Miguel Mediavilla Guisasola

Integrating game-theory in the supplier selection process for complex items: an action research program to develop a systematic process for practical application

Thesis for the degree of *Philosophiæ Doctor*
PhD Supervisor: Prof. Olga Rivera Hernáez

San Sebastián, April 2020

University of Deusto
Deusto Business School

Program of Business and Territorial Competitiveness, Innovation and Sustainability



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Jakintzak askatuko zaitu.

El saber te hará libre.

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D. José María Arizmendiarrieta

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Carolina, Amaia und Eva:
alles für Euch.

Ich liebe Euch.

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Abstract

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Practitioners in purchasing management are usually focused on leveraging how to increase competition among suppliers. In recent years, there has been a growing interest in the industry and academia around the application of game-theory for supplier selection since it has been considered one of the best suited theories to tackle negotiations.

Utilising the game-theory jargon and for the purpose of this dissertation, the supplier selection process will be considered a *game*, i.e. a situation in which *players* have conflicting interests and *its theory* copes with the study of multi-person decision problems. In fact, game-theory suggests reasonable solutions for classes of games and examines their properties: that means that it may be used for explanation, prediction, or prescription of *games* in various circumstances. These studies however have been mainly descriptive and the knowledge about the design characteristics, application and impact of these supplier selection models is still limited.

Our aim is to contribute to this debate by presenting the empirical application of a systematic process to design and execute game-theory based supplier selection processes, especially for technically complex items. Our research purpose is to support a buyer so as to be able to design and execute a supplier selection process in which: there is a **big number** of qualified **supplier** (***players***) that **compete** in a **predefined** manner (***order***), in order to win a pre-established **award** (***payoff***). Then, it will possible to **influence** the potential **decisions** from **suppliers** (***strategies*** or choices) by the **buyer's** interest. In other words, game-theory could consequently help buyers to create more competition (or cooperation for other purposes out of our scope), which may contribute to balance the outcome of imperfect markets.

This doctoral thesis has worked on industrial case studies with strong focus on complex items to be purchased and has utilised the following elements from game-theory in supplier selection processes: (a) game-trees and backward-induction principle from the bargaining theory, and (b) two-phase game with a reverse auction and a subsequent consecutive negotiation of *take-it-or-leave-it*. In these cases, we have not only described

the supplier selection processes (*what* has been done), but also the *how*s and *why*s of our decisions. Specially interesting has been also the research on *how* product engineering methods and tools can increase the performance of the game-theory for the supplier selection processes. The role that product engineering can play on successfully applying game-theory to the supplier selection has been also analysed and discussed.

Our findings suggest that application of game-theory can enhance the chance to have better performance from the supplier selection process by: (1) providing a better prediction of the negotiation outcome, (2) prescribing, in consequence, the best fitting *game*, and (3) increasing competition between suppliers. Also, observations from our industrial cases confirm that product engineering methods and tools can be crucial to apply effectively game-theory (e.g. pay-off calculation).

The work of this doctoral thesis is classified within three main research topics (RT) and has the following keywords:

- **RT1:** Game-theory application to negotiations & bargaining within supplier selection process for complex items
- **RT2:** Leverage competition on the supplier selection process
- **RT3:** Strategic and tactical purchasing management (part of the wider field of *Purchasing and Supply Management*)
- **Keywords:** supplier-selection, game-theory, purchasing, negotiation, auction, bargaining, backward-induction

The main contributions of the doctoral thesis are:

Contribution No.	Description
Contribution 1	Better understanding of the *how*s and *why*s to apply systematically game-theory to supplier selection processes of complex items, so as to enhance its effectiveness.
Contribution 2	Description of *what*, *how* and *why* methods & tools from product engineering can support the application of game-theory to supplier selection processes of complex items.

(table continues from previous page)

Contribution No.	Description
Contribution 3	Description and evaluation of the usage of game-theory (by means of bargaining and/or auctions) for the procurement of complex items in two industrial cases.
Contribution 4	Description and evaluation of a two-phase negotiation in a real-world case that showed a superior performance, confirming the results suggested from the analytical research.
Contribution 5	Creation and evaluation through an industrial case of a modified japanese reverse auction that overcomes several weaknesses of the regular japanese auction.
Contribution 6	Development of a valid and novel four-stage process that eases the systematic application of game-theory to supplier selection processes of complex items.
Contribution 7	Test of the performance regarding the application of game-theory to supplier selection processes of complex items.
Contribution 8	Identification of the current limitations in the literature review on the application of game-theory to the supplier selection processes of complex items.

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Preface

This doctoral thesis is submitted to the University of Deusto for partial fulfilment of the requirements for the degree of *Philosophiae Doctor*.

This doctoral work has been performed at the program of *Business and Territorial Competitiveness, Innovation and Sustainability* in San Sebastián (Spain), with Prof. Olga Rivera Hernáez as main supervisor.

During the field work there have been several applied research projects to advise industrial companies on selected research topics contained in the doctoral thesis. These companies financed partially the work executed by the PhD candidate.

Additionally, the two case studies included in the doctoral thesis have been partially included on academic publications (papers on indexed journals) from the author. These works have been already published or are under correction of minor changes (see chapter 1.5. for a detailed list of publications). The following chapters of this doctoral thesis have ideas and concepts that have been also presented on published papers from the same author of this dissertation:

- Chapter 2. Literature review on game-theory and supplier selection process
- Chapter 3. Action research as a research strategy
- Chapter 4. Summarised description of the case A, case B and the cross-case study
- Chapter 5. Selected results from the case A, case B and the cross-case study
- Chapter 6. Selected conclusions and limitations

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- A **Ibon** y sus compañeros (**Pello, Miguel, Jabi**), pilar fundamental del origen de esta investigación. Abrazos. Os agradezco que confiéis en mi conocimiento y en mis decisiones.
- Y el más sentido abrazo para **Juan Verzier**. Mi querido amigo. Mi primer cliente de consultoría en gestión de compras y el comprador más habilidoso que he conocido. Gracias por confiar en mí durante nuestras complejísimas negociaciones. **Te recuerdo. Te recordaré**.

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Primero la verdad que la paz

●●●

Prof. Dr. Miguel de Unamuno

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Abbreviations

C	Contribution
CEO	Chief Executive Officer
CFO	Chief Financial Officer
EGT	External Grand Theories
P	Publication
QFD	Quality function deployment
RFI	Request for information
RFQ	Request for quotation
RP	Research Project
RT	Research topic
RQ	Research question
SCM	Supply Chain Management
T	Teaching activities
TCO	Total Cost of Ownership
TIOLI	Take-it-or-leave-it
VRIN	Valuable, rare, inimitable and non-substitutable

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1. Introduction

1.1. Problem outline

In the past few years the purchasing function has evolved from an administrative to a strategic function (Kerkfeld & Hartmann, 2012; Paulraj, Chen, & Flynn, 2006) that contributes to enhancing the competitive position of the firms (J. Carter & Narasimhan, 1996; Ellram & Carr, 1994; Trent & Monczka, 1998). In fact, the purchasing function is responsible for the quality and costs of purchased goods, and has also the lead for supplier management (Anderson & Katz, 1998; Cooper & Ellram, 1993; Ellram & Carr, 1994). In the academia, this research topics are part of the *Purchasing and Supply Management* field, which is defined by Monczka, Handfield, Giunipero, & Patterson (2008, p. 12) as the "strategic approach to planning for and acquiring the organization's current and future needs through effectively managing the supply base".

Purchasing and Supply Management has gained its independence from *Supply Chain Management* and it is considered to be an established discipline (Harland et al., 2006), increasingly gaining autonomy over the years both in research and practice (Spina, Caniato, Luzzini, & Ronchi, 2013). Linked to this growing importance of purchasing within the industry and the academia, since 2010 the author has been closely involved as consultant and/or practitioner in the creation of many strategic purchasing plans in several companies from different sectors around the world (among others automotive, household appliances, fast-fashion textile, civil engineering or farm engineering).

From an academic perspective, it could be said that the author has worked in the "the process of planning, implementing, evaluating, and controlling strategic and operating purchasing decisions for directing all activities of the purchasing function toward opportunities consistent with the firm's capabilities to achieve its long-term goals" (Carr & Smeltzer, 1997, p. 201). But the author likes to say that he has simply helped practitioners to define *what* they want to achieve with their purchasing categories, i.e. to define their purchasing objective(s) (e.g. cost reduction, improved product quality or service, or increased value added).

However, from a managerial perspective, that falls somehow short of the mark if these *what*s are not immediately linked to certain *how*s, which enable to operationalise the purchasing objectives by means of strategies, policies and/or practices. That is necessary in order to contribute to business success (Van Weele, 2009) and typically can start defining these purchasing strategies by using the seminal work of Kraljic and his purchasing portfolio matrix (Kraljic, 1983). Kraljic's matrix has become the standard in the field of category management and purchasing portfolio models (Gelderman & Van Weele, 2005; Monczka et al., 2008; Tassabehji, 2010) and practitioners easily understand how that matrix categorizes every purchase into one out of four quadrants, according to their profit impact and supply risk: routine commodity, bottleneck, leverage and strategic. Academia has stated that each of these quadrants requires a differentiated purchasing strategy and a supporting set of purchasing practices (Caniëls & Gelderman, 2005; Gelderman & Van Weele, 2003, 2005; Van Weele, 2009). In the field experience of the author, many well experienced purchasing executives could follow (to some extent) intuitively some of these generic strategies.

Nevertheless, to put in practice the strategies (e.g. exploit buying power) and related practices (e.g. auctioning) is not an easy job and takes a lot of time and effort from experienced purchasing professionals. In that sense, the author, as experienced consultant in the field, has been asked by many companies to support them especially in the deployment of the strategies, typically similar to *terminate partnership, find new supplier* or *exploit buying power.*

That brings to the *never-ending-challenge* for these types of buyer-supplier relations: how to leverage competition among suppliers? This is nothing new to the industry since it is widely accepted that purchasing policies can significantly improve sales margins through realizing substantial cost savings (Van Weele, 2009) and therefore provide an opportunity for firms to contribute to a position of competitive advantage (Anderson & Katz, 1998; Hawkins, Randall, & Wittmann, 2009). On the contrary, certain *more cooperative* purchasing practices (e.g. close working relationships with suppliers) can allow companies to create sustainable competitive advantage by enabling to build and leverage beneficial inter-organizational relationships (Chen, Paulraj, & Lado, 2004; Porter, 1980)

During one of the industry projects that the author had, a precise question arose from a well experienced Purchasing Director:

Is there any scientific approach which could really help us in the practice to maximise competition among suppliers? We need fresh ideas to run away from the well-known aggressive negotiation with suppliers or just the simple recommendation of releasing new suppliers!

We could not mention him any comprehensive and innovate supplier selection processes but only few generic advices, all of the them which are well known for everybody with a basic understanding of the purchasing processes. That managerial problem called the attention of the author as a researcher and made him to refocus his research from a strategic purchasing perspective to the tactical purchasing. This tactical purchasing can be defined as "the sum of determining purchasing specifications, search and selection of the best supplier, and the preparation and execution of any negotiations with the supplier in order to establish and sign the legal contract" (Van Weele, 2009, p. 9). Among these activities, supplier selection is considered a key task to allow the supply management function to act as a strategic contributor to the firm (Krause, Pagell, & Curkovic, 2001), although it is also considered as a potential source of complex, and difficult decision making problems (Huang & Keskar, 2007; Weber, Current, & Benton, 1991; Yigin, Taşkin, Cedİmoglu, & Topal, 2007).

Therefore, for this doctoral thesis we consider that supplier selection is a critical process within purchasing management in which the competition among suppliers is operatively promoted. As a consequence, we will argue that the supplier selection process can benefit from a more systematic application of game-theory to correct possible market imperfections. In fact, among the external grand theories, game-theory has been considered "the best suited [theory] to tackle negotiations" (Spina et al., 2016, p. 28). In fact, the *Purchasing and Supply Management* body of knowledge has extensive literature reviews that have shown that game-theory has been the most common theory to explain [purchasing] negotiations and auctions (Giunipero, Bittner, Shanks, & Cho, 2019; Spina, Caniato, Luzzini, & Ronchi, 2016).

In the industry, game theory has often been used by means of auctions in order to find a suitable supplier through the introduction of competition. However, evidences from

current literature show that there is limited knowledge about the design and application of supplier selection processes based on game-theory (Hawkins et al., 2009; Schoenherr et al., 2012; Spina et al., 2013; Tassabehji, 2010), with the existing research being simply descriptive or prescriptive in nature and mainly booming in the period 2000 to 2010.

Hence, the aim of this research is twofold. First, it will provide new insights about the design and execution of a supplier selection process based on game-theory applied to the procurement of complex items, Second, it will show evidence of the impact that a more systematic the application game-theory can have on the effectiveness of the supplier section process.

1.2. Research context

This doctoral thesis has been developed in close contact with seven companies (and seven case studies) from different sectors and regions in Europe and Latin-America and therefore it is well assured that the research questions arose from a real managerial problem to be solved.

The author has worked as active change agent in all the seven case studies, being part of the different working teams from the case companies. Four cases were related to the definition of strategic purchasing plan and the remaining three case studies were focused on how to apply game-theory to their respective supplier selection processes. The following Table 1 shows the contribution of each case study to the dissertation:

Case study	Description
Research project RP1	Harbour cranes engineering company. Action research project included in the dissertation (**CASE A**): bargaining
Research project RP2	Textile sector company. Project to support the strategic purchasing management of the company.
Research project RP3	Steel Construction company. Project to support the strategic purchasing management of the company.
Research project RP4	Automotive sector company (Tier 1&2). Action research project included in the dissertation (**CASE B**): auction & bargaining
Research project RP5	Home appliances company. Project to support the strategic purchasing management of the company.
Research project RP6	Equipment solutions for the restaurant & catering, laundry and refrigeration industries. Project to support the strategic purchasing management of the company.
Research project RP7	Automotive sector company (Tier 1). Action research project to support the Commercial Area in the preparation of game-theory based negotiation with OEM companies (ongoing at the time of writing the dissertation) & training

Table 1. Overview of research projects with industrial case companies during the PhD project period and selection of cases A and B included in the dissertation

This unique opportunity to work together with companies in the industry has provided an excellent opportunity to provide deep insights from the practice and enabled a practical validation of our research. Anyway, to work with these companies has also influenced some aspects of our research:

- On the one hand, the research projects developed with the case companies were focused on the procurement of complex items, i.e. highly engineered and customized products that are usually utilised on engineered-to-order or make-to-order manufacturing contexts (see chapter 4 for detailed information on the case companies and their sectors and products). Therefore, the scope of the doctoral thesis has been logically focused on complex items, excluding other research related to commoditized items or products.
- On the other hand, most of the companies knew that some tools from game-theory (usually auctions) have been usually put into practice to promote competition in the procurement of goods, but none of them had experience on their usage. Nevertheless, this aspect enabled a much easier application of game-theory to the industrial cases as a possible lever to promote more competitive supplier selection processes (versus other possible grand theories discussed in the literature).

The research developed in this doctoral thesis has been partly financed by the case companies that took part on the field work. The PhD candidate was hired by the different companies to advise them during the challenges described in the cases and research granted projects. Obviously, the role as a change agent in the cases has influenced the research direction, as usually happens with action research based projects[1].

Nonetheless most of the case companies have never put any restrictions to the research design, execution, documentation and/or spreading of the results. In fact, the full trust from the top management of the case companies has enabled the author to achieve an exceptional research freedom to propose new hypotheses and empirically test them in real-world supplier selection processes (especially in the case A and case B that are included on the field work).

[1] See chapter *3. Research-methodology & -program* for further discussion.

The only general demand from the case-companies has been to keep their company names confidential, as well as not to show real data and results with the real values. Therefore, along the dissertation there will be aspects that could not be fully shown in order to maintain the needed confidentiality with the case companies. Only one of the case companies (RP7) did not allow to utilise the primary data from the research due to confidentiality reason with their own customers and strategic projects. The non-disclosure-agreement contract that the PhD candidate signed upon starting the field work strictly regulates how to comply with the data and information that has been generated in the research process. Anyhow, the field work has obviously enriched the view of the PhD candidate in the application of game-theory to supplier selection processes (RP7 is still an ongoing project).

Finally, the author must state that he has developed this doctoral thesis as a part-time student, while working as full-time management consultant and part-time associate professor at different universities and business schools in Spain, UK and Germany.

1.3. Research questions

As already introduced, studies on game-theory application to supplier selection process found in the literature have been mainly descriptive and knowledge about the design characteristics, application and impact of these supplier selection models is still limited. Therefore, the following research questions (RQ) aim to overcome that gap by not only describing the application of game-theory to the supplier selection process (*what* has been done), but also the *how*s and *why*s of the decisions and rationale behind:

(RQ) Can game-theory enhance the effectiveness of the supplier selection processes for complex items in the industry? And if yes, how can game-theory be adapted and systematically deployed:

I. **specifically, in bargaining (i.e. non-auction-based) and utilising backward-induction principle?**

II. **specifically, by combining auctions and bargaining?**

III. **specifically, can product engineering methods and tools enhance its effectiveness?**

1.4. Research program design

The doctoral thesis is classified within three main research topics (RT):

- RT1: Game-theory application to negotiations & bargaining within supplier selection process for complex items
- RT2: Leverage competition on the supplier selection process
- RT3: Strategic and tactical purchasing management (part of the wider field of *Purchasing and Supply Management*)

The Figure 1 contains the execution timeline of the doctoral thesis activities, including[2] the publications (P), contributions (C) and teaching activities (T) of the period 2014-2020. Denote that during the first semester 2016 and 2019 the author had several private issues that made him difficult to keep the regular working pace expected for the doctoral dissertation.

Figure 2 contains a summarized view of the research program and the key activities of the doctoral thesis: literature review, construction & evaluation of the systematic process for applying game-theory to supplier selection process and, finally the quality criteria for validating the research.

Finally, the Figure 3 shows the relation and influence among the three RT, including the related publications (P) and contributions (C). The research content has evolved slightly during the time, refining its scope and clarifying how the different RT are related. Additionally, the topic *Mechanism design theory* was initially not included on the RT1. Anyhow, after fruitful discussions during the presentation of the conference communications P11 and P12 at EUROMA 2017, this topic was specifically reviewed in the literature and included as part of literature review on game-theory.

[2] A summary of publications and contributions is found on chapter 1.5. and 1.6. Also, the annexes contain the detailed description of each publication and teaching activity.

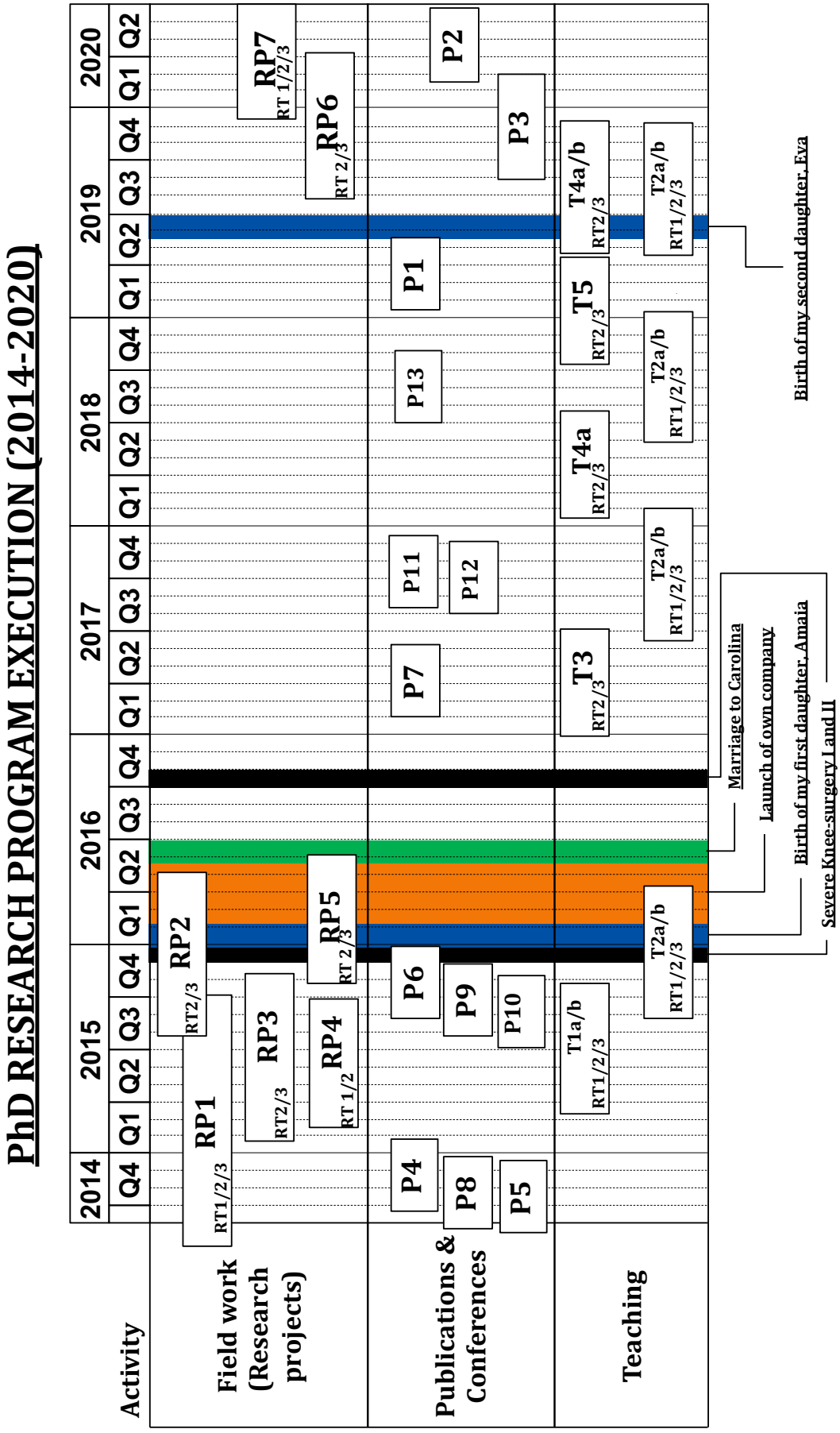


Figure 1. PhD research program execution and summary of activities

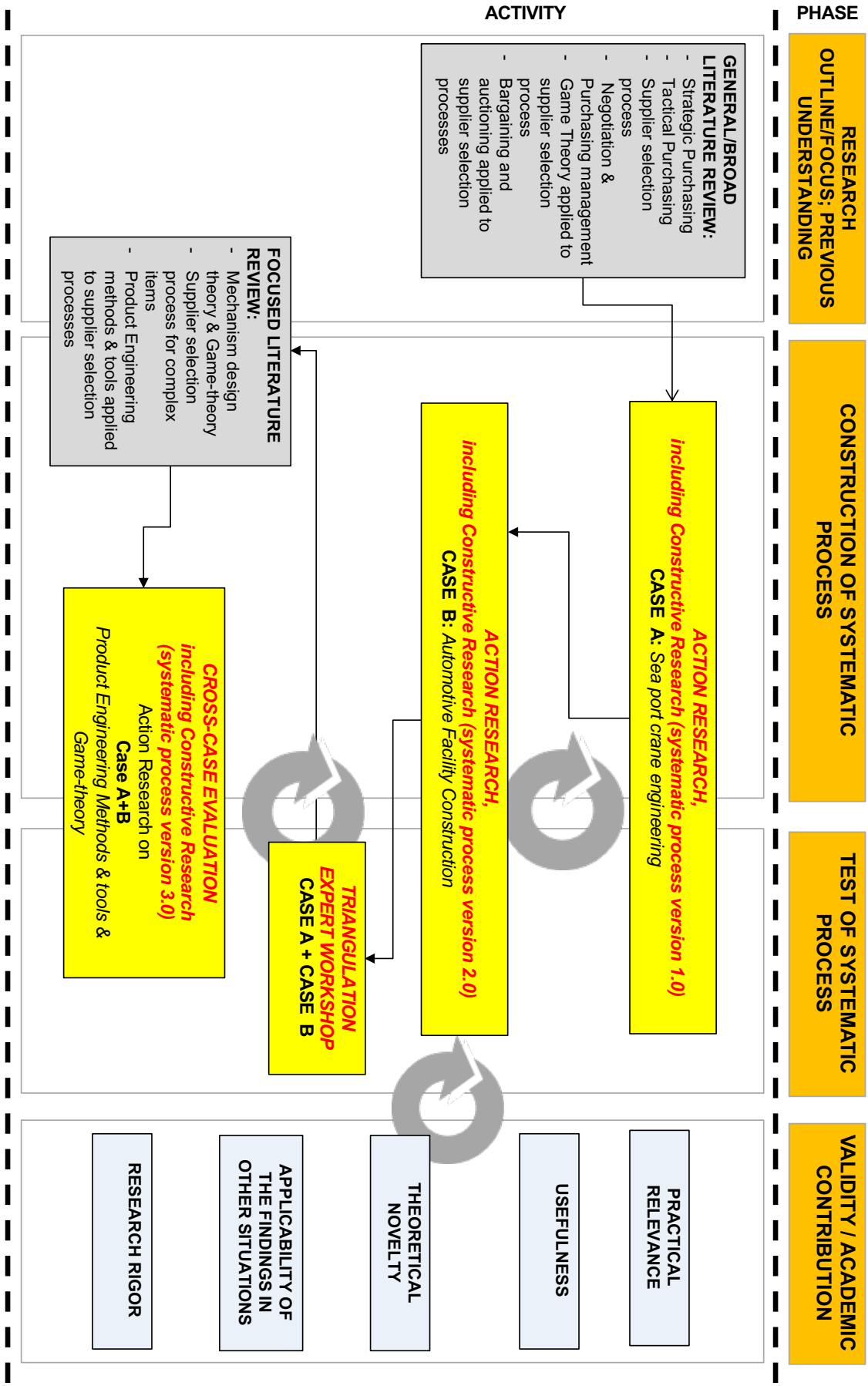


Figure 2. Research program: phases, activities and outcomes

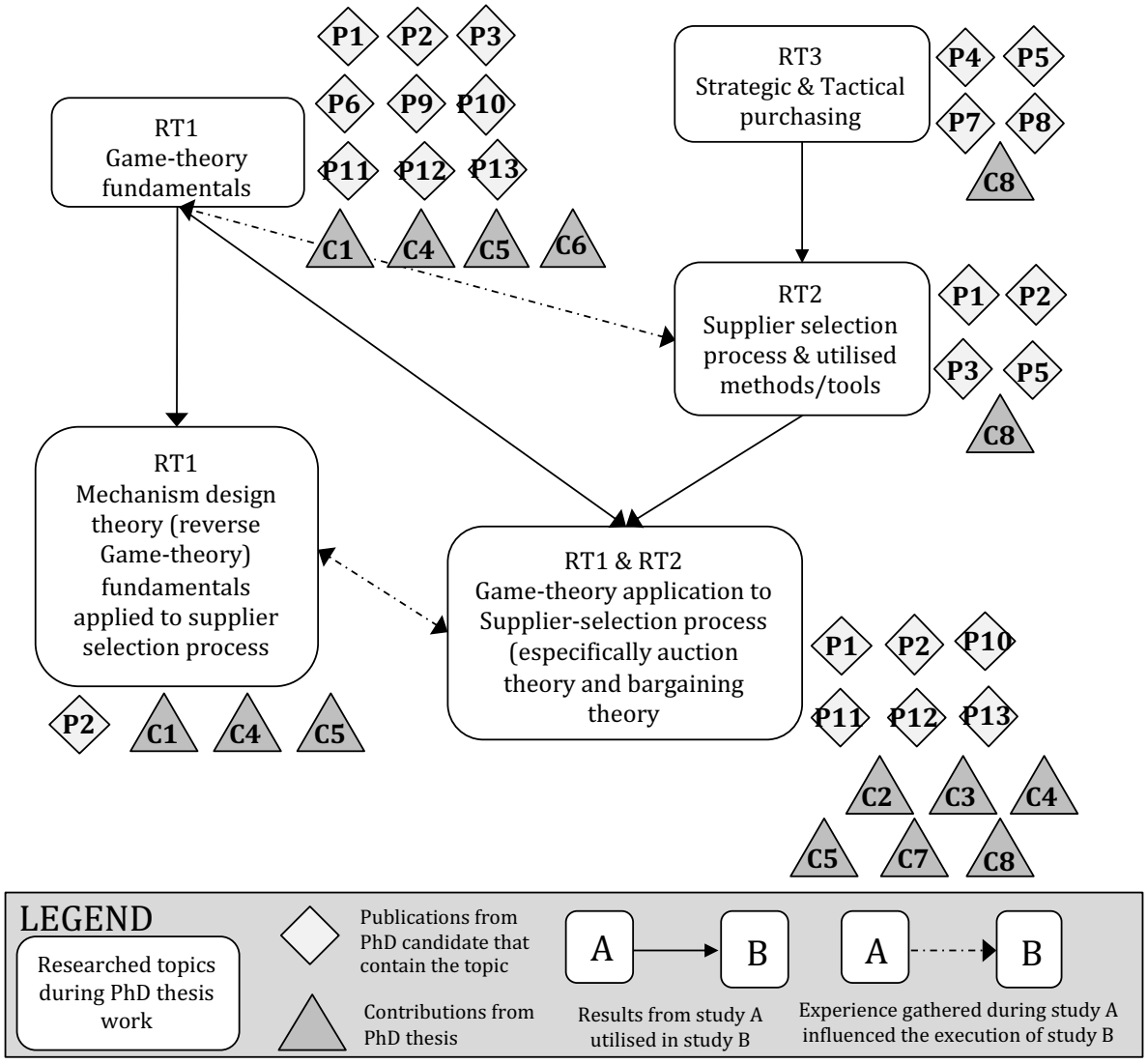


Figure 3. Linkage of research topics and related contributions & publications

1.5. Research outcome: publications, projects & teaching

During the doctoral thesis the author has had different outcomes that assure the necessary external evaluation regarding the quality of the research.

On the one hand, the author has been granted by seven companies to execute applied research projects on topics related to the doctoral thesis – which has enabled to execute and observe real-world cases. On the other hand, the results from the research and the applied research projects have been published in three Scopus/JCR ranked journals, several publications by international publishing houses and presentations on international conferences. Finally, there has been a pedagogical outcome on the RT, namely the creation of a case-study and the design and teaching on undergraduate, postgraduate and executive programs.

The Table 2 summarises the thirteen publications (P), seven research granted projects (RP) and eight teaching assignments (T) executed during the doctoral thesis. Additionally, the chapter *Annexes* (pages 263 to 277) includes a comprehensive explanation of the content and key contribution from the author on each research outcome of the doctoral thesis

Outcome	No	Description
Journal Papers	3	(**P1**) Published on *Dirección y Organización*, No. 67, April 2019, 37-45 (SJR 2018: 0.128) (**P2**) Published (*online 2020, June 4*) on *Production Planning and Control* (JCR 2018: 3.340) (**P3**) Published on *DYNA*, Vol. 95 No. 3, 570-575 (JCR 2018: 0.629)
Book Chapters	4	(**P4, P6**) Book chapters published on Springer Publishing (**P5**) Book chapter published on Anaya-Pirámide (**P7**) Case study published on IESE Publishing **All of them International Publishing Houses*
Conference Communi-cations	6	(**P8-P9**) APMS 2014 and 2015 (**P10**) Operations Research OR 2015 (**P11-P12**) EUROMA 2017 (**P13**) CIO 2018 **All of them International Conferences*
Research granted projects	7	Sectors: (**RP1**) Harbour Cranes Engineering; (**RP2**) Textile; (**RP3**) Steel Construction; (**RP4**) Automotive; (**RP5**) Home-appliances; (**RP6**) Industrial Appliances; (**RP7)** Automotive
Teaching of seminars	8	(**T1a/b**) University of Strathclyde (postgraduate) (Scotland) (**T2a/b**) Aragon Automotive Cluster (executive) (**T3**) IESE Business School (executive) (**T4a/b**) University of Mondragon (postgraduate) (**T5**) University of Mondragon (undergraduate)

Table 2. Summary of publications, research projects and seminars

1.6. Research contributions

The main contributions in the doctoral thesis are summarised as follows (Table 3):

Contribution No.	Description
Contribution 1	Better understanding of the *how*s and *why*s to apply systematically game-theory to supplier selection processes of complex items.
Contribution 2	Description of *what*, *how* and *why* methods & tools from product engineering can support the application of game-theory to supplier selection processes of complex items.
Contribution 3	Description and evaluation of the usage of game-theory (by means of bargaining and/or auctions) for the procurement of complex items in two industrial cases.
Contribution 4	Description and evaluation of a two-phase negotiation in a real-world case that showed a superior performance, as forecasted by the analytical research.
Contribution 5	Creation and evaluation through an industrial case of a modified Japanese reverse auction that overcomes several weaknesses of the regular Japanese auction
Contribution 6	Development of a valid and novel four-stage process that eases the systematic application of game-theory to supplier selection processes of complex items
Contribution 7	Test of the performance regarding the application of game-theory to supplier selection processes of complex items
Contribution 8	Identification of the current limitations in the literature review on the application of game-theory to the supplier selection processes of complex items

Table 3. Summary of contributions

1.7. Thesis Structure

Figure 4 shows the structure of the thesis in each phase of the research program (left hand side), including the key topics for each chapter, outcomes and the relation between the chapters:

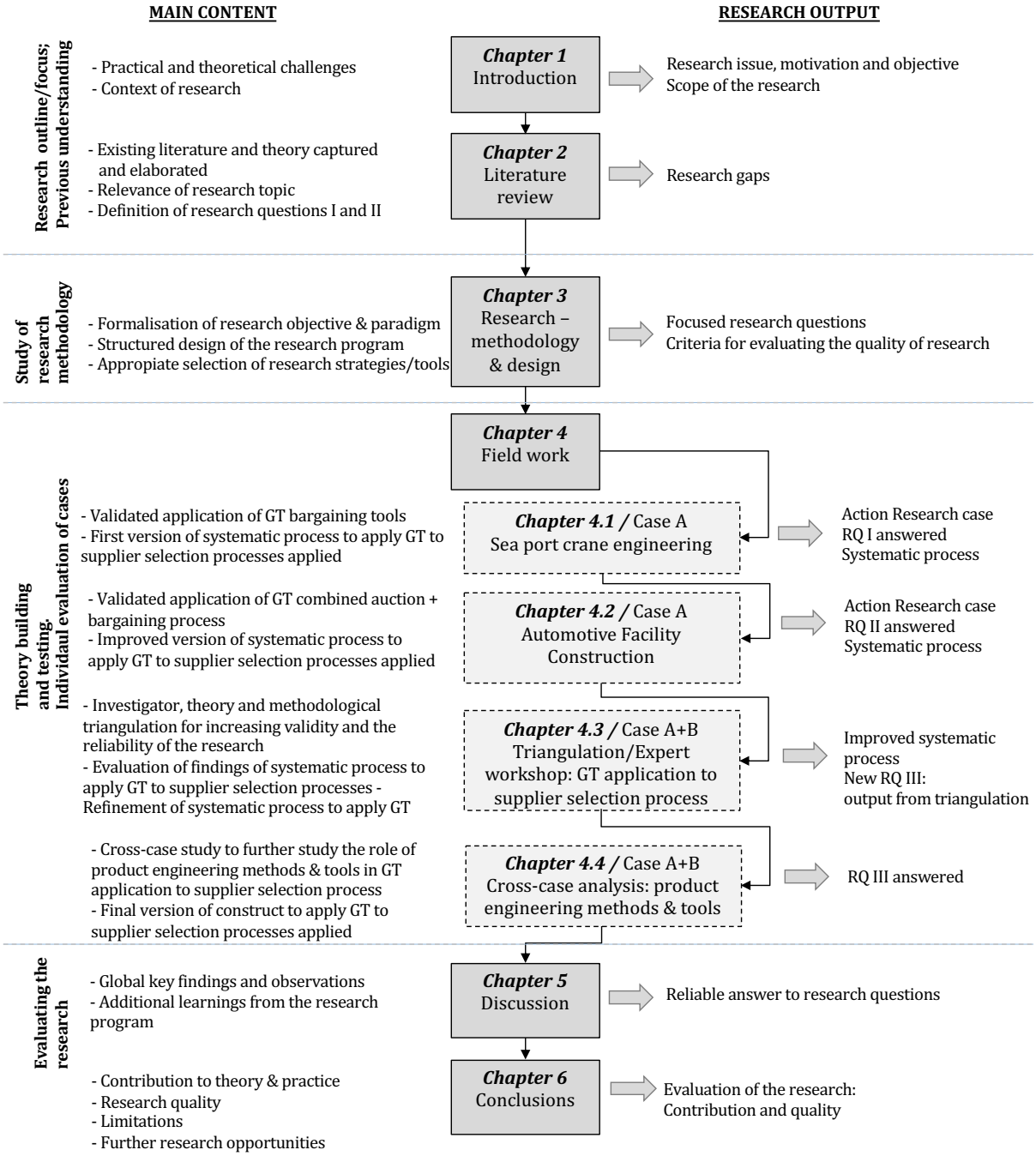


Figure 4. Scheme of the thesis structure

Pages 17 to 242 have been excluded from the dissertation in anticipation that there may be a contract of assignment of rights to third parties from the author.

The excluded pages include the following chapters: 2, 3, 4, 5 and 6.

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Annexes

Annex A) Detailed research outcomes

P1	JOURNAL PAPER (04/2019)
Mediavilla M., Mendibil K. and Rivera, O., How to negotiate with dominant suppliers? A game-theory perspective from the industry, Dirección y Organización, No. 67, April 2019	
INDEXED	SCOPUS (SJR 2018: 0.128), Latindex with 33/36 quality criteria fulfilled
RELEVANCE TO THE THESIS	This paper contains the first case study carried out within the dissertation We present our systematic process for applying game-theory to supplier selection process and describe one of the first non-auction-based game-theory application in a supplier selection process, using backward induction Additionally, there is a literature review on game-theory focusing on bargaining. Regarding methodology, action research is widely discussed as proper research method for this participatory case study. The study is focused on the research theme RT1/RT2, but also has a partial contribution to RT3. This paper answers the research question RQ.I and contributes to C1, C2, C3 and C4.
AUTHOR'S CONTRIBUTION	Main researcher in the design and execution of the case study. The documentation of the case has been also done by the author.

2	JOURNAL PAPER (2020)
Mediavilla M., Mendibil K. and Bernardos C., Making the most of Game Theory for supplier selection process, Production Planning & Control, in press, 2020. *Published online on 2020 June 4 (https://doi.org/10.1080/09537287.2020.1773560)*	
INDEXED	Science Citation Index (JCR 2018: 3.340)
RELEVANCE TO	This paper presents the latest status of my research, especially the

THE THESIS	application of our systematic process for applying game-theory to supplier selection process. It contains a two-phase game (auctioning and bargaining in a real supplier selection process for the construction of a new facility for the automotive sector). Our literature review on game-theory and supplier selection process is also well structured and has been recognized as a very detailed job by reviewers. Finally, we discuss how we have applied action research as research method for the participatory case study. This work answers RQ.II and contributes towards C1, C2, C3 and C4. The study is mainly focused on the RT2 and RT3, while has a summarized overview regarding RT1
AUTHOR'S CONTRIBUTION	Main researcher in the design and execution of the case study. Additionally, the author had the role of documenting onsite the whole case evolution.

P3	JOURNAL PAPER (2020)
Mediavilla, M., & Bernardos, C., Mendibil, K., Rivera, O. (2020). How to improve supplier selection for complex items using product engineering: perspectives from the Industry, DYNA, Vol. 95 No. 3, 570-575	
INDEXED	Science Citation Index (JCR 2018: 0.629)
RELEVANCE TO THE THESIS	This paper presents the cross-case study from the two cases executed in the field work. It responds to the topic of what, how and why the methods & tools of product engineering can enhance the performance of the systematic process for applying game-theory to supplier selection process. This work answers RQ.III and contributes towards C2 and, mainly, C3. The study is mainly focused on the RT1 and RT2.
AUTHOR'S CONTRIBUTION	Main researcher in the design and execution of the cross-case study.

P4	BOOK CHAPTER (10/2014)
Book-chapter (selected post-conference contributions, pp. 51-58): Martinez S., Mediavilla M, Bäckstrand J. and Bernardos C., Alignment of the purchasing strategy to the business strategy: an empirical study on a harbour cranes company. *In Grabot, B. et al. (2014), Advances in Production Management Systems. Innovative and Knowledge-Based Production Management in a Global-Local World, Springer Berlin Heidelberg, 2014 (ISBN: 978-3-662-44732-1)*	
INDEXED	Springer Berlin (International Publishing House)
RELEVANCE TO THE THESIS	This book chapter presents an initial status of my research, focused on the strategic purchasing management (RT3). It makes also sense, since it contains the necessary previous research on RT3 before executing the case RP1 which is finally described in the journal paper P2. It is linked to the doctoral thesis on the literature review on strategic purchasing management. The chapter is linked to research theme RT3.
AUTHOR'S CONTRIBUTION	Main researcher in the design, execution and documentation of the case study. Regarding the formal writing of the paper, the author has had a supporting role to other colleagues.

P5	BOOK CHAPTER (10/2014)
Book-chapter (pp. 116-138): Mediavilla M and Bernardos C., Procesos hospitalarios y operaciones logísticas. Parte segunda. La función de compras en hospitales. *In Mediavilla, M. et al. (2014), Logística Sanitaria: retos y nuevas tendencias, Ediciones Pirámide (Anaya, España), 2014 (ISBN: 978-8436832488)*	
INDEXED	Anaya-Pirámide (International Publishing House)
RELEVANCE TO THE THESIS	This book chapter presents a comprehensive review of our literature review on the research themes RT1, RT2 and RT3. Even though the chapter has a wide list of academic references, the targeted reader were practitioners. Therefore, the chapter is very practically oriented. It is linked to the doctoral thesis as it

	contains a general literature review of all relevant research topics. The study had a partial contribution to contribution C1.
AUTHOR'S CONTRIBUTION	This book chapter was prepared and written by the author and his co-author. We have had a very equal work content on the creation of this extent literature review.

P6	BOOK CHAPTER (10/2015)
Book-chapter (selected post-conference contributions, pp. 199-206): Mediavilla M, Bernardos C. and Martinez S., Game theory and Purchasing Management: an empirical study of auctioning in the automotive sector. *In Umeda, S. et al. (2015), Advances in Production Management Systems: Innovative Production Management Towards Sustainable Growth, Springer International Publishing, 2015 (ISBN: 978-3-319-22758-0)*	
INDEXED	Springer Publishing (International Publishing House)
RELEVANCE TO THE THESIS	This book chapter is an improved version of the publication P8 (conference paper), which introduced our (stepwise richer) literature review on game-theory applied to supplier selection process. An improved game-theory process was also part of this work. This chapter gives a *first version* answer to the research question RQ.II and contributes to C1, C2, C3 and C4. The study is mainly focused on the research theme RT2 and RT3.
AUTHOR'S CONTRIBUTION	Main writer of the chapter and the main researcher of the case (design, execution and documentation).

P7	CASE STUDY (12/2016)
Mediavilla M and Lago A., PACECO: The Purchasing Decision for the Fénix Project (P-1158-E)	
INDEXED	IESE Publishing (International Publishing House)
RELEVANCE TO THE THESIS	Together with Alejandro Lago (Full Professor at IESE Business School), the author has prepared a case study for MBA and Executive education, which is related to the strategic and tactical purchasing

	decision (research theme RT3). This case also allows to have a deep view on the supplier selection processes and its relationship with the strategy (research theme RT2).
AUTHOR'S CONTRIBUTION	Writer of the main body since he has been the researcher on the real case study. This case study is a simplified version of our research project RP1

P8	CONFERENCE COMMUNICATION (09/2014)
Advances in Production Management Systems (APMS) 2014, Ajaccio, France Martinez S., Mediavilla M, Bäckstrand J. and Bernardos C., Alignment of the purchasing strategy to the business strategy: an empirical study on a harbour cranes company	
INDEXED	International Conference (peer-reviewed)
RELEVANCE TO THE THESIS	Conference communication that has been later improved and published as book-chapter P3.
AUTHOR'S CONTRIBUTION	See P4

P9	CONFERENCE COMMUNICATION (09/2015)
Advances in Production Management Systems (APMS) 2015, Tokyo, Japan Mediavilla M, Bernardos C. and Martinez S., Game theory and Purchasing Management: an empirical study of auctioning in the automotive sector.	
INDEXED	International Conference (peer-reviewed)
RELEVANCE TO THE THESIS	Conference communication that has been later improved and published as book-chapter P5.
AUTHOR'S CONTRIBUTION	Onsite presenter. For additional details see P6.

P10	CONFERENCE COMMUNICATION (09/2015)
International Conference on Operations Research 2015, Vienna, Austria Bernardos, C., Mediavilla, M. and Martinez, S. (2015), Game theory and Purchasing Management: an empirical study of extensive games in harbour cranes sector	
INDEXED	International Conference (peer-reviewed)
RELEVANCE TO THE THESIS	As researcher, the author wanted to submit a communication to this conference to put under stress our theoretical background on game-theory. This international conference usually gathers a group of theoreticians on game-theory; therefore, the aim was to receive a critic and feedback on the theoretical game-theory background. The feedback was positive, and the main interest of others researcher laid on how to calculate the payoffs of our game. The communication is focused on the research theme RT1, and partly present an answer to the research question RQ.I Its contribution is equally spread among C1, C2, C3 and C4 (but with a more theoretical focus than in other conferences or papers).
AUTHOR'S CONTRIBUTION	Main researcher doing the design, execution and documentation tasks during the case. The author also prepared the main body of the communication.

P11	CONFERENCE COMMUNICATION (07/2017)
24th EUROMA International Conference 2017, Edinburgh, Scotland Mediavilla, M., Bernardos, C. and Mendibil, K. (2017), Designing reverse auctions: an automotive sector study	
INDEXED	International Conference (peer-reviewed)
RELEVANCE TO THE THESIS	This conference communication has been crucial, since it was the basis job for the journal paper P3. During the conference, it was presented one of our latest status of: literature review on game-theory applied to supplier selection process, the game-theory

	based process and the application of the auction theory combined with bargaining. We gained a lot of valuable feedback that helped us improving our work. This communication answers the research question RQ.II and contributes towards C1, C2, C3 and C4. The study is focused on the research theme RT1 and RT2.
AUTHOR'S CONTRIBUTION	Onsite presenter of the conference communication. Furthermore (as detailed in P3), the authors have been the main researcher in the design and execution of the case study. Additionally, the author had the role of documenting onsite the whole case evolution.

P12	CONFERENCE COMMUNICATION (07/2017)
24th EUROMA International Conference 2017, Edinburgh, Scotland Mediavilla, M., Mendibil, K. and Bernardos, C. (2017), Game theory in supplier selection process: An action research study	
INDEXED	International Conference (peer-reviewed)
RELEVANCE TO THE THESIS	This conference communication has been important, since it was a part of our posterior journal paper P1 (published on DYO, Scopus ranked). During the conference, it was presented the latest version of our literature review on game-theory applied to supplier selection process, the game-theory framework and the application of the backward induction tool. It was a helpful discussion to refine our description of the case and usage of game-theory tools. This communication (as P1 does) answers the research question RQ.I and contributes towards C1, C2, C3 and C4. The study is mainly focused on RT1 and RT2.
AUTHOR'S CONTRIBUTION	Onsite presenter of the conference communication. Furthermore (as detailed in P2), the author has been the main researcher in the design and execution of the case study. The documentation of the case has been also done by the author.

P13	CONFERENCE COMMUNICATION (07/2018)
12th International Conference on Industrial Engineering and Industrial Management (ICIEIM)& 22nd Congreso de Ingeniería de Organización (CIO), Girona, Spain Mediavilla, M., Mendibil, K. and Rivera, O. (2018), "How to negotiate with dominant suppliers? A game-theory perspective from the industry", Proceedings of CIO 2018 conference, Girona, Spain.	
INDEXED	International Conference (peer-reviewed)
RELEVANCE TO THE THESIS	Similarly to P10, this conference communication has been important since has helped us to refine aspects included on the journal paper P1. specifically: an improved version of our game-theory framework and a detailed explanation of how to utilize the backward-induction game-theory tool. This communication answers the research question RQ.I and contributes towards C1, C2, C3 and C4. The study is mainly focused on RT1 and RT2.
AUTHOR'S CONTRIBUTION	Presenter onsite and the main researcher in the design and execution of the case study. The documentation of the case has been also done by the author.

Due to confidentiality reason the research granted project do not contain specific information on which companies have participate in each project. Instead, we describe the sector, scope and location of the company:

RP1	RESEARCH GRANTED PROJECT 2013-14
Strategic procurement plan 2013-2016	
FINANCED BY	Harbour crane sector. Spanish company located in Madrid that provides engineering, construction and field services.
RELEVANCE TO THE THESIS	The author was able to put in practice concepts related to RT3 and its deployment. Additionally, it could be tested the framework on RT1 and RT2, specifically we could test on a real supplier selection process the results related to the RQ.I. This case had its main contributions to C3 and C4
AUTHOR'S CONTRIBUTION	Main researcher & consultant of the project team (two researchers and three purchasing professionals from the company). Hired by the President and Chief-Executive Officer (CEO) of the company.

RP2	RESEARCH GRANTED PROJECT 2015
Operations Strategy analysis framework for deploying the business strategy in the fast-moving value brand textile industry	
FINANCED BY	Textile sector company located in the Basque Country (Spain), which is dedicated to the design and procurement of sport clothing.
RELEVANCE TO THE THESIS	Within a wider Operations Strategy Project, we could put in practice aspects from RT3 and RT2. The focus was to have a better strategic procurement plan, including a more detailed definition of the supplier selection process. It made contributions to C1.
AUTHOR'S CONTRIBUTION	Senior research leading an extended team formed by an onsite Junior Researcher and two core members from the company. Hired by the CEO of the company

RP3	RESEARCH GRANTED PROJECT 2015
Strategic purchasing plan 2015-2018	
FINANCED BY	Steel Construction company doing Steel Global Project Management, including engineering (design, connections, calculations and workshop drawings), manufacturing, painting, international logistic and on-site erection of all kind of Steel Structures, which is located in the Basque Country (Spain)
RELEVANCE TO THE THESIS	Similar scope to RP1 and RP2 on RT3. The author was able to put in practice concepts related to RT3 and its deployment, as well as to discuss models to better perform the supplier selection process for an Engineer-to-Order company.
AUTHOR'S CONTRIBUTION	Main researcher & consultant of the project team (two researchers and one purchasing professional from the company). Hired by the President & CEO of the company.

RP4	RESEARCH GRANTED PROJECT 2015
Design and execution of a supplier selection process for the construction of a new automotive production facility in Mexico	
FINANCED BY	Spanish automotive group located in the Basque Country and specialized in metal forging for safety components.
RELEVANCE TO THE THESIS	This Project has been one of our most important field studies, since it has been widely described on our journal paper P3. This supplier selection process enabled us to design, execute and document a real supplier selection process that had two stages (auction & bargaining). It is mainly focused on RT 1 and RT2 and contributed to C2 and C3.
AUTHOR'S CONTRIBUTION	Main researcher and lead consultant of a team composed by two researchers and two executives (as core members) from the company. The author was onsite in Mexico during the execution of the supplier selection process.

RP5	RESEARCH GRANTED PROJECT 2015-16
ONE supply chain in Latin-America: definition and roadmap 2015-2020	
FINANCED BY	German company that is one of the world's leading companies in the sector and the largest home appliance manufacturer in Europe.
RELEVANCE TO THE THESIS	Within a broader scope (i.e. Supply-Chain, including purchasing on it), this project had a similar scope to RP1, RP2 and RP3 on RT3. The author was able to create theoretical model related to RT3 and its deployment. In addition, we could plan what to do and when in the roadmap on RT1 and RT2. Due to the nature of a multinational company, it was not possible to deploy the framework for supplier selection process applying game-theory during the project execution, since corporate functions were already developing an own model.
AUTHOR'S CONTRIBUTION	Main researcher and consultant leading a team of five well experienced professional onsite. The tasks were the design, execution and onsite coordination.

RP6	RESEARCH GRANTED PROJECT 2019-20
Evaluation of Strategic purchasing management	
FINANCED BY	Spanish company of equipment solutions for the restaurant & catering, laundry and refrigeration industries.
RELEVANCE TO THE THESIS	Within the strategic purchasing plan development, this project had a similar scope to RP1, RP2, RP3 and RP5 on RT3. For that purpose, concepts and insights from the RT1 and RT2 have been utilised to have more effective and efficient bargaining.
AUTHOR'S CONTRIBUTION	Main researcher and consultant with the support of a junior researcher. The tasks were the evaluation of the strategic purchasing management and the support to design a main development paths for the future strategic purchasing concept.

RP6	RESEARCH GRANTED PROJECT 2019-2020
Advisory role & training to Commercial Directors on how game-theory is applied to supplier selection processes	
FINANCED BY	French origin multinational company of the automotive sector, which acts as Tier-1 to all major automotive OEMs.
RELEVANCE TO THE THESIS	The author was able to put into practice the systematic process for applying game-theory to supplier selection process but from the perspective of a supplier participating in an awarding. That has led to develop a way of working to do "reverse engineering" of auctions and bargaining from the major OEMs. Relevant to RT1 and RT2, and impacts C2, C3 and C4.
AUTHOR'S CONTRIBUTION	Main researcher, trainer & consultant of the project.

T1a	RESEARCH SEMINAR DESIGN & TEACHING
"Strategic Procurement Management" (MSc level), 16 hours of onsite teaching; credit value: 15	
HOSTED BY	University of Strathclyde (Scotland)
RELEVANCE TO THE THESIS	This MSc module is linked to RT 2 and RT3, specifically by providing the students insights into Strategic purchasing Management. The programme presented the EXP (Excellent Purchasing) Model, which summarizes the purchasing functions and processes at strategic, tactical and operational levels. Insights from RP1 and RP3 were utilised.
AUTHOR'S CONTRIBUTION	Senior Lecturer who designed, taught and marked the module. The author led a junior researcher who helped with the documentation and organisation.

T1b	RESEARCH SEMINAR DESIGN & TEACHING
"Organisational Buying Behaviour and Structures" (MSc level), 16 hours onsite teaching; credit value: 10	
HOSTED BY	University of Strathclyde (Scotland)
RELEVANCE TO THE THESIS	This MSc module is linked to RT1 and RT2 by focusing on the buyer-seller relationships including the individual and group behaviours and relationships in procurement scenarios. Moreover, this course familiarizes the students with a brief introduction to Advanced Negotiation Techniques (game-theory application to PU). Insights from RP1 and RP4 were discussed.
AUTHOR'S CONTRIBUTION	Senior Lecturer who designed, taught and marked the module. The author led a junior researcher who helped with the documentation and organisation

T2a	RESEARCH SEMINAR DESIGN & TEACHING
"Strategic Purchasing Management" (Executive Education), 12 hours onsite teaching, part of a wider Executive Program on Operations Management	
HOSTED BY	Aragon Automotive Cluster (Spain)
RELEVANCE TO THE THESIS	Introduction to RT2 and RT3 to executives taking part on the course, also utilising the case study P6 and some insights from RP 1, RP2, RP3 and RP4.
AUTHOR'S CONTRIBUTION	Lecturer in charge of the design, teaching and marking of the module. The module has received evaluation >4 out of 5 points from the student during the four editions.

T2b	RESEARCH SEMINAR DESIGN & TEACHING
"Advanced Negotiation Concept", 9 hours onsite teaching, part of a wider Executive Program on Operations Management (2015, 2017 and 2018)	

HOSTED BY	Aragon Automotive Cluster (Spain)
RELEVANCE TO THE THESIS	Presentation of the theoretical background of RT1 and RT2, especially focusing on game-theory utilisation for supplier selection process. Insights from RP1 and RP4 were utilised.
AUTHOR'S CONTRIBUTION	Lecturer in charge of the design, teaching and marking of the module. The module has received evaluation >4,5 out of 5 points from the student during the four editions.

T3	RESEARCH SEMINAR DESIGN & TEACHING
"Strategic Purchasing" utilising the case study P6, 2 groups x one Session (80 minutes) within the Operations Strategy module (eight sessions) included on "Programa de Desarrollo Directivo" (PDD).	
HOSTED BY	IESE Business School (Spain)
RELEVANCE TO THE THESIS	Introduction to RT2 and RT3 to more than 100 executives at IESE Business Schools, utilising the case study P6 -which is based on insights from RP1.
AUTHOR'S CONTRIBUTION	Lecturer in charge of the design, teaching and marking of the module. The module has received evaluation >4,5 out of 5 points from the students on the two groups.

T4a	RESEARCH SEMINAR DESIGN & TEACHING
"Strategic Purchasing Management" (MSc level), 8 hours onsite teaching (2017, 2018, 2019 and 2020)	
HOSTED BY	University of Mondragón (Spain)
RELEVANCE TO THE THESIS	Introduction to RT2 and RT3 to practitioners taking part on a MSc on Production Management, utilising the case study P6 and insights from RP1, RP2, RP3, RP4 and RP5. Brief introduction to game-theory application for supplier selection process by presenting a summarised view of P1 and P2.

AUTHOR'S CONTRIBUTION	Lecturer in charge of the design, teaching and marking of the module. The module has received evaluation >9 out of 10 points from the students on the last two editions

T4b	RESEARCH SEMINAR DESIGN & TEACHING
"Introduction to advanced negotiation: game theory applied to supplier selection processes" (MSc level), 10 hours onsite teaching (2019 and 2020)	
HOSTED BY	University of Mondragon (Spain)
RELEVANCE TO THE THESIS	Presentation of the theoretical background of RT1 and RT2, especially focusing on game-theory utilisation for supplier selection process. Insights from RP1 and RP4 were utilised.
AUTHOR'S CONTRIBUTION	Lecturer in charge of the design, teaching and marking of the module.

T5	RESEARCH SEMINAR DESIGN & TEACHING
"Strategic Purchasing Management" (BSc/Undergraduate level), 16 hours onsite teaching (2018 and 2019)	
HOSTED BY	University of Mondragon (Spain)
RELEVANCE TO THE THESIS	Introduction to RT2 and RT3 to undergraduate student taking part on a BSc on Industrial Organisation, utilising the case study P6 and insights from RP1, RP2, RP3, RP4 and RP5. Brief introduction to game-theory application for supplier selection process by presenting a summarised view of P1 and P2.
AUTHOR'S CONTRIBUTION	Lecturer in charge of the design, teaching and marking of the module (subject taught in English)

Annex B) Paper P1, case study A in harbour crane industry

Electronical access to the article published as
Mediavilla, M., Mendibil, K., & Rivera, O. (2019). How to negotiate with dominant suppliers? A game-theory perspective from the industry. Dirección y Organización, 67, 37-45.

https://www.revistadyo.es/index.php/dyo/article/view/542/563

Annex C) Paper P2, case study B in the automotive industry

Electronical access to the article published as
Mediavilla, M., Mendibil, K., & Bernardos, C. (2020) Making the most of game theory in the supplier selection process for complex items, Production Planning & Control, published online on 2020 June 4, DOI: 10.1080/09537287.2020.1773560

https://doi.org/10.1080/09537287.2020.1773560

Annex D) Paper P3, cross-case A+B study

Electronical access to the article published as
Mediavilla, M., & Bernardos, C., Mendibil, K., Rivera, O. (2020). How to improve supplier selection for complex items using product engineering: perspectives from the Industry, DYNA, Vol. 95 No. 3, 570-575

https://dx.doi.org/10.6036/9240

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