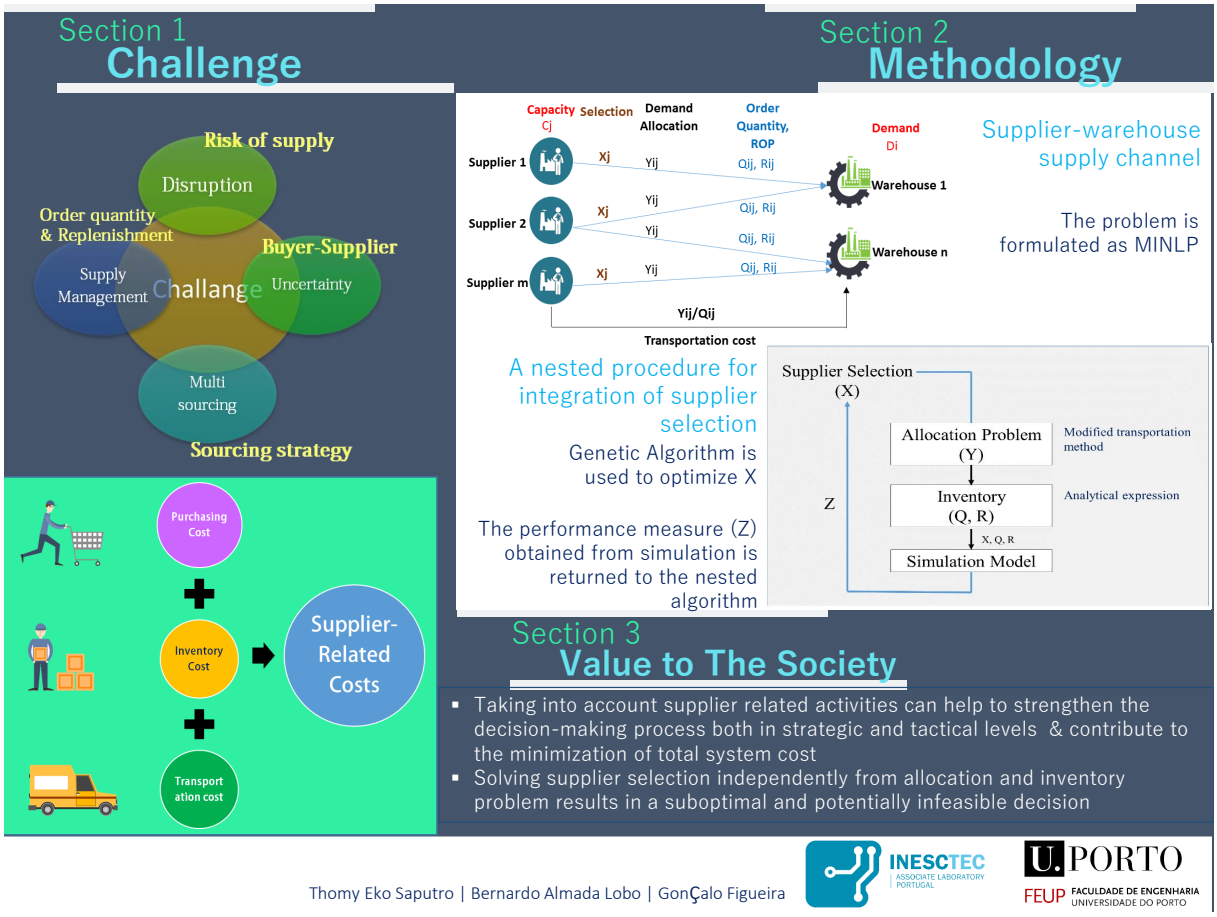
Our approach represents an effort to better understand these patterns of demand, specially focusing on the impact of the evolution of multiple diseases co-existence over time and across people from different contexts and with different individual characteristics.

Hence, with the study of probabilities and patterns on the evolution of health conditions and the development of this simulation model we hope not only to make a scientific contribution to the field, but also to assist health managers and policy-makers improve healthcare delivery. By providing a tool that enhances the understanding of the complex and dynamic interrelations between healthcare demand and its main drivers and produces accurate forecasts on healthcare demand, we aim to contribute to a more informed planning of the capacity and resources needed to deliver healthcare, and to a better knowledge on epidemiologic trends and regional disparities.

Simulation-Optimization for the Integration of Supplier Selection and Inventory Management

Thomy Eko Saputro*, Gonçalo Figueira*, Bernardo Almada-Lobo*

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



1 The Challenge

Suppliers play a vital role in the inbound process of any supply chain. Selecting an appropriate supplier helps firms to maintain the continuity of supply efficiently. The purchased items generally can be categorized into non-critical, leverage, bottleneck and critical items. Items are considered critical when there is a high risk in supply, due to a small number of suppliers and their limited availability, and when they significantly impact profits. For this type of items, supplier selection should be done thoroughly. This might imply looking at different supplier-related activities when selecting them.

There is a vast amount of literature that integrates order allocation into supplier selection. However, very few studies have considered stochastic inventory management, which has a huge impact on the operational costs that will occur. In this study, supplier selection is framed comprehensively by considering inventory management and inbound transportation.

We consider a problem which includes a multi-warehouse and multi-suppliers network. This study aims at determining appropriate suppliers which fulfill the demand for each warehouse under a multi-sourcing strategy. In a multi-sourcing strategy, demand needs to be appropriately allocated from two or more suppliers to each warehouse such that the order allocation should not exceed suppliers′ capacity.

Due to stochastic demand, a continuous review (Q,R) policy is used, where Q and R represent the order quantity and the reorder point, respectively. The larger the quantity, the less the number of replenishments, which will reduce transportation costs. However, holding costs will increase. The reorder point R is more related to the trade-off between holding costs and service level.

Furthermore, disruptions in supply can severely impact the entire supply chain. Hence, mitigating their impact is crucial to protect buyers from shortages and maintain the performance of the supply chain. In a multi-sourcing strategy, disruptions influence supplier selection since suppliers might have different abilities to react to unexpected disruptions and restore normal supply network operations. Due to disruption, supplier lead time and lead time demand would be higher than the stated lead time. Solving this type of problems is not straightforward. It requires a holistic approach to incorporate disruption in the supplier selection and inventory model.

2 The Methodology

The integration of supplier selection is a combinatorial optimization problem, which determines for each supplier j, with given unit cost and capacity, whether it is selected or not (Xj) and the order allocation from different warehouses i (Yij). This type of problem can be formulated as a mixed integer non-linear programming problem (MINLP). The objective function is to minimize annual costs which are associated with purchasing costs, inventory costs, and transportation costs. Purchasing costs are not only associated with variable purchasing cost but also fixed contractual cost. Inventory costs include setup, holding, and shortage cost. The transportation costs constitute a fixed and variable cost which correspond to the delivery between suppliers and warehouses.

Due to the stochastic demand and non-linear cost function, this problem cannot be easily tackled by exact approaches. In addition, the disruptions need to be modeled realistically in the evaluation of the solution. Therefore, a solution approach is developed based on the simulation-optimization in order to appropriately represent the disruptions and obtain a more realistic estimated total cost. We use a nested algorithm which consists of a genetic algorithm (GA) to search the solution space of the variable X (as can be seen in Figure 1), and subroutines for the other variables. The simulation model runs as a stochastic evaluator of the solution.

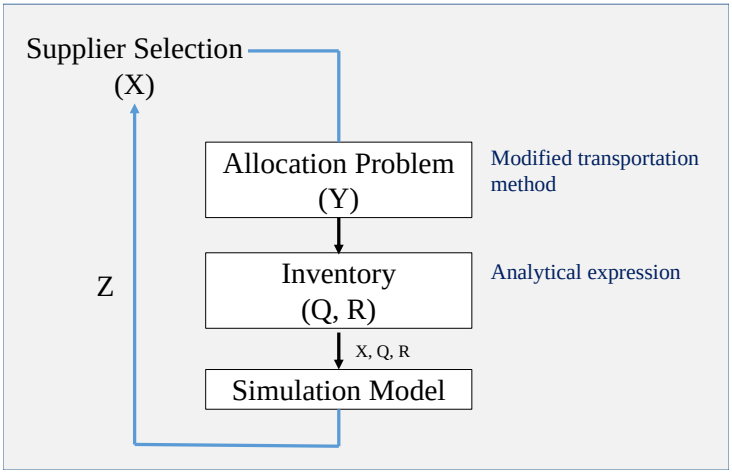


Figure 1: The solution approach based on the nested procedure

In the solution procedure, GA iterates on values of X (supplier selection). Given the value of X, the decoding procedure is initialized by solving allocation problems (i.e., determining Y) considering the

transportation cost. According to the allocation (Y), inventory decisions associated with order quantity (Q) and reorder point (R) are calculated by using analytical expressions. The solutions containing supplier selection (X) and inventory decisions (Q, R) are then passed to the simulation model to be evaluated with respect to the demand uncertainty and disruptions. The performance measure (Z) based on the purchasing, inventory, and transportation cost is returned. Using this approach, good solutions can be obtained within reasonable computational times.

This method is applied to a variety of problem instances and the impact of input parameters of inventory and transportation on decisions and performance is analyzed. This analysis is expected to provide managerial insights which can be useful for taking action on the supply issue.

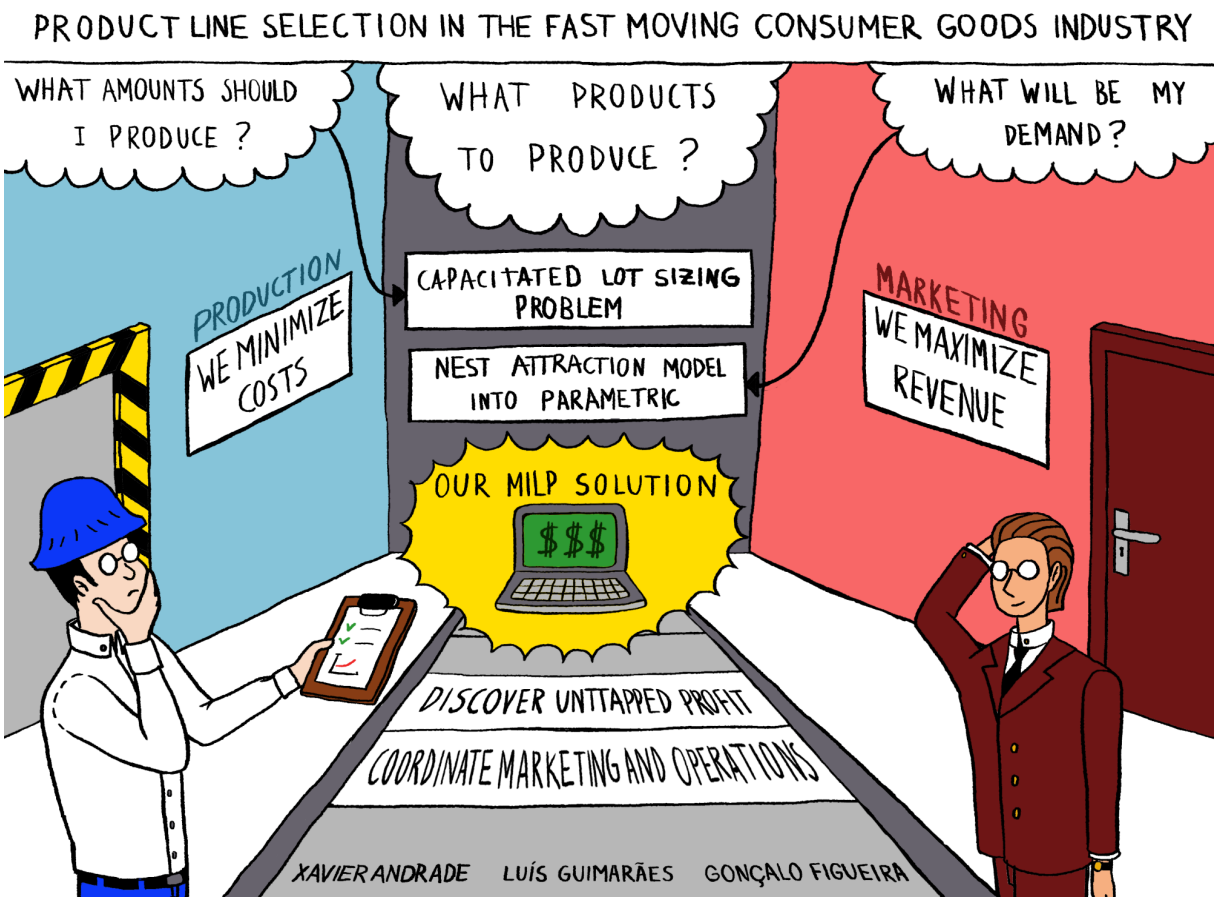
3 The value to Society

Taking into account supplier related activities, such as in the proposed model, can help to strengthen the decision-making process both in strategic and tactical levels, and contributing to the minimization of total system cost. In general practice, firms typically do not consider inventory management and inbound transportation early in the phase of supplier selection. However, solving supplier selection independently from allocation and inventory problems results in a suboptimal and potentially infeasible decision. For critical items indicating a high purchase volume, a huge part of expenses can be spent on inventory and transportation cost. On the other hand, when the suppliers′ contractual (fixed) cost takes a huge part, optimizing inventory and inbound transportation would be difficult to reduce the total system cost. Therefore, it is essential to perform decision-making jointly in supplier selection and inventory management. This study demonstrates these issues, proposes a method to address them, and provides some managerial insights.

Product line selection in the fast-moving consumer goods industry

Xavier Andrade*, Luís Guimarães*, Gonçalo Figueira*

* *INESC TEC and Faculty of Engineering*



1 The Challenge

When discussing the performance of a company, although both revenue and costs must be accounted simultaneously, it is common that they are managed separately. While the pressure to generate revenue usually falls on the sales and marketing officers, guaranteeing a desirable margin is the responsibility the production managers, as to keep costs low. These perspectives conflict, yet the need for interfaces between them, from a managerial standpoint, is recognized by both. We study the product line selection problem, involving both production and sales-based decisions, for the fast-moving-consumer goods industry.

The fast-moving-consumer goods industry is characterized by capital intensive plants and low-margin high-volume products, with diverse assortments being offered as a result of fierce competition. Limited power over price forces firms to operate efficiently and exploit economies of scale. Moreover, the substantial time loss and investment associated with the extending such assortments make capacity a hard constraint. When compared, for instance, to the staple goods industry, additional variety is observable and purchases are more erratic. This stresses the importance of considering inventory management in

the product line selection, notably when margins are small and desirable service levels are high. Regarding this aspect, previous approaches only account for the average production inventory. A multi-period approach, considering carry-over inventory and enabling the trade-off between setup and inventory cost under dynamic demand and capacity constraints, was not developed.

Product line selection studies have modeled consumer purchases as a single choice process, that maximizes the utility of a deal for a customer segment. A more recent trend is the use of attraction models, where the purchase probability is the share of the attractiveness of a deal in the array of choices. While the products in a category might be substitutes, and subject to cannibalization, these interactions are not pairwise transversal (red bus/blue bus problem). In the assortment literature, to overcome this property (independence of irrelevant alternatives), a general attraction model is adequate to level demand recapture, and a d-level nested attraction model is fitting for partitionable decisions (e.g. hard goods). Consumer choice in the fast-moving-consumer-goods industry can be reduced to close and distant substitutes (e.g. different kinds of potato chips versus different kinds of snack subcategories, such as potato chips and popcorn) without severe loss of realism. Although this decision can be modeled sequentially, forecasting aggregate demand of subcategories is not a challenge.

2 The Methodology

Given the difficulty of the managerial trade-offs involved and the significance of the impacts, a formulation for product line selection which is suitable for fast-moving-consumer goods is developed. We propose a mixed-integer linear programming model which considers the specificities of this industry, analyze its benefits, and test it on real-world like instances. We optimize the production decision (products and quantity) in a product category based on the economic results of the manufacturer. We model the problem as a capacitated lot-sizing problem, with demand resulting from a consumer choice model with a subcategory and a product levels. The demand for subcategories is arbitrary, as is the interactions between them. Downstream, at the product level, share of a product in a subcategory is the output of an attraction model.

The attraction model for customer choice dictates that, once a product is removed from the subset of offered products, its demand is either recaptured by the remaining elements from the assortment or by the competition. This sort of behavior is reasonable if the products are close substitutes, but does not provide an accurate representation of choice when considering distant substitutes. In order to model product interactions inside a category, we fully parameterize the share of and substitutability between subcategories. The share of each product in a subcategory is then computed as in an attraction model, nested in the parametric structure, as illustrated in Figure 1. While maximizing its revenue, the manufacturer wants to minimize the operational costs associated with the product line. As this industry is capital intensive capacity management is a necessity. The trade-off between setup and inventory costs, given a multi-product setting and non-stationary demand, becomes decisive in this situation.

The model is extended with three implementation-based considerations. (1) Fix costs throughout the planning horizon for cases where product development and administrative costs are not negligible. (2) Shared setups between products with some commonality. Similarly to the subcategories defined for the market structure, manufacturing can have categories of products that share a portion of the production preparation procedure. (3) Safety stock, when it is representative and accountable, is needed to wholly consider the holding costs. Forcing the inventory levels to be above a multiple of the standard deviation of the demand for each product, reflects the necessity of considering comprehensible inventory policies. As this effect is non-linear, we apply piecewise linearization to extend the product-line selection model.

3 The value to Society

Our work contributes to the literature by considering an additional level in the product structure with parametric demand and interactions. This bypasses the independence of irrelevant alternatives, and grants flexibility to the interactions at a product category level. Furthermore, we provide a multi-period

approach that enables production and carry-over inventory to be managed under capacity constraints and non-stationary demand. Lastly, we introduce an extension to manage the exchange between market share and demand predictability. With the novel market structure, we facilitate modeling consumer choice in cases similar to fast-moving-consumer goods industry. Moreover, with the integration of the demand model into the capacitated lot-sizing problem with setup times, we expect to uncover untapped profits in the various companies' product line strategies.

Furthermore, we assess the value of optimal product-line selection in the fast moving consumer goods industry by comparing the results of the mathematical programming approach with the commonly used heuristics. We test the methods on instances with different cost proportions, market price sensitivities, and plant capacities. The parameter ranges for instance generation are inspired on a real-world scenario, and the tests ensure our conclusions which hold in the parameter ranges. We measure the influence of the type of market, the magnitude of costs, and resource utilization on the performance of the approach. Proper product line selection will minimize demand cannibalization by products with lower margins. Hence, we observe how a market's price sensitivity will impact operational performance under different strategies. It is expected that bigger margins result in broader product lines. However, this assumption may not hold under different price sensitivities. Lastly, we test the influence of reduced plant capacity in the performance of various product line strategies, under different external conditions.

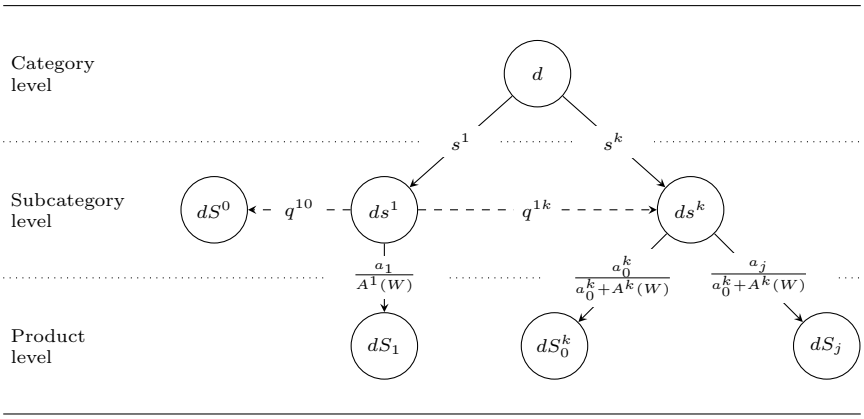


Figure 1: General market structure for this problem. The share of and recapture between subcategories is determined exogenously. Inside subcategories product share results from an attraction model.

End to End & Special Sessions Abstracts

MobFood Project: Mobilization of Scientific and Technological Knowledge in Response to the Challenges of the Agrifood Market

Carla Teixeira*, Mafalda Carvalho†, Sara Martins‡

**PortugalFoods, †IST, ‡INESC TEC and Faculty of Engineering, University of Porto*

MobFood - Mobilization of Scientific and Technological Knowledge in Response to the Challenges of the Agri-food Market has as main goal the development of an agri-food sector totally sustainable, resilient, open, safer and with an effective utilization of resources being consumer-driven. The project is organized into 7 main research Working Packages (WP): Resources Valorization; Sustainable Packaging; Nutrition Health and Well-being; Quality and Food Safety; Authenticity and Traceability of Products; Logistics; Consumer.

Within this set the identification of the critical points of an agri-food supply chain, where enormous amounts of waste are generated, is one of the main challenges of this sector. In the European Union, 88 million tons of food are annually wasted, representing an expenditure of 143 billion euros. This waste of food is not only an ethical and economic issue, but also an environmental and social one as it has contributed to the depletion of natural resources. There is therefore a clear need for the development of tools to assist different stakeholders in integrating good practices and forms of collaboration in order to achieve a sustainable supply chain considering economic, environmental and social aspects.

In this presentation, we will provide a glance of WP Logistics that is focused in the logistics of a sustainable and collaborative agri-food supply chain. The objectives of this WP are:

- Identification of the motivations, constraints and logistical requirements of the agri-food sector for the creation of a sustainable system;
- Mapping of the logistics processes along the agri-food supply chain;
- Identify best practices in logistics management, promoting business strategies for sustainability;
- Identification of indicators related with the three pillars of sustainability for performance evaluation and monitoring of companies in the sector;
- Tool to support the decision-making process towards the creation of sustainable agri-food logistics systems.

This work is focused in two specific flows of the agri-food sector: the meat supply chain and the fruits and vegetables supply chain. While in the first supply chain there is already an established reverse logistic flow, in the second this is not the case and new flows should be explored. The complexity of the supply chain and the reverse logistics of meat flows will be described in this presentation, as well as, the methodology that is being used in the project to ultimately develop an innovative framework to support the process of collaborative decision-making in the agri-food logistics processes.

Revenue management system for the car rental business

Beatriz Brito Oliveira*, Paula Raicar† , Delfina Acácio† , Maria Antónia Carravilla*, José Fernando Oliveira*

*INESC TEC, Faculty of Engineering, University of Porto †Guerin Car Rental Solutions

The car rental business is a sector regularly studied in the Revenue Management (RM) literature. The inherent flexibility and mobility of the resources (the cars) make it relevant and different from other traditional RM-application businesses, such as air travel or hotels. Nevertheless, in practice, companies struggle to keep up with multiple challenges often overlooked by the academic literature. Guerin, a Portuguese car rental company, is currently developing, alongside FEUP, a Revenue Management system that is able to overcome these challenges and accommodate realistic requirements.

Some of the main challenges car rental companies tackle, and increasingly so over the past few years, concern the internet sales channels, especially brokers acting as intermediaries and comparing prices of several competitors. The amount of information available, the speed with which competitors change their prices, and the difficult access to specific pricing information constrain the usual pricing procedures, with substantial impact on profitability and market share. Moreover, as costs are heavily correlated with the unoccupied fleet, the utilization of the cars is impacted and impacts the pricing policies.

To overcome these challenges, the RM system presented compares the company's and the competitors' prices for the myriad of products that they sell - the rentals. Then, it updates the prices based on a fast and adaptative heuristic that reacts based on fleet occupation and pricing positioning. This tool allows automating the pricing procedures, thus improving the occupation of the fleet throughout time, and, consequently, the company's profit and market position. In this presentation, we will describe the context of the problem, and the overall idea and main building-blocks of the RM tool. Finally, we will discuss the main challenges and lessons learned with the implementation of this tool and future steps to improve it.

Power transformers health diagnostics and prognostics

Luis Guimarães*, Luis Dias*, Miguel Ribeiro*, Armando Leitão*, Manuel Matos*, Leonel Carvalho*, Ricardo Bessa*, Nuno Rocha†, Paulo Mira†, Rui Vilhena†, Nuno Martins†

**INESC TEC and Faculty of Engineering, University of Porto †EDP Produção*

Power transformers represent a large share of maintenance costs and capital investments for operators in the power grid, from producers to distribution network operators. Pressured to become more cost-efficient and by an aging fleet, these companies are eager for decision support systems to assist in these decisions. Many of them perform, on a routine basis, several condition assessment tests but their results are analyzed separately. Researchers have presented several approaches to address this issue, but their holistic models are either highly dependent on user-defined weights or black-box approaches hard to interpret by managers.

The aim of this project was to develop, together with EDP Produção, a methodology capable of being used to identify/prioritize short-term interventions and establish long-term replacement needs based on the transformersâ technical condition. The first of the two models developed, diagnosis the current condition by merging known physical models and expertsâ opinion with data-driven models to establish a condition assessment of the power transformer identifying both the failure type and its severity. The second, uses a degradation model to incorporate the effects of environment, technology and operation in the estimation of the power transformerâs remain useful life.

In this talk, we discuss the main industry challenges, describe the practical application, compare the methodology advantages/disadvantages against the ones in the literature and pinpoint future work directions.

Blockchain: beyond the hype. Use case for SCM and other cases

Mário Amorim Lopes*

*INESC TEC and Faculty of Engineering, University of Porto

No different from other disruptive innovations, the blockchain is surrounded by a lot of hype. There are already hundreds of startups conceiving new products based on the blockchain, and many more trying to jump on the bandwagon of the blockchain frenzy. However, there is a lot going beyond the hype. Indeed, the blockchain may well be one of the foundations empowering the supply chains of the future. It will also produce substantial impact on Operations Management, but much of it is not fully understood yet.

In this talk we will take a look at what is the blockchain â its strengths and weaknesses â from an Operations Management perspective, some potential use and business cases for Supply Chain Management and also for other fields such as e-governance, law and financial markets. We will also leave some open problems waiting to be addressed by savvy researchers, in particular three:

1. Information, and how the blockchain may help connecting multiple decision makers with thousands of information sources;
2. Automation, and how companies may leverage on smart contracts to execute and audit much of the transaction logic governing relations between businesses;
3. Tokenization, and how digital claims or virtual money (tokens) may mirror real assets such as production, inventory and financial assets, facilitating sharing, trading and exchanging among multiple participants, opening a new realm for vertical and horizontal coordination of firms.