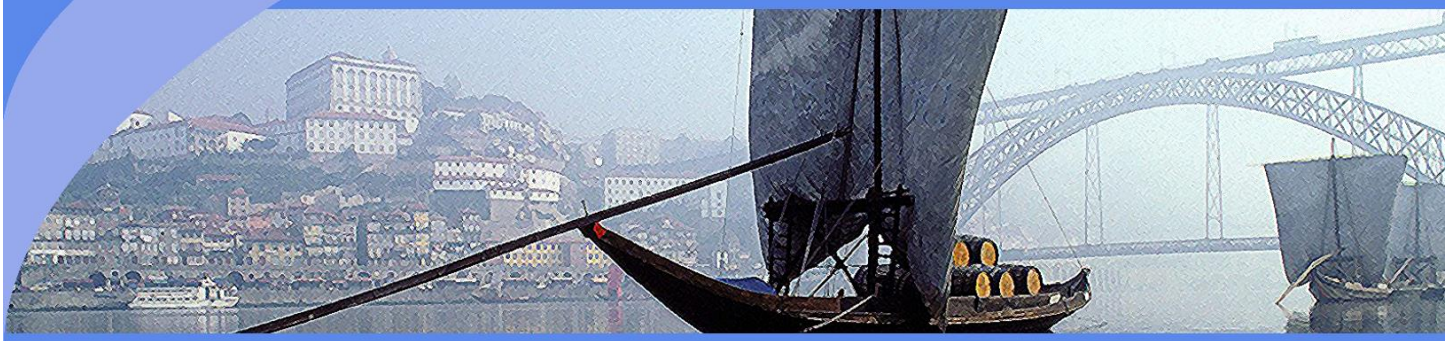
IEMS'15

6th Industrial Engineering and Management Symposium



The Impact of DEGI Research on Society

Casa das Artes
6.Jan.2015

http://paginas.fe.up.pt/~degi/iems15

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6th Industrial Engineering and Management Symposium:
The Impact of DEGI Research on Society

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Miguel Oliveira

Sara Martins

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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 review:

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

Organised by:

DEGI – Department of Industrial Engineering and Management

Faculty of Engineering

University of Porto

Casa das Artes, January 6$^{\underline{th}}$, 2015

Welcome!

We warmly welcome all the attendees of IEMS'15, the 6th Industrial Engineering and Management Symposium, a joint organization of DEGI[1] and PRODEIG[2].

This symposium aims to focus on the contribution to society of the research made by the students of the doctoral program and by the researchers of DEGI. All the IEMS since the first one in 2010 have been held in emblematic sites of Porto: Casa do Infante, Museu Nacional Soares dos Reis, Biblioteca Municipal Almeida Garrett, Casa da Música and Fundação Dr. António Cupertino de Miranda. This year we must thank Casa das Artes and Direção Regional de Cultura do Norte for providing us this venue for free.

This year, after lunch, we will have a bigger "END to END" session with four talks involving DEGI's researchers and the partners from the companies. During this session we will have the opportunity to follow projects that involve companies and research groups of DEGI from one END to the other END.

The work of our students, originating from four continents, is however the main reason for IEMS to exist. For this sixth symposium the scientific committee had the tough task of choosing 12 presentations out of the 27 abstracts that have been submitted. This choice was made having in mind the different research areas within DEGI.

The following picture has been built with the text of the 27 abstracts and is the showcase for the research that is being done in our department.

www.wordle.net

We wish you a fruitfull IEMS'15
The Organizing Committee

[1]Department of Industrial Engineering and Management of FEUP
[2]Doctoral Program in Industrial Engineering and Management of FEUP

Casa das Artes, Porto, January 6th, 2015

Information for Participants

Symposium Venue

The symposium will take place at Casa das Artes, managed by Direção Regional de Cultura do Norte (DRCN). This venue incorporates pleasant gardens with two buildings: Casa das Artes and Casa Allen.

Oral communications of IEMS'15 will occur in the *Auditorium* of Casa das Artes, coffee breaks at the *Sala de Exposições* of Casa das Artes, and the lunch will be served in the ground floor of Casa Allen (across the garden).

You may access the place through two entrances, with the following addresses:

- Entrance in front of Casa das Artes: Rua Ruben A, n.º 210, 4150 – 639 Porto;
- Entrance in front of Casa Allen: Rua António Cardoso, n.º 175, 4149 – 011 Porto.

GPS coordinates:
Latitude: 41.923°
Longitude: 8.383°

Tel.: (+351) 226 000 454
Email: casadasartes@culturanorte.pt

The nearest metro stop is "Casa da Música" (1500 meters walking). There will be no private parking.

(a) Casa das Artes

(b) Casa Allen

Lunch

The lunch will be served at the Ground Floor of **Casa Allen** (across the garden). Lunch is a courtesy of DEGI–FEUP.

Internet

There is wi-fi access in the whole building. The wi-fi password will be provided to participants of IEMS'15 during the check-in.

Casa das Artes, January 6$^{\underline{\text{th}}}$, 2015

Guidelines for Speakers

- Arrive at your session at least 10 minutes before it begins and copy your presentation to the laptop available in the room.
- Time your presentation to fit in the allotted time (15 minutes plus 5 minutes for Questions & Answers).
- The room is equipped with a video projector and laptop computer.
- Presentation certificates will be available at the end of the symposium.

Guidelines for Voting for the Best Elevator Pitch Award

The elevator pitches are available in this Book of Abstracts, near each extended abstract, and at the IEMS'15 website: `http://www.fe.up.pt/~degi/iems15`. During the breaks, the elevator pitches will also be displayed near the auditorium.

A bulletin containing thumbnails of the elevator pitches will be distributed to all participants. Each participant has three votes.

Program Schedule

Tuesday, January 6th

Chair: Pedro Amorim

Opening Session: 9:20 – 9:30 (*Auditorium*)

– Maria Antónia Carravilla

Session A: 9:30 – 10:50 (*Auditorium*)

A.1 – Integrating management and interaction perspectives for service design - the MINDS framework
Jorge Grenha Teixeira, Lia Patrício, Ko-Hsun Huang, Raymond P. Fisk, Leonel Nóbrega

A.2 – Modeling and Measuring Robust Bus Schedules
Joana da Hora Martins, Teresa Galvão, Ana Camanho

A.3 – One-σ quality in forest fire management - waste in non-value-added activities, rekindles and false alarms
Abílio Pereira Pacheco, João Claro

A.4 – Effective design of backroom storage facilities in retail food stores
Maria João Pires, Pedro Amorim, Joaquim Pratas

Coffee-Break: 10:50 – 11:20 (*Sala de Exposições*)

Session B: 11:20 – 12:40 (*Auditorium*)

B.1 – Supply Chain Risk Rating: Capturing the Big Picture
João Dias da Silva, Alcibíades Guedes

B.2 – An Optimization-Simulation approach for the Network Redesign Problem of Pharmaceutical Wholesalers
Sara Martins, Pedro Amorim, Gonçalo Figueira, Bernardo Almada-Lobo

B.3 – Managing misalignments in the implementation of a health screening program
José Coelho Rodrigues, João Claro, Ana Cristina Barros

B.4 – The impact of servitization on the performance of manufacturing firms: An empirical investigation in the elevator industry
Miguel Leichsenring Franco, Bernardo Almada-Lobo, Rui Sousa

Lunch: 12:40 – 14:00 (*Casa Allen*)

Chair: Vera Miguéis

Session End to End: 14:00 – 16:00 (*Auditorium*)

E.1 – Improving the inventory management of food e-commerce activities through darkstores
Pedro Santos (Sonae MC), Pedro Amorim

E.2 – Using Analytics to Enhance the Practice of Shelf Space Management
Jorge Liz (Sonae MC), Teresa Bianchi-Aguiar

E.3 – Reliability Engineering applied to Wind Turbine Generators
José Pinheiro (EDPR), Armando Leitão

E.4 – Large-scale optimization in periodic direct promotional mail creation
Liliana Bernardino (Sonae MC), Luís Guimarães

Coffee-Break: 16:00 – 16:30 (*Sala de Exposições*)

Session C: 16:30 – 17:50 (*Auditorium*)

C.1 – Flexible and Reconfigurable Layouts in Complex Manufacturing Systems
Maria Manuela Azevedo, José António Crispim, Jorge Pinho de Sousa

C.2 – Supplier Selection in the Food Supply Chain
Eduardo Curcio, Pedro Amorim, Bernardo Almada-Lobo

C.3 – Mixed-Model Assembly Line Balancing in the Footwear Industry
Parisa Sadeghi, Rui Rebelo, José Soeiro Ferreira

C.4 – Assessing and planning for the future needs of the healthcare workforce
Mário Amorim Lopes, Álvaro Santos Almeida, Bernardo Almada-Lobo

Best Elevator Pitch Award and Closing Session: 18:00 – 18:10 (*Auditorium*)

– José António Sarsfield Cabral

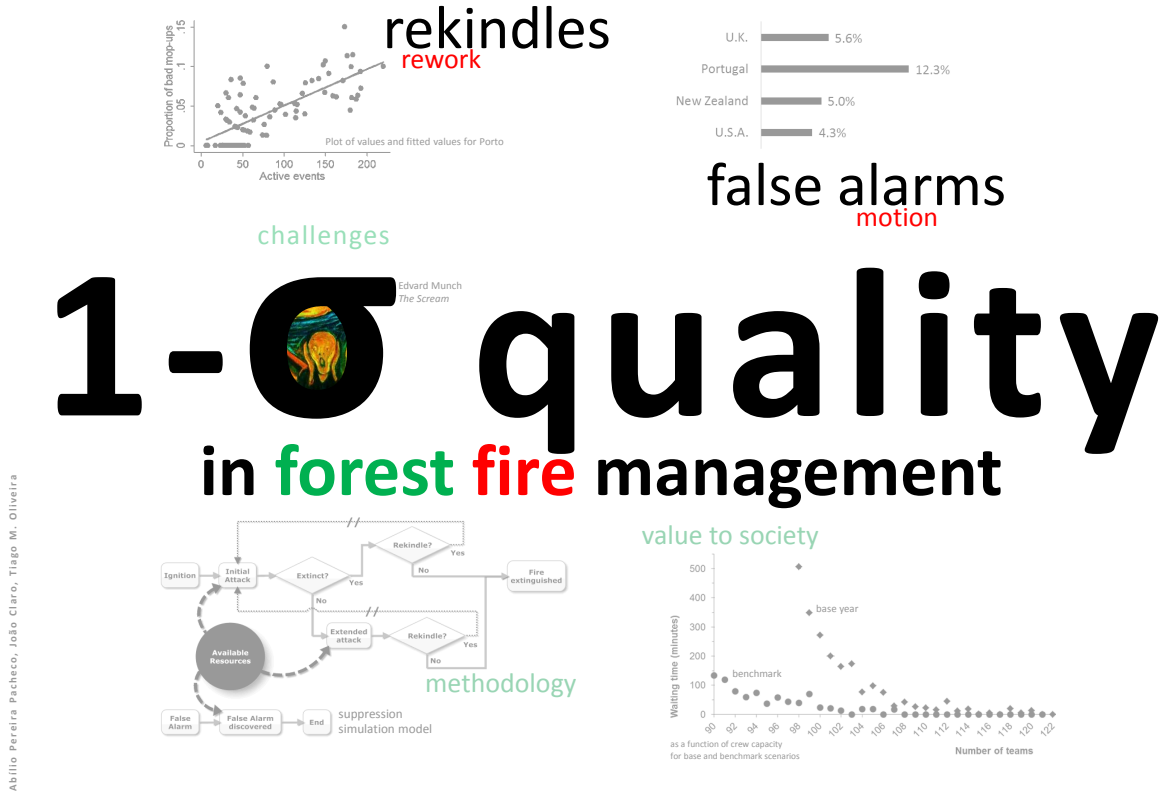
Abstracts

One-σ quality in forest fire management

— waste in non-value-added activities, rekindles and false alarms —

Abílio Pereira Pacheco * †, João Claro * †, Tiago M. Oliveira ‡

* *FEUP - Faculty of Engineering of the University of Porto,* † *INESC TEC - INESC Technology and Science,* ‡ *Grupo Portucel Soporcel*



1 The Challenge

A long time after many business activities started seeking to achieve six sigma quality in their operations, in Portugal, fire suppression operates at a one sigma quality level with disappointing performance results expressed by too many rekindles (in Lean terminology, rework caused by defects and inappropriate processing) and false alarms (motion) on the fire suppression system. As an illustration, in 32,357 incidents that the suppression system handled nationally in 2010, 12.3% were false alarms (FA) and 13.0% were rekindles (RK), and these proportions rise during the summer. Together, they represent a high burden on forest fire suppression resources, but despite the relevance of these phenomena in Portugal, related research is still scarce.

RKs are re-ignitions of a previous fire that re-burn an area where left fuel later ignites due to latent heat, sparks, or embers. Throughout the 2010 summer, Portugal had 14,551 primary fires (PF), of which 17.2% rekindled into an additional 2,497 fires, leading to a total of 17,048. That summer accounted for 94.7% of the annual burnt area of 132,241 ha. Several authors suggest that the number of rekindled

fires is higher than the officially reported and expert-judgment elicitation in field interviews performed by the authors points to the double. Even assuming that the available information is correct, this is a concerning situation that has been getting worse over the years, and results from ineffective mop-up operations, despite effective initial attacks (IAs). Ineffective mop-ups and lack of surveillance result in RK that often become large fires. These are usually bigger than the wrongly judged extinguished PF, with larger burnt areas, considerable damage, and increased danger of fatalities, even when the initial perimeter was just tens of meters.

FA daily peaks are exactly coincident with the peaks of requests of suppression resources for real new forest fires. Since fire departments cannot presume that a call is a FA and must respond as they would to a fire, the deployment of crews to non-existing fires, causes them to be unavailable for real fires, deprived of time to rest and recover, or hastily redeployed from other incidents, prematurely abandoning mop-up efforts and possibly creating conditions for fires to rekindle. In the little research available about FA, we have found values for the U.S. (between 4.1% and 4.4%), New Zealand (between 4.6% and 5.4%), and the U.K. (5.0% in Derbyshire, 6.2% in South Wales). As for RKs, the proportion is also extremely high, e.g., in the US, they account for 3% to 6%. These figures suggest that there is still room for improvement and reveal futile suppression efforts that contribute to an overload of the suppression system.

Seeking to contribute to address this gap, our purpose is to organize and provide an overview of the problem in Portugal. We start by verifying if evidence exists that the high proportion of RK in Portugal is related to the double duty of Portuguese firefighters to perform IAs and mop-up operations[doi]. Then we propose a discrete-event simulation (DES) model of a forest fire suppression system designed to analyze the joint impact of the PF, and the non-value-added fire suppression activities (RKs and FAs) on the system performance[doi]. In a fire prone country with an extensive wildland urban interface, where the average number of fires in the last decade surpasses 50% of the whole EU Mediterranean region, increasing suppression effectiveness is critical to avoid that small fires become mega-fires in high fire danger days.

2 The Methodology

Our study was designed based on a literature review, field trips, informal meetings, formal recorded interviews, dispatch center visits, actual RK observation, and the cross analysis of the forest fires database of the National Forest Authority (ICNF) and the fire suppression interventions database of the Civil Protection National Authority (ANPC). For the study of RKs at a national level, we used Microsoft ExcelÂ® and MapPoint Europe 2011Â® for the pivot tables and maps, IBM SPSS Statistics 19Â® for descriptive statistics, and STATA/IC 12Â® for regression analysis. For the joint impact study of RKs and FAs, the DES model was implemented in Â®ARENA and applied to the district of Porto, Portugal, for the critical period of the forest fire season, between July and September 2010. There are four key motives for the choice of this district: it has a high number of fire occurrences; the proportion of RKs and FAs is slightly below, but still in line with national figures; 84% of the occurrences, corresponding to 96% of the burnt area, occur in the three-month period considered; and 2010 is the only year with appropriate data on FAs available.

Our first goal (and hypothesis) was to find whether there was evidence that in days with more occurrences, the firefighters are compelled to prematurely abandon fire mop-up operations, thus promoting more RKs. In other words, we wanted to know if the high number of RKs was associated with the pressure to immediately combat all new fires, to prevent them from becoming big fires. To accomplish this, we conducted a linear regression study, considering two variables. We consider as explanatory variable the number of fires that were simultaneously fought in each day (active fires). For the first component of the dependent variable, we counted the number of fires with a bad mop-up in each day, i.e., the fires erroneously declared extinct, and origin of some later RK. However, because it is expected that bad mop-ups increase with adverse climatic conditions and the number of daily fires, we divided this component by the number of active fires in that day. To count the number of fires with a bad mop-up in a particular day, we performed a detailed treatment of the database to uncover the genealogies of RKs, identifying for each RK the bad mop-up that originated it.

In the analyses of the joint impact of PFs and non-value-added fire suppression activities, the DES model, the databases were used, jointly with non-parametric statistical analysis, to parameterize and validate

the model, which was subsequently used with sensitivity and optimization analyses to understand the impact of PFs, RKs and FAs on system performance, particularly on the "point of collapse", the system dimension below which the mean time between the alarm and the IA starts to grow exponentially.

3 The value to Society

From the study of RK genealogies, we concluded that the additional forest fires (successive generations of RKs) had their origin in only 7.4% of PFs. We found that their proportions increase in days with more occurrences, with a statistically significant positive relationship for six of the seven districts with a relevant number of RKs, preliminarily supporting the hypothesis of premature abandonment of mop-up operations, as a result from the pressure to immediately attack starting fires (IA) by the same crews. Moreover, we organize, and relate the set of physical, natural, technical and organizational factors that influence their occurrence, and we perform a more detailed analysis of RK dynamics in the districts of Viana do Castelo (the only non-significant) and Porto (where the higher significant correlation was found) highlighting specific organizational and natural challenges to a successful mop-up effort and providing further evidence of RK hazardousness.

With the DES model we studied the behavior of the system's point of collapse, comparing the historical base scenario with a benchmark scenario built with reference values for RKs and FAs, and also as a function of the number of fire incidents, considering historical variations. We found that bringing RKs and FAs down to benchmark levels, would lead to a reduction in the point of collapse of approximately 9.8%. This means that managing FAs, will lead to a lower number of occurrences in the system, which reduces pressure and releases resources that become available for real fires and to invest more time in mop-up, thus reducing the number of RKs, contributing again to reduce the number of occurrences, and so on, in a positive feedback loop. We found also that a decrease of 1% in the daily rates of occurrences lead to $0.85 - 0.96\%$ reduction in the number of required suppression teams. Since 98% of occurrences are of human origin (arson, negligence or accidental) this indicator provides a relevant threshold for the investment in prevention: a reduction of 1% in occurrences allows for a reduction of the point of collapse of one firefighting team, inverting the vicious circle "more fires, more teams". A final analysis aimed at comparing the point of collapse criterion with a cost criterion. Two simulation optimization analyses, with each of the criteria, led to the same result in the minimum number of crews, supporting the relevance of the point of collapse as a useful indicator in capacity decisions for a suppression system.

Our work contributes to address a research gap, and features a novel application of simulation to suppression systems, as a screening tool to support more holistic analyses. These results are useful for operational decision-making and provide relevant information on the trade-off between prevention and suppression efforts. Reducing FAs and RKs to benchmark values would significantly reduce pressure on firefighting teams, enabling more effective suppression operations. Finally, we suggest management practices to mitigate both problems and increase the level of quality of forest fire suppression in Portugal to at least a three sigma quality level.

Non-stated objectives regarding the Portuguese HCs: the results of a qualitative study

Ana Simões * †, Américo Azevedo * †, Suzete Gonçalves‡

* *FEUP - Faculty of Engineering of the University of Porto,* † *INESC TEC - INESC Technology and Science,* ‡ *Centre of Research in Health Studies, University of Coimbra*

1 The Challenge

In many countries health systems have encouraged hospitals to be more autonomous. As a result, they have often been seen in isolation from each other. This autonomy has benefits, but on the other hand hospitals need to be seen as a part of wider network. In fact, they need to work closely with other hospitals. Since it's impossible that each hospital offers a complete range of services, they need to join forces to make better use of scare expertise. The Portuguese health system horizontal integrations among hospital services have been conducted to answer to this challenge.

In 1999, a new organizational model to deliver hospital care, the Hospital Centre (HC), was created. A HC consists in the integration of two or more hospital units. The official stated aims of the HC creation were resources rationalization and value creation to the National Health Service users. Between 2005 and 2009, 17 HC were created and nowadays there are 23 HC in Portugal.

The ultimate goal of this research is to define a performance evaluation framework for HCs.The increase number of evaluations based on outcomes (outcomes evaluation) has become the central focus of

accountability-driven evaluation. This accountability movement is related to demonstrating responsible use of public funds to achieve politically desired results. However, these numbers don't show the human perspectives of those been evaluated. Therefore, it's important to provide a critical context when we analyze the quantitative data and also to understand the impact/change in the life of the people involved in the evaluation.
The main purpose of this study is to ascertain the most important non-stated objectives and benefits of Portuguese HCs creation expected by HC internal stakeholders and external key-informants. Key-informants are healthcare managers and academic experts with current or past experience in planning, implementing and managing HCs. These non-stated objectives and benefits are an important input to the HC evaluation framework to be developed in the next phase of this research project. This evaluation framework, that also considers the official objectives of the HC, will be more complete and adjusted to reality if it considers the expected objectives regarding the perspectives of these two groups of people.

2 The Methodology

A qualitative research design was conducted to take advantage from a holistic overview of the Portuguese HC context. We tried to capture the understanding, expectations and inner opinions of the key informants and HC internal stakeholders that have a deep Knowledge and attentiveness. We need to define the major performance dimensions to consider in this research project. Probably it would be possible to do that with a survey research, but doing that we wouldn?t be able to understand the integration process and the integration context that would give some explanations to the choose of certain dimension to be included in the model.
The rich data resulting from this qualitative study offers the opportunity to gather new insights from the HC experience. This is even more relevant due to the lack of information about the HC creation and implementation in Portugal. Therefore, a qualitative research design was used to gather feasible data that wasn't available in any other form.
The interviews were conducted in two stages: first with key-informants and later with HC internal stakeholders. Regarding the external key-informants, the research team selected the following healthcare managers: one Ex-Secretary of State for the Health Ministry; one Ex-board member of the Central Administration of the Health System (ACSS); two Ex-board members of the Regional Administration of the Health System; four Ex- and current HC board members; and three academics with expertise in healthcare management. With regards to the HC, the interviews were conducted with clinical and non-clinical staff. We conducted 28 interviews: 11 interviews with key-informants and 17 with internal stakeholders.
Two semi-structured interview guides were developed (one for key-informants and another one for the internal stakeholders) based on the literature review and research team experience. The interview main objectives were to collect information about: integration objectives; integration drivers; main benefits expected; the main difficulties faced nowadays by the HC; the disadvantages of the HC; factors that contributed to successful and unsuccessful cases of the HC integration and the main challenges faced by the HC.
Transcripts of the interviews were analyzed using NVivo 10. Content analysis was used as a research method to analyze data. An initial coding scheme was developed based on prior relevant research findings. As analysis proceeded, additional codes were developed, and initial coding scheme was revised and refined.

3 The value to Society

The information gathered with this qualitative study gave us a comprehensive idea of objectives, benefits and other concerns that are most valued by the HC internal stakeholders and by external key-informants regarding the HC creation.
In figure1 are presented the objectives defined during the data analysis. They were distributed between three evaluation dimensions: Organizational, Patient and Professional.
The interviewees also pointed out that the main reasons for the successful integrations were the leading

process, followed by the local authority support and the way organizational cultures differences were managed. According to both groups of interviewees the main challenges faced by the HC board are to define a strategic plan for the HC with clear objectives regarding the enhancement of the integration benefits, the definition of internal and external communication strategies and choosing strong leaders for the process.

Organizational	Patient
Resources rationalization	**Improve access/Reduce inequalities**
Improve Scale Effect	Improve physical access to hospital care
Operational (marginal) costs reduction	Reduce the waiting time to ambulatory care
Improve negotiation capacity	Reduce the waiting time to surgery
Improve Hospital care delivery	**Improve perceived quality by patient**
Reduce infrastructures duplications	Improve healthcare service to community
Reduce duplication equipment/technologies	Better response to community needs
Improve performance of the internal processes	Improve proximity to patient (humanization in healthcare delivery)
Improve Quality	
Improve organizational safety	**Professional**
Improve organizational quality	**Improve professional conditions**
Increase hospital units specialization	Develop training programs adapted to organizational goals
Improve management	Promote team work
Improve leadership processes	**Improve work climate**
Improve Human resources management	Increase the involvement of healthcare professionals regarding management aims
Improve information system management	Promote actions regarding professionals motivation (acknowledge)
Improve articulation with other care levels (vertical integration)	Improve expectations management mainly in changing processes

Figure 1: Objectives

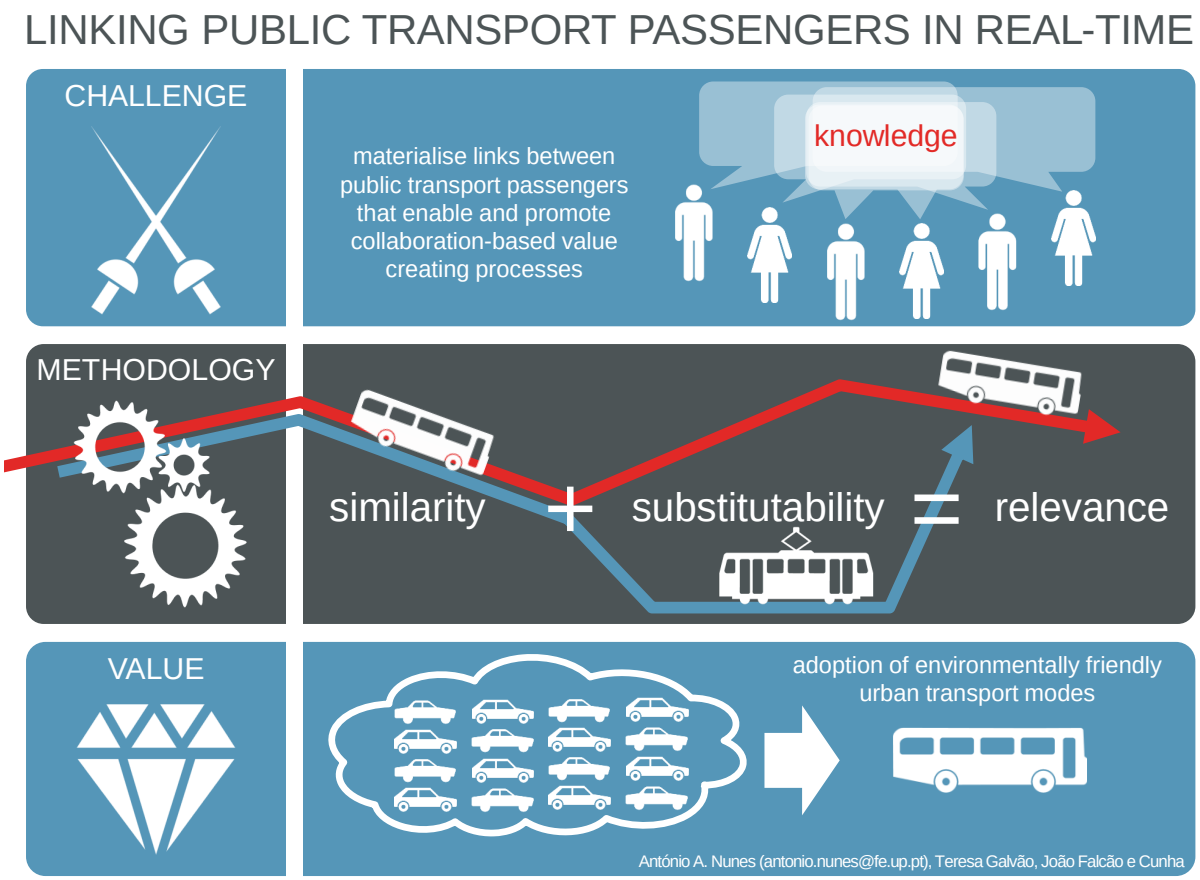
Acknowledgements

This study was developed in the scope of a PhD individual Scholarship funded by FCT - Fundaçao para a Ciencia e a Tecnologia (Portuguese Foundation for Science and Technology)

Linking public transport passengers in real-time

António A. Nunes*, Teresa Galvão*, João Falcão e Cunha*

* *FEUP - Faculty of Engineering of the University of Porto*



1 The Challenge

Recent advances in information and communication technologies allowed for collaboration between customers to emerge across many service domains. Social media leverage existing social structures, binding knowledge that is distributed amongst its users as a value creating process. Social networking services, for example, take advantage of tangible social structures such as friendship and professional relationships to harvest information and distribute it to the audiences concerned. Other examples exist, such as recommendation and rating systems, which rely on underlying social structures that are often invisible to their users. These may be shared ideologies or interests that come together as crowdsourced reports and let others know what to expect from future consumption experiences. Leveraging social media as a value creating process has become popular across several industries such as retail, tourism, and media, but has had limited impact on passenger transport. It is argued that links between public transport passengers have specific characteristics that are not easily captured by existing social media services. Hence the

present challenge can be summarised in the following question: how to materialise links between public transport passengers that enable and promote collaboration-based value creating processes?

2 The Methodology

Links between public transport passengers are spatiotemporally specific. In most cases, travel patterns do not correlate with existing social structures. Take friendship as the simplest example, it may not be useful for passengers to share their knowledge of a public transport system with their acquaintances because it is unlikely they will make any use of it. However, there are many other passengers in a transport system that could indeed make use of such information, those whose travel patterns are either similar or feasible substitutes. This accounts for the spatial specificity between desirable links. Additionally, it is noted that most information about a transport system is highly circumstantial. For example, getting information about a service delay or crowding of a particular vehicle is only useful while it is occurring. That justifies the temporal specificity element. In essence, the present methodology aims to capture the spatiotemporal likeness of travel patterns to create, for each passenger and particular time instant, a rank of other passengers that are most useful to be linked with. That allows them to collaborate by sharing information using their mobile devices through a dedicated social networking service. The methodology for linking passengers consists of the following three looping steps.

The first step relates to forecasting the destination of ongoing passenger journeys. Linking passengers in real-time based on their travel patterns requires knowing where each ongoing journey is likely to terminate, so that it is possible to determine its likeness to other journeys. Hence, when a passenger initiates a journey in public transport, the first step consists of carrying out a regularity analysis from his or her travel history to infer the most likely destination of that journey. This step is a learning process, which improves with the number of records of the travel history of a passenger, and with the regularity of travel habits. Note that this step requires journey origins to be known, for example from live Automated Fare Collection (AFC) system data or from usage of a mobile ticketing application.

The second and main step is to establish for each passenger a ranking of peers to be linked with. This creates temporary social networks centred on each passenger, which must be restructured continuously in very short time intervals to remain up-to-date and useful. Peers who are relevant to a passenger are considered to be those who may have information about his ongoing journey, a feasible alternative, or a combination of both. In other words, the peers who are carrying out a similar or substitute journey at a given time instant. Hence, each peer is scored based on two measures, of similarity and substitutability respectively, which added together provide an overall measure of relevance to establish the ranking. This second step is computationally demanding requiring a streamlined algorithm to perform vast amounts of calculations in real-time.

The third step only applies to entry-only public transport ticketing systems, i.e. those where passengers "check-in" at the beginning of journeys but do not have to "check-out" at the end. The Andante system in Porto is an example of an entry-only ticketing system. In those systems, additional logic is required to estimate the destination of each individual journey to build the travel history required for carrying out regularity analysis in the first step of the loop. Methods for estimating the destination are well documented in the literature, and are largely based on the assumption that the most likely destination of a passenger journey is the origin of the next one. Nevertheless, each entry-only system will have its own particular characteristics requiring this step do be adjusted accordingly. The work carried out so far in this project has already demonstrated that the methodology is feasible, and has yielded interesting results from experiments to validate it using historical AFC system data. It is currently being adopted into a pilot project in partnership with private firms and travel operators that aims to deliver an innovative ticketing mobile service and to improve public transport experience.

3 The Value to Society

The ubiquitous adoption of mobile devices with powerful computation abilities and access to data communication networks is a contemporary feature of our society. It offers an unprecedented opportunity

for leveraging distributed knowledge on the move and in real-time through crowdsourcing, which this research is attempting to seize for the ease of public transport use. The associated benefits are clear. First and foremost, this research aims to facilitate the adoption of environmentally friendly urban transport modes, which in turn may alleviate traffic congestion. Additionally, the distribution of knowledge may assist public transport passengers to make informed decision regarding their travel choices, and match the experience to their preferences and requirements. Lastly, the knowledge that is shared may be aggregated for analysis by public transport operators for improving their services, giving them a better understanding of travel demand patterns, and allowing timely action upon incidents that are reported in real-time.

Stability within the Container Loading Problem - Towards a safe and efficient transportation of cargo

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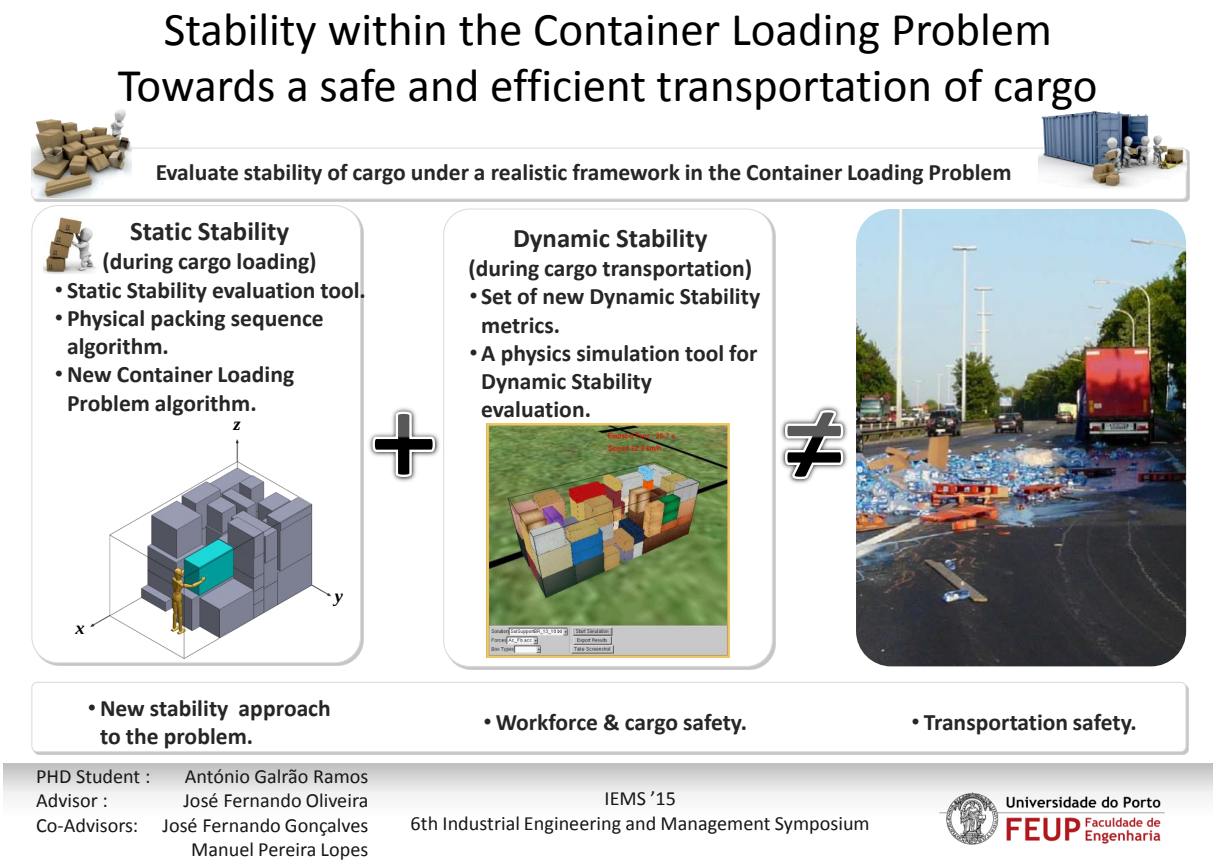

1 The Challenge

The cargo transportation sector in Europe is facing nowadays a wide number of challenges that go beyond the common purpose of cargo transportation management, that is, transporting the correct product, in the correct quantity, to the correct location at the lowest cost, in the correct instant and the desired quality. Environmental and safety issues are having an increasing importance at all organizational levels of supply chains. One of the main challenges that this sector faces, arises from the strategy of the European Commission to cope with the scenario of rising oil prices, growing congestion and looming climate change. It established the goal of achieving a 60% reduction of the CO_2 emissions, and of oil dependency by 2050, without limiting freedom of movement.

Another challenge arises from the new "IMO/ILO/UNECE code of practice for packing of CTU's" (to be published by the end of 2014 by the International Maritime Organization, the International Labour Organization and the United Nations Economic Commission for Europe), the "European best practices guidelines on cargo securing", by the European Commission and the new road worthiness directive by the Council of the European Union, published on the 29^{th} of April 2014. All these documents will produce a seizable impact on cargo safety practice, as a result of new technical requirements and the definition of responsibilities for the security of the cargo for the various parties of the supply chain. As a main goal, they have to tackle problems related with cargo accommodation within cargo transport units (CTU), since, for safety reasons, it is of the utmost importance that when cargo is placed on the transport vehicle, it is done in a way that it will neither endanger persons nor goods and it cannot slide or fall off the vehicle. This is a major concern on road transport, since according to the European Union, the failure of the securement of cargo contributes to up to 25% of accidents involving trucks. It is thus expected that the need for increased efficiency and security in the transportation sector will drive companies to adopt cargo planning tools that can be effectively used in practice.

The optimization of the spatial arrangement of cargo inside transportation vehicles or containers to maximize the CTU space utilization, is a problem that has been addressed in the field of operations research. Known in the literature as the container loading problem (CLP), this real-world driven combinatorial optimization problem addresses the optimization of the spatial arrangement of cargo inside transportation vehicles or containers so that the utilization of the containers space is maximized. As an assignment problem, it can have two basic objectives, the maximization of the value of the cargo loaded, when the number of containers is not sufficient to accommodate all the cargo, or the minimization of the cost of containers, when they are sufficient to accommodate all the cargo.

However, its solutions will be of limited applicability in real-world scenarios, if the spatial arrangement of cargo is addressed without considering real-world constraints that have a strong influence on the cargo arrangement inside the container. Constraints such as cargo stability, container weight limit or cargo orientation constraints are just a few examples.

Cargo stability is strongly related with the the safety of cargo transportation and is considered in the literature as one of the most important CLP constraints. However, the existing approaches have modelled stability in an over simplified manner, without realistically reflecting stability. The aim of this work is to develop an approach of the cargo stability constraint under a realistic framework to incorporate within the CLP, and simultaneously addressing safety, and space optimization in transportation.

2 The Methodology

In order to achieve the proposed goal we began by distinguishing between two types of cargo stability: static stability and dynamic stability. Static stability concerns the stability of the cargo during the loading operations, and dynamic stability addresses the stability of the cargo during transportation.

Static stability is usually approached in the CLP literature by enforcing the full base support or partial base support constraints. The full base support constraint states that a box that is not on the container floor, must have its base in contact with the top surfaces of other boxes. This approach does not necessarily meet real-world needs, since it does not allow the overhanging of boxes, and penalises the objective of maximization of the space usage.

Static stability is concerned with the stacking and standing of the cargo on the container floor. To evaluate static stability we developed an approach based on the static mechanical equilibrium conditions applied to rigid bodies. The proposed approach allows the evaluation of the stability of the loaded cargo each time a box is loaded in the container, without the need to take into account the percentage of base support.

Static stability is also closely related to the actual sequence in which the boxes are loaded inside the container. However, since the objective of CLP algorithms is to maximize the usage of space, the sequence by which solutions are generated by CLP algorithms, that is, the sequence by which the algorithm fills the space, is not the actual loading sequence. As such, we were required to develop a physical packing sequence algorithm (PPSA) to determine the actual sequence by which each box is placed inside the

container in a specific location determined by a CLP algorithm. The developed PPSA incorporated our static stability evaluation approach and used a *Wall Building* loading approach for operations efficient purposes.

In the next step we developed a new CLP algorithm that incorporates our static stability approach and our PPSA. The proposed algorithm is a multi-population biased random-key genetic algorithm that combines a genetic algorithm, responsible for the evolution of coded solutions (chromosomes), and a constructive heuristic algorithm responsible for decoding the chromosome, generating a solution and evaluating its fitness. The CLP algorithm was tested using a well-known benchmark dataset. The computational experiments showed that, on average, with our static stability approach, it is always possible to achieve a higher percentage of space utilization than with the classical full base support condition.

Following the achievement of static solutions for the CLP, we addressed dynamic stability. Within the CLP literature dynamic stability is not frequently addressed. It is usually treated as a soft constraint that states that a box is dynamically stable if it has at least three lateral surfaces in contact with other boxes or with the container walls. When considering all the forces that act on the cargo during transportation, this constraint does not guarantee a real-world dynamic stable solution.

The dynamic stability analysis of a system of boxes during transportation is rather complex, since it requires a high number of variables, such as, mass, friction coefficient or velocity, and some are time dependent. It was considered by the authors that it would be more effective to develop a set of metrics, to incorporate in the CLP, that could realistically reflect dynamic stability.

To this purpose, a set of metrics based on the allowable movement of boxes inside the container were proposed, to evaluate the dynamic stability of a cargo arrangement. To evaluate the displacement of boxes inside the container along the $x-$, $y-$ and $z-axis$, a compacting procedure was developed. The proposed metrics were validated by a physics simulation tool. This simulation tool, based on the physics engine Bullet, simulated the movement and interaction of the boxes of a cargo arrangement inside a container, as a result of a set of forces applied to the container.

3 The value to Society

Multiple contributions resulted from this research project. The work that was developed is of special interest to researchers in the Operations Research field that deal with the CLP, since it provides a more realistic approach to stability. It also provided a simulation tool that can be used by other research fields that address cargo safety. The outputs of the project are expected to contribute to the increase of cargo, workers, and transport safety and to promote the efficient transportation of goods, that in the present scenario of rising oil prices, growing congestion of roads and looming climate change is a condition for maintaining the prosperity of the European Union.

Acknowledgements

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R&D Project Selection Incorporating Risk Management

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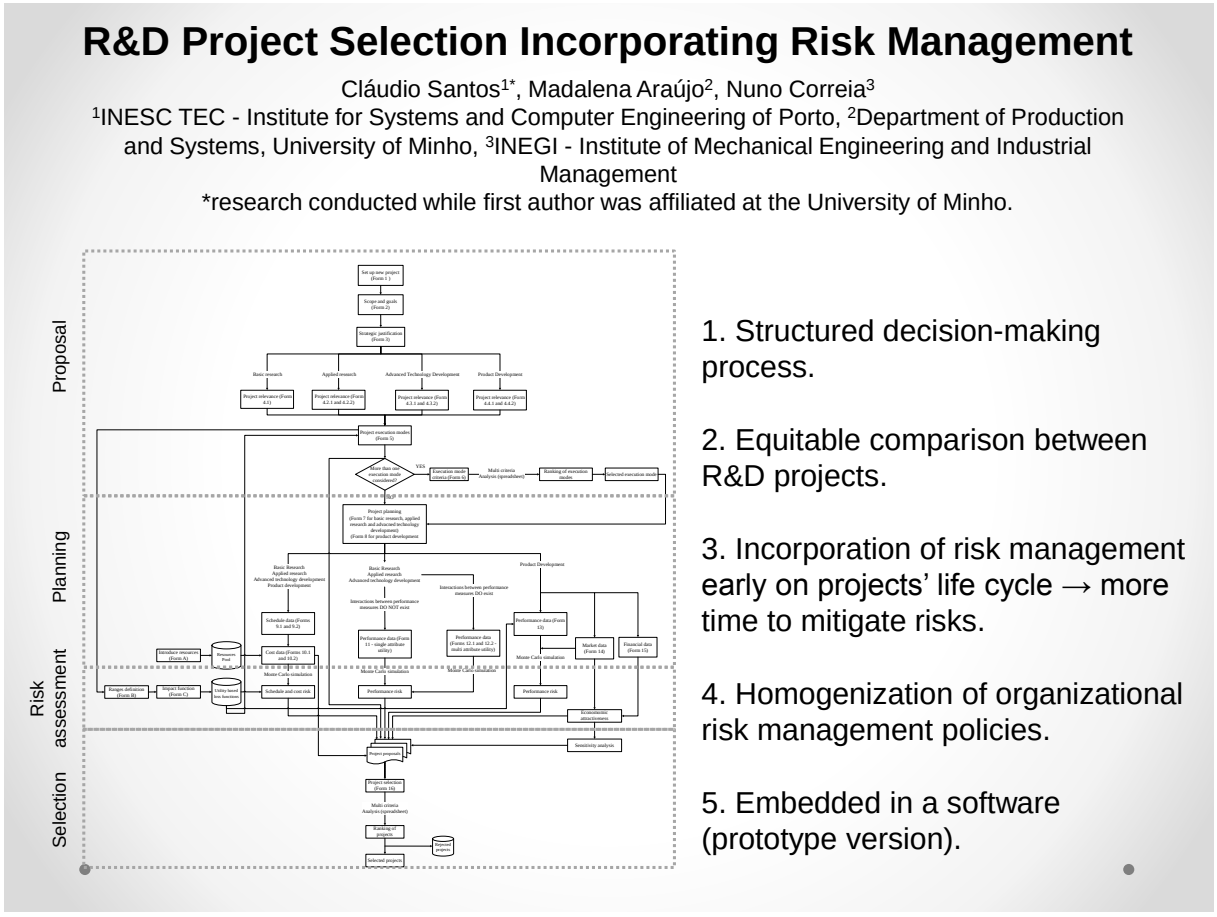

1 The Challenge

Project selection is an organizational activity related to the decisions made about the strategic guidelines of the organization for the future. Resource limitations impede organizations from engaging in every project, so careful consideration should be taken to ensure that the most promising projects are selected. Given the diverse nature of R&D projects, they should be compared equitably during selection, using appropriate criteria. R&D projects also present uncertainty and risk, since they aim at developing solutions with a degree of novelty. Current R&D project selection methodologies, although addressing risk and uncertainty, do not take into consideration different perspectives on risk, driven by the readiness levels of technologies and the scale of R&D projects, and few proposals have been made with respect to the homogenization of organizational risk management policies.

2 The Methodology

The purpose of this research is to present a novel R&D project selection methodology that addresses risk early on the project's life cycle. The new methodology shall meet the following critical requirements of an integrated project selection methodology, which were identified from literature (Archer, N. P. and Ghasemzadeh, F. 1999. An integrated framework for project portfolio selection. International Journal of Project Management, 17, 207-216; Verbano, C. and Nosella, A. 2010. Addressing R&D investment decisions: A cross analysis of R&D project selection methods. European Journal of Innovation Management, 13, 355-379):

- ensure strategic (qualitative) coherence by acknowledging both internal and external business factors, along with the implications of economic factors (quantitative) in project selection;
- use indicators and criteria that are suitable for the type of R&D project under consideration;
- organization in a number of stages to enable a logical approach for project selection;
- reflect the overall objectives of the organization and perspectives on risk for different types of R&D;
- reflect the effects on resource competition;
- incorporate risk controlling or re-evaluation mechanisms at milestones or gate reviews of projects.

The project selection methodology proposed in this research incorporates the widely known three types of R&D: basic research, applied research and advanced technology development. A fourth type of project is considered, namely product development, related with development, industrialization and launch of new products. These types of projects have different goals, and for this reason, only projects of the same type should be compared with each other, using appropriate criteria (Tidd, J., Bessant, J. and Pavitt, K. 2005. Managing innovation: integrating technological, market and organizational change, West Sussex, England, John Wiley and Sons, Ltd.). In the methodology, the proposal of a new project involves the introduction of a set of information about the scope, strategic justification and relevance of the project, that are directly related to the default criteria used to compare the projects in the selection stage. The information requirements for candidate projects were mapped using a review on the criteria used in different projection selection models proposed in the literature.

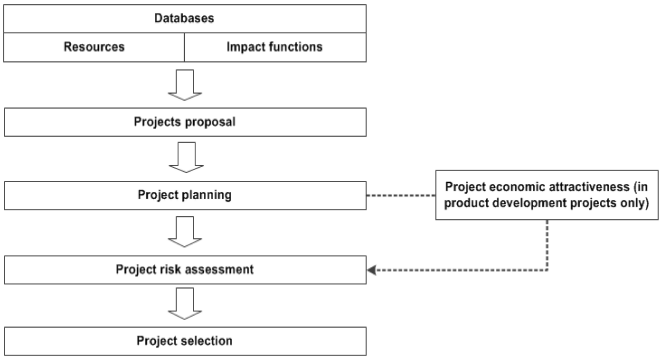

Figure 1: R&D Project Selection Stages

Different types of R&D projects cover different orders of magnitude in terms of duration and cost. Additionally, there are the numerous perspectives over risk inside an organization. The methodology enables the clustering projects proposals estimations of duration and cost into ranges to support greater homogenization of organizational risk management policies. Once projects duration and cost ranges are defined inside the organization, an impact function (a "loss function") is assigned to each one of them. The impact function is a utility function and works as an approximation of the organizational risk perspectives over the projects' cost and duration ranges. Monte Carlo simulations performed on estimations of schedule, cost and performance, along with the impact functions, enable the quantification of schedule, cost and performance risks for each project.

The methodology proposed for project selection was assessed in the industrial partner. A post mortem analysis was conducted on three product development projects. The feedback from the CTO was satisfactory, specifically concerning the criteria proposed for select product development projects. The CTO also expressed that clustering of projects into ranges can contribute to a more rational project management inside the company.
This new methodology incorporates a considerable number of tools, and in order to facilitate its implementation in real settings, a software written in VBA language for Microsoft Excel was developed.

3 The value to Society

The proposed methodology has several implications to how organizations manage the selection of technology development projects. The early categorization into different types of R&D and product development projects enables a more equitable comparison between projects. Managers are also able to observe a logical sequence in the project selection process.
The early integration of risk management enables more time for managers to address them. The quantification of risks through project ranges and impact functions contribute to greater homogenization of organizational policies and practices in risk management. Risk levels can be updated throughout the execution of projects as more information is gathered, through a mechanism of risk management and control.
This research is aligned with a trend in decision analysis announced four decades ago, concerning the transition from "decision analysis" towards "decision information systems" (Baker, N. and Freeland, J. 1975. Recent Advances in R&D Benefit Measurement and Project Selection Methods. Management Science, 21, 1164-1175.). This requires extra attention in information flows that feed project proposals. Nowadays, with the advancement of information technologies which enable substantial productivity gains in the management of information flows, and the importance of knowledge in innovation performance, this trend becomes even more relevant.

Acknowledgments

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Supplier Selection in the Food Supply Chain

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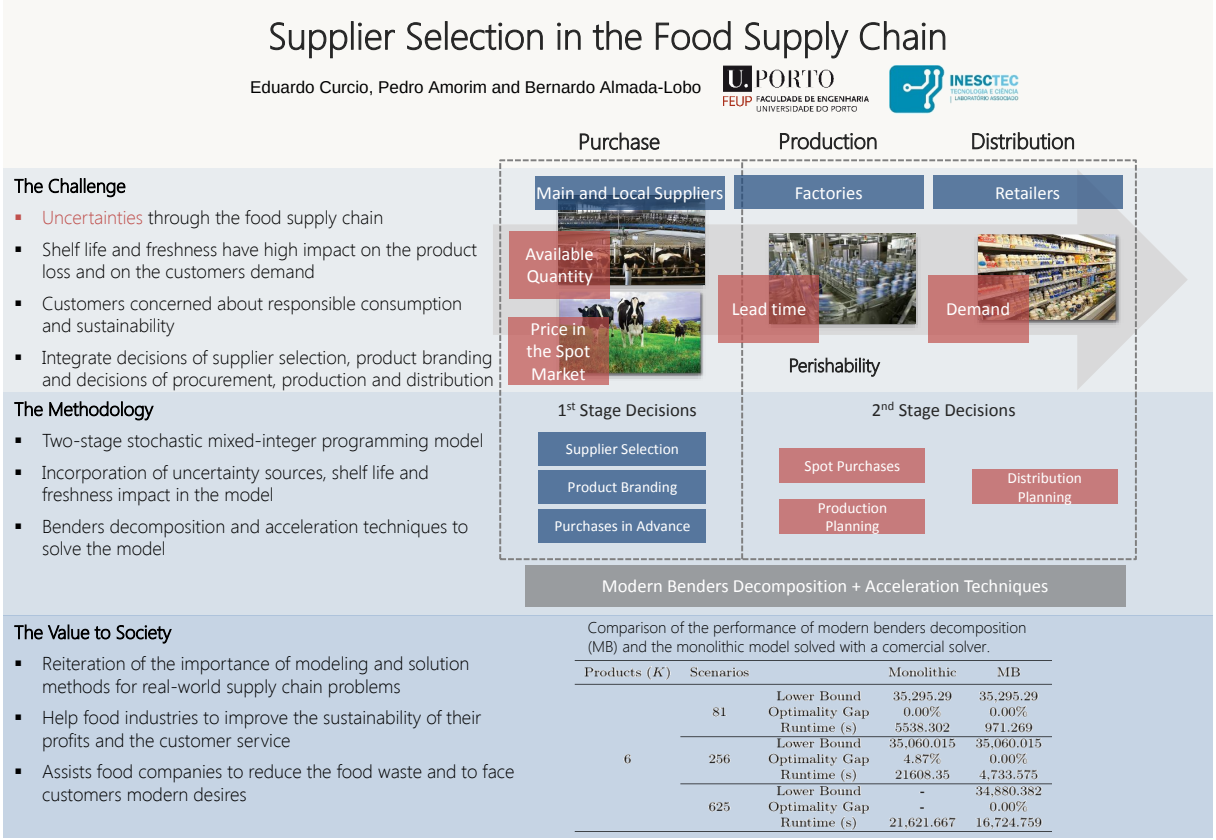

1 The Challenge

The challenges faced in food supply chains are at the interception of several disciplines and go beyond the traditional industry concerns. Particularly, in the process food industry, companies have to deal with high uncertainties both upstream and downstream of the supply chain. These uncertainties are related to an ever increasing product variety, more demanding customers and a highly interconnected distribution network. This implies that companies operating in the process food industry need to manage the risk/cost trade-off.

Moreover, food industries have to deal with freshness and spoilage of the products, which have a high impact on the product loss and on the customers' demand. In terms of spoilage, the European Commission estimates that 39% of total food spoilage, excluding losses at the farm level, is generated at the processing stage. Freshness plays an important role in the customer purchasing stage. An empirical research shows that customer willingness to pay decreases throughout the course of the products' shelf-life. It is clear that freshness and spoilage are critical drivers in this industry and should be taken into account in the decision process. Furthermore recent researches showed that spoilage can be managed and controlled by a risk averse attitude while planning the supply chain.

Corporate social responsibility is another relevant aspect. Customers are not only more exigent in terms of quantity, quality and freshness, but also more concerned about purchasing responsible consumption products (products branded as sustainable, natural, fair-trade or local). Therefore, several recent researches from both practitioners and researchers show that customers are inclined to pay premium prices to buy responsible consumption products. The selection of the type of raw material of a product may have an impact on this customers behaviour.

Effective and efficient decision support models and methods for supply chain planning are critical for the food industry, which is the largest manufacturing sector in Europe with a turnover of 1,048 billion euros and employing 4.2 million people. Some authors state that since the characteristics of food supply chains are significantly different from other supply chains, the standard methods for supply chain management perform poorly when applied to process food industries. This occurs mainly because many of the standard tools do not take into account aspects such as products shelf-life and perishability effects on customers' demand. In addition, there is a lack of quantitative models that also integrate strategic, planning and operational decisions through the supply chain stages.

Looking at these concerns, the main scientific challenge is to develop a model that best integrates the decisions of suppliers selection, product branding and the decisions of procurement, production and distribution planning. The model should contain the main characteristics and particularities of the food industry and assist companies to give better decisions than the actual tools. Moreover the model has to be solved in order to deliver quality decisions and better results to the food companies.

2 The Methodology

This work addresses the joint decision of choosing which type of suppliers to select, the products' raw-material (that defines the product branding) and decisions of procurement, production and distribution planning. We focus on companies that process a main perishable raw material and convert it into perishable final food products.

These conditions happen for instance in the dairy, fresh juices and tomato sauce industries. Within this scope strategic and tactical decisions are integrated in a common quantitative framework. We consider a setting in which companies have their plants and distribution channels well implanted and, therefore, the supply chain strategic decisions that are considered address the supplier selection and the related product branding - in this case either local or mainstream.

Within this context a two-stage stochastic mixed-integer programming model is proposed to tackle the integrated supplier selection problem. In the first-stage we decide if the product will be made with local or mainstream raw materials (which will define its branding) and the quantities to be procured in advance from each type of supplier (local and mainstream suppliers). In the second-stage, we decide on the produced and transported quantities as well as on the quantities procured in the spot market (Figure 1).

The model aims at maximizing the expected profit and minimizing the risk of low customer service. Besides the integrated approach of the model, four critical uncertainty sources are incorporated. The uncertainties through the supply chain are related to the suppliers raw material availability, suppliers lead time, suppliers spot market prices and demand for final products. The distribution functions that represent each uncertainty source were withdraw from the literature, and based on that the instances were generated.

Moreover, the model takes into account relevant aspects of this particular supply chain. Both final products and raw-materials have limited shelf-life and can be spoiled. The freshness impacts the customer demand, in a way that the demand and willingness to pay of the customers decreases when a product is closer to its shelf-file. We also considered different prices of products and raw-materials when they are branded as local or mainstream.

Because of the size of the stochastic model, commercial solvers were not able to solve it. To solve the model we developed a solution method based on multi-cut modern benders decomposition and generalized disjunctive programming. This solution method decompose the entire model into a master problem, that

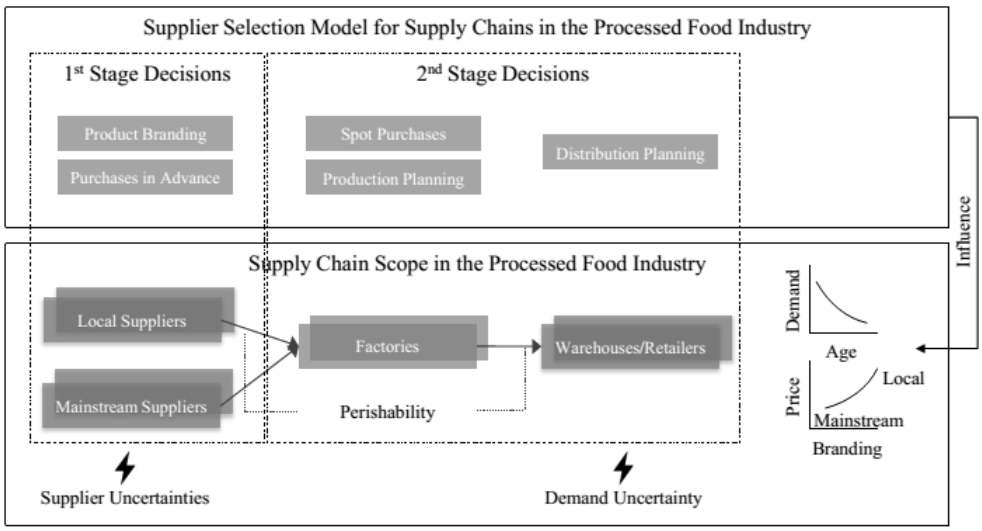

Figure 1: Supply Selection Model Framework

is a relaxed version of the model, and a subproblem, that is the feasible version of the model. By solving these problems in a interactive way and adding optimality cuts into the master problem, large stochastic problems can be solved efficiently.

The solution approach was essential in order to achieve high quality solutions for more realistic instances. Furthermore, we compared the performance of several benders decomposition variants and convergence acceleration techniques for a considerable number of instances.

3 The Value to Society

Through the model developed, we aim to create value for all the stages in the food supply chain, from food suppliers to customers. The model proposed focuses in giving quality decisions for food companies in order to increase their efficiency and effectiveness. We expect that the integrated decision support helps food industries to improve the sustainability of their profits and the customer service under several uncertainty sources.

By incorporating spoilage and shelf-life drivers into the plans, we are concerned about reducing the food waste, the spoilage rate and the environmental impact of the food supply chain. These aspects are directly linked to the companies' environmental impact and to the quality and the price of the products to customers. Moreover, our approach assists food companies to face customers modern desires, offering not only products based on low cost, but also products based on responsible consumption. These aspects are also related to the development of suppliers economy and the competitiveness of food industry companies. With the development of a decomposition solution method for this problem, we reiterate the importance of modern solution methods for real-world supply chain problems.

The rolling-horizon inventory-routing problem with transshipments

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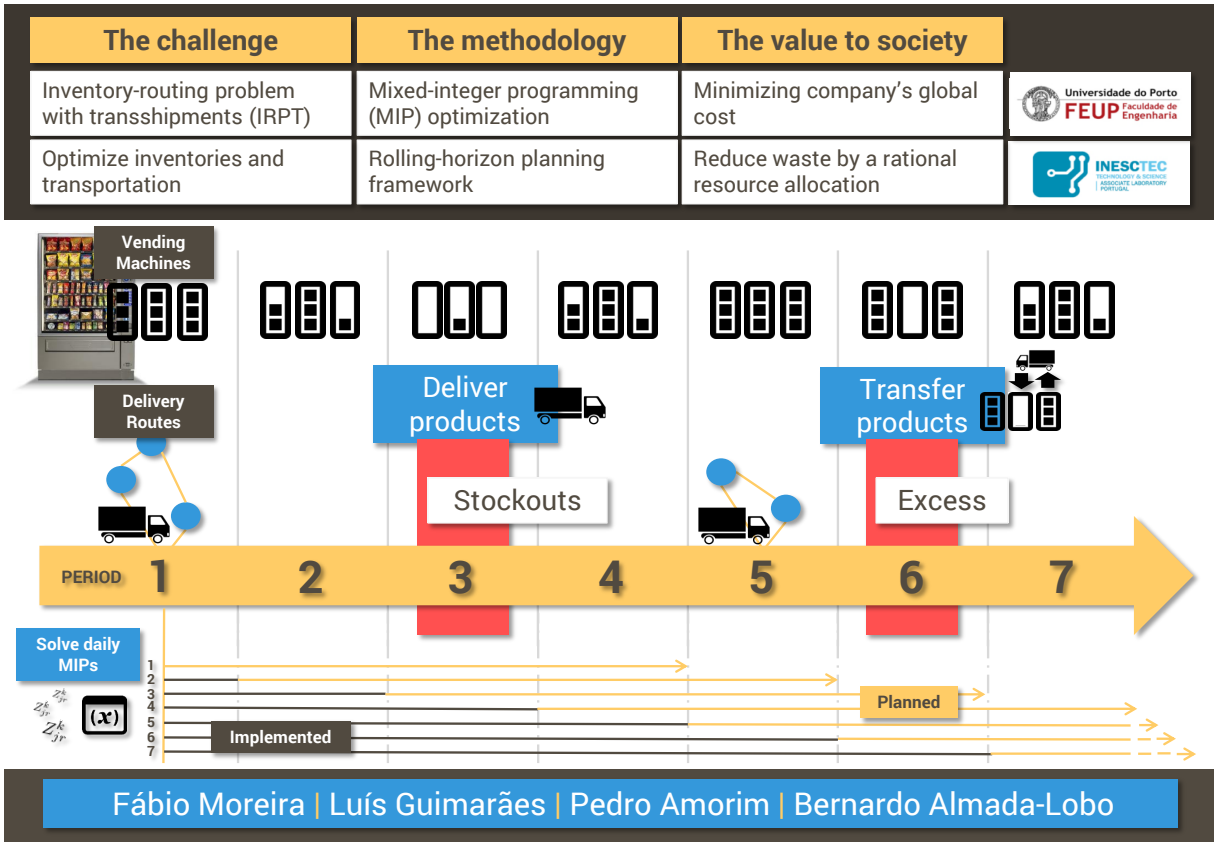

1 The Challenge

The inventory-routing problem (IRP), which integrates inventory management and distribution decisions, is amongst the most demanding and critical challenges in operations management. The problem considers a supplier that delivers a mix of products to a set of retailers. Decisions include (1) How much to deliver to each retailer; (2) When to make deliveries; (3) How to route vehicles such that inventory and transportation costs are minimized while meeting retailers' demands. Many examples show that the joint optimization of sequential activities in supply chains can achieve large cost savings even when applied to simple real-world contexts. However, realistic models capable of describing business-tailored features are still scarce in the literature. Furthermore, the size of the instances addressed by current solution methods is quite small due to the inherent complexity of integrated planning problems. This research is the first to introduce lateral transshipments executed by owned vehicles in the IRP, enabling the possibility to

move products between retailers. This realistic feature is commonly used in a wide range of industries with the objective of smoothing inventory variations that emerge when facing demand fluctuation. In the presence of forecast errors, the imbalances created by this fact can be tackled by re-allocating inventory among retailers.

The mismatch between supply and demand will be consistently reduced by taking the necessary measures in the surrounding periods. The objective is to provide robust plans that are able to minimize inventories, transportation and stockout costs. Furthermore, this approach is completely inline with the necessities of real-world problems as it provides various systematic mechanisms to promote stability. An intuitive example of a real IRP with transshipments is the vending machine industry (see Figure 1) where a supplier has to deliver a mix of products to its machines (which represent stores or retailers in other businesses). Sometimes it is necessary to re-allocate products from one machine to another either because the demand changes or products are close to perish.

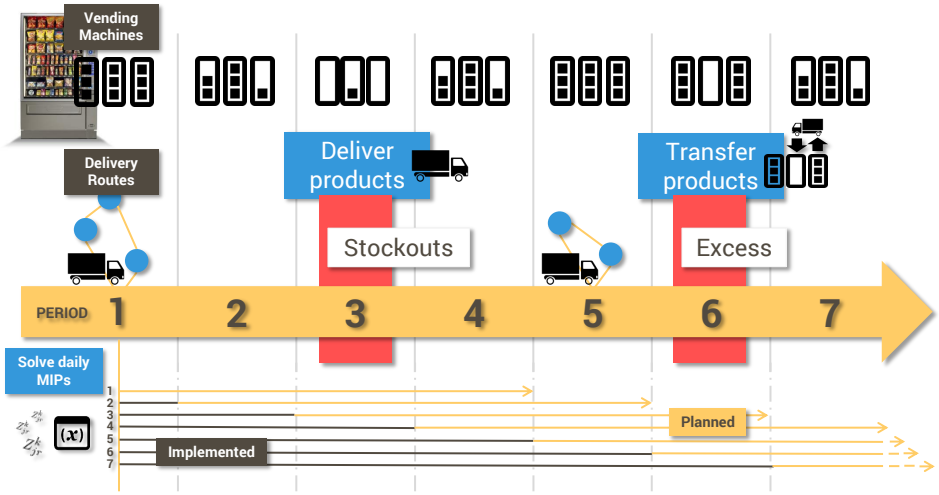

Figure 1: Stockouts are solved by delivering more products (period 3) while excesses of stock are solved by transferring products between retailers (period 6). MIPs are solved in the beginning of each period, after updating demands of the previous period.

2 The Methodology

In order to solve the inventory-routing problem with transshipments, we propose a new mixed-integer programming (MIP) model. The model can be applied to a wide range of IRP versions since it can tackle problems with multiple suppliers, vehicles, products and periods. Additionally, each vehicle can transfer products from a retailer to another, performing lateral transshipments.

To prove the utility of allowing lateral transshipments in the IRP, we apply the model in a rolling horizon planning scheme where the demand in the model corresponds to forecasts. The rolling horizon planning works as follows. Initially, an IRP is solved considering a given planning horizon. Afterwards, only the decisions corresponding to the beginning of the planning horizon are implemented in practice. In the beginning of a new planning iteration, when new information about sales and stocks at retailers becomes available, the conditions for optimizing the remaining periods are changed and the current solution may no longer be valid. Therefore, the model is run again with updated information and the considered planning horizon slides forward, fixing the information contained in the previews periods.

With the objective of simulating a rolling horizon planning we propose the methodology depicted in the flowchart of Figure 2. In the example, a planning horizon of 4 days is iteratively solved and advanced one day at a time to consider the following 4 days. In each daily planning iteration, the model is fed and solved with information that becomes available at the end of each day (in gray). We use this framework

to compare the basic IRP against the IRP with transshipments aiming to show the benefits of inventory re-allocations.

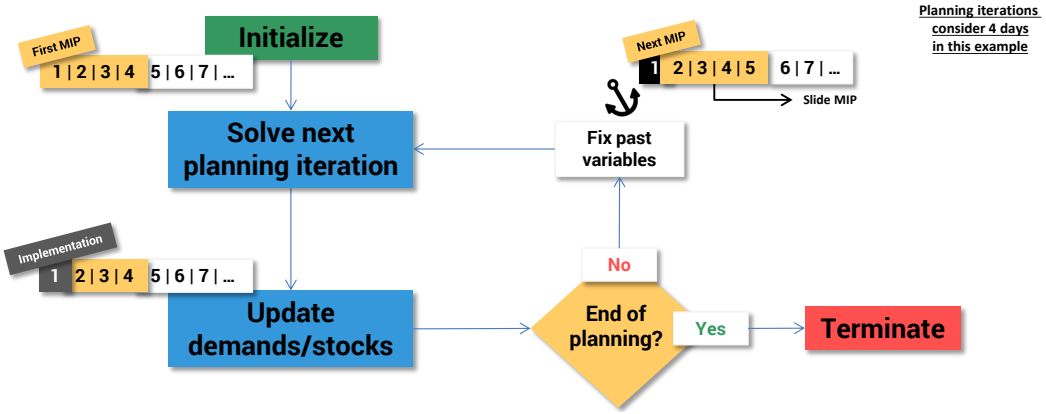

Figure 2: Framework to simulating a real-world situation by rolling horizon planning

3 The value to Society

The integration of different planning problems is the next step in order to achieve larger gains arising from operations research. Indeed, when a company decides to integrate its planning processes, alone or cooperatively, there is not only a direct benefit for the company itself but also plenty of indirect benefits that are absorbed by the surrounding entities. Particularly with the IRP, companies are able to reduce inventory and transportation costs while increasing the service level. From the perspective of the consumer, products are available at the right quantity and at the right time, meaning that several sources of waste are largely reduced as resources are allocated more rationally. In addition, the models developed in this work can be applied to a wide variety of process industries such as oil products, food, electrical components, vending machines, automatic teller machines (ATM), and apparel. The inclusion of lateral transshipments in the IRP extends the possible applications of this problem, as it constitutes a mechanism to overcome difficulties cause by the variance of real-world events that vary from business to business.

New Solution Approaches for the Surgical Cases Assignment Problem: Mixed Integer Programming vs. Biased Random-key Genetic Algorithm

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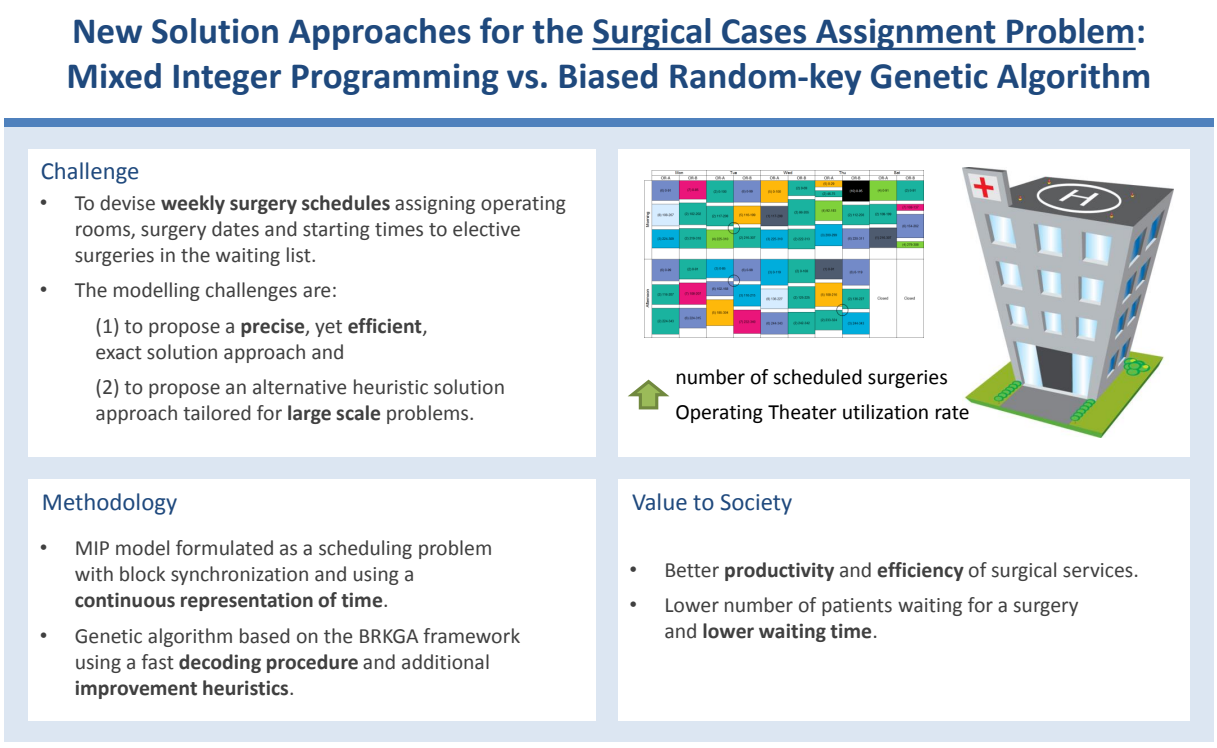

1 The Challenge

This study addresses the surgical cases assignment problem (SCAP) appearing at large hospitals. The problem consists in generating a weekly surgery schedule assigning operating rooms (ORs), surgery dates and starting times to a set of elective surgeries in the surgical waiting list. Admissible schedules are subject to resources availability and capacity constraints as well as to patient priority and waiting time rules. Moreover, a surgeon is allowed to operate in multiple ORs during the same day and working shift, but not at the same time. Due to the long waiting lists and the scarcity of ORs, our aim is to maximize the number of scheduled surgeries as well as the average OR utilization rate. The majority of the approaches

found in the literature tackle this problem in two separate phases: advance and allocation scheduling. The first consists in assigning the surgery dates, while the second consists in sequencing patients within each day. However, this separation often leads to inferior quality solutions, because the optimal result requires the coordination of both phases. Our first aim is to propose an integrated approach considering both advance and allocation scheduling.

There are other integrated approaches in the literature. However, they employ a discrete representation of time. It means that, in order to avoid the overlap of patients of the same surgeon in parallel ORs, the time is discretized in intervals from 10 to 30 min and special non overlapping constraints restrict the starting times of surgeries. In this approach the size of the interval is a trade-off between precision and computational complexity. Lower intervals lead to a more precise representation of the problem, but also to an exponential increase in the amount of memory and computational time required to solve the problem, which for larger instances is prohibitive. Therefore, our second aim is to propose an exact model using a continuous representation of time. The modelling challenge is to propose a precise, yet efficient, exact solution approach. Moreover, we aim to propose an alternative heuristic solution approach tailored for big size instances and compare the quality of solutions and required computational times.

2 The Methodology

The proposed exact solution approach is based on a mixed-integer programming model formulated as a scheduling problem with block synchronization and using a continuous representation of time. This model is inspired by efficient formulations for the travelling salesman problem (TSP), making an analogy between the cities of the TSP and the ORs a surgeon work in a given day and shift, thus sequencing surgeons periods of work and avoiding overlaps. The model uses three sets of decision variables to represent a solution, one denoting the patients scheduled in each day, another determining the sequence of surgeons in each OR and day, and a last one assigning the working periods of surgeons in each OR and day. The working periods are continuous variables whose values are defined as a function of the other variables, leading to a precise and efficient model. Figure 1 shows a sample schedule generated with the continuous model solved by a state of the art Linear Programming (LP) solver. It is a sample weekly surgery schedule with 5 days and 2 ORs and 2 shifts by day. Each box represent a surgery, the different colors represent the surgeons and the numbers inside each box show the surgeon id and the start and end time of each surgery. In this example, there is a cleaning time of 17 min after each surgery and no surgeon turnover time, which is the time required for a surgeon to change from one OR to another. Is is worth noting that the OR utilization rate is high and that some times a surgeon changes from one OR to another in a very small amount of time (signed in the Figure with a circle), leading to even higher utilization rates.

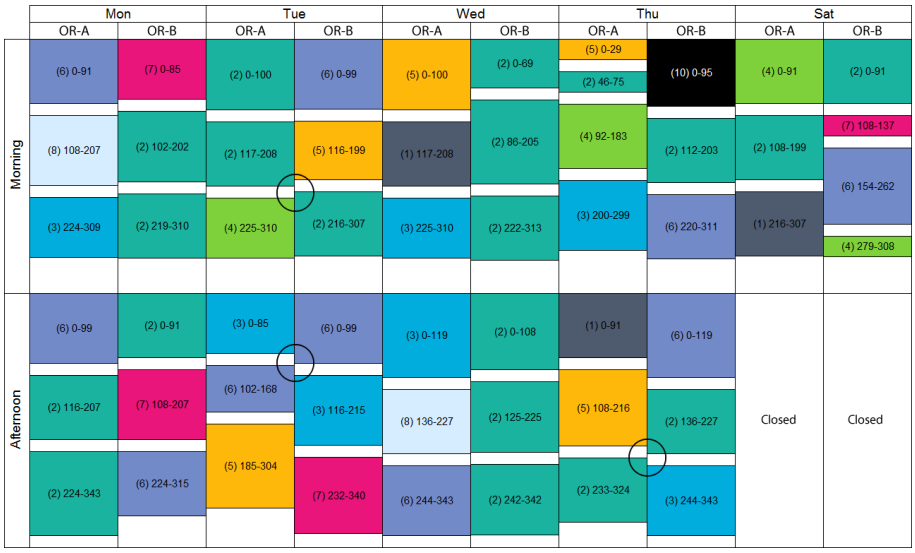

Figure 1: Sample Neurosurgery schedule generated by the continuous model

In order to address big instances appearing in real cases, a heuristic solution approach is proposed based on the biased random-key genetic algorithm (BRKGA) framework and on an original decoding procedure. This framework was selected based on its good performance tackling similar scheduling problems. The BRKGA is a population based metaheuristic which evolves a population of individuals, each one representing a surgery schedule, through successive generations. Each individual is a vector of random-keys and requires a decoding procedure to be converted into a valid surgery schedule. This decoding procedure, known as decoder, is crucial for the performance of the algorithm since it consumes most of the computational time. The proposed decoder receives as input a vector of random-keys, which defines the sequence in which patients are scheduled, and uses lists of resources availability periods to define the operating room, day and starting time of each patient.

3 The value to Society

The performance of the two proposed approaches is evaluated using a set of instances based on real data. Two sets of instances were generated, one representing regular size instances and another large size instances. Also, three different solution methods are applied to each set of instances: a discrete model presented in a previous work, the proposed continuous model and the proposed heuristic. Finally, two comparisons are performed for each set of instances: the discrete model against the continuous model and the continuous model against the heuristic. Preliminary results show that the proposed MIP model, using a continuous representation of time, outperforms in terms of quality of solutions the model using a discrete representation of time in all instances. On average, the model was able to produce solutions with an objective function value more than 53% better than the discrete model. In its turn, the BRKGA outperforms the MIP in terms of quality of solutions in most part of the cases. In the solutions in which the BRKGA was better, the relative difference was less than 5%, showing that both proposed methods are able to produce high quality solutions.

The elective surgery schedules devised by the two proposed approaches are able to maximize the number of scheduled surgeries as well as maximize the average OR utilization rate. As a result, they bring straightforward benefits to society, both from patients as well as from hospital managers perspective. From the patients stand point they contribute to reduce the number of patients waiting for a surgery and from a managerial point of view they have the potential to optimize the utilization of resources. Both solution approaches also contribute to popularize the adoption of optimization tools in hospitals as they are able to devise high quality schedules in a reduced amount of time. The heuristic has the advantage of not requiring a commercial LP solver, which is not affordable for the majority of the hospitals.

Modeling and Measuring Robust Bus Schedules

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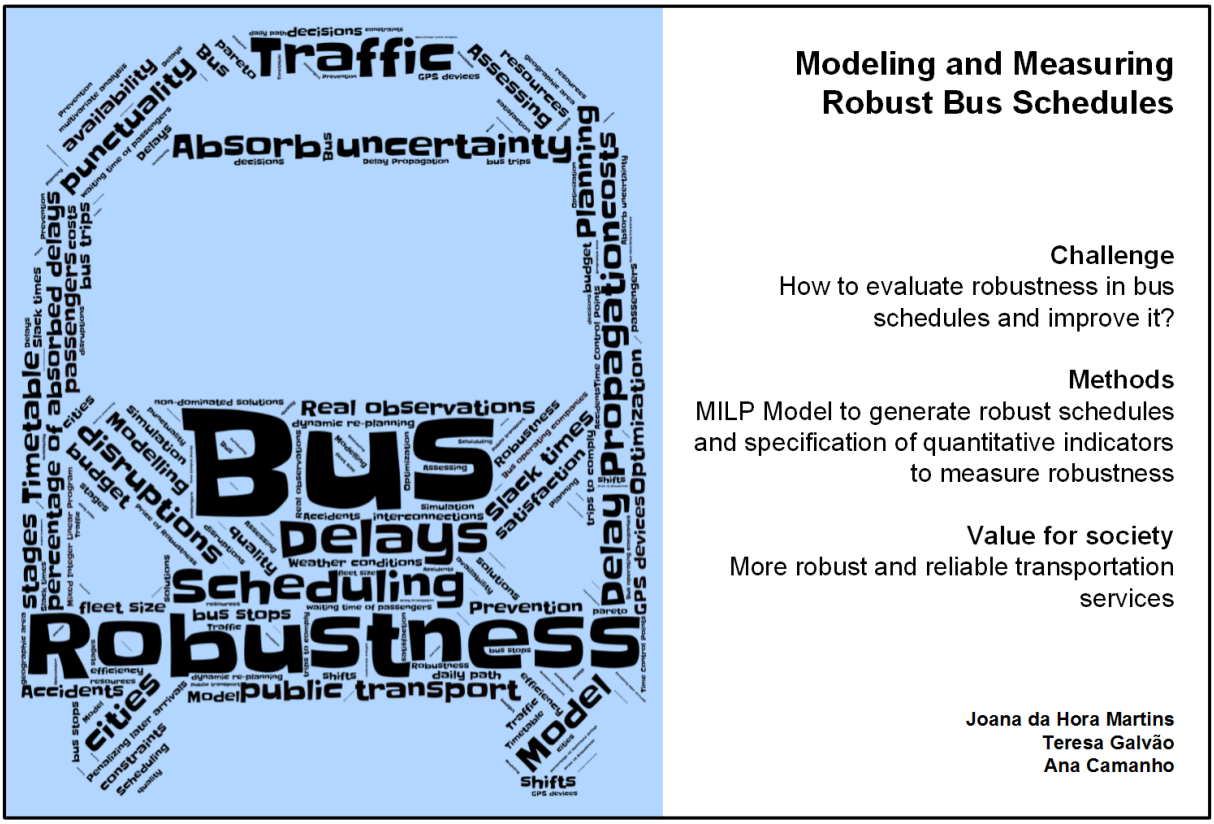

1 The Challenge

Daily operations of bus transportation systems are highly exposed to uncertainty, caused by non-foreseen events such as traffic, accidents or weather conditions.

Managing uncertainty within bus systems is a challenge. This issue can be addressed using enhanced planning tools, such as robust scheduling or dynamic re-scheduling. This work develops a method to improve the robustness of preexisting schedules for bus lines, considered separately.

Robust scheduling is a research topic widely explored concerning transportation systems by rail and airplane. However, studies regarding robust bus scheduling are still emerging, alongside with the investment on technology to retrieve on-line data from bus vehicles. Therefore, this work addresses a leading edge topic.

The robustness of a bus schedule is related to its ability to absorb delays (i.e. the solution is able to keep feasibility under disruptions). Commonly, slack times are included in bus schedules to absorb delays, thus increasing cost. The main objective of this work is to endow bus schedules with the ability to absorb uncertainty with the smallest deterioration of the preexisting schedule.

2 The Methodology

The objective of this work was pursued with the development of a Mixed Integer Linear Programming (MILP) model to optimize the allocation of slack times in a preexisting bus schedule, enhancing its ability to absorb delays with the smallest cost.

The MILP model developed allows the improvement of robustness of preexisting bus schedules. A set of real observations is used to incorporate into the model the scope of real events characterizing the system. Considering the preexisting schedule and the set of real observations, the objective function of this model pursues the minimization of variability of delays from schedule alongside with the minimization of earlier and later deviations from schedule. The model incorporates specific penalties for each minimization feature (i.e. earlier deviations, later deviations and variability from schedule). The decision variables of this model are the slack times to be further incorporated in the preexisting bus schedules. The slack times defined by the model are further incorporated into the current schedule, originating a robust schedule able to absorb uncertainty.

This work includes the development of measures to quantify the robustness of bus schedules. Two measures were considered particularly adequate to evaluate robustness: the percentage of delays absorbed by a schedule and the price of robustness (i.e. the ratio between the objective function value of the robust schedule and that of the preexisting schedule).

The model was applied to a real case study concerning the bus route 206 operating in Porto. This route operates with five coordinated shifts with non-even headways, following a non cyclic path. The model was implemented using the CPLEX solver of IBM. The data set with real observations for this case study was gathered by the Portuguese company OPT - Optimização e Planeamento de Transportes SA, with resource to GPS devices which are implanted within all buses operating in Porto. The resulting data set was further arranged to feed the model properly.

3 The value to Society

This work aims at improving the robustness of preexisting bus schedules, implemented in real transportation systems. Improving the robustness of bus schedules will endow the schedules the ability of keeping the transportation service as planned even when unforeseen events occur. The implementation of these methods in real schedules will lead to more reliable transportation services.

Acknowledgements

This work was partially supported by the Project NORTE-07-0124-FEDER-000057, funded by the North Portugal Regional Operational Programme (ON.2 - O Novo Norte), and by national funds, through the Portuguese funding agency, Fundação para a Ciência e a Tecnologia.

Supply Chain Risk Rating: Capturing the Big Picture

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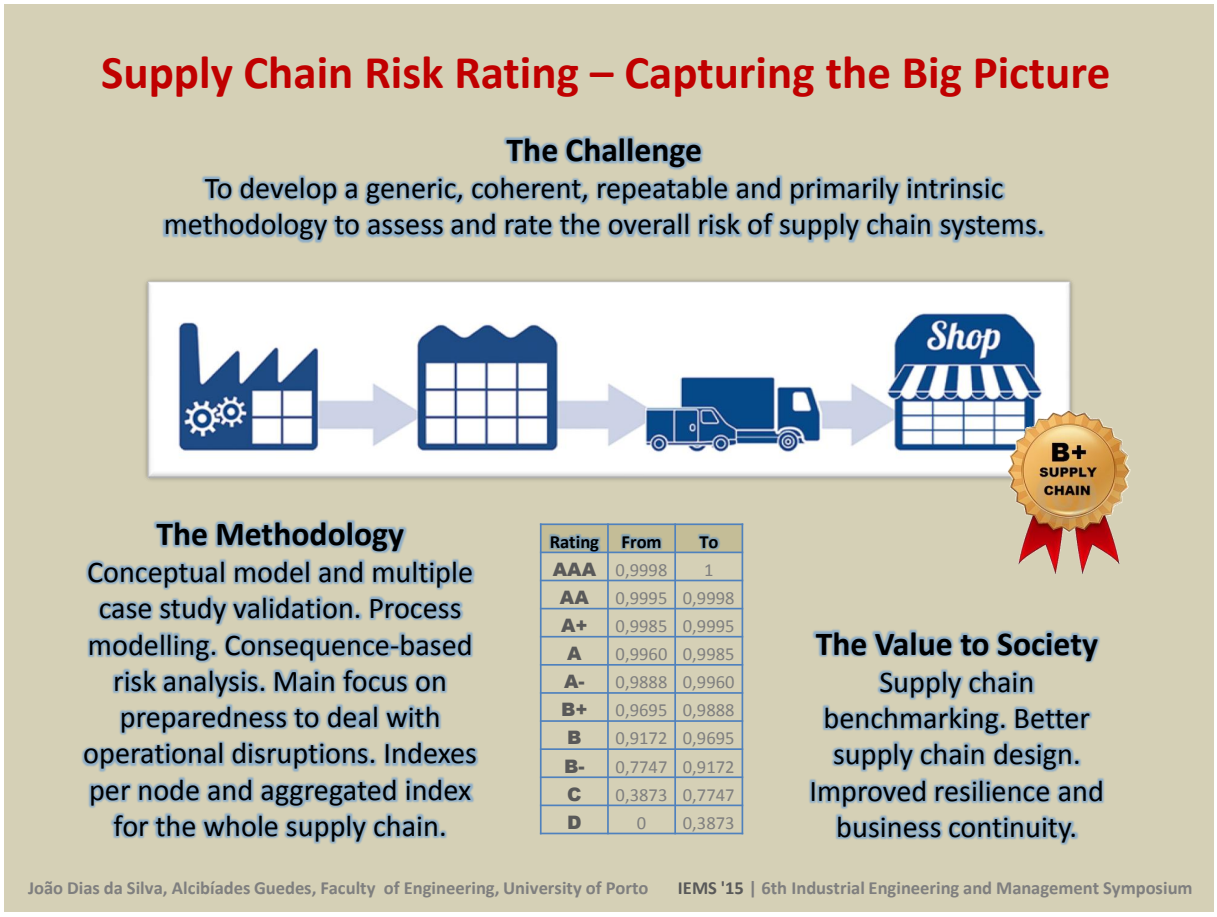

1 The Challenge

Risk management theory and practice have evolved more than ever in recent years, as a result of increased competition at global scale, terrorist events, geopolitical issues and natural disasters, as well as the establishment of totally new paradigms in the business environment, such as the so-called "VUCA World" (Volatility, Uncertainty, Complexity, Ambiguity). The design of long and complex, yet sustainable and effective, supply chains has therefore become of utmost importance, and so has the need for methods and tools that can assist in measuring and monitoring the risk level in those supply chain systems.

Numerous risk management frameworks and endless types of supply chain related risks can be found in the available scientific literature, and several business corporations have developed their own supply chain risk and resilience management methodologies along time. Most approaches are based on the standard

cyclic risk management process (identification, analysis, evaluation, treatment) and target individual risks. Some other risk assessment approaches are particularly focused on the supply side and take into account different criteria in order to determine supplier rankings, mainly as a decision making tool. Very few authors have tackled the topic of "aggregate risk" in the supply chain, as a measure or rating of the overall risk of a certain supply chain system (from upstream to downstream). Yet, the "aggregate" concept has been extensively addressed and advocated by standard enterprise risk management models, and its importance and usefulness for managers have been confirmed by several behavioural risk analysis studies. Thus, the following research questions have been formulated: (RQ1) "Which common criteria and modelling procedures should be used to assess risk in the supply chain, so as to ensure consistency among all its sections, aggregation levels and throughout time?", and (RQ2) "What are the requirements and what is the most appropriate methodology to rate the overall risk level of supply chain systems, regardless of industry and market characteristics?"

2 The Methodology

This research project is essentially exploratory and its major goal is to conceive an innovative and suitable framework for aggregated supply chain risk assessment and rating. The final model is being implemented and tested for its completeness (scope), depth (level of detail), consistency, versatility, accuracy and performance, through multiple case studies.

In response to the above research questions, we developed a generic, coherent, repeatable and primarily intrinsic methodology to assess and rate the overall risk in supply chain systems. 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" we mean that the proposed rating methodology should be stable and consistent throughout time, allowing current output to be compared with future results. Finally, by "primarily intrinsic" we mean that the proposed methodology should be fundamentally based on observed features and objective measures obtained from within the system, rather than on perceptions or estimates about risk.

It is perhaps important to note that, no matter how thoroughly most corporations are able to identify, assess and treat their main set of risks, they will usually fail to foresee some relevant type of risky event or circumstance, or, more often, they will be surprised by the actual frequency or disruptive power of some known risks. Our methodology entails a totally different and, to the best of our knowledge, innovative approach. Instead of trying to identify and rank all types of plausible risks in a supply chain system (which is obviously a useful exercise), our main focus is on the system resources and processes, and on the potential disruptions that may affect the operational flows, whatever causes them. How well is the supply chain prepared to cope with those disruptions, be them in the physical or transactional layer? Our rating should be able to give a satisfactory answer to this question.

First, the supply chain is mapped as a process network, with each process/node corresponding to a different location (production or storage facility) and including possible inbound/outbound transport sub-processes. This modelling approach is very flexible and rather frequent in business environments, especially those engaged in certification schemes. A simplified "business impact analysis" procedure is then conducted at each process/node, by determining potential impacts and required cut-off operational recovery levels, and checking the process/node for its preparedness/compliance status concerning each of the required resources involved (e.g. people/labour, facilities, equipment/machinery, vehicles and transport routes, inventory, IT infrastructure and systems, data, telecommunications, energy supplies and other utilities). Compliance indexes are computed for each SKU/node pair as a cumulative sum of exponential terms (maximum sum per node = 1) and are then aggregated through geometric means (across sections of the supply chain, i.e. upstream and/or downstream, for the same SKU) and weighted averages (within the same stage/section of the supply chain, for several SKUs or business units; business volumes are taken as the weighting factors). We also apply several adjustment factors to the section/overall results, concerning other supply chain risk related drivers such as network complexity, operational process ownership or volume concentration (of supply/demand, i.e. upstream/downstream of the focal firm).

The final index is a decimal number between 0 and 1, and the corresponding rating appears in a roughly exponential sequence of 10 levels (D corresponds to the worst performance and highest risk; AAA corre-

sponds to the best performance and lowest risk). Table 1 details the rating scale.

Table 1: Rating Scale and Corresponding Index Intervals

Rating	D	C	B-	B	B+	A-	A	A+	AA	AAA
From	0	0,3873	0,7747	0,9172	0,9695	0,9888	0,9960	0,9985	0,9995	0,9998
To	0,3873	0,7747	0,9172	0,9695	0,9888	0,9960	0,9985	0,9995	0,9998	1

This methodology has already been tested in lab supply chain samples and is about to be tested in at least two real cases, according to the initial research plan: a multinational manufacturer of electronic components and a national food retailer. This methodology has been presented, in its early stages, at the ISCRIM Research Seminar 2012 (PT), and, more recently, at the POMS 2014 Conference (US). Future research may also include the application of this methodology to service networks.

3 The value to Society

The overall assessment of supply chain risk tends to be an increasingly relevant topic, not only under the scope of standard risk management implementations, but also due to its role in strategic management activities such as supply chain design and internal/external network benchmarking. In recent years, the World Economic Forum has consistently produced the annual Global Risk Reports and has classified "Resilience" as a "21st Century Imperative". The American National Standards Institute (ANSI) and ASIS International (a global community of security practitioners) have jointly published "Supply Chain Risk Management: A Compilation of Best Practices" in March 2014, and this document has been in review by the International Standardisation Organisation (ISO) since September 2014, possibly envisioning its publication under the ISO standards scheme. ISO has also established a new Technical Committee ISO/TC 292 on the field of "Security", which is set to start operating from January 2015, whose scope includes general security management, business continuity management, supply chain security, resilience and emergency management, fraud countermeasures and controls, security services, homeland security, among others. These developments clearly show the importance of the proposed topic and, in a certain sense, help validate the approach.
The ultimate goal of this project is to build a better perception of risks in supply chains, thus helping strategic, tactical and operational decisions, adding transparency and reliability to processes, improving business continuity and fostering value creation.

The Impact and Evolution of Productivity on Modern Industrial Management

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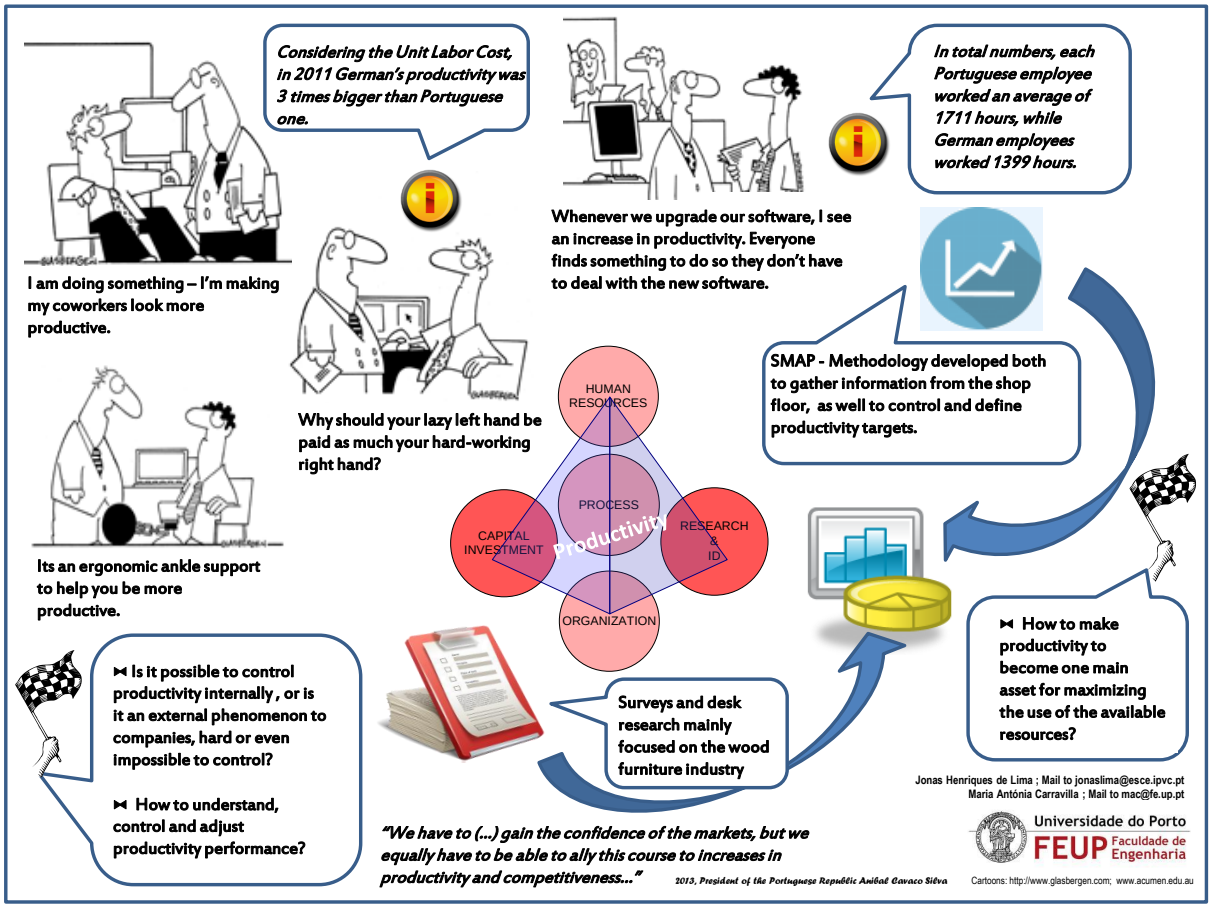

1 The Challenge

In a raw analysis on the ability to create wealth in Europe, several asymmetries amongst the countries came to light. Is productivity one of the main factors to justify those differences? Are productivity rates conditioning productive strategies (even social ones) in industrial countries for decades?

There are several quantitative definitions for productivity. Depending on the sector or type of business (industry or services), it is possible to develop a countless number of indicators with different utilities and reliabilities. Commonly associated with productivity is the Unit Labor Cost (ULC), which is the man hour cost of every produced product, or the salary investment for every worked hour. From this simple rate, we may conclude that in 2011 German's productivity was 3 times superior than Portuguese productivity, although each Portuguese employee worked an average of 1.711 hours, while German employees worked

1.399 hours. Of course, this is a perspective based on average figures, and so, neither all industries nor all companies have this very same performance.

An analysis of the evolution of productivity by activity sector may therefore provide valuable information about which sectors are contributing to the global economy by losing importance (pulling the average productivity down) or by growing (pulling it up).

Having this in mind, this dissertation intents to rise/respond to some questions, for example:

- What is the importance of productivity for the development of some economic sectors and for the general evolution of the countries?
- Is it possible to control productivity internally (by whom?), or is it a phenomenon external to companies and therefore hard or even impossible to control?
- How to understand, control and adjust the productivity performance?
- How to make productivity become one main asset for maximizing the use of the available resources?

This essay will follow a constructive approach mostly based on the research hypothesis mentioned above.

2 The Methodology

Productivity results from the interactions of the triangle worker-company-environment. It is therefore relevant to divide this influence into two areas: one related to the characteristics of the individuals, the teams and the type of work (here called internal); the other connected to exogenous, corporate and environmental factors (here called external). Some of these factors can be controlled by companies to influence the levels of productivity – generality understood as internal factors.

Other factors, concerning the environment – not under the control of the decision makers – will influence and motivate decisions that ultimately impact the process of correcting or increasing productivity. These external factors will also establish the level of success that each company achieves in implementing measures that take them to new steps of productivity.

It will be useful to quantify the weight of these two groups in specific markets and businesses. Regardless of the importance of those groups, thematic literature frequently identifies some factors as being prevalent in the productivity pyramid (here called the five vertices of productivity) (Figure 1).

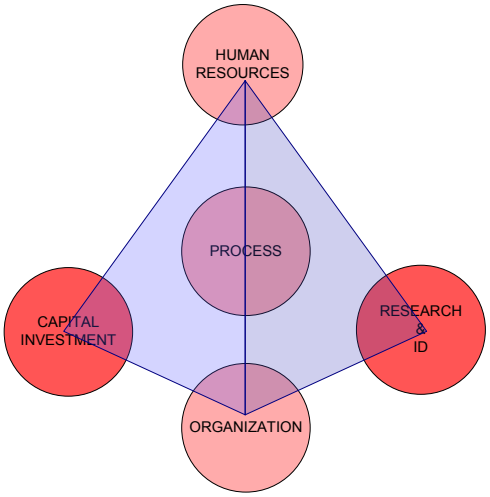

Figure 1: Understanding Productivity

This work aims to understand how the factors listed above affect productivity and, if possible, identify the type of connection (correlation or causality) between them. In order to achieve this, we will need to

design a correlational field study, where we intend to make some associational inferences and measure the relationship between productivity and several independent variables. To do so, we will use questionnaires, interviews and other data gathering techniques (depending on which type of data we are considering: management, financial, production or other) so that we can measure both qualitative and quantitative indicators, mainly applied on the Portuguese wood furniture industry. The choice of this industry results from the combination of 4 (four) characteristics that lead to a preponderant disposition and sensitivity towards productivity subjects:

- Massive dependence of human labor;
- Relevance in the national industry;
- Substantial levels of automation;
- Players presenting different rates of exportation.

We expect to build theoretical explanations and test theoretical predictions from participants' understandings and own experiences. For that, as said, we will elaborate surveys and interviews, define adjusted productivity indicators, and analyze the productivity evolution according the adjustments on other variables.

We intend to develop a pragmatic approach to monitor and increase productivity levels, a system named SMAP© (Sistema de Melhoria e Aumento de Produtividade) that will be one of the outputs of this work. This development will be preceded by a literature review to find the main conceptual frameworks and empirical studies that already exists.

3 The value to Society

One of the main motivations to improve productivity relates to the fact that current sales margins are not compatible with flaws, inefficiencies, redundancies or mistakes. The client today is not willing to pay for mistakes and inefficiencies, therefore, a way for organizations to be competitive is by increasing their efficiency and, consequentially, their productivity.

In fact, raw materials are easily obtained; Machinery (technology) is widely spread, and processes are well known. So, where can we get a really competitive advantage? The answer is in how we use the available resources, that is, on productivity. In other words, the switch from Mass Production to Order Production, the decreasing of global stock levels and the multi references diversification, promotes productivity to a crucial role for the survival of organizations in an ever more competitive system.

One of the main goals of this work is to clarify Productivity theories and concepts, highlighting their increasing importance within modern engineering and industrial management. The ambition is to clarify, systemize and develop a management tool that may not only control but positively influence the way resources are used.

Integrating management and interaction perspectives for service design - the MINDS framework

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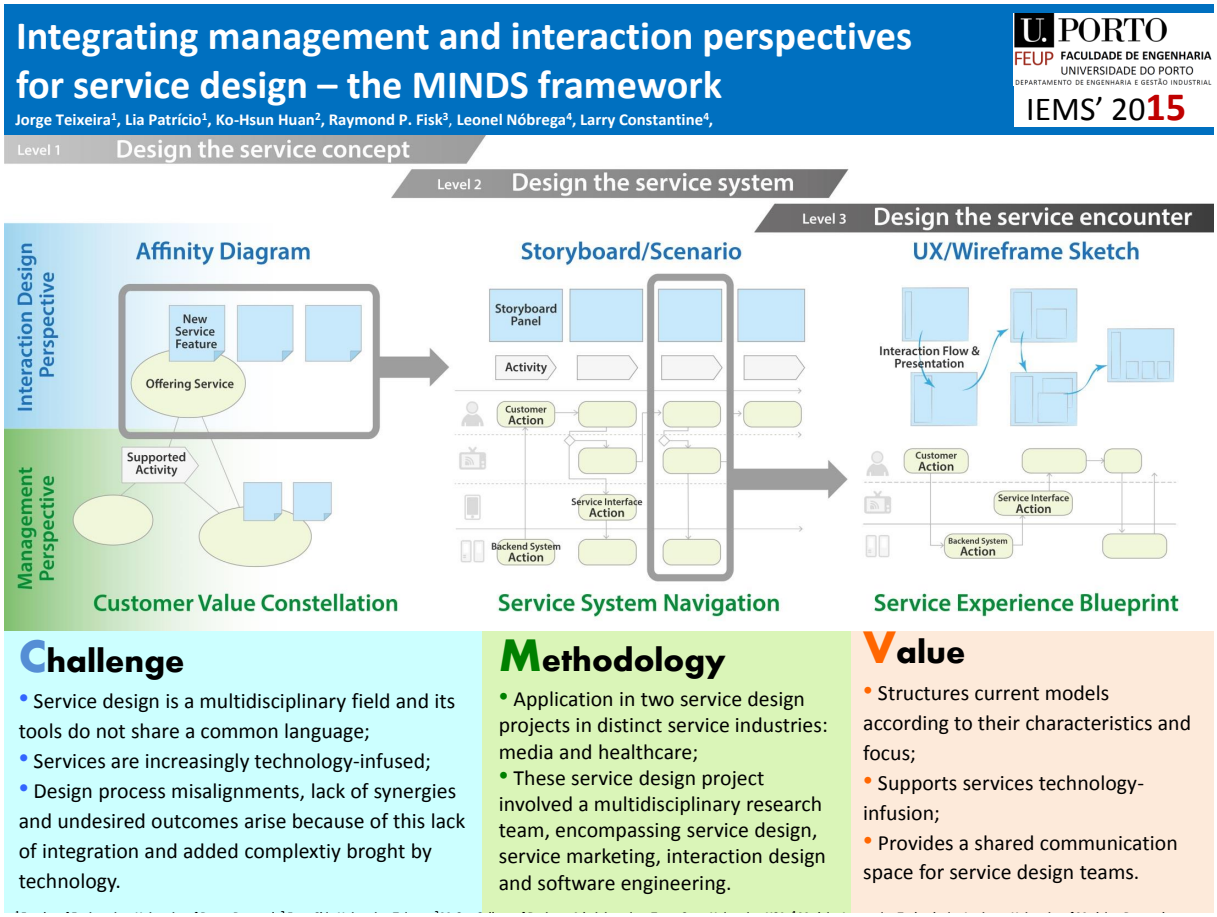

1 The Challenge

Customers now have interactive devices for every context and activity (Google, 2012) and service providers face new challenges as the Internet of Things (Atzori et al., 2010) gains traction. With this expansion of available service channels or interfaces, where a company seeks to manage a relationship with a customer (Rayport and Jaworski, 2004), customer journeys are becoming more complex and the number of potential service encounters is increasing. Technology not only brings more service interfaces, but they must be carefully orchestrated to support desired customer experiences (Berry et al., 2002). Haphazard deployment of new technologies in a service setting can do more harm than good (Bitner et al., 2000; Burke, 2002; Rayport and Jaworski, 2004).

To meet this accelerated rate of technology-infusion, service design has added interdisciplinary capabilities in technology-oriented fields, primarily by building bridges with interaction design (Forlizzi, 2010; Holmlid, 2007, 2009; Miettinen et al., 2012; Sangiorgi, 2009). Interaction design focuses on understanding human engagement with digital technology and designing more useful and pleasing technology artifacts (Kaptelinin and Nardi, 2006). This led to the emergence of an interaction perspective in service design (Sangiorgi, 2009), which focused on the contributions from interaction design to create the visual appearance and navigation of technology-enabled service interfaces. Still, service design is multidisciplinary and brings together expertise from different fields (Moritz, 2005) including services marketing, operations management and information systems (Patrício and Fisk, 2013). These have their own way of approaching service design and can be conceptualized under a distinct perspective, a management-oriented one. This management perspective builds on service marketing, service operations, and strategic management. It also has a stronger focus on the business concerns of the service provider. The management perspective deals with the service value proposition and service delivery process, including the backstage and frontstage orchestration. Since management and interaction design approaches emerged from different disciplines, they do not share the same language and tools, which may lead to communication problems within design teams. These problems result in design process misalignments, lack of synergies, and undesired outcomes, because decisions taken by management and interaction design are interdependent (Gorb and Dumas, 1987; Tether, 2008). For example, it avoids the design of a login process with process-oriented management models that only later is discovered not to conform with specific interface interaction design guidelines. To address the challenges posed by technology-enabled service interfaces and to integrate service design management and interaction perspectives, we present the Management and INteraction Design for Services (MINDS) framework.

2 The Methodology

The development of the MINDS framework followed a design research methodology (Buchanan, 2001; Hevner et al., 2004; March and Smith, 1995; Peffers et al., 2007). Design research can be seen as a problem solving process (Hevner et al., 2004), and design scientists strive to create artifacts, i.e. constructs, models, methods, and implementations that are innovative and valuable (March and Smith, 1995). MINDS is an interdisciplinary framework comprising a set of combined models that provide a shared language and process to integrate and bridge the work of service designers from both management and interaction design perspectives. MINDS is structured according to three levels of service design; service concept, the service system and each service encounter (Patrício et al., 2011). To design the service concept MINDS bridged customer value constellation, to depict existing and new service offerings and concepts, and affinity diagrams to explore and prioritize service features for each new service concept. At the service system level MINDS combined service system navigation to structure the design of technology-enabled multi-interface services, with storyboards to describe and visually depict the desired customer journeys. Finally, at the service encounter level, MINDS combines service experience blueprints, to depict the service deliver process in a multi-interface context, with interaction sketches, to depict the technology-enabled service interfaces.

The MINDS framework was conceptualized, developed and improved as part of two service design research projects, undertaken in collaboration with service providers from healthcare and media industries. These projects provided rich settings for MINDS development and validation, as they involved multidisciplinary teams engaged in a full-fledged service design effort, since initial customer analysis to functional prototyping, or deployment, of new services. The scope of both projects required experts in service marketing, service design, interaction design, software architecture and software engineering to collaborate and share knowledge. Both projects took place in service industries with intensive technology-infusion and aimed at create innovative multi-interface services. MINDS framework enabled the design team to deal with the multidisciplinary and technology-enabled nature of these projects. Also, these applications of MINDS in two different service industries, media and healthcare, bode well for the framework applicability in other service settings.

MINDS was first applied in a three-year project involving the design of new and improved services for a multimedia group that provides cable TV, internet, mobile phone, landline phone and other associated services. Following a design-science research approach, the project involved a qualitative study with 17 in-depth interviews with residential customers. This study enabled an in-depth understanding of the

customer experience and enabled the identification of opportunities for developing new services. In the end, the team delivered a fully functional, cross-platform and multi-device prototype that was subjected to two rounds of user testing for further improvement.

The second research project focused on supporting skin cancer patients in their follow-up routines, while facilitating the process of sharing medical information with dermatologists. In this project the service design team had a broader set of stakeholders (partner company, partner research institution, patients, dermatologists and primary care physicians) with whom communication was essential. MINDS models were used to involve stakeholders, share findings and validate concepts along the design process. This project involved 8 in-depth interviews with dermatologists in a private practice, a general hospital and a cancer hospital and 12 in-depth interviews with skin cancer patients, and patients at a screening facility, prior to any diagnosis. With the support of MINDS a smartphone application for patients was developed, enabling them to take more accurate pictures and manage historical records of their moles, while making them available for their dermatologists through a web portal. These pictures could also be shared with other physicians through the country' s national electronic health record. Reminders and notifications were also implemented.

3 The value to Society

The MINDS framework represents an effort towards the evolution of service design as an interdisciplinary field, through integration of management and interaction design perspectives. MINDS adds to current research on service design models (Alves and Nunes, 2013; Diana et al., 2009; Miettinen, 2009; Segelstrom and Holmlid, 2009, 2011; Stickdorn et al., 2011) and answers to research priorities (Ostrom et al., 2010) by conceptualizing and integrating two perspectives: (1) the interaction perspective, grounded in interaction design; and (2) the management perspective grounded in service marketing, operations management and strategic management. This conceptualization helps service designers with different backgrounds to position their perspectives and models, thus taking advantage of their complementarities. Through the MINDS framework, elements of the service design team with management and interaction design backgrounds can work on their reference models, taking advantage of their specific strengths, but can also better understand how the different models and design decisions are interconnected.

The application of the MINDS framework to two service design research projects showed that our approach: guides service designers through the rich maze of models and techniques, from distinct perspectives, and through the different service design levels; supports the design of multiple technology-infused service interfaces, portraying their interactions and contributing for a coherent customer experience; establishes a common ground for communication and a shared view between service design team elements; and supports stakeholder involvement through rapid and low-fidelity prototyping.

Managing misalignments in the implementation of a health screening program

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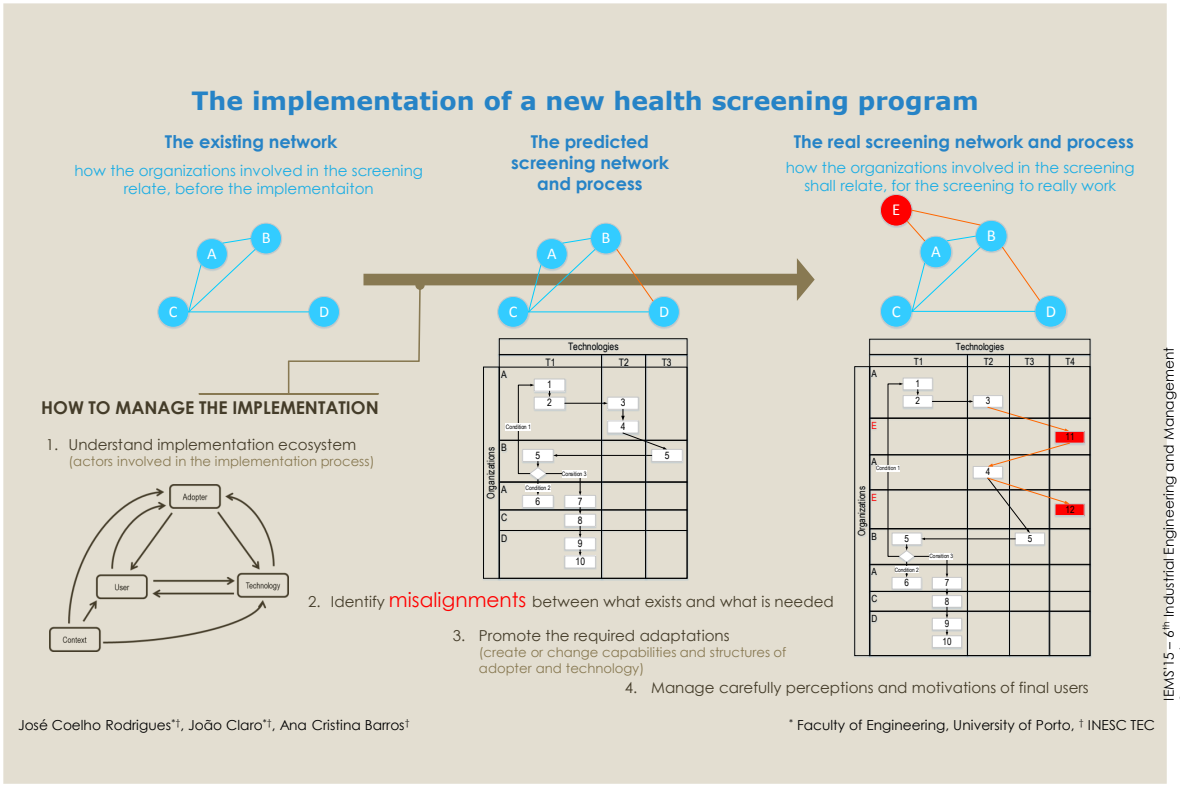

1 The Challenge

Misalignments between innovations and adopters are a major cause of productivity losses in early stages of implementation projects. Their management is particularly challenging when the adopter is a network of organizations, instead of a single organization, a setting that is becoming increasingly important as a key organizational structure in many industries, such as healthcare. This work uses multiple case studies to examine implementations of technological innovations in networks of preventive healthcare in Portugal. We aim at adding to the body of knowledge of an important, yet understudied, topic in technology management, and providing guidelines to help managers achieve higher levels of performance in implementation projects.

The full realization of the potential of technological innovations requires an understanding of how they diffuse and are adopted, either by individuals, by organizations, or by networks of organizations. For

organizations and networks, a successful assimilation of the innovation depends critically on the implementation process, i.e., the activities between the adoption decision and the incorporation of the innovation in the adopter's routines, or its abandonment.

The focus of our study is the management of one of the major challenges faced by implementation managers: overcoming the misalignments between the technology being adopted and the organization or the network where it is being implemented.

It is well established in the literature that misalignments result from a lack of compatibility between innovations and adopters, and emerge dynamically and unpredictably during implementations. Misalignments can be divided in two categories: technical and structural. Technical misalignments are incompatibilities between the capabilities of the adopter and the capabilities required to use the technology. Structural misalignments are incompatibilities between the structure of the technology and the structure of the adopter.

Misalignments might be reduced by changes in the technology or in the adopter, through mutual adaptation cycles. Both types of change may be initiated by implementation managers, aiming at reducing the negative impacts and augmenting the positive impacts of misalignments in the performance of the adopter and in outcome of the implementation. This mutual adaptation process is very difficult to plan and has largely unpredictable outcomes.

Research on misalignments between technological innovations and adopters, in the context of implementations in networks of organizations, is scarce. Networks of organizations are usually complex scenarios, featuring organizations with independent power structures but mutual dependence, as they jointly seek to provide a product or service. The management of implementations, and misalignments in particular, in networks of organizations becomes far more challenging than in other loci of adoption, due to the fact that many implementation decisions will have to be orchestrated between multiple organizations, and the fact that the dynamics of network evolution depend not only on each individual organization, but also on their mutual alignment, and network management practices (decisions and actions).

The goal of this research is to study implementations of technological innovations in networks of preventive healthcare organizations. By carrying out this study we aim at developing an overall understanding of the dynamics and influences that take place in innovation implementation processes in the context of networks of organizations. For this purpose, we are working with Administração Regional de Saúde do Norte (ARSN) on a set of implementation projects of a health screening program, in several locations in the North of Portugal. Misalignments, and related management actions, are being studied in depth through multiple case studies of these implementations.

The goal of each implementation project is to reach all the population that needs to be screened in its assigned geographic area. The screening program is specified through a very well defined screening process to be followed at each location, and is supported by specific equipment to perform a medical exam, and software to support the exchange of information. It involves several healthcare providers (primary care units – PCU – and hospitals – H) and ARSN (the coordinator of the screening program) as networks of the adopters. We study how the implementation processes unfold in each network of organizations, to identify the misalignments between the network and the technology (screening process, machine, and software), the main challenges resulting from those misalignments, and how the implementation is being managed, namely to overcome them.

2 The Methodology

We selected cases of implementations of technological innovations in preventive care, to be included in an embedded multiple case design, representing different network structures, and implementation outcomes. The case studies focus on the implementation process, the implementation management practices used throughout the process, and the implementation outcome. In our multiple case design, the unit of analysis is an implementation of a health screening program in a network of healthcare providers. A total of eight implementations were studied.

Case studies provide a suitable research design for examining and clarifying the type of complex processes that we address. They allow collecting data in greater depth, and thus are appropriate for the large number of actors and factors involved in implementation processes, as well as the large uncertainty regarding which are critical. We focus on projects that have taken place over close time frames, to be able to collect data in close time periods, and use grounded theory-building methods for data collection and analysis.

For each case, we conduct multiple semi-structured interviews to obtain different perspectives and cross-check responses about factual issues. Interviews are based on a protocol structured after familiarization with the technologies and network operations of each case. They are recorded to achieve a higher level of accuracy. Data collected are transcribed immediately after the interview using analysis software. Based on an initial evaluation of those data and the contributions that they provide for the study, we improved the protocol for the following interviews. Interviews are coded using descriptive coding for a deeper analysis of their content, and a summary report for each case is produced and reviewed by peer researchers and key informants. Interview data are analyzed using pattern matching, and a construct database is built.

A cross-case synthesis allows the identification of implementation management practices that might differentiate (more) successful implementations.

3 The Value to Society

We have carried out and transcribed close to 50 interviews, and collected documents about the technology, its use, and its implementation plans. We are completing the coding of interviews and documents, while at the same time building the construct database. The following step of cross-case synthesis will allow us to derive and provide guidelines to help managers achieve higher levels of performance in implementation projects such as these.

The final results will include technological, managerial and policy insights regarding implementations of technological innovations in networks of healthcare organizations. They will be particularly useful for implementation managers leading future implementations of similar technologies in preventive care networks. We expect the insights from this work to assist managers in improving the assessment of alignment problems in implementations, and overcoming misalignments better and faster, avoiding situations of strong resistance to the efforts to routinize the technology, and long suspensions of the project.

Flexible and Reconfigurable Layouts in Complex Manufacturing Systems

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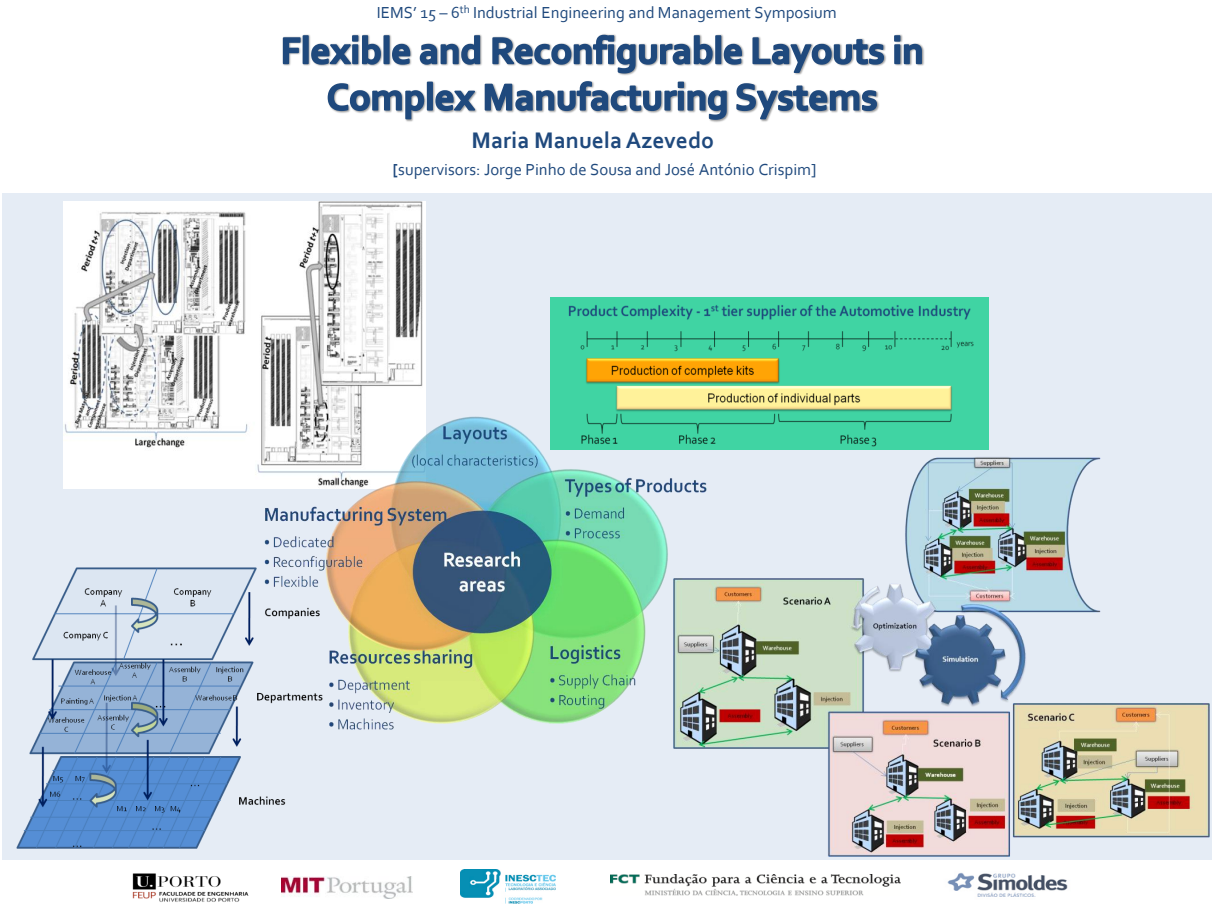

1 The Challenge

In a world with increasing uncertainty and accelerated changes, companies need advanced and innovative tools to quickly and efficiently respond to emerging and unexpected requirements. This is particularly critical with SMEs (Small and Medium Enterprises) as they are very vulnerable to changes in normal business environments. In fact, given the high variety of products manufactured simultaneously and the ever decreasing lifetime of these products, the need for adjustments in the layout of the companies also grows proportionally. Quite often machines are large and difficult to move, and therefore most of the times these changes are not performed or they are continually postponed. Frequently, new machines are located in unplanned places, creating difficult material flows, and thus decreasing efficiency.

The Facility Layout Problem (FLP) has been extensively studied. However, the existing works focus only

on locations of production departments, or warehouses layout, or machine location, but not all of them at the same time. As far as we are aware, there are no studies focusing on layout design involving all departments, resources (e.g., machines) and flows of a facility in an integrated approach.

This work aims at creating a decision support framework capable of analyzing and assessing different strategies and solutions in what concerns the reconfiguration of facilities. To design this approach we have taken into account a set of general requirements directly derived from the real problematic situations of a case study: a first tier supplier of the automotive industry. In our real-world case study, at Simoldes Plásticos Group, there is a set of geographically separated facilities (3 factories with 3 warehouses and other production departments) that can each produce and store the same type of products and components. Each facility has more or less the same department structure, with the same type of equipment and machines. These facilities are served by a distribution system with trucks to move the raw materials, components and/or products between them. Currently, each facility has warehouses that store the same raw materials, components and products since the production process is common to the factories.

Our model supports the design and re-configuration of flexible layouts at different levels, strategic and operational, reflected in large and small changes (see figure 1). At the strategic level scenarios are identified and tested (e.g., separate production and warehouse infrastructures). At the operational level layout corrections and readjustments are identified and tested (e.g., materials flows).

2 The Methodology

This research considers a complex manufacturing system involving multiple facilities, complex products, and layout reconfiguration constraints. Thus, the problem consists in finding the best physical organization of facilities (departments, machines, workstations, warehouses, etc) and the best flows of products and raw materials, fostering flexible and efficient operations. The problem was modeled as a mixed-integer program (MIP), based on a Facility Layout Problem (FLP) model, with multiple objectives (minimize cost, maximize flexibility, ...) with unequal areas.

The proposed approach is based on the combination of two sub-models: the first defines the relative position of the departments inside the various facilities, and the second determines the detailed layout, with the definition of machine positions (inside departments) and the associated physical flows.

Our model allows for two re-configuration types: small and large changes (see figure 1 for an example). Large changes are required when departments need to be moved from one facility to another or change their position in the same facility, possibly as a result of the arrival of new projects. Small changes are more frequent and consist of reconfigurations inside a department by adding/dropping machines, or by redirecting the flows of materials and products in progress.

3 The value to Society

This project aims at creating a useful tool to support the design and re-configuration of flexible layouts, allowing more efficient operations, in rather dynamic environments. Our integrated approach contributes to narrow the literature gap identified concerning the lack of an integrated approach that includes layout design at different levels and material flows.

In particular for the industrial partner, Simoldes Plásticos Group, our approach should help the decision maker decide if a reconfiguration is needed and suggest what kind of reconfigurations should be made. These reconfigurations could be simple or large rearrangements, maybe involving one or more facilities of the company. These rearrangements differ in the deepness and frequency of the modification.

Given the complexity of the problem under analysis and the set of potentially interesting requirements, this approach allows the analysis of different scenarios, such as the centralization of warehouses in one facility, or the production of each product in a specific factory. The results of this type of analysis will

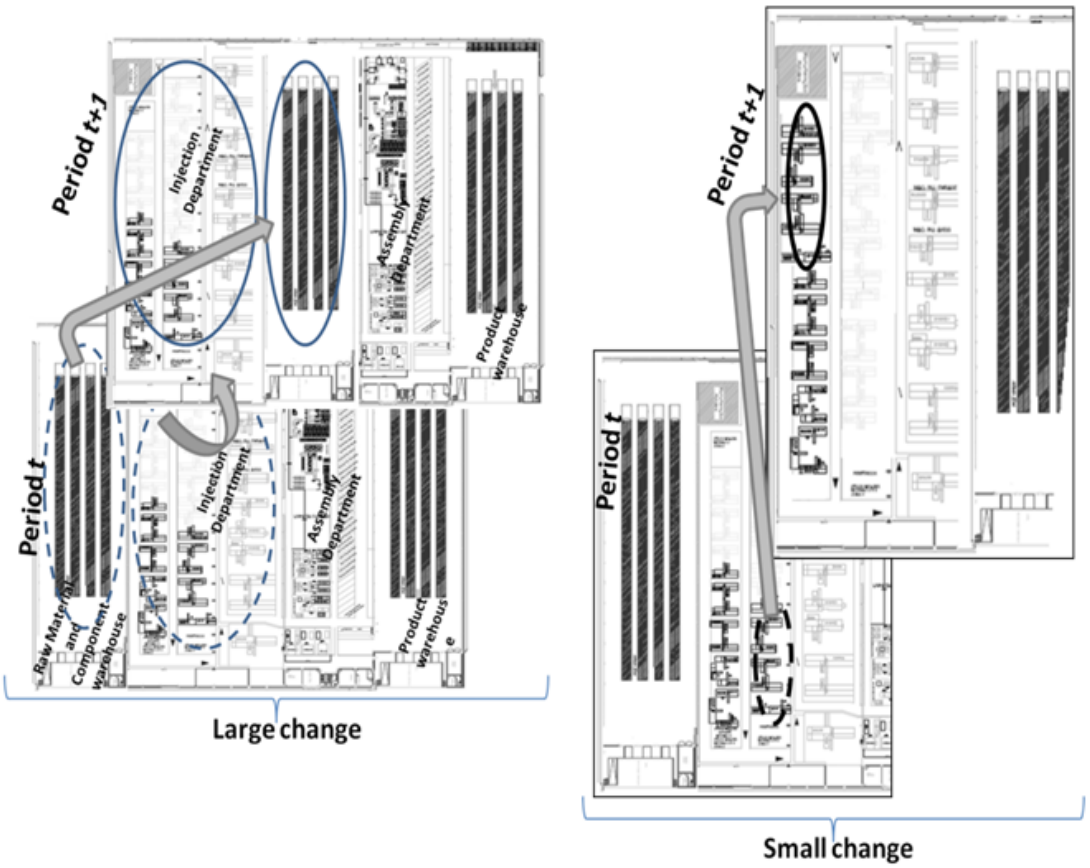

Figure 1: Example of Large and Small changes in a layout.

hopefully lead to interesting, valuable guidelines for supporting strategic / tactical decision-making.

Acknowledments

The authors acknowledge the financial support from FCT, the Portuguese Foundation for Science and Technology (under grant SFRH/BD/33731/2009) and from the MIT Portugal Program. This research is partially supported by project "NORTE-07-0124-FEDER-000057" financed by the North Portugal Regional Operational Programme (ON.2 / O Novo Norte), under the National Strategic Reference Framework (NSRF), through the European Regional Development Fund (ERDF), and by national funds (FCT).

Effective design of backroom storage facilities in retail food stores

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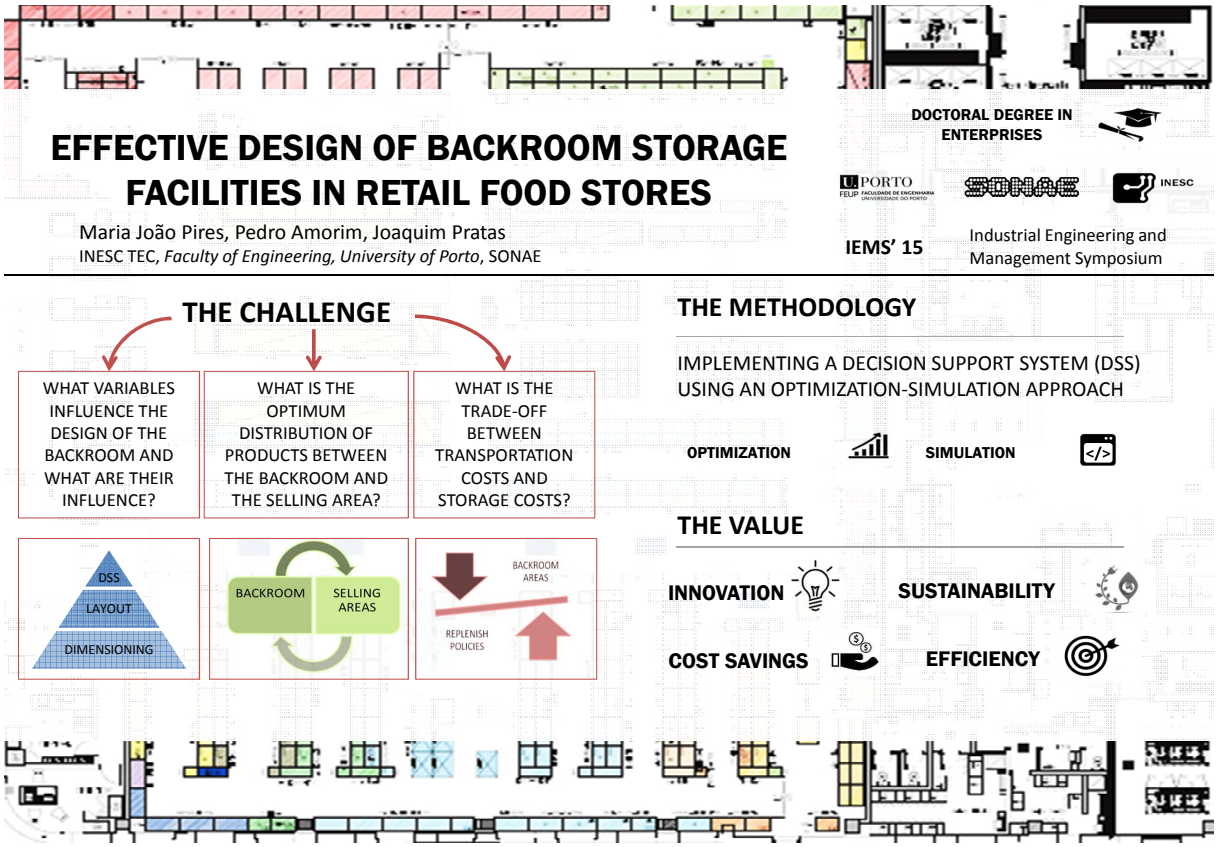

1 The Challenge

Nowadays, backroom storage in retail food stores is crucial to act as a buffer against strong demand lifts yielded by an ever increasing promotional activity and to accommodate e-commerce activities. An example of a layout is presented in Figure 1.

Despite having similar functions to a distribution warehouse, backroom storage facilities have particularities that deserve a distinct analysis. These facilities have to coexist with the selling area, which competes for the same space, and account for the shelf replenishment process. This work fills a gap in the existing literature as most of the research has focused solely on distribution warehouses. The main objective of this project is to investigate the peculiarities of backroom storage facilities in retail food stores, as well as to formulate quantitative models that define their design and sizing. We expect through this research, to help answer:

- What are the main departments of the backroom facilities in a food retail store and which factors

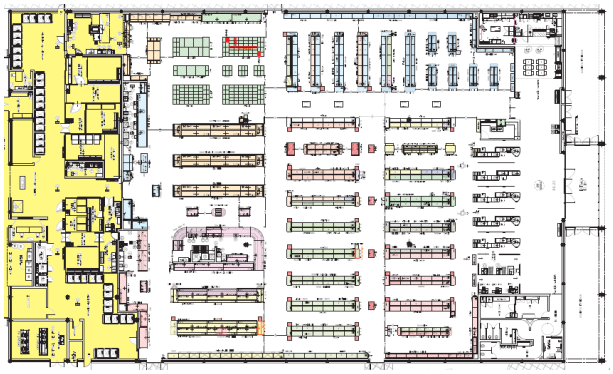

Figure 1: Example of a store layout

influence their dimension;

- What is the optimal design of the backroom storage facility that allows better performances of the store and better replenishment of products on the shelves and other indicators;
- What is the expected reduction in stock-outs and spoiled products by using a systematic approach for backroom storage design;
- Which products really need to be stored in the backroom storage and why;
- What is the relation between backroom facilities and e-commerce operations;
- Is an integrated approach more suited than a hierarchical one;
- What are the advantages, disadvantages and suitability of an optimization-simulation approach for backroom storage design.

2 The Methodology

The main problems in retail food stores are related to constructional defects, inappropriate architecture, store design and nonexistence of standardized guidelines for backroom storage facilities. This work aims to tackle exactly this last issue by proposing an integrated model for the design of backroom storage in retail food stores that integrates both optimization and simulation. We intend to study leading European grocery retailers and give new insights into current literature by formulating innovative optimization-simulation models that will build on case-study analyses and surveys to be performed. Performance models of in-store logistics will also be incorporated to provide feedback on the quality of the proposed design. This effective design will seek for the most efficient, flexible and robust flow of products in the shortest space and the lowest possible cost. In the existing research of warehouse design there are frequently used analytic models, which are more design-oriented, and simulation models, that are more analysis-oriented. However, there is an important need to integrate both approaches to achieve more flexibility in designing and analyzing warehouse problems. In the present work, the hybridization of optimization and simulation is proposed. Therefore, we pretend to build an integrated model with three phases: dimensioning the warehouse areas, design the warehouse layout and finally create a decision support system.

Further notice that there is a significant gap between research and practice in warehouse design and operations, which indicates that cross-fertilization between the groups of practitioners and researchers appears to be very limited. This gap is also filled with the present project as real-world data and practical concerns will drive the theoretical developments. Moreover, the models and methods proposed will serve as the basis of a decision support system.

3 The value to Society

With this project we expect to achieve cost savings in the construction of the warehouse as well as in operational and maintenance activities of the backroom storage facilities. Other objective is to attain greater space occupation and to minimize the distances traveled by the employees between the store and backroom which would reduce work accidents. We also aim to achieve better store performances as well as in-store logistics, which would result in reduced stock-outs and obsolescence. Overall, this project will improve backroom storage in retail food stores and potentially in other type of retailers with similar requirements. This research will be done in association with Sonae and it also aims to create value for the company, so they can design their stores for the different insignias in an efficient, standardized and profitable manner.

Assessing and planning for the future needs of the healthcare workforce

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1 The Challenge

Healthcare human resource (HHR) planning has been identified as the most critical constraint in achieving the well-being targets set forth in the United Nations' Millennium Development Goals. Moreover, the effective use and deployment of personnel is critical to ensure efficient service delivery in terms of cost, quality and quantity. Failure to do so may result in an oversupply or shortage of clinical staff. While the former may lead to economic inefficiencies and misallocated resources under the guise of unemployment or inflated costs through supplier-induced demand, the latter is linked to a more extensive list of negative effects, including but not limited to: lower quantity and quality of medical care as few resources exist to provide the necessary services and the visits are shorter; work overload of the available physicians and nurses, resulting in sleep-deprived professionals, ultimately compromising patient safety; and queues and waiting lists resulting from insufficient medical staff, causing avoidable patient deaths.

But planning the healthcare workforce required to attend to the health needs of the population while providing service levels that maximize the outcome and minimize the financial costs is a complex task. The problem can be stated as assessing the right number of people with the right skills in the right place at the right time to provide the right services to the right people. The literature available on the subject is vast but sparse, with no consensus established on a definite methodology and technique, making it hard for the analyst or policy maker to adopt the recent developments, or for the academic researcher to improve such a critical field.

In sharp contrast to other scientific areas where a set of well-defined methodologies and techniques is generally adopted and refined to solve a given problem, in HHR planning *methodologies* (the conceptual scope of analysis) and *approaches* (the technical apparatus applied upon a particular method) abound, with still no commonly-accepted or favoured procedure to accurately forecast workforce requirements. Methodologies found in the literature are loosely based on either supply-based approaches, demand-based approaches, or a combination of both. Supply-based studies construct their research on the estimation of the expected supply of medical workforce by accounting for the intakes, drop outs (mortality, retirement, etc.) and migration flows in order to maintain the present ratio of practitioners, using 'stock-and-flow' models for that purpose, and this analysis can also be complemented with other factors affecting the efficiency and effectiveness of the care services delivered, namely the *productivity* or the *skill mix* of the workforce. Demand-based studies, on the other hand, focus on the external factors that may drive people to require healthcare services. Like in any other market, the determinants of aggregate demand are demography, income and preferences. Moreover, for countries where medical care is mostly an out-of-pocket expenditure, demand is restricted by the patients' ability to pay. If a patient requires medical attention and is unable to finance it, this *need* for health care will not translate into *effective* demand, despite its existence. Studies usually target one of these two possible ways of looking into demand: either by quantifying the current, effective demand, measured in terms of utilisation rates and projecting these base values according to the evolution of the demand drivers; or by assessing the epidemiological needs of the population, or potential demand, measured through morbidity and mortality rates as well as other health disease trends.

In short, the main objectives of this research project are: i) review the literature in search for the a comprehensive and robust approach to HHR planning; ii) assess and evaluate current imbalances in the healthcare sector; iii) develop a quantitative model to forecast the future needs of the healthcare workforce, incorporating the identified gaps; iv) conceive a policy-oriented framework, running on top of the quantitative model, to produce different policy scenarios and key performance indicators for each scenario.

2 The Methodology

We want to contribute to this research field in several ways, in the end providing a model for accurate and reliable HHR planning, and a policy-oriented framework for improved guidance.

First, we review the literature by conducting a meta-research analysis on how the field evolved, track which methodologies have been used and are still in use to this day. Based on this knowledge, we propose an approach for tackling such a complex problem. Our results so far indicate that a reliable HHR forecast requires a comprehensive approach to the problem, integrating both supply- and demand-based dimensions. Considering the results obtained in the meta-research, we propose the following functional model (Figure 1).

Second, develop a methodology and a set of key indicators to help in assessing and evaluating current imbalances in the medical workforce, thus pinpointing potential gaps (shortages or surpluses) in the system. Such analysis is critical to calibrate any model to be developed in the future. Otherwise, if present gaps are ignored, future projections may propagate this initial offset. This critical step will be validated resorting to a Delphi panel of experts.

Third, develop an integrated model combining both a supply- and demand-based approach. Simulation will be used given the large number of variables and the highly complex non-linearities of the system. It will include both a representation of the training processes with a focus on productivity and the skill mix, as well as projections for the future demand based on the role played by epidemiology and the evolution

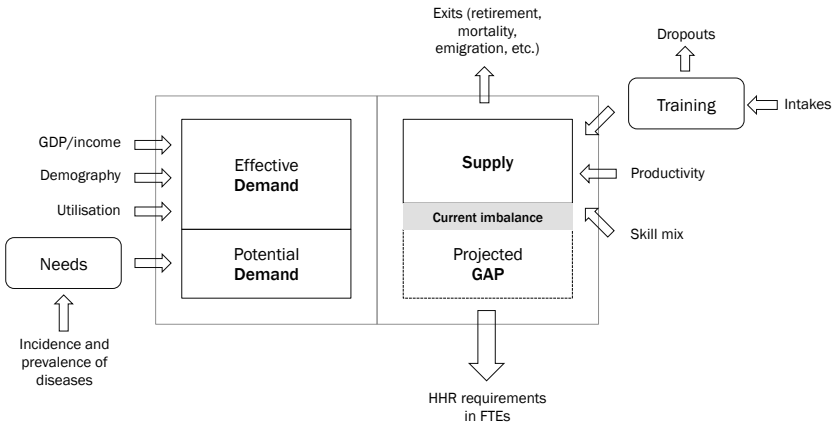

Figure 1: A functional diagram depicting an integrated model for HHR planning.

of demography. This model will be used to conduct HHR planning in the Portuguese healthcare system, and will be validated by through backward projections (i.e., forecasting from sometime in the past).

Fourth, from the results obtained with the simulation model, more specifically how supply and demand evolve and the resulting gap, if any, we will devise a linear programming model to assist in controlling the increases and decreases in the vacancies for medical school necessary to narrow the projected gap. This way, policy makers can minimize the variance for the whole horizon (smoothing) and the risk of potential disruptions that could arise from exceeding capacity limits in education schools.

Finally, the quantitative model will feed a policy-oriented framework to be developed in order to assist policy makers and other public stakeholders in planning their HHR workforce.

3 The value to Society

Benefits are severalfold. From an economic perspective, the efficient use and allocation of resources is, per se, a considerable welfare benefit. By avoiding shortages, we also avoid a potentially abnormal surge in labour wages that increase healthcare service costs, paid either directly by the patient or through the public budget, paid by the taxpayer. By avoiding surpluses, we escape potential unemployment and/or a downward pressure on wages in the healthcare sector or any other markets, as unemployed labour will try to find work elsewhere, generating negative externalities in other sectors as well. Finally, and perhaps most significantly, by avoiding shortages of medical staff we are preventing some of the unintended consequences aforementioned, namely lower quantity and quality of medical care and sleep-deprived professionals, therefore avoiding potential human losses.

A multiservice approach based on mobile technologies to foster the use of public transport

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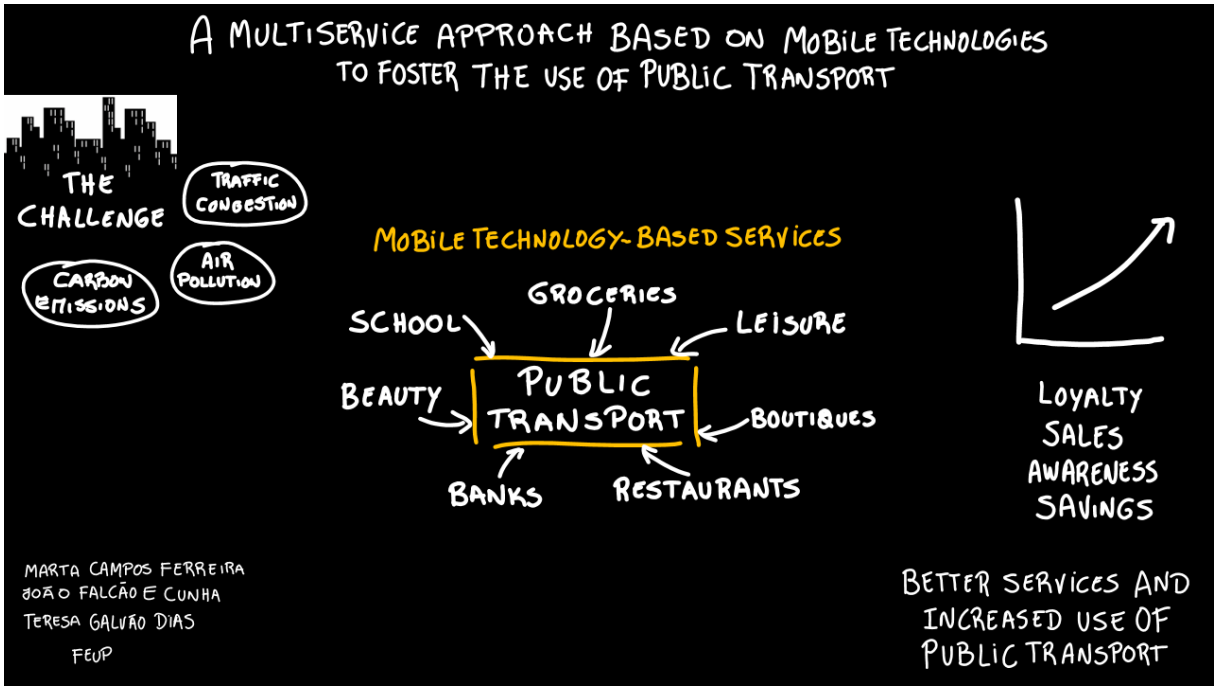

1 The Challenge

Public transport plays an important role in decreasing traffic congestion, reducing carbon emissions, and promoting a sustainable mobility. Despite the significant benefits of using public transport means, many commuters are reluctant to make the switch. New technologies are key to improve the public transport service, reduce the barriers of travelling with sustainable transport means and thus increase the use of public transport.

Several mobile-based service solutions have been studied and developed in order to simplify the way of travelling and using public transport. Most of them are focused on services related with the trip itself, such as mobile ticketing, real-time traffic information and timetables, and interactive journey planners. However, the transport system must be considered holistically and in context. Every trip has a purpose, such as work, school, recreation, social, and this requires a multiservice approach.

The conceptual model of this multiservice approach is based on mobile technologies, which are a unique channel of interaction between service providers and customers, and connects city services (e.g. restaurants, boutiques, groceries, banks) with public transport. This multiservice approach represents a step towards a sustainable and seamless mobility.

2 The Methodology

In order to explore new and complementary ideas to foster the use of public transport, we created a Facebook group to discuss these ideas. The participants were recruited and selected by the major Public Transport Operator in the city of Porto, who solicited participation through their website and information inside the vehicles. In order to get as much heterogeneity in terms of various demographic factors (gender, age, occupation), 37 travellers were selected, from which 26 participated in the discussions. We also organized face-to-face meetings and focus group sessions with potential and regular customers, Public Transport Operators from the city of Porto and companies connected to local businesses of the city.

When asked about what would propel them to use public transport more often, several suggestions emerged. Nevertheless, the most discussed and supported idea by the users was to establish partnerships with other service providers like museums, restaurants and cinemas, and reward the use of public transport. These partnerships may include discounts, combined packages, reduced prices, deals, marketing campaigns and others.

New technologies are essential to make these initiatives more effective and targeted. For example, services made available through personal mobile devices allow companies to interact directly with their customers and customize the offer. Service providers acquire knowledge about their customers, through their mobility profiles and consuming habits, and are able to target their offerings to a specific audience. It is also important to measure the effectiveness and efficiency of the campaign to improve future service offerings. Currently, if Public Transport Operators want to partnership with other service providers, it is difficult to direct marketing and communication efforts and is even more difficult to measure the impact of the initiative.

This multiservice approach is represented in Figure 1 through a conceptual model. The objective is to encourage people to use cleaner transport modes during their daily commute. This can be achieved through different ways, but here we present a holistic approach, where different city services (cinemas, restaurants, museums, hairdressers, gyms) partnership with Public Transport Operators to target service offerings to a specific segment. Through new technologies these initiatives can be easily measured in terms of awareness, engagement, sales and loyalty, which is essential to improve future initiatives. The conceptual model of the multiservice approach can be divided in four steps: 1) analyse mobility profiles and interests; 2) target and deliver service offerings; 3) measure the efficiency and effectiveness of the campaign; and 4) improve future service offerings.

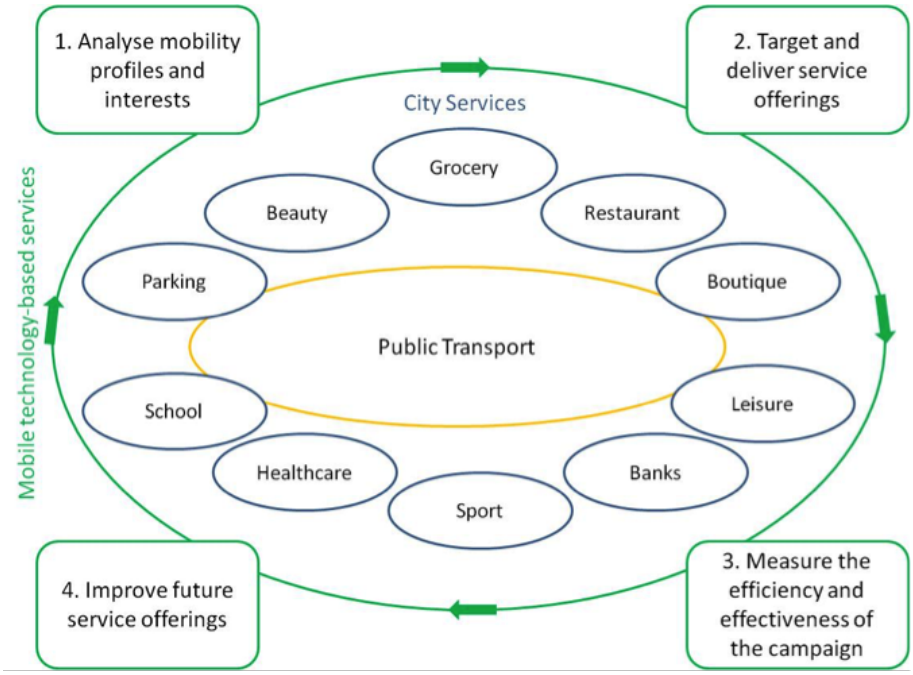

Figure 1: Conceptual model of the multiservice approach

The multiservice approach can be materialized in several practical examples and business models. We developed a mobile ticketing application for Android devices that enable users not only to buy and validate travel tickets but also to acquire discounts and offers at restaurants, boutiques, gyms and other service providers with points earned with the purchase of travel tickets. The more customers travel, the more points they earn and the more discounts and deals they have access to.

3 The value to Society

Nowadays, there are few initiatives that link public transport to other service providers; they work separately towards individual objectives. And when those initiatives occur it is difficult to measure their impact. Public Transport Operators could envision several benefits from this multiservice approach based on mobile technologies: increased loyalty, increased use of public transport, better image and marketing results. It also represents a boost to local businesses, due to increased awareness, loyalty and sales. Customers benefit from convenience, availability, better services, and increased savings.

The impact of servitization on the performance of manufacturing firms: An empirical investigation in the elevator industry

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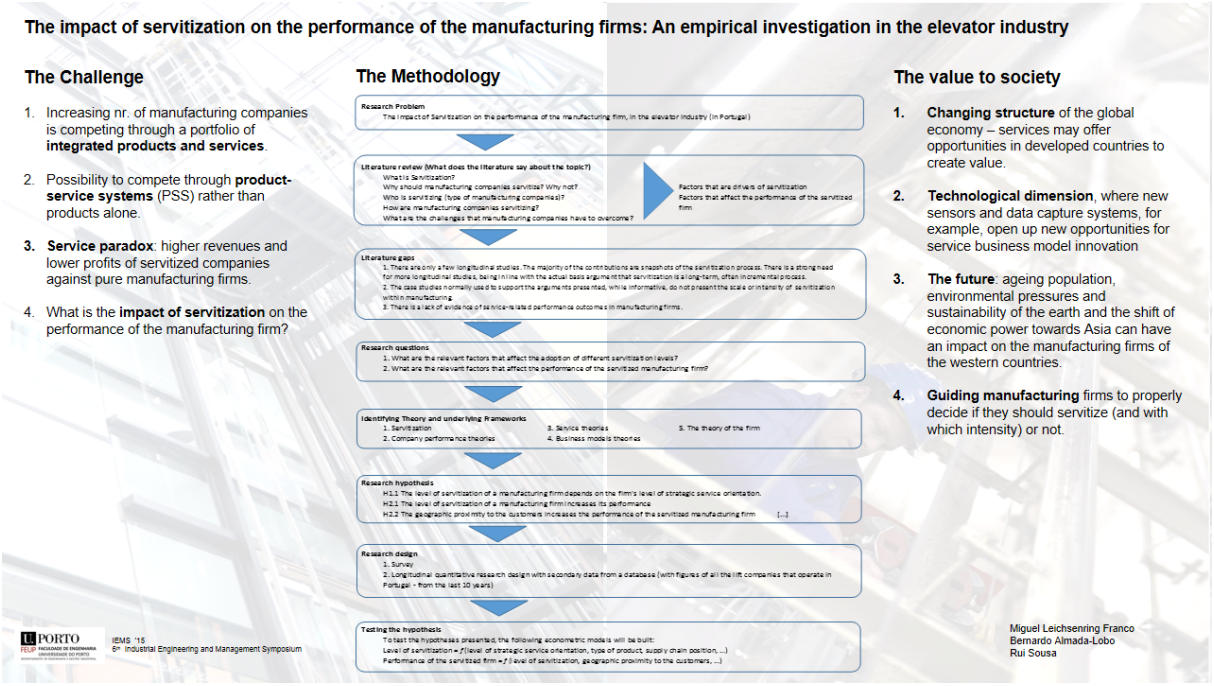

1 The Challenge

The boundaries between manufacturing companies and service firms are breaking down across the world. Today an increasing number of manufacturing companies is competing through a portfolio of integrated products and services. This is a services-led competitive strategy and the process through which it is achieved is commonly referred to as servitization. Therefore servitization can be seen as a transformation process that gives the manufacturing company the possibility to compete through product-service systems (PSS) rather than products alone. Simply put, servitization can be seen as a process of creating value for the company and for the customer by adding services to products. There are various servitization levels, that can be positioned on a product-service continuum ranging from traditional manufacturers merely offering services as add-ons to their products, to service provision where services are the main part of their value creation process.

But what is the impact of servitization on the performance of the manufacturing firm?

Successful servitization demands that manufacturers adopt new and alternative practices and technolo-

gies to those traditionally associated with production operations. A prevailing challenge is to understand these differences and their underpinning rationale. Although product-service combinations seem to provide higher revenues in comparison to offering the physical product alone, empirical evidence seems to suggest that servitized companies are delivering lower profits than pure manufacturing firms: the so called service paradox.

In the literature one can only find a few longitudinal studies (research studies that involve repeated observations of the same variables over long periods of time)and the majority of the contributions are still snapshots of the servitization process. There is a strong need for more longitudinal studies, in line with the actual basis argument that servitization is a long-term, often incremental process. The case studies normally used to support the arguments presented, while informative, do not present the scale or intensity of servitization. There is also a lack of evidence of service-related performance outcomes in manufacturing firms.

This study contributes to fill these gaps by developing and empirically testing a conceptual model with longitudinal data from the elevator industry and data from a survey, aiming at answering the following research questions:

RQ1: What are the relevant factors that affect the adoption of different servitization levels?

RQ2: What are the relevant factors that affect the performance of the servitized manufacturing firm?

2 The Methodology

Multiple factors can affect the adoption of different servitization levels and the performance of the servitized manufacturing firm. According to the literature these factors can be grouped into six rationales: a) the strategic factors, b) the financial-economic factors, c) the marketing factors, d) the environmental factors, e) the technological factors and f) the legal factors. Our research aims to model the level of servitization of manufacturing firms and the performance of the servitized manufacturing firm, and to understand what the relevant factors are.

Based on a previous literature review, aforementioned gaps were identified and the two presented research questions were defined. Using data from a survey study involving the lift companies and also the customers of this industry (RQ1), and longitudinal quantitative data from a database which contains financial data (over the last ten years) from all the 82 lift companies that operate in Portugal, using variables like product and service revenues, profit, number of workers, quantity of front-offices, etc.(RQ2), will help test for several research hypothesis. We will therefore try to determine what are the relevant factors that affect the adoption of different servitization levels and to measure the relationship between performance of a manufacturing company and several independent variables (factors).The result of the research shall be an econometric model that relates the performance of the servitized manufacturing company with the relevant tested factors.

3 The value to Society

Taking into account the changing structure of the global economy, servitization, more than ever, may offer opportunities for manufacturing firms in developed countries to create value.
Moreover, technological advances, like new sensors and data capture systems, may open up new opportunities for service business model innovation in manufacturing firms around the world.
Finally, aspects like the ageing population, environmental pressures and the sustainability of the earth

and the shift of the economic power towards Asia may have an impact on the performance of the manufacturing firms of the western countries. Servitization may constitute an opportunity for them to ensure their competitiveness.

We expect that the outcome of this research will be helpful in guiding and providing manufacturing firms with a technical analysis so that they can properly decide if they will servitize (and with which intensity) or not.

Hospital materials - systems based simulation of alternative supply chain strategies

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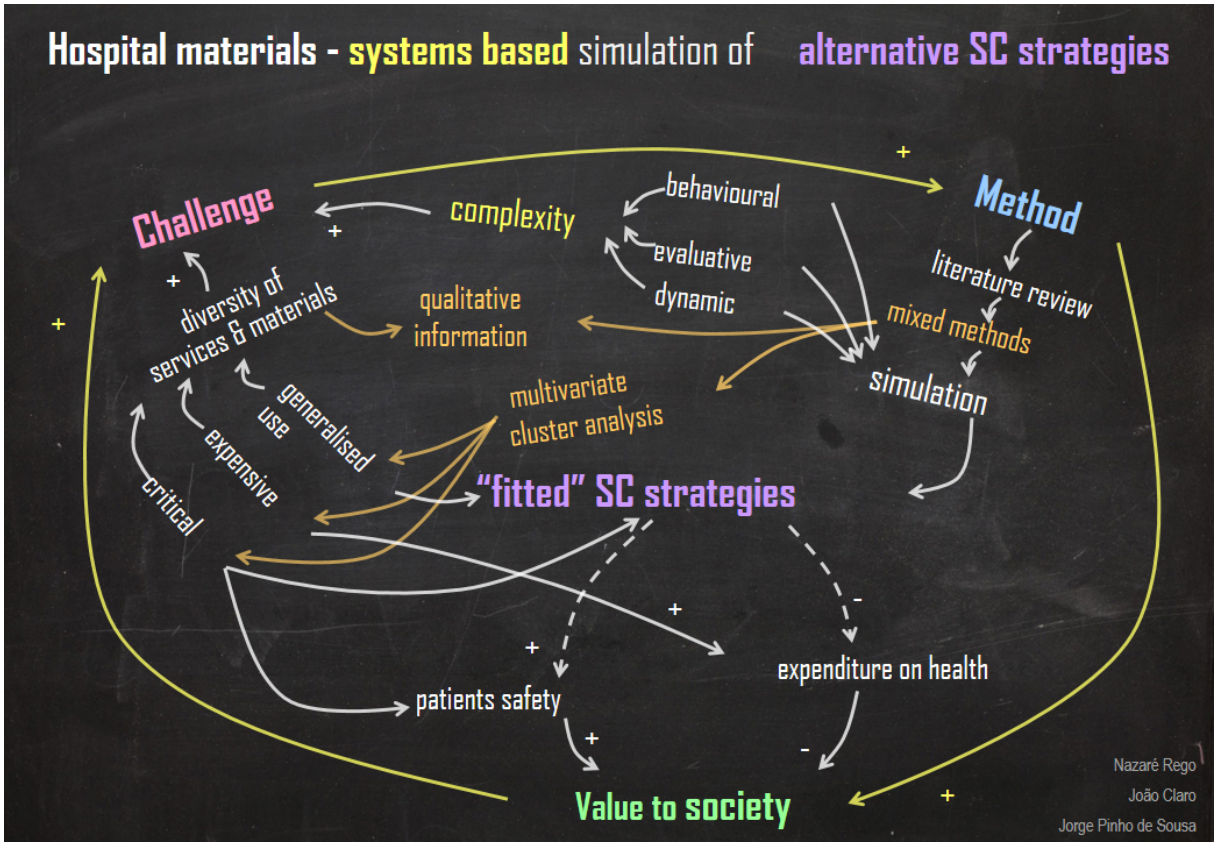

1 The Challenge

Healthcare supply chains are often considered as *complex systems*. In management contexts, such systems arise whenever there are populations of interacting agents (persons, organizations, or communities) that act on their limited and local information.

The supply chain of a hospital must gather all resources needed to assure the provision of a great variety of services through a network of diverse and relatively autonomous entities (mainly wards), this requiring managing the flows and inventories of a great diversity of materials, especially in the case of a general hospital. It must also assure a high service level, as the occurrence of stock-outs can significantly damage the confidence of clients (especially, health professionals) on the system and, in extreme situations, threaten the patients' lives. In this context, the various stakeholders involved in the decision process often have different perspectives of what "good" system performance is, and individuals' reactions to

the system state (namely, to the information they obtain about that state) highly influence subsequent system performance.

The objective of our work is to establish a connection between the characteristics of the pharmaceutical and medical/surgical products consumed in a hospital and the operational capabilities of their supply chains, by:

- first, identifying some groups of materials that are typical in terms of the capabilities they need from the hospital system supply chain;
- second, associating those groups with recommended supply chain operational strategies; and
- third, simulating some of these strategies to highlight their relative advantages and disadvantages, taking into account the specificities of the context.

2 The Methodology

In a pilot phase of the study, we have collected qualitative information from two general hospital systems: two CEOs and seven supply chain and pharmacy managers were interviewed, with the main objective of finding out *if* and *how* supply chain management was affected by the type of services provided and the characteristics of the items that flow through the systems.

Subsequently, we have used quantitative transactional data from one of these hospital systems to identify a few groups of homogeneous materials in terms of the operational capabilities they require from the supply chain. The groups defined by this procedure were compared with the gathered qualitative information and with segments described in previous literature.

Finally, we have used simulation to analyse some alternative operational strategies for some of the groups of materials identified. The developed simulation models take into account elements of complexity that are observable in healthcare settings, namely, elements of *dynamic*, *behavioural* and *evaluative* complexity.

3 The value to Society

In the last decades, there has been a continuous growth in health expenditures as a share of GDP in most OECD countries. Although this economic effort has been accompanied by significant improvements in health services, there is a collective concern for control of costs and for systems efficiency.

In Portugal, hospitals are accountable for approximately 40% of total current expenditure on health, and more than 75% of these arise at public hospitals (own calculations, using 2012 data by National Statistics). Supply costs account for 30% to 40% of the operational costs of a typical hospital (own calculations, using the 2009 Financial Statements of the top seven Portuguese hospital systems in terms of pharmaceuticals consumption in 2012; proportion in line with what has been observed in the US - see e.g., Burns and Lee, 2008).

In recent years, we have observed a reduction of the total budgets of hospital systems that may have a significant negative impact on quality, availability and safety of the services provided.

A clear identification of a small number of homogeneous groups of items, in terms of the capabilities they require from the hospital system supply chain, and the linkage of these groups with specific appropriate operational supply chain strategies (defined in terms of operational capabilities, processes and resources) facilitates the task of the managers when deciding which supply chain strategy to apply and how to implement it, and contributes to increasing the efficiency and the effectiveness of the supply chain system, as it favours a better targeting of actions and managerial and financial (e.g., concerning safety stock levels) efforts.

Moreover, in a sector where traditionally changes are difficult to implement and sustain, and where multiple stakeholders are involved, the development of simple supply chain management *policy simulators*

facilitates the observation and analysis of the effects of alternative decisions and the conciliation of the involved, often conflicting interests.

Mixed-Model Assembly Line Balancing in the Footwear Industry

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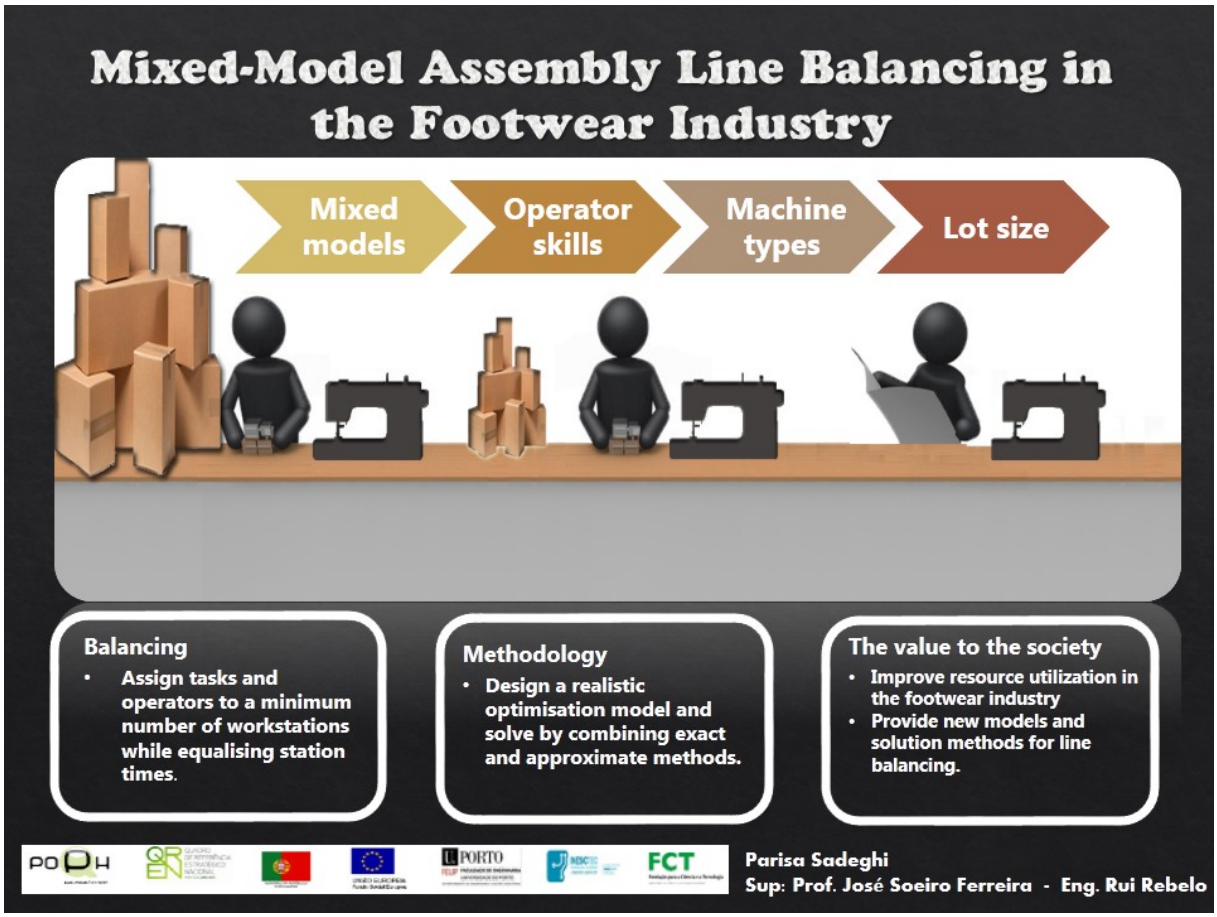

1 The Challenge

Portuguese footwear industry is expanding its export market, improving the competitiveness and mapping out a new future. This is largely due to investment in new equipment and in R&D.

The production of a pair of shoes encompasses various phases: cutting, pre-stitching, stitching, pre-assembling and assembly. Connecting, improving and speeding up these phases is an important matter for the companies. In this context, we intend to contribute for an appropriate operation of new automated stitching lines, namely the one developed for a specific company. It should be mentioned that the stitching line usually is the most critical of the assembly lines.

This work concerns a *Mixed-model Assembly Line Balancing Problem (MALBP)* in the footwear industry. There are dissimilar models of shoes in the line, at the same time, each model having different routings,

tasks with precedence constraints and various processing times. Tasks must be assigned to specific workstations, which are regarded as a combination of operator and machine. The operators are classified according to their skills and machines are of different types. The stitching line (unpaced line) has a new type of buffers, located between stations, which are also intended to avoid a warehouse. Shoes components are put inside boxes and the boxes move between buffers/workstations. Each box contains parts of the same model, equal size and identical colour, although they can be linked to different client orders. Boxes can move in any direction. A critical issue of the research is to determine the ideal number of items inside each box, which may influence the total processing time; on the other hand, portions of the client order should be produced appropriately at the same time to be packed as soon as possible.

The main challenge is to balance the *MALBP*, in this case assigning tasks and operators to a minimum number of workstations while equalising the station times and taking into account a daily target. The company is running solutions based on the acquired experience, solutions that should be improved and/or evaluated. An optimized balance is very important: blocking and/or starvation of workstations are not at all convenient for a quick response to clients. A good balance will also reduce costs and space requirements.

2 The Methodology

The *MALBP* in the footwear industry is tackled by two main approaches: One is based on *simple heuristics* and the other encompasses the design of a *realistic optimization model* of the line.

In what concerns the use of heuristics we undertook an adaptation/extension of the *Ranked Positional Weighs* method *(RPW)* for the *MALBP*, due to the complexity of the current problem, namely in terms of mixed models and equipment selection process. The adaptation took into account various aspects such as: determining the necessary number of operators of each type/skills, the number and types of machines needed and prefixing some operators to specific tasks. Additionally, the extended method tries to smooth the workload among the operators/machines.

It is expected that this(constructive)heuristic will produce relatively good solutions in a short time. The solutions are being analysed by simulation and tested in the company. This first approach is also convenient for the design of a realistic and useful line model.

The other approach, developed in parallel, considers an optimization model for the *MALBP* and the construction of adequate solution methods. As mentioned, and according to the vision of the company, the objective is to reduce the number of workstations and to smooth the stations load. The first tests for small instances were already performed with *Cplex* software. However, the complexity and dimension of the model led us to start conceiving a solution method based on an articulation of exact and heuristic methods. This stage of the work is still under research.

Prior to such approaches, as mentioned, a lot size phase takes place to determine the ideal number of items within each box moving in the line. This is achieved using the earliest completion time dispatching rule. The size of the boxes is an input parameter for the solution methods.

The results obtained will be evaluated and validated in close cooperation with the industry. Simple heuristic methods are usually implemented in a shorter time - a benefit for the company, they may offer good solutions and contribute to the development of more sophisticated approaches. It will also be interesting to assess the results of both approaches together since, very often, "sophistication" does not necessarily mean more suitable from a practical standpoint.

3 The value to Society

Portugal is one of the major players in the footwear industry. In 2013 Portuguese footwear exports increased 8% and reached a total value over 1.700 million Euros, corresponding to 74 million pairs.

With this research we expect to contribute to the innovation, efficiency and competitiveness of the

footwear industry. Line balancing optimized solutions will expedite planning and increase resource utilization, by reducing the number of workstations and smoothing operator's workload.

Although a particular assembly line is under research, the outcomes may be extended to other companies.

On the other hand we believe some relevant results to the field of *MALBP* will be achieved. It is a complex optimization problem in a new assembly line projected in Portugal, and we are not aware of similar cases in the literature.

Optimum design of complex engineering systems with humans-in-the-loop

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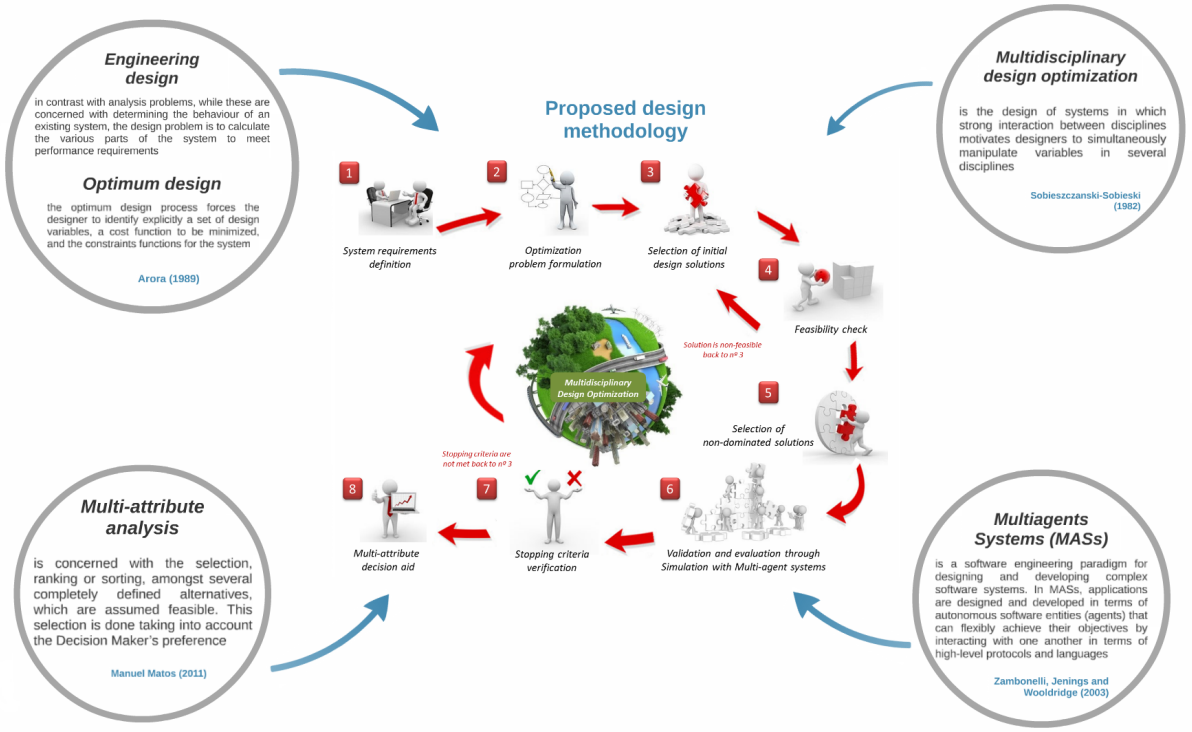

1 The Challenge

Today engineers try to design the perfect ships, aeroplanes, power plants, factories, intelligent buildings, hospitals or even intelligent cities. All of these are engineering hard systems that have in common the fact that are manmade structures, within which people interact with machines and equipment, to perform several tasks in order to reach different goals, either to travel, to produce energy, to take care of patients, or to improve lifestyle.

On the other hand, each one of these examples can be seen as a complex engineering system made of several smaller subsystems whose interdependency does not allow deducing its overall performance from the individual analysis of each one of its parts. Most of them are also designed to maintain their operationality and performance levels under different external effects and extreme situations, though in many cases humans take part in the decision process necessary to deal with those occurrences. As an example, a ship must not sink as a consequence of bad weather, and a hospital should continue working even when there is no external electrical supply.

The aim of this work is to search a design methodology which is able to predict the performance of these kind of systems in initial phases of their project, taking into account human decision as part of it.

2 The Methodology

The engineering design process is iterative and involves several steps that will lead, by the end, to the development of a new product or system. How we get there, the steps that are followed, define a design methodology, such as: conventional design, experimental design, optimum design, and multidisciplinary design optimization.

Since we are dealing with large engineering systems, prototyping in most cases is too costly, so we must rely on theoretical design approaches. Conventional design is based on the designer's experience and intuition. Optimum design requires the designer to formulate and solve a single optimization problem and today is extensively used in structural engineering. Multidisciplinary design optimization (MDO) evolved from optimum design, it proposes several architectures to deal with multi-objective problems where it is necessary to manipulate simultaneously variables in several disciplines, providing the means to design complex systems and finding non-dominated solutions for the problem.

However, as far as we know, neither of the mentioned methodologies is able to deal fully with the kind of design problems previously mentioned, and mainly with human interaction. To show it, we are going to present a conceptual problem which is similar to the examples, but much simpler. We intend to show that to deal with these problems it becomes necessary also to interpret the results found using MDO by means of using multi-attribute analysis tools to find the preferred solution(s) and finally use distributed simulation and multi-agent systems to incorporate human decision which influences the system performance.

The problem to resolve is as follows: a team leader intends to transport a set of packs using three of his collaborators trough a bridge. They want to optimize both the weight of the bridge and the time of transport. Analysing this problem we may reason:

1. If we only intended to minimize the weight of the bridge assuming a maximum weight for each man and weight carried, that would be a trivial structural optimization problem where the design variables would be the bridge dimensions (optimum design);
2. On the other hand, if we want to minimize both the bridge weight and the time to cross the bridge, we can modify not only the bridge dimensions, but also the amount of weight carried by each person (backpack problem). This leads to a multi-objective problem, which has several non-dominated solutions, that may be found making use of traditional MDO architectures;
3. Including a human-in-the-loop (the team leader), he would be able to control when each element starts to cross the bridge, inserting new variables and leading to other results. This, however, is very difficult to model, requiring, in our point of view, to use multi-agent systems together with distributed simulation. This information may be used either to change the solutions previously found or to find the best procedure in which team leaders must be trained;
4. Finally, after having a set of non-dominated solutions it is still very hard to pick one since it is necessary to find means to compare different performance measures (time and weight), so we must assist the decision maker in the selection of its preferred solution following a multi-attribute decision aid approach.

So our proposal is to use a multidisciplinary design architecture to obtain several non-dominated solutions which are then used in multi-agents distributed simulation scenarios, either to obtain different solutions or to gather information that may be used in leadership training. Next, solutions are presented to a decision maker using multi-attribute decision aid techniques. Figure 1 represents the design methodology.

3 The value to Society

With this work we expect to contribute to find ways to design engineering hard systems that rely on human decision for their operation, and that may take into account very different requirements.

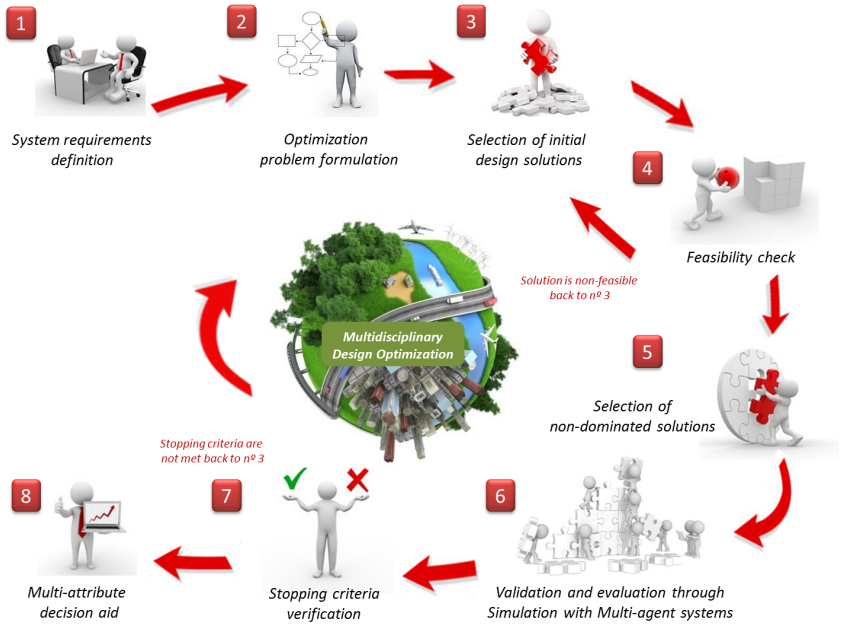

Figure 1: Optimum design methodology proposal to take into account human decision during operation

Some of the systems, we hope, may have some impact on our society development towards globalization, sustainability and on the wellbeing of the population. In other words we hope that the methodology can improve the design of some means of transportation such as ships and planes; may provide ways of including requirements and constraints to take into account environmental impact as part of the design process; and may allow developing new safer infrastructures which are friendlier to the common user.

Scheduling Crane Operations in Rail-Rail Transshipment Terminals

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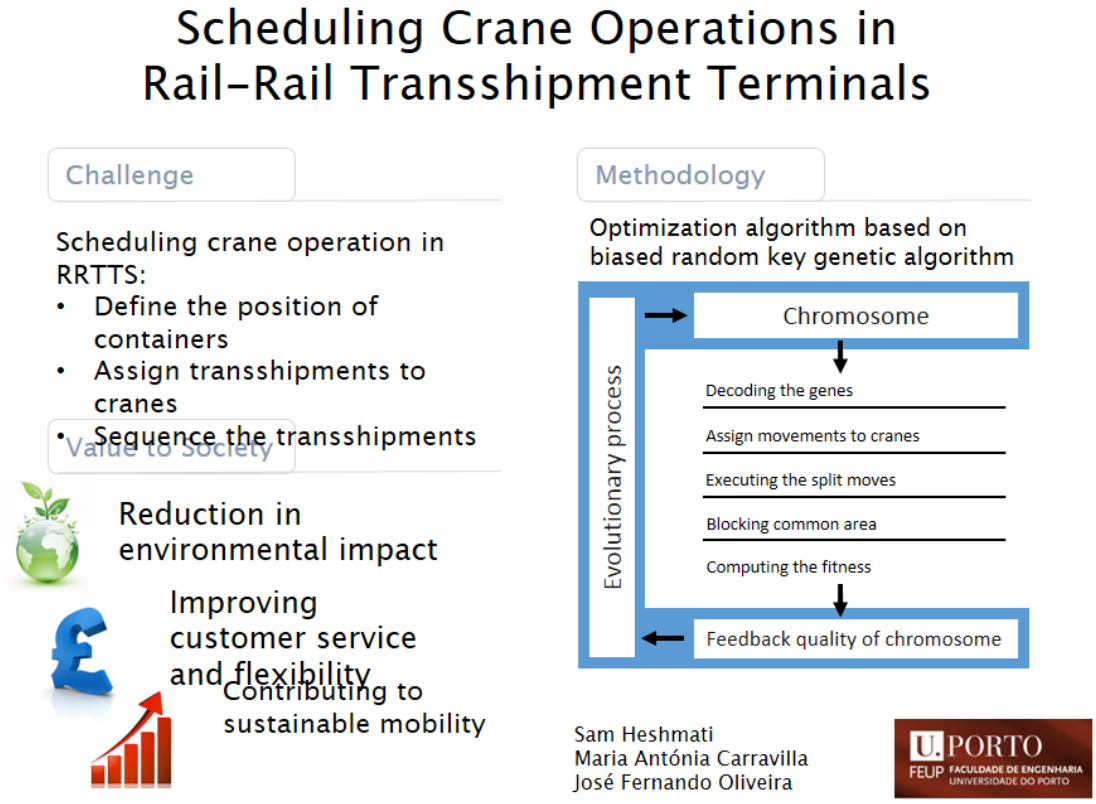

1 The Challenge

Freight transshipment terminals in rail networks are special transshipment nodes for processing the train loads, where the loads are collected, rearranged, intermediately stored, loaded, and/or picked up. The rail-rail transshipment terminal (RRTT) is an emerging technology in railway systems and freight transshipment terminals. RRTTs are intended to increase the transport frequencies and the number of destinations to be reached as well as offering more suitable operation times for shippers and other customers at terminals with higher reliability compared to the conventional classification yards.

RRTTs consist of a number of rail tracks, where freight trains are positioned in bundles to be served (one train per track), rail-mounted gantry cranes to move containers between different freight trains, and shuttle cars serving as a sorting system. This is a complex system with sophisticated operations which requires good schedules and collaboration of resources.

In this study, we are aiming at analyzing scheduling crane operations (SCO) in RRTTs from an operational point of view. The policies concern the decision on the positions of containers on outbound trains, assigning container moves to cranes by considering either disjoint working areas or overlapping areas for the cranes, and sequencing the container moves per crane, while minimizing the total transshipment time, are going to be tackled.

2 The Methodology

The SCO is an operational problem that has to be solved for every bundle of trains arriving at the transshipment yard in RRTTs. It includes three sub-problems of a typical rail-rail transshipment problem. First, the SCO assigns each container a position on the outbound train with the proper destination in such a way that the overall containers' movement distance is minimized. It is done by considering the capacity constraints of the wagons of trains. Next, it assigns container moves to cranes. This can be executed under a static or dynamic policy, when managing crane influence areas. Finally, the schedule of container moves per crane is determined. The global objective of the problem is to minimize the total processing time of the cranes, while minimizing the number of the containers left behind on the yard. Obviously, as few containers as possible should be left behind on the yard (and as many containers as possible should be loaded).

The algorithm proposed in this study is based on biased random key genetic algorithm (BRKGA). It uses a random key which comprises random real numbers in the interval $[0, 1]$. All the offsprings formed by crossover in BRKGA are feasible solutions. Therefore, much of the feasibility issues are moved into the objective function evaluation. The role of the BRKGA is to evolve the encoded solutions, or chromosomes, which represent the sequence of container movement and the final position of each container. Figure 1 illustrates the sequence of steps applied to each chromosome generated by the BRKGA. The blue blocks represent the evolutionary process and the black block is the decoder.

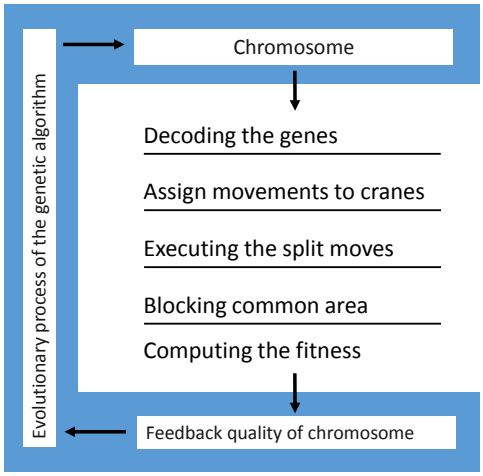

Figure 1: Architecture of the algorithm

A chromosome represents a solution to the problem. Each chromosome is made of $2n$ genes, where n is the number of the containers that should be transshipped, i.e.

$$Chromosome = \left(\underbrace{gene_1, ..., gene_n}_{\text{movement sequence}}, \underbrace{gene_{n+1}, ..., gene_{2n}}_{\text{final position}} \right).$$

The first n genes are used to obtain the movement sequence of the containers and the last n genes are used to obtain the final position of the container.

The decoding algorithm starts with decoding the chromosome and generating the movement sequence of the containers. Afterwards, based on the second part of the chromosomes, a wagon on outbound train is assigned to each container considering the capacity of the wagons and size of the containers.

We consider a yard with multiple cranes, where the influence areas of the cranes overlap. The movements are assigned to each crane based on the start and final zone of the movement using a simple rule to minimize the processing time of the each crane in the common area. To avoid the collision of the cranes, the common area is blocked for one crane whenever the other crane enters. As two cranes cannot simultaneously be present in the common area, waiting time is introduced in the schedule of one crane by decoder algorithm whenever the other crane is present in the common area.

When the starting position of a transshipment operation is located in one crane's area and the final position in the area of the other crane, an indirect move has to be executed. The crane in the starting area picks up the container and puts it in the sorter system, where the container will be transferred to the working area of the second crane. The second crane processes the container to its final position. The container is handled more than once which implies one extra pick up and drop of the container by a crane and depends on the sorting system. The extra movement should be added into the schedule of the second crane. To this end the decoder algorithm fits the extra movement in the best position in schedule of the second crane.

As mentioned before, leaving a container on the yard is not desirable. When calculating the fitness, penalty costs need to be integrated into the objective function, which penalize solutions proportionally to the size of the containers left on the yard. Therefore, the fitness function is the total time of the cranes' processes plus the cost of leaving a container to the yard.

3 The value to Society

This study deals with the scheduling crane operations (SCO) problem in rail-rail transshipment terminals (RRTT). In this combinatorial optimization problem the containers have to be transshipped among trains by multiple cranes. The SCO problem involves three decisions: (1) to define the position of containers on outbound trains, (2) to assign transshipments to cranes, and (3) to sequence transshipments for each crane. We addressed an optimization algorithm based on biased random key genetic algorithm (BRKGA) for a transshipment terminal with multiple cranes.

The effects of developing suited decision support systems based on this method in rail-rail transshipment, go beyond the cost reduction. Firstly, RRTTS provide shorter lead-times in the terminals, and thus in the chain, secondly it allows flexibility in operation for shippers and other customers at terminals. Finally, RRTTs can play an important role to increase shifting freight traffic from road network to the railway system which reduces environmental impact (i.e. CO_2 emission) and also relieves the congested roads of major trading countries.

An Optimization-Simulation approach for the Network Redesign Problem of Pharmaceutical Wholesalers

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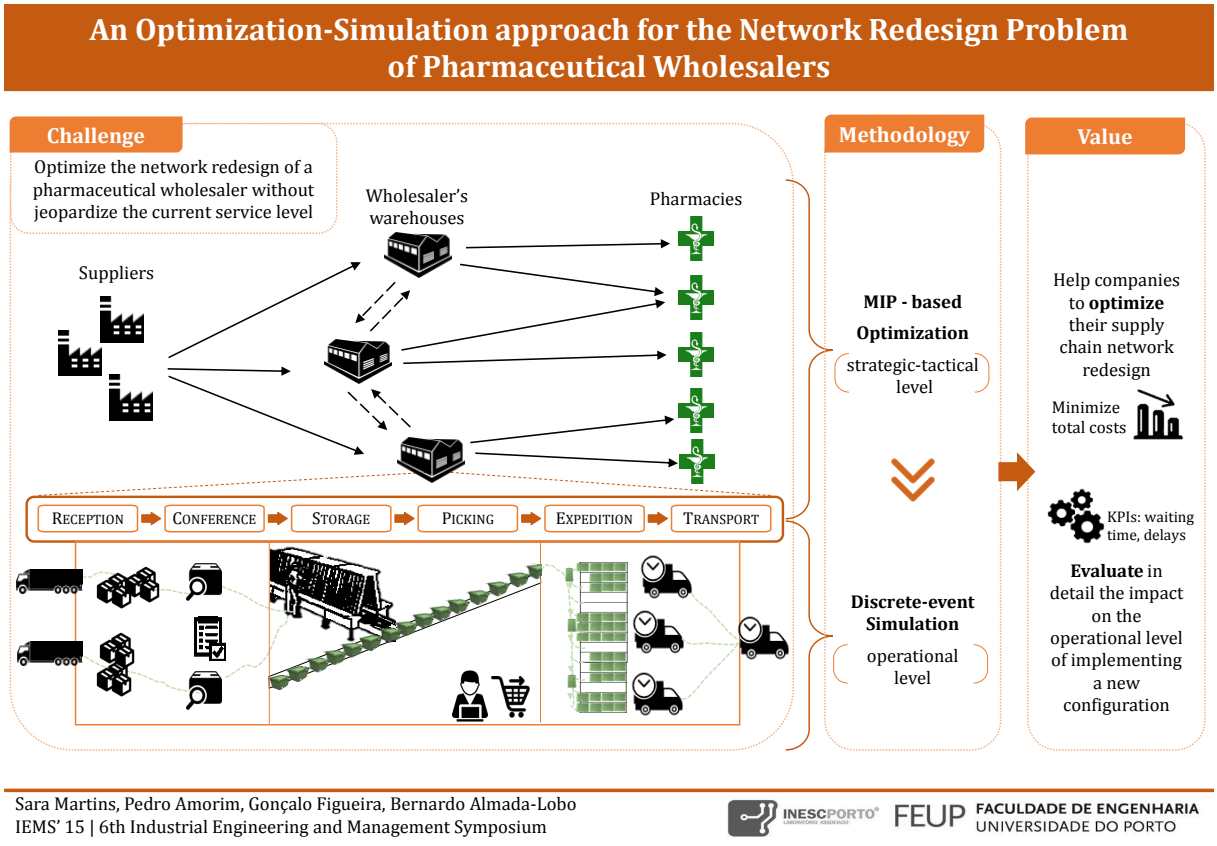

1 The Challenge

Pharmaceutical wholesalers purchase large quantities of pharmaceuticals to manufacturers that are stored in their warehouses and later distributed to retailers (pharmacies) according to their demand. Because of the high number of manufacturers, products and retailers, wholesalers play an important role in the pharmaceutical supply chain. Most pharmaceuticals have exclusive manufacturers, so having an intermediary between suppliers and retailers yield significant advantages for both, as it simplifies the supply chain management.

The pharmaceutical industry is a very regulated market. Many distribution procedures are outlined by regulatory entities and prices are usually fixed, being the margins of each part of the supply chain imposed. Wholesalers are the ones with the lowest margins, about 4%, while manufacturers can reach margins above 70%. These numbers together with product exclusivity underline the bargaining power of pharmaceuticals' manufacturers that depreciate their service of delivery, having long and highly variable

delivery lead times. However, this behavior is changing because of generics acceptance and growth in the market, predicting a shift in the pharmaceutical supply chain management.

In the downstream of the supply chain, the economic crisis is changing the purchasing behavior of pharmaceutical retailers, ordering more frequently in lower volume, reaching up to 3/4 deliveries a day, thus burdening wholesalers' distribution systems. Nevertheless, some retailers are beginning to think about adopting a Vendor Management Inventory (VMI) system with one wholesaler, that would allow to redefine their distribution system.

These developments allied with the reduced margins and market regulations are making wholesalers rethink their network design (Figure 1) in order to adapt to the new necessities, reducing costs and maintaining their competitiveness.

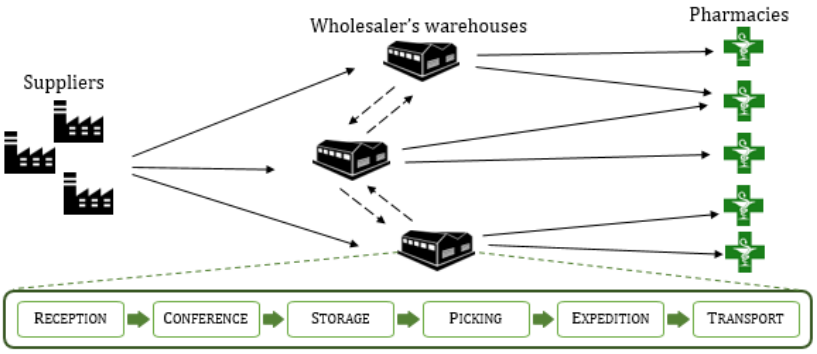

Figure 1: Supply chain network design of a pharmaceutical wholesaler.

In the pharmaceutical industry the time of response of a wholesaler and the availability of products are of upmost importance for the customers, thus being important indicators of the service provided and competitive edges. Therefore, for a company already established in the market, customers are used to have a certain service level, so they are expecting at least that same level after a company transformation. As a result, the network redesign of a wholesaler has to be carefully studied with the logistics and marketing departments, analyzing how a solution affects the operational procedures and how that would affect the customer service level. In a competitive market, such as the case of pharmaceutical wholesalers a small variance on the service can result in substantial sale losses. This happens in our case-study, specially because the market share of the company is growing and the company's main driver is the rationalization of the network.

2 The Methodology

This work proposes an optimization-simulation approach for the network redesign problem of pharmaceutical wholesalers. The aim is to optimize the strategic-tactical decisions of wholesalers' supply chain network design and evaluate operationally the solutions obtained, with the objective of minimize the wholesaler total costs without jeopardizing the current service level. The number and location of the warehouses to maintain, open or close and the reallocation of customers are the main strategic decisions to analyze. Due to the high costs that the distribution system presents in this industry, the function of the warehouses is also questioned. Understand whether they should operate as cross-dockers or storage facilities as well as questioned the need of lateral transshipment is critical. Moreover, because of the influences that these changes have on the warehouses' operational level, the capacity of the distinct activities performed, such as reception, picking and transport, has to be incorporated to achieve an integrated view of the best network design.

Because a wholesaler activity is very time dependent, with multiple orders taking place at the same time and in a large scale, modeling the different operations and its relationships by means of mathematical programming would be very complex and it would result in an intractable formulation. Therefore, in order to simplify the model and at the same time get a clear picture of the impact of implementing a new

design, both from an operational and market point of view, this work proposes an optimization-simulation methodology.

First a mixed integer programming model is formulated, at a macro level, to optimize the main strategic-tactical decisions and then a discrete-event simulation based on real-world operational conditions evaluates the solution. This methodology allows to simplify the optimization model, to understand the pressure that the redesign will cause on the operational activities and to quantify how the proposed changes would reverberate in the customer service level.

Using the company's current warehouses and others alternative locations, the results shown that keeping the company's five warehouses but changing one of them to cross-docking could provide savings up to 4%. Moreover, if an earlier ordering window at lunch time was imposed, the redesign would not cause delays beyond the acceptable.

3 The value to Society

For businesses in which the details are critical and very time sensitive, this approach of integrating optimization and simulation allows to obtain accurate and robust solutions. The models proposed help companies to optimize their supply chain network design and evaluate in detail the impact on the operational level of implementing a new configuration. Moreover, this methodology can help companies to quantify solutions that they might be discussing empirically.

This methodology was used to analyze the supply chain network redesign of a Portuguese pharmaceutical wholesaler. Fixed costs of opening a warehouse, operational costs regarding the warehouses activities, such as picking, conference and distribution, inventory and unsatisfied demand were considered and optimized. The models proposed were validated by the company and the final results demonstrated that annual savings of about 3% to 4% could be achieved depending on the strategy chosen to be implemented. For this company, the delays on the vehicles departure from the warehouses were a very important indicator, because the customers are very strict in the delivery time window, and a delay might result in lost sales. Because one of the main goals of the company was to ensure the customers time window of deliveries, the use of the simulator allowed to identify the delays that each solution imposed and make what if analysis to promote possible modifications in the strategy solution so that the customer service level be benefit. The strategy that optimizes the network redesign, change one of the current warehouses to cross-docking, would result in a reduction of the number of customers visits in that warehouse, thus impacting the customer service level. Therefore, it was recommended a phased implementation, where first an optimization of the current network design is performed with a smooth reduction of the number of customers visits, to see their reaction. If the responses are positive the function of the warehouse is changed to cross-docking, otherwise it remains only with the optimization of the current network design.

Operational Planning in Dynamic Manufacturing Networks of SMEs

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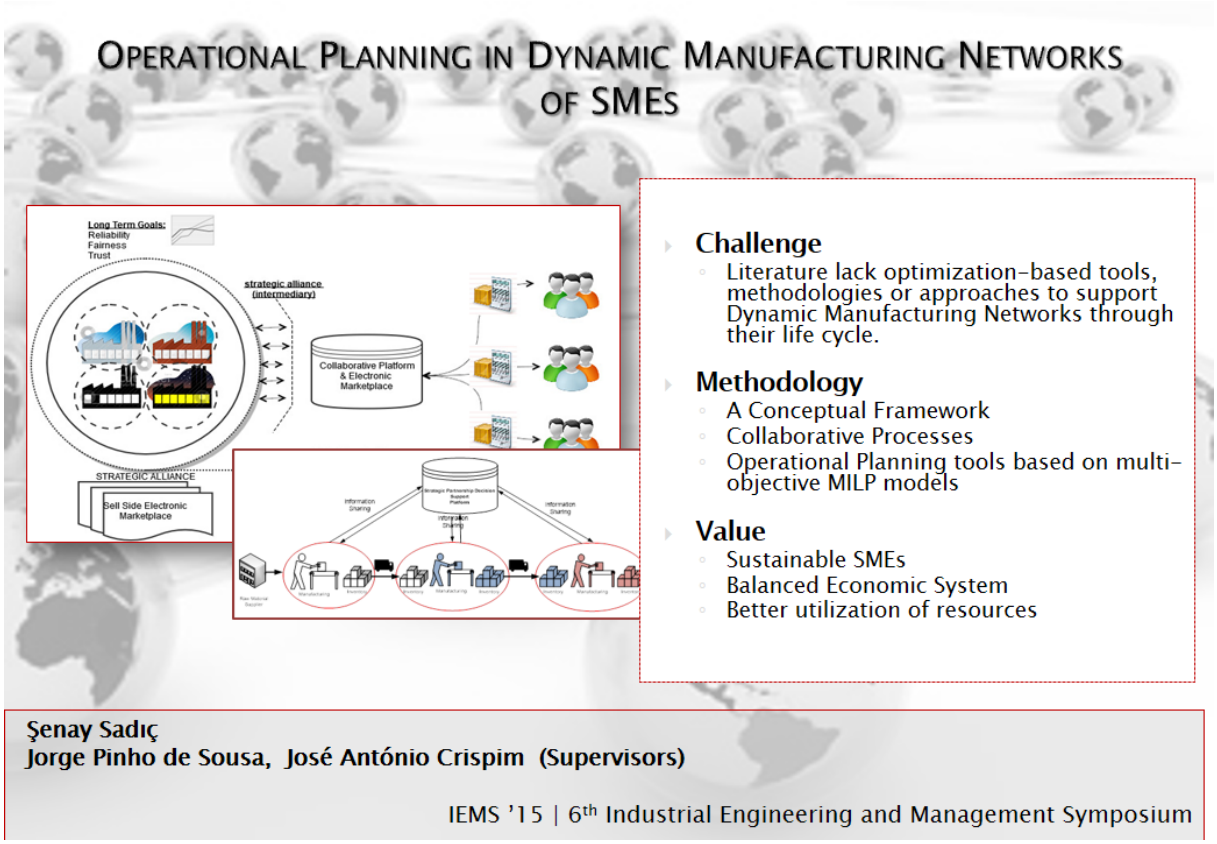


1 The Challenge

Due to their small scale and domestic market and/or Original Equipment Manufacturer (OEM) dependent business models, Small and Medium Enterprises (SMEs) are particularly vulnerable in an increasingly networked economy. From an SME perspective, collaboration and cooperation are not only keys to performance improvement but also for survival and sustainability. Nevertheless, by pooling dispersed resources, distinct core competencies and sharing risks, collaborative networks of SMEs hold the potential to tear down these barriers and reach a performance level that is at least as efficient as their multi-national corporate competitors.

The Dynamic Manufacturing Network (DMN) paradigm was developed as an extension of the Virtual Enterprise (VE) concept, applied to the discrete complex product manufacturing industry. While in less demanding industries it is possible to organize and control collaborative networks with partnership strategies, discrete manufacturing industries require real time information sharing, significant visibility and control over the manufacturing processes. Discrete complex production manufacturing industries

(such as semiconductor, high tech, automotive, electronics, defense, etc.) are characterized by complex, multi-level bills of materials, multiple options for product configurations, complex environments for product life cycle planning and management, a multi-tier production structure and multiple sales channels. DMNs can capture the complexity of these industries by taking cost advantages of geographically dispersed partners under dispersed demand conditions, dealing with disruptions and providing on time delivery in a multi echelon manufacturing environment with autonomous partners.

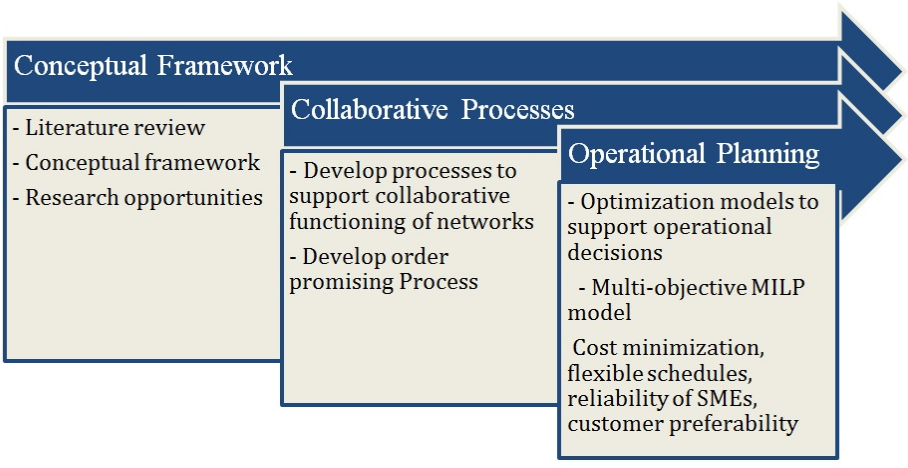
While planning of DMNs is very complex and may require the adoption of advanced mathematical models and common processes, the DMN literature is still at its infancy and lacks optimization-based techniques, methodologies or approaches for life cycle management. DMNs require decision support tools for both strategic and operational level. Even though our main contribution is intended to be in the operational level, we also contribute to the DMN literature by reviewing the requirements of the underlying business models and developing collaborative processes that enable DMN operations. The ultimate goal is to support DMN planning in a fair, sustainable and adaptable collaborative environment.

2 The Methodology

The DMN business model is characterized by resource pooling, centralized decision making, real time information sharing and enterprise integration. Forming and operating DMNs require the development of a collaborative platform and the provision of detailed real time information on partner capabilities, costs, management requirements, quality and processes. By directly interacting with potential partners, such a platform should retrieve the required information for network configuration and planning, support common processes and monitor manufacturing execution.

A DMN platform should be able to create a joint operational plan that orchestrates manufacturing and transportation of product components between selected DMN partners, track execution of assigned plans and tackle deviations from the initial plan or supply related disruptions. The study involves three consecutive stages as depicted in the figure. To better understand the requirements of the DMN business model, a conceptual framework has been developed based on a comprehensive revision of the DMN literature and related research areas. We have presented our findings in a high level business model that virtually integrates dispersed manufacturers and customers through a sell side electronic marketplace.

Figure 1: Methodology



While the high level ICT structure works as the integration platform, DMNs require common, automated adaptive business processes. In a second part of this study we have developed an Order Promising process to assist communication and integration of manufacturers and customers. DMNs are order-driven networks that are normally formed through long term integrated strategic alliances, and the development of these collaborative processes is crucial for their functioning. Finally we have developed multi-objective mathematical models to support DMNs in their operational decisions. The developed Mixed Integer Linear Programming (MILP) model takes into account available capacity and real time

cost data of members. The model decides the DMN structure and production quantities, inventory and transportation lot sizes, while considering several objectives such as total cost, scheduling flexibility, and reliability of manufacturers and preferences of customers.

3 The value to Society

SMEs are small scale companies that are highly affected by the economic fluctuations. Despite their individual vulnerability and weakness, as a community they tremendously contribute to economy and employment. According to Eurostat statistics, in 2012 the number of micro, medium and small-sized enterprises in EU-27 adds up to more than 20 million. These enterprises employ more than 86 million people that represent 66.5 percent of all EU employment. During 2012, SMEs as a whole had a contribution of 57.6 percent to the whole gross value added generated by the private, non-financial economy in Europe. The contribution of manufacturing SMEs to the manufacturing sector was around 707 billion Euros, representing 44 percent of the whole financial gains.

Through DMNs, SMEs can benefit from increased overall performance and access to international markets. This study specifically extends these benefits by providing an optimization based decision support tool that considers several objectives as minimum cost, maximum operational flexibility, maximum partner reliability, etc. It is especially important to consider the multi objective nature of DMNs since their business model is based on an integrated platform of several parties (manufacturers, customers, a strategic alliance).

While there are several gains of this model in a short run perspective, the most highlighted gain would be the increased survival capability of SMEs. Supporting SMEs will create a sound industrial environment, where rules are not imposed by big corporations but rather represent collective decisions taken by members of a well-balanced networked economy. DMNs can in fact be the stepping stone from a competitive to a cooperative economy, promoting a long term focus and a sustainable usage of earth's resources.

Acknowledgements

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Optimizing Shelf Space in Food Retail

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1 The Challenge of Managing Shelf Space

While shopping, customer choices are highly influenced by in-store factors, in particular during their frequent unplanned purchases and out-of-stock situations. Accordingly, a clever arrangement of products on the shelves can boost demand and ultimately the stores' financial performance. With the increasing number of products available for the same scarce space, shelf space planning has become more and more challenging and retailers strive to get the right goods to the right places at the right time.

The traditional space planning tool is a planogram (see Figure 1), which is a blueprint of the shelves showing the exact location where each product should physically be displayed and the number of facings (visible units) that the product should hold. Despite the recent adoption of commercial software programs, creating planograms is still largely a manual and highly time consuming process. These software solutions focus on simplicity, allowing for realistic views of the shelves, the ability to quickly handle products and providing powerful analysis reporting. However, they rarely present efficient tools for automatic planogram generation, only providing simple heuristics and pools of allocation rules.

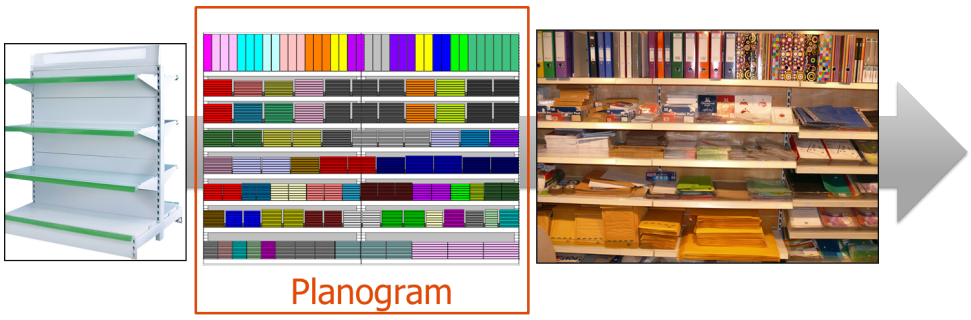

Figure 1: Shelf Space Management with Planograms

We have worked closely together with the Portuguese leading food retail chain to tackle their shelf space management problems and develop a Decision Support System (DSS) to help deciding the best allocation of products on the shelves.

Prior to this project, planograms were manually planned by following merchandising rules either defined internally or advised by category captains (key suppliers with strategic recommendations regarding category management decisions). The process was very time consuming, with an empirical use of space elasticity, lacking formal performance evaluation criteria and heavily depending on the space managers experience. Our challenge was to bring analytical methods into the practice, aiming the automatic generation of planograms capable of improving the return on space and reduce out of stock situations without disrupting (but somehow questioning) the company policies.

2 Analytical Approach

The shelf space management practice usually involves two distinct phases as depicted in Figure 2. In the first phase, space managers carefully study the products assortment and the merchandising rules to decide the best arrangement for the existing space. At this point of the process, stores are grouped into clusters which share similar space and sales patterns. Afterwards, in a second phase, the store specific planograms are created by adjusting the planograms designed for the corresponding clusters.

To better fit this reality, our decision support system - GAP (Automatic Generation of Planograms) - is built on top of two modular methods: (1) GAP Generation which is responsible for the generation of the role-planograms for the clusters and (2) GAP Replication which creates the store tailored planograms by adapting the products facings to the performance of the stores while keeping the allocation guidelines present in the role-planograms.

Both methods were developed in a modular fashion and hierarchically apply innovative optimization models, combined with heuristics, to derive the best allocation of products on the shelves. Besides deciding the number of facings for the products, the methods go beyond the ones published so far by determining the sequencing and positioning of the products on the shelves, and respecting real word constraints derived from the merchandising rules. For that purpose, the formulations shifted from those traditionally found in the literature based on the multi-knapsack problem to commodity flow formulations. Additionally, goal programming approaches are used to handle the non-linearities present in the objective function of the problem. The proposed optimization models and algorithms are able to simultaneous deal with the complexity of real-world instances but also to be efficient enough to allow their practical use.

On top of the algorithmic advances, one of the most relevant features of GAP is its flexibility. GAP Generation includes the possibility of incorporating different types of merchandising rules, allowing the company to test different strategies or to shape the planograms according to the current practice. The number of facings can also be determined to meet different goals, such as the equilibrium of coverage days, the correspondence with sales shares or the maximization of sales based on space elasticity effects.

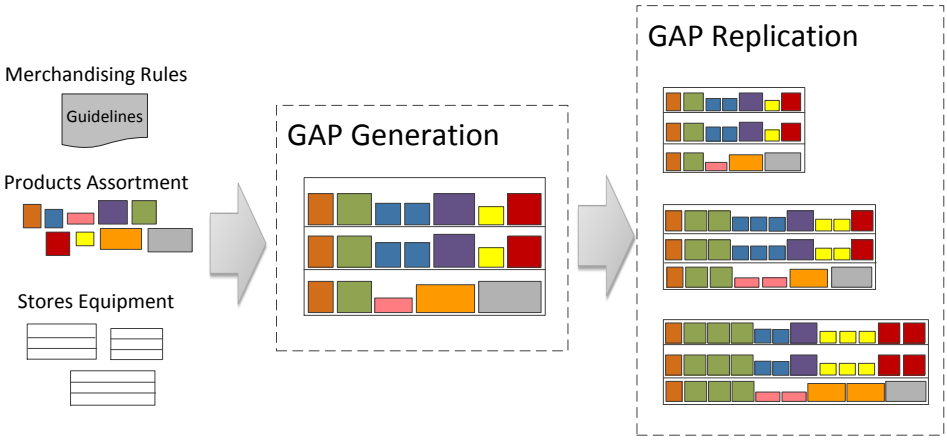

Figure 2: GAP Generation and GAP Replication

3 Impact on the Food Retailer

The project started in 2011 and the resulting DSS has been implemented and used by the company since 2013. GAP is implemented as an add-in to the company's commercial space planning software, taking advantage of its visual and analysis capabilities. The average planograms have from 100 to 200 products and are solved in less than 10 minutes.

Up to now preliminary results indicate a 52% reduction on the time spent generating planograms and the adequacy of the analytical approach to the business practice. As the effects of the planograms on the sales are harder to estimate, this analysis has not been done so far. Additional major benefits include trade-off analysis between solutions biased towards profit maximization or towards the company's rules, the validation of the products assortment with respect to the space available and the increase in image standardization across the stores, more difficult under a manual process.

In our opinion, these results were possible due to some key factors which had a crucial contribution to the project success. To ensure the space managers engagement, the effort to not create any disruptions with the current practice and the flexibility of the approach played a vital role. Additionally, the parameterization effort has been reduced to the minimum level by automating the detection of most parameters. For example, the merchandising rules, difficult to be expressed otherwise, were extracted by analyzing existing planograms.

In the highly competitive retail environment of today, retailers can indeed benefit from analytic tools to better manage space and increase their profitability. We believe that this work is an important contribution in this direction both by bringing additional realism into academia and by proving the value of advanced analytics in practice.

Dissolving the boarders of hierarchical production planning

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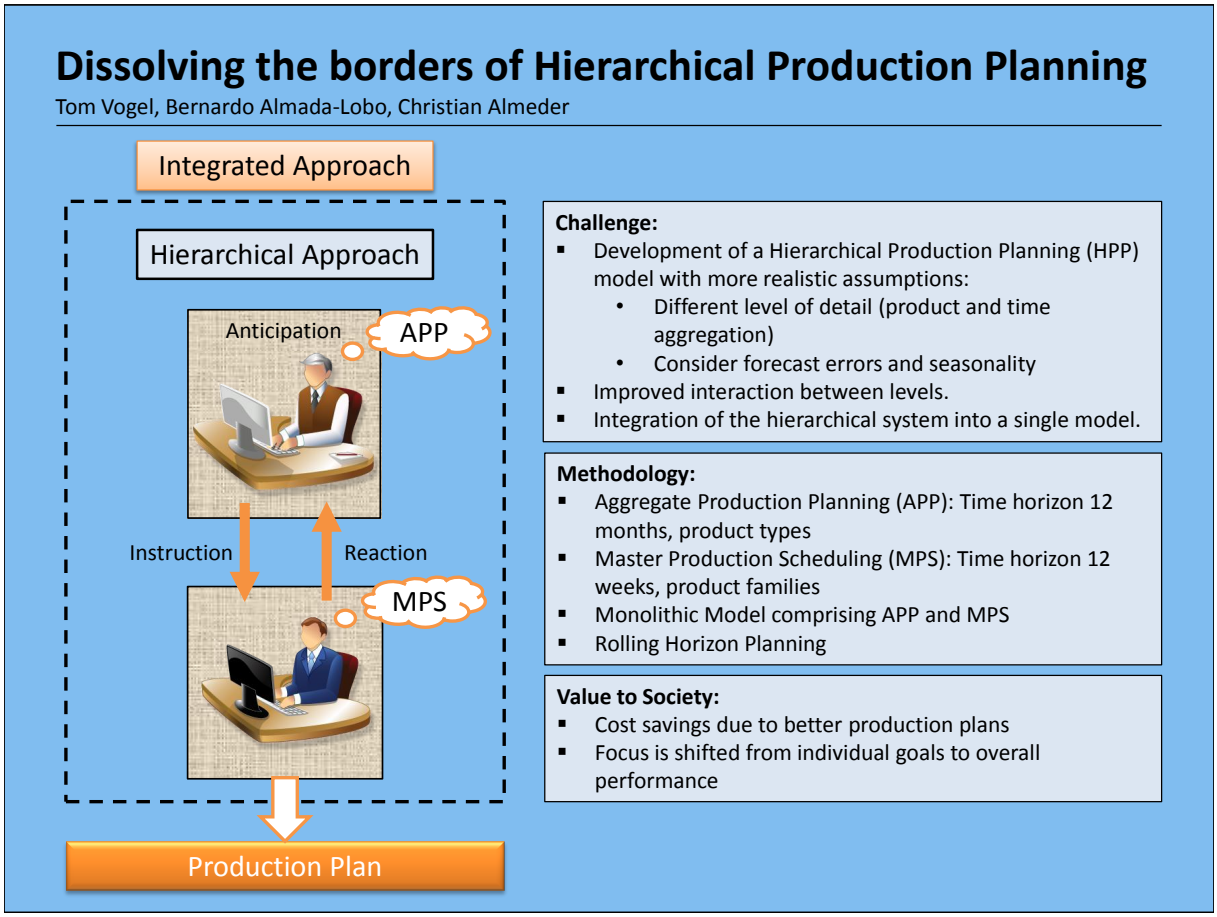

1 The Challenge

In an industrial company the production is typically planned with the Hierarchical Production Planning (HPP) approach. The basic idea is that the (optimal) decisions of an upper level impose constraints to the lower level. Normally, the levels differ in terms of the decisions which have to be made, the time horizon (long-, mid-, short-term), and the level of detail regarding time and product (types, families, end-items, items). Ideally, the levels map the hierarchical structure of the company with its responsibilities. Besides that the complexity is reduced due to the decomposition into sub-tasks. Hereby the research community has focused on developing and improving solution methods for these manageable problems. However, optimizing sub-problems separately can lead to sub-optimality regarding the overall problem. Research has revealed that the interaction between the decision levels is crucial as well.

The existing literature often neglects parts of the basic assumptions of the HPP which are different aggregation degrees, different planning horizons, and increasing uncertainty levels. Sometimes that is done because authors concentrate on a specific industry which does not require the incorporation of all points. Other papers focus more on providing a good long-term plan and to develop an appropriate disaggregation method. In our work we want to consider the mentioned assumptions regarding time granularity and level of detail, such that the planning levels reflect really different levels of decision. Furthermore, we want to incorporate forecast errors and seasonal demand on a rolling horizon basis. The latter is a common approach to create plans in an uncertain environment. The idea is to build a plan for a certain planning horizon. However, only the first periods are implemented, the other periods are updated when replanning takes place in the subsequent planning period.

An alternative to HPP is the so called Monolithic Model (MM) which incorporates all decision levels into one single model. In the literature such an approach was rejected most of the times because it does not represent the organizational structure and probably requires too much computational effort. Other reasons were the assumptions that it is not possible to integrate different aggregation degrees, different planning horizons or increasing uncertainty levels. Our goal is to develop exactly such an MM which considers these points and to compare it with the HPP on several test scenarios.

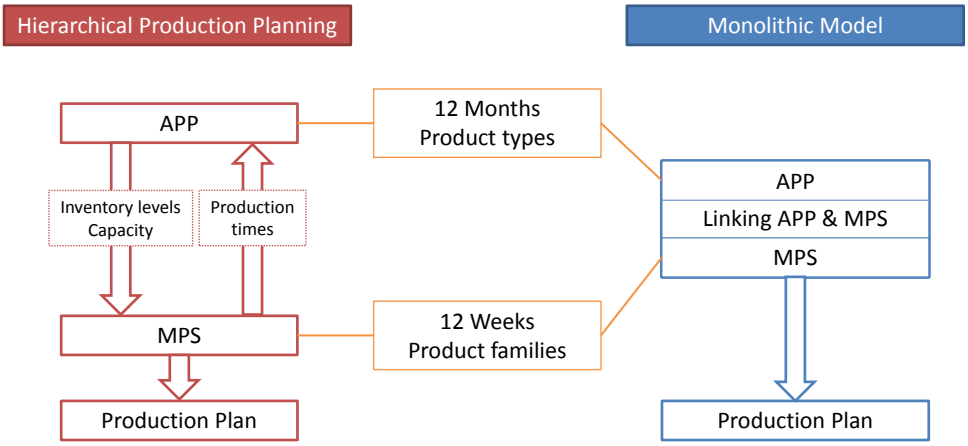

Figure 1: Comparison of HPP and MM

2 The Methodology

The HPP considered consists of two levels, Aggregate Production Planning (APP) and Master Production Scheduling (MPS). Both levels are different in terms of periods, planning horizon, degree of aggregation and decisions, which maps the reality as accurate as possible. The APP has the following main characteristics:

- Time horizon: 12 months
- Degree of aggregation: product types
- Decision variables: production amount, number of production lines, inventory levels

The number of production lines is an integer variable, thus the APP is modeled as a mixed-integer linear program (MILP). The capacity (number of lines) and the inventory level of the last period are submitted to the MPS level as instruction. The MPS level has the following main characteristics:

- Time horizon: 12 weeks
- Degree of aggregation: product families

- Decision variables: production amount, setups, inventory levels, backorders, overtime

Because the setup state is a binary variable the MPS is modeled as an MILP as well. MPS gives feedback by sending production times to APP, called reaction. At APP setups are neglected, therefore the production time has already to consider some buffer for setups. That type of interaction is called anticipation. This is done based on the MPS results. We apply the HPP on a rolling horizon basis such that the interaction between both levels can be tested also for the long-term.

The MM has to consider APP, MPS, and the interaction of both levels (anticipation, instruction, reaction). Further adjustments are necessary in terms of overlapping periods, i.e. when both levels are planned simultaneously. For instance, the inventory level is determined on both levels. However, in the overlapping periods it is sufficient to consider it only at the detailed level. The aggregate inventory results implicitly.

Computational tests show that the MM delivers better results for most of the instances. Although the computational time is higher than for the HPP it is still acceptable. However, the fact that the MM does not always outperform the HPP reveals several points. First of all, it supports the fact that even exact methods are heuristics if they are applied on rolling horizon basis. Furthermore, it gives space for further research to investigate in which circumstances HPP or MM are more reliable. The subsequent question is then how these two approaches can be improved to reach similar results.
The models were implemented in OPL and solved with the help of CPLEX 12.6. The rolling horizon planning was realized by using OPL script.

3 The value to Society

Improving the existing way of planning the production has several positive impacts to society. Costs which could be saved in production make a company more competitive and might provide the same products for lower prices to the customer. Furthermore, more detailed plans could reduce backlog and lead times as well as overtime.
By utilizing the MM the decision makers focus is shifted away from the optimization of sub-tasks. The solution for the overall problem becomes more important than the sometimes conflicting goals of the different levels. This can also impact positively the general culture in a company.

Acknowledgments

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Integrated approaches for tactical production and distribution planning

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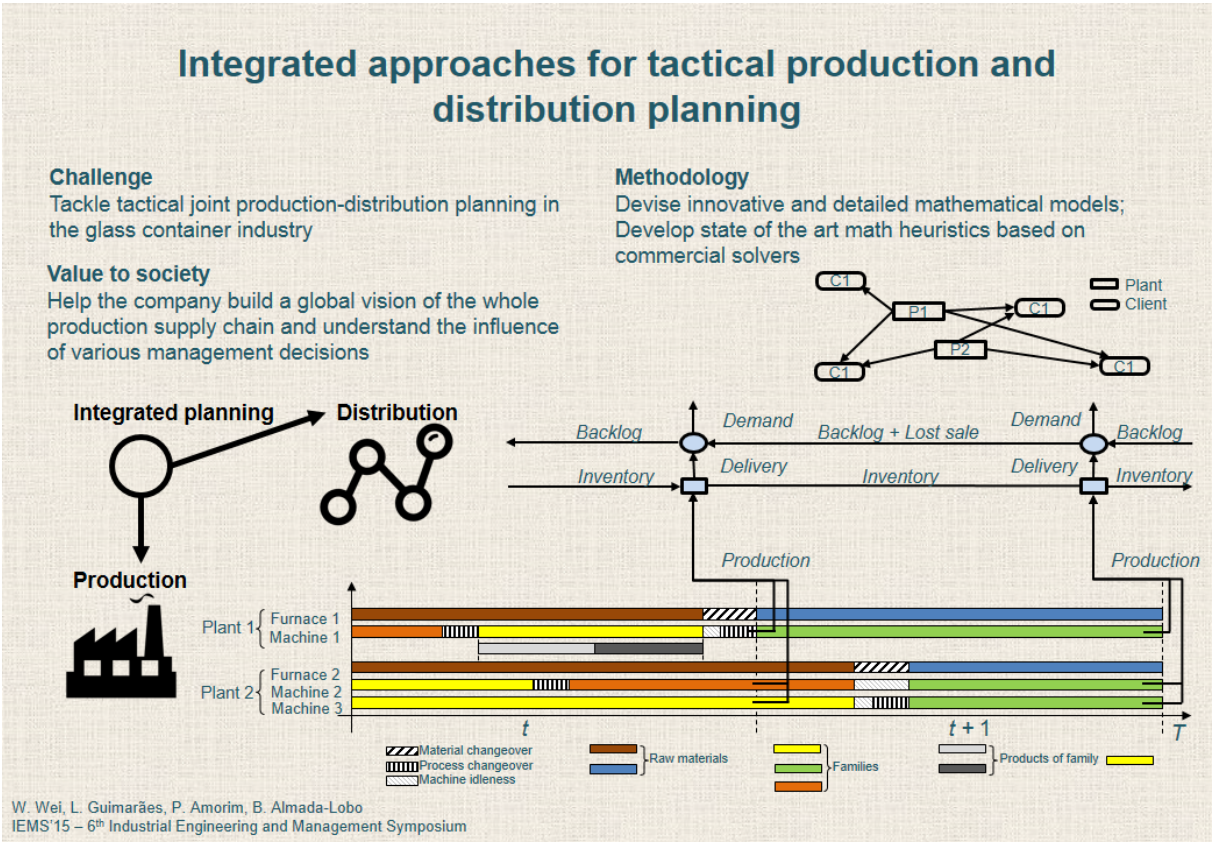

1 The Challenge

In many production supply chains, raw materials are gradually transformed to end products through a series of production stages and then delivered to scattered clients to satisfy their demands. In enacting production plans, companies emphasize on determining the utilization of production entities, production sequences and quantities of various products, whilst in the distribution planning process, the "best" delivery strategy, replenishment and inventory levels will be identified and planned for afterwards. With market globalization and international trade expansions, it is imperative for many companies to optimize their production and distribution systems simultaneously in a most efficient and economical possible way such that the overall costs are minimized and all clients' requirements are satisfied.

The consideration of interrelated production stages, such as the situation where the input of a production stage is the output of another one, and the incorporation of multiple KPIs in decoupled systems, such as back order rate, inventory levels, delivery in-full, leads to a very complex planning problem. Our industrial example tackles the mass production of glass containers which are manufactured at the rate of thousands of products per minute per production line. The company has 42 production lines, 5 plants and

16 clients scattered in an international region. Due to the large volume of information to be processed, a fast acquisition of an optimal solution is challenging. Thus having an exact algorithm to solve the problem to optimality is computationally expensive and unpractical. Beyond traditional modelling and solution techniques, state of the art mathematical formulations and heuristic solution approaches devised based on the problem characteristics deserves a dedicated study.

In this work, we study a model that integrates production and distribution planning in the tactical level with a yearly planning horizon and its validation on our industrial example. We propose formulations from two different approaches and develop solution methods which are particularly efficient for this problem.

2 The Methodology

The major concern of this problem is not only to synchronise the production and distribution plans in tactical level but also to address practical issues associated with the production process in the operational level, such as dependencies between production stages, sequence dependent setup times and costs, etc. We propose two mixed-integer linear programming formulations to model this integrated planning problem in a tactical level, which incorporates the key production stages and determines for each product, the location and quantity it is produced as well as the supply quantities to each client from each plant. These two formulations differ in the way the production sequences are modeled. The first one is a sequence-oriented model based on the concept of using a collection of pre-defined sequences which describe the items to be produced and their order. The information of production lots changeovers is already indicated in each sequence. The second one is a product-oriented model incorporating production lots changeovers decisions in the model and implicitly optimizing them during the solution procedure. The so-called disconnected sub-tour elimination constraints, which can be of an exponential size, are then required to ensure the connectivity of the subsequences induced by setup decisions.

The production environment is highly capacitated such that not all demand can be satisfied. The unfulfilled demand is either shifted to successive production periods as backlog at some costs or penalized as lost sale. The consideration of backlog and lost sales also warrant the existence of a feasible solution. As a respond to seasonally varied demands, a moderate amount of products are produced in advance and stored in the plant with some inventory costs. In the production process, the concept product families is adopted to group technologically similar products sharing some resources or consuming the same resources such that the model could be formulated in a more compact way.

To solve this large-sized problem, we devise a fix-and-optimize heuristic with an adapted variable neighborhood search (VNS) technique to handle the integer variables combined with a state of the art exact solver to address the sub-problems emerging form the approach. The hybridization can find a good solution within reasonable computation time considering its practical intent.

3 The value to Society

This model is valuable since it considers a complex and practical industrial case and combine production and distribution echelons. We intend to provide a tactical planning for business practitioners to optimize this production-distribution system. With the help of such a model, companies can have a global vision of the whole production supply chain for an entire year. The multi-plant assignment of products allows the company to figure out less profitable entities (production lines, plants, ...), and to react either by adjusting those entities to global needs or by expanding (or reducing) the size of those entities.

With substantially reduced computation times, our model can be used periodically in this industrial application to make long-term decisions. The company can also use this approach to understand the influence of various management decisions and make improvements in operational efficiency and cost savings, therefore, finding themselves a better position in the marketplace. With highlighting the essential attributes of production supply chain, the sequence-oriented formulation and the product-oriented formulation can be possibly applied to other related types of industrial cases.

End to End Abstracts

Improving the inventory management of food e-commerce activities through darkstores

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Food e-commerce activities are known for having high supply chain management costs and demanding customer service levels. With the growth of the e-commerce, its traditional logistic model of picking the SKUs directly from the physical store the customer is assigned to, is being challenged. In a quest for streamlining current processes, Sonae MC decided to open a warehouse fully dedicated to satisfy e-commerce clients (known as darkstore). This warehouse has only part of the whole product assortment (the fast-movers) as its functioning will be integrated with a regular store to supply the remaining (long-tail) products. Using a simulation-optimization approach we were able to design a tailor-made inventory policy for the new warehouse that leverages the benefits of on-line purchasing behavior. In fast moving products, the new replenishment policy results in a decrease of around 20% of inventory costs compared with a traditional approach. The bottom-up methodology allowed for estimating the required storage space and initial inventory at the darkstore. Moreover, the impact of the e-commerce activity on the regular store and the reasoning of the split of assortment between locations was validated.

Using Analytics to Enhance the Practice of Shelf Space Management

Teresa Bianchi-Aguiar [†] [‡], Elsa Silva [†] [‡], Luís Guimarães [†] [‡], José Fernando Oliveira [†] [‡], Maria Antónia Carravilla [†] [‡]

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While shopping, customer choices are influenced by in-store factors, in particular during their unplanned purchases and out-of-stock situations. The arrangement of products on the shelves becomes crucial in this context turning shelf space management a key factor to retailers' competitiveness. Recently, the shortage of shelf space and the increasing number of products available have greatly magnified the importance of how merchandize is displayed. Accordingly, we developed a Decision Support System to help deciding the best allocation of products on the shelves across Sonae's stores. Prior to this project, the process was very time consuming, with an empirical use of space elasticity, lacking formal performance evaluation criteria and heavily depending on the space managers experience. Our challenge was to bring analytical methods into the practice aiming to improve the return on space and reduce out of stock situations without disrupting (but somehow questioning) the company policies.

Reliability Engineering applied to Wind Turbine Generators

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Improving the reliability of systems and components has always been the major aim of the reliability engineer. Most practical problems involve choosing between several alternatives to attain the biggest improvement in reliability. We will present a new practical application of the proportional hazards modelling (PHM) technique in dealing with wind turbine time between failures. PHM is basically a non-parametric technique based on the assumption of a loglinear hazard function which can be applied to assess the effect of observed factors on reliability in many engineering applications. These factors, or explanatory variables, can include materials, design, location, manufacturing, operating and environmental characteristics.

Large-scale Optimization in Periodic Direct Promotional Mail Creation

Luís Guimarães [† ‡], Bernardo Almada-Lobo [† ‡], Hugo Simões [† ‡], João Pedro Pedroso [† ‡]

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Nowadays consumers are constantly being targeted with one-to-one marketing campaigns making them increasingly demanding regarding the offers received. Despite the recent advances in technology, direct mail promotions are still one of the most effective tools to promote customer visits if the right coupons are sent. This project addresses the creation of the periodic mail campaigns problem in the biggest retailer in Portugal. Sonae sends every second month to all its loyalty card holders a mail with up to sixteen discount coupons. The task of assigning the right offer to the right clients (to foster higher response rates) obeying to all business goals and constraints is an ultra-large-scale problem as trillions of alternative solutions are possible. To tackle this complexity we have designed a parallel algorithm capable of exploring the underlying structure of the problem, which is then decomposed based on mathematical programming and genetic algorithm to provide high quality solutions. The approach is able to improve current practice by up to 20% and drastically reduce the time required to create new mailing campaigns.