UNIVERSIDAD DE SEVILLA

DOCTORAL THESIS

Decision-Making Support for the Alignment of Business-Process-Driven Organizations with Strategic Plans

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A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

in the

IDEA Research Group
Department of Computer Languages and Systems

November 27, 2017

Acknowledgements

Looking back, I can say that I have enjoyed my time as a Ph.D. student. On a professional level, this experience has allowed me to become part of research and university world, and has taken me out of my comfort zone on numerous occasions. However, it is not the professional plane that interests me at this time. Although it is true that I have enjoyed this stage, writing a doctoral thesis is not "small potatoes", and there are occasions on which the support of certain people is essential to gather the necessary forces carry on. For that reason, I cannot miss this opportunity to dedicate a few lines of thanks to these people.

First of all, I would like to express my gratitude to my thesis director, for involving me, without whom, this doctoral thesis would not be a reality. Thanks Mayte, for showing me the world of university and research, for being as involved as I am in this work, for being available at any time of day to listen to the latest idea that has just occurred to me, to improve those ideas with your advice and suggestions, but above all for transmitting to me the passion and enthusiasm that you yourself have into this. I feel that more than a thesis director, I have had (and still have) a friend.

To IDEA, my research group, because they have provided an environment where ideas can be shared and discussed, and because they have been concerned about my well-being during this time. Special thanks to Rafael Martinez, who has shown absolute commitment to the promotion, contribution and improvement of everything that has passed through his hands. A special nod goes to Ángel and Luisa for the extra suffering I put them thought. Of course, my thanks also goes to the other colleagues of the Department of Computer Languages and Systems, who have welcomed me as one more member, and with whom numerous of talks and coffees have been shared.

To my colleagues of Xerox Research Centre Europe, for being my hosts during the stay and for integrating me from day one in the "afterworks". Thanks in particular to my colleagues in the Process Intelligence group, Adrian and Mario, for showing me alternative points of view, other ideas and opportunities and for making me enjoy the work.

To my friends of Nueva Carteya, for their affection and support, because, although we have only occasionally met, they were there when they were needed, and for being true friends. To my friends in Seville, my second family, because without you none of this would make sense, and for making me see that, although we have to be responsible with obligations, life is much more than just that.

To my parents, Vicente and Josefina, for showing unconditional support, and for understanding my absences on family occasions with a smile and a few words of encouragement. To my sister Rocío, for demonstrating that what one really wants, with effort, can be achieved. Keep showing that you, and only you, mark your own limits.

Eli, there are no words to describe how grateful I am to the universe for crossing our paths. Your encouragement and support in this thesis from only an infinitesimal part of the things for which I owe you my gratitude Thank you for making me happier every day.

Agradecimientos

Echando la vista atrás, puedo decir que he disfrutado de mi etapa de doctorando. En el plano profesional, esta experiencia me ha permitido conocer muy de de cerca el mundo de la investigación y la universidad y me ha sacado de mi zona de confort en numerosas ocasiones. Sin embargo, no es el plano profesional el que me interesa en este momento. Aunque es cierto que he disfrutado de esta etapa, escribir una tesis doctoral no es "moco de pavo", hay ocasiones en las que el apoyo de las personas es fundamental para sacar las fuerzas necesarias que te ayuden a continuar. Por esa razón, no puedo dejar pasar esta ocasión para dedicar unas palabras de agradecimiento a esas personas.

En primer lugar, me gustaría expresar mi gratitud a mi directora de tesis, por liarme, ya que de otra manera esta tesis doctoral no sería realidad. Gracias Mayte, por mostrarme el mundo de la investigación y la universidad, por estar tan involucrada como yo en éste trabajo, por estar disponible a cualquier hora del día para escuchar la última idea que se me acaba de ocurrir, por mejorar esas ideas con tus consejos y sugerencias, pero sobre todo por transmitirme la pasión y entusiasmo que pones en esto. Siento que más que una directora de tesis, he tenido y tengo una amiga.

A mi grupo de investigación IDEA, porque ellos han sabido proporcionar un entorno donde compartir y discutir ideas, y porque han velado por mi bienestar durante este tiempo. Un agradecimiento especial a Rafael Martinez, que ha mostrado una disposición absoluta para aportar, contribuir y mejorar todo lo que ha pasado por sus manos. No puedo dejar de hacer un guiño a Ángel y Luisa ya que ellos me han sufrido especialmente. Por supuesto, también al resto de compañeros del departamento de Lenguajes y Sistemas Informáticos, los cuales me han acogido como uno más, y hemos compartido numerosas de tertulias y cafés.

A mis compañeros de Xerox Research Centre Europe, por ser mis anfitriones durante la estancia e integrándome desde el primer día en los "afterworks". Gracias en especial a mis compañeros del grupo Process Intelligence, Adrian y Mario, por mostrarme otros puntos de vista, otras ideas y oportunidades y por hacerme disfrutar con el trabajo.

A mis amigos de Nueva Carteya, por su cariño y apoyo, porque aunque nos vemos poco, han demostrado estar cuando se les necesita y ser verdaderos amigos. A mis amigos de Sevilla, mi segunda familia, porque sin vosotros nada de esto tendría sentido, y por hacerme ver que hay que ser responsable con las obligaciones, pero que la vida es mucho más que eso.

A mis padres, Vicente y Josefina, por mostrar un apoyo incondicional, y por comprender mis ausencias en ocasiones familiares con una sonrisa y unas palabras de ánimo. A mi hermana Rocío, por demostrar que lo que realmente se quiere, con esfuerzo, se consigue. Sigue demostrando que tú, y sólo tú, marcas tus límites.

Eli, no hay palabras para describir lo agradecido que le estoy al universo por haberte interpuesto en mi camino. Tus ánimos y tu apoyo en esta tesis es sólo una infinitésima de las cosas por las que te estoy agradecido. Gracias por hacerme cada día más feliz.

Abstract

Jose Miguel Pérez Álvarez

Decision-Making Support for the Alignment of
Business-Process-Driven Organizations with Strategic Plans

Business plans are documents in which the *Board and Executive Teams (BETs)* of organisations depict each and every aspect of the company. The operational and the strategic plans constitute two important components of a business plan. The former collects all the activities that can be performed at the company to provide the products or services that are offered; The latter specifies the direction and objectives for the company, devises goals, and identifies a range of strategies to achieve its targets.

Overall, companies follow the direction established in the strategic plan, but this is frequently highly complex since several factors might affect the evolution of the organisation. The complexity and number of influences mean that humans make decisions based on their local knowledge about the company, their previous experiences, and/or even on intuition, instead of on an quantitative analysis of how these decisions can affect the business plan achievement.

In this thesis dissertation, methodologies and mechanisms are proposed to help decision-makers settle decisions aligned with the direction established by the company. The capacity to help in the decision-making process is considered by Gartner^{TM} to be crucial for the systems that support the operations of the company (called *Business Process Management Systems (BPMSs)*). For this reason, these methodologies and mechanisms are integrated into a set of *Decision Support Systems (DSSs)*.

The types of decisions that can be made within an organisation vary widely. Several proposals for their improvement can be found in previous work, and hence, after a systematic analysis of the literature, three types of decisions have been detected as crucial but not widely supported by the current *DSSs*: (1) decisions that route the *Business Process Instance (BPI)*; (2) decisions regarding the value of the input variables; and (3) decisions concerning which *Business Process (BP)* should be executed. Three *DSSs* are proposed in this thesis, each aligned with one of the aforementioned types of decision.

The *DSSs to route of the BPI* constitutes one of the most widely-known fields of study in the context of decision-making, but previous proposals lack the semantics to enrich the data involved in decisions. Previous proposals only take into account the information related to the instance under decision, and they remain unaware of the overall status of the company. The *DSS*, to routes the *BPI* presented in this thesis, proposes a language that allows the evolution of other instances, processes, or data stored in external repositories to be included into the decisions.

It is fundamental to make decisions regarding the input values (such as the quantity to invest, and the number of employees to assign to a task). The choice of one value or another for key data can directly influence whether the company achieves success or failure. In order to ascertain the best input data, both former instances

and business process models must be analysed. This information is used in this thesis to suggest the range of values within which the variables under consideration are aligned with the strategic plans. Since the information employed to extract knowledge of former *BPIs* is stored in databases, a methodology is also proposed that validates the alignment of the data of these former instances with the business model.

Previous approaches are related to decisions made during the execution of a process; however, the choice of which *Business Process should be executed* also constitutes a decision in itself. This decision can affect the status of the organisation, and can therefore affect the achievement of the objectives specified in the strategic plans. This is why the governance decisions also have to be aligned to the strategic plans. To this end, a methodology to model both processes and goals is proposed. This model is designed by humans (business experts), thereby making it possible to validate its correctness in accordance with the activity of the organisation in the past. The most important feature of this proposal is the provision of a mechanism for the simulation of how a decision to perform one action or another can affect the status of the company.

The *DSSs* and techniques proposed in this thesis dissertation improve the decision-making capacity in four aspects:

1. Helping users make better decisions, based on the overall status of the company and what has happened in the past.

2. Ensuring that the decisions made are aligned with the strategic plans, so that everyone involved in the organisation makes decisions in accordance with the goals defined for the company.

3. Taking advantage of the information stored regarding past executions of the business processes of the company.

4. Taking advantage of the knowledge of the employees who have a full understanding of how the company works, while still including reasoning about why one decision is made as opposed to another.

In addition, these techniques are oriented towards: being user-friendly by business experts; contributing towards a better understanding of how the actions performed in the organisation can affect the attainment of the defined goals; and towards allowing information that can be used by third parties to be extracted from the organisation.

The *DSSs* and related proposals carried out in the context of this thesis dissertation have been extracted from real-world companies, and real-world examples have been used to illustrate the proposals.

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To Elisa.

Part I

Preface

Chapter 1

Introduction

1.1 Context and Motivation

Companies describe their intended future in the business plans, a set of documents that describes a roadmap of the business, outlines goals and details how to achieve the objectives.

Business planning offers multiple benefits for large companies and start-ups, such as providing an understanding of the business, finding equity funding, and recruitment. However, for the context of this dissertation, it is important to highlight that a business plan is the main tool that *Board and Executive Teams (BETs)* of companies possess for the definition of the business and of the decisions that help towards achieving their goals.

The business plans connect the dots of the different elements in the business, and hence *BETs* attain a better picture of the entire organisation. The strategy planning permits the alignment between tactics and strategies, to answer such queries as: Do the sales connect to the marketing expenses?; Are the products aligned with the target market?; and, Do the covering costs also include long-term fixed costs, product development, and working capital needs? In summary, business planning is employed to take a step back and look at the larger picture of the business and its components [17].

As will be explained in thoroughly in Section 2, a business plan is composed of several sub-plans, that describe the various aspects of the company and the business. However, for the context of this dissertation, the two key sub-plans are the **operational** and **strategy plans:**

As explained in detail in Section 2, a business plan is composed of several sub-plans that describe the various aspects of the business. However, for the context of this dissertation, the two key sub-plans are the **operational** and **strategy plans**:

- **Operational plans** present highly detailed information about the activities and procedures performed in the company: the activities and tasks that must be undertaken; who has the responsibility for each task; and when the timelines must be completed. In order to describe the operational plans, organisations may use business process models. A business process consists of a set of activities that are performed in coordination within an organisational and technical environment to achieve an objective [145].

- **Strategic plans** determine the direction for the organisations, by devising goals and objectives and the identification of a range of strategies to achieve these goals. The strategic plans provide a general guide for the management of the organisation in accordance with the priorities and goals of stakeholders. Therefore, the direction defined in those strategic plans is called the *right direction*,

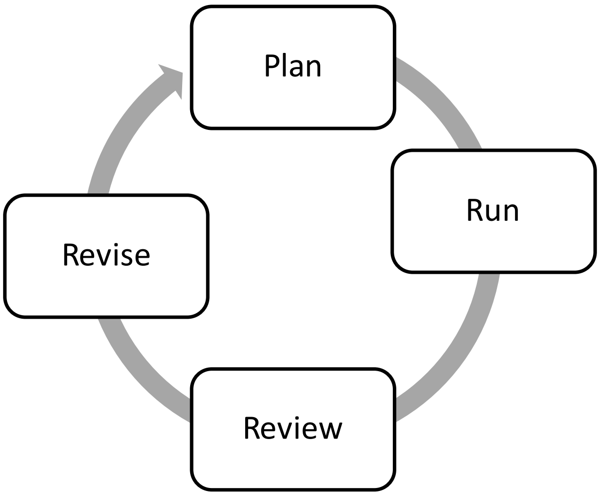


FIGURE 1.1: Business plan life-cycle

and every department of the organisation has to work in concordance with this *right direction*.

As can be seen in Figure 1.1, business plans accomplish a life-cycle to support ongoing changes. The first step is to create the plan, and this is usually a task of the *BET* of the company. Once the business plan is designed, it is carried out by the managers of the various areas. It is always important to track the results obtained and the actions that have brought them about. It is often necessary to revise and analyse the evolution of the company in order to validate the plans developed and the assumptions made [17].

The execution of the business plans implies carrying out the instructions laid out in the plans. In order to help in the automation of the operational plans, companies usually incorporate commercial *Business Process Management Systems (BPMSs)* to carry out their daily processes. These systems represent software that supports the implementation, coordination, and monitoring of the execution of the business processes.

In process orientation, business processes are the main instrument for the organisation to run an enterprise [59]. This implies that the overall organisation can be viewed as a set of business processes working together to achieve the objectives of the company. Therefore, in process orientation, operational plans can be fully supported by using business processes.

Some of the processes and activities described in the operational plans include/implies decisions that users have to make. Those decisions affect the achievement of the goals defined by the *BET*, and for this reason it is necessary to provide the decision-makers with support.

Organizations are also interested in the detection of the possible deviations of the plans under execution. To this end, techniques, such as *Business Intelligence (BI)* [55], are commonly applied. The *BI* techniques are technology-driven process for the analysis of the data produced by the organisation systems and for the presentation of actionable information to help the *BET* better understand what is happening and to spot deviations. *BI* systems can also help companies identify market trends.

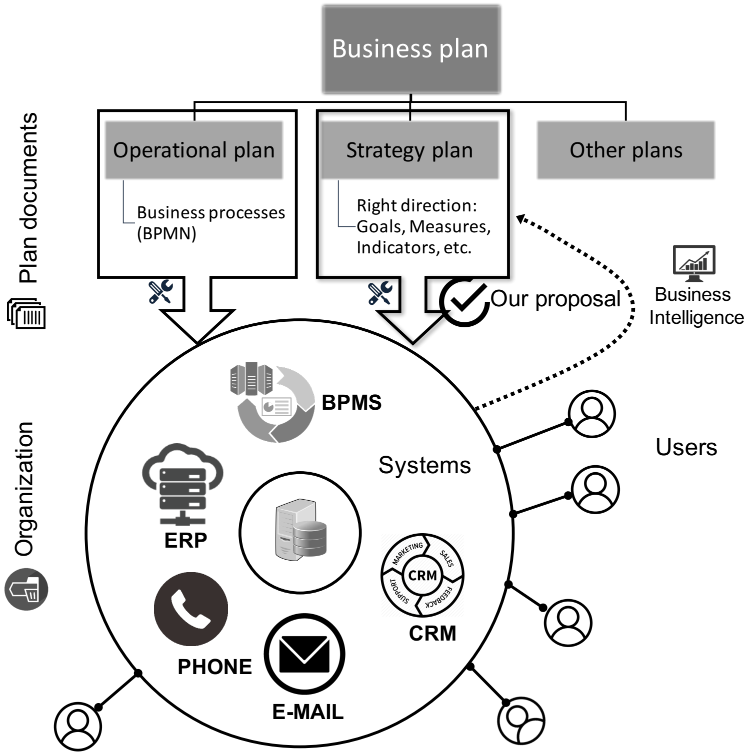


FIGURE 1.2: Relation between Business plan and organisation

These *BI* techniques are needed since strategic plans are not integrated into the business processes. This thesis addresses this issue: how to implement strategic plans and make better decisions to maintain the alignment of the overall working of the organisation with the direction established by the *BET* in the strategic plans. Thanks to this approach, the *BET* is able to ensure that the decisions made by users within the organisation are being taken in accordance with the *right direction* defined, which reduces the number of deviations, which are detected by using *BI* techniques.

1.2 Problem Statements

The research questions addressed herein include:

- **RQ1. In which parts of the business process are the decisions made?** In other words, what parts of the operational plans (implemented using Business Processes) affect the correct achievements of the strategic plan? Business processes might be composed of elements coming from various perspectives (data, gateways, decision rules, etc.). It is therefore important to identify the position of the critical points at which decisions are made, since decision elements need to be introduced at those points. Depending on the components found, it would be necessary to analyse decision-support techniques exist to help business managers in their decisions.

- **RQ2. According to the current state of the art, how can the decisions be improved for each decision point found?** Depending on the type of element used for the incorporation of the decision into the system, various techniques

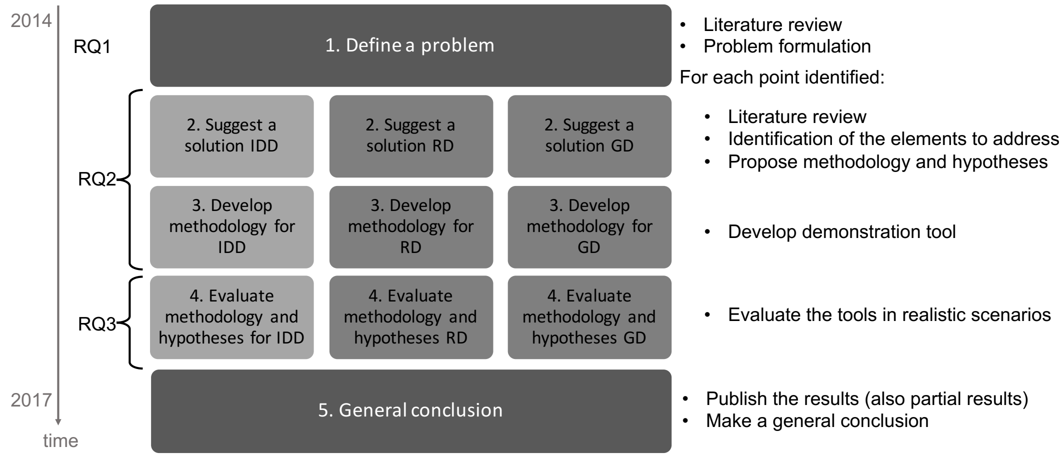


FIGURE 1.3: Research methodology

are available for application. Although the decisions can be made in any of a wide range of scenarios, those related to the use of business processes in the strategic plans are analysed.

- **RQ3. How can the element introduced be integrated into a real scenario?** The evaluation of the proposals in a real context is fundamental, and decisions must be made by business experts. Therefore, the elements introduced to offer decision-support have to be easy to use and easily understood by non-technical staff. It is essential that these elements are introduced in a user-friendly way.

1.3 Research methodology

The research approach of this PhD dissertation is inspired by the Design Science (DS) research methodology provided by Peffers et al. [103]. The research methodology used can be seen graphically in Figure 1.3. This started with a general literature review and problem definition. The decision support was then selected and three different types of decisions were identified: *Input Data Decisions (IDDs)*, *Route Decisions (RDs)* and *Governance Decisions (GDs)*.

For each of those points identified, a specific literature review has been performed. Derived from the literature review, a methodology has been proposed and the hypotheses formulated. Two demonstration tools have been developed that have been applied in scenarios, using real-world samples.

During the development of the various elements identified, partial results have been published. This PhD dissertation collects all these results and presents the conclusion.

1.4 Contribution

Table 1.1 shows the main contributions published in the context of this thesis directly aligned with one of the three decision points analysed. The publications shown in Table 1.3 are the fruition of collaborations, where certain aspects of the thesis have been applied in other contexts. Both Table 1.1 and Table 1.3 are sorted by *year* of publication and identified using a unique identifier (*ID*). The column *Type* categorizes the contribution as Journal Article (JA), Tool (T), Conference and Workshop Paper (CWP) or United States Patent (USP). The column *Status* shows the current situation of the contribution; this status can be Published (P), Accepted (A), Under Review (UR), or Registered (R). Finally, the last column shows the title, authors, and the forum in which the contribution was published, or to which it has been sent.

ID	Year	Type	Status	Title & Authors & Publisher
J1	2014	JA	P	Decision-Making Support for the Correctness of Input Data at Runtime in Business Processes. *María Teresa Gómez-López, Rafael M. Gasca and José Miguel Pérez-Álvarez.* International Journal of Cooperative Systems 23(4) (2014). Impact index 0.47. (Computer Science, Information Systems, **Q4**).
T1	2014	T	R	MARTIN: MAking Reasoning for daTa INput. *José Miguel Pérez-Álvarez, María Teresa Gómez-López and Rafael M. Gasca*
C1	2016	CWP	P	Process Instance Query Language to Include Process Performance Indicators in DMN. *José Miguel Pérez-Álvarez, María Teresa Gómez-López, Luisa Parody and Rafael M. Gasca.* EDOC workshops 2016, Vienna, Austria, September 5-9, 2016, pages 1-8, 2016
C2	2016	CWP	P	Governance Knowledge Management and Decision Support Using Fuzzy Governance Maps. *José Miguel Pérez-Álvarez, María Teresa Gómez-López, Angel Jesús Varela-Vaca, Fco. Fernando de la Rosa Troyano and Rafael M. Gasca.* Business Process Management Workshops 2016 **[CORE C]**
P1	2017	USP	A	Data Management Externalization for Workflow Definition and Execution. *José Miguel Pérez-Álvarez, Mario Cortes Cornax, Adrian Mos and Yves Hoppenot.* United States Patent and Trademark Office
P2	2017	USP	A	Form Generation and Externalization in Workflow Execution. *José Miguel Pérez-Álvarez, Mario Cortes Cornax and Adrian Mos.* United States Patent and Trademark Office
C3	2017	CWP	A	Domain-Specic Data Management for Platform-Independent Process Governance. *Mario Cortés, José Miguel Pérez-Álvarez, Adrian Mos and María Teresa Gómez-López.* International Conference on Conceptual Modeling - Forum (Main conference is **[Core A, SCIE: Class 2]**)
C4	2017	CWP	P	A Model-Driven Framework for Domain Specific Process Design and Governance. *Adrian Mos, Mario Cortes Cornax, José Miguel Pérez-Álvarez and María Teresa Gómez López.* BPM Demos 2017 (Main conference is **[Core A, SCIE: Class 2]**)

ID	Year	Type	Status	Title & Authors & Publisher
J2	2017	JA	UR	Methodology for decision-making support of Business Process input data based on previous instances. *José Miguel Pérez-Álvarez, María Teresa Gómez López, Luisa Parody and Rafael M. Gasca.* Expert Systems With Applications. Impact index in 2016: 3,928 (Computer Science, Artificial Intelligence, 18/133, **Q1**)
J3	2017	JA	UR	Data Object Verification according to Business Process Models and Data Model. *José Miguel Pérez-Álvarez, María Teresa Gómez López and Rafael M. Gasca.* Knowledge and Information Systems. Impact index in 2016: 2,004 (Computer Science, Information Systems, 67/146, **Q2**).
T2	2017	T	R	Tool for Data Object Verification according to Business Process Models and Data Model. *José Miguel Pérez-Álvarez, María Teresa Gómez López, Rik Eshuis, Marco Montali and Rafael M. Gasca*
J4	2017	JA	UR	Tactical Business-Process-Decision Support based on KPIs Monitoring and Validation. *José Miguel Pérez-Álvarez, Alejandro Maté, María Teresa Gómez López and Juan Trujillo.* Business & Information Systems Engineering. Impact index in 2016: 3,392 (Computer Science, Information Systems, 22/146, **Q1**)

TABLE 1.1: Main contributions

Contribution *J1* proposes a *Decision Support System (DSS)* for assistance in choosing valid values of input data, and is therefore focused on acting on *IDD*. The proposal analyses the *Business Data Constraints (BDCs)* extracted from the strategic plans and the business process model in order to infer the most appropriate input data to achieve the objectives of the process. This contribution presents an algorithm to traverse the *Business Process Management (BPM)* by collecting the *BDCs* associated to activities or as invariants to the whole process. The *Constraint Programming (CP)* paradigm has been used in the *DSS* to infer the correct input values at each decision point. Finally, with the objective of validating this proposal, tool ***T1***, called *MARTIN: MAking Reasoning for daTa INput*, has been developed. This tool is integrated into the *BPMS* and works at runtime.

A method that enables a decision to be made regarding how to route *Business Process Instances (BPIs)* is presented in ***C1***. The proposal takes into account the environment in which the instance is being executed, that is, the status of the organisation. In this contribution, a language called *Process Instance Query Language (PIQL)* is proposed. This language allows the definition of variables, based on information on the running instances. Moreover, mechanisms to route the *BPI* based on this variables are also proposed, that is, the environment in which the instances are being executed.

Contribution *C2* studies the relation between the *BPM* execution and the evolution of the *Key Process Indicators (KPIs)* of the company. For instance, consider a business process called "invest in social media publicity" whose objective is to increase the sales (indicator "volume of sales"). In this direction, this contribution proposes: the use of *Fuzzy Governance Maps (FGMs)* to model this knowledge, which can be extracted from the strategic plans; and an engine that allows business experts to predict the status of the organisation by using these *FGMs*.

In *P1*, the problem of data management in *BPMS* is addressed. Each *BPMS* manages the data by using its own mechanisms, and for this reason each *DSS* has to be developed ad-hoc, otherwise the development of custom connectors/wrappers is needed in each case. In this contribution, mechanisms to externalize the data management, and the integration within the *BPMS* are proposed. Therefore this is a component to build *DSSs* for both *IDDs* and *RDs*.

A similar problem is addressed in **contribution *P2***, but in this case it is related to the input data introduced by users. The issue is similar to that presented in *P1*, since the *BPMSs* share no common mechanism to manage forms. To this end, in this contribution, a mechanism to externalize forms is proposed.

A high-level *Domain Specific Language (DSL)* for modelling *BPM*, and the mechanisms to generate standard *Business Process Model and Notation (BPMN)* is proposed in **publication *C3***. The last *P1*, *P2* and the *DSS* previously proposed for *IDD* and *RD* can be integrated within this approach. In addition, mechanisms to automate the deployment into commercial *BPMSs* is also proposed.

Publication *C4* presents a complete tool that validates the proposals laid out in *C4* and *J1*. The basic technologies employed in the development of this tool include: the *OSGi/Equinox* environment provided by *Eclipse* as the base; the *Eclipse Modelling Framework*, and its ecosystem to manage the models; *Sirius*; *Xtext*; and similar technologies to generate editors, from among a large number of other third party dependencies.

J2 is an extension of *J1* that takes advantage of the analysis of former instances, in order to extract useful knowledge regarding the behaviour patterns of the variables involved in the *BDC*. The way in which to extract this knowledge, and use it to improve the decision-support for input data and to offer better recommendations, is presented in this proposal.

Contribution *J3* proposes a methodology to ensure that the business objects stored in the database are correct in accordance with the business process. This is an important issue due to the fact that data models and activity-oriented business process models come from various paradigms, and recommendations of the *DSSs* can be erroneous if the data on the analysis and knowledge extraction is incorrect. To validate this proposal, tool ***T2*** has been developed. This tool is an extension of the eclipse-based editor of Activiti^{TM} in which the users can model the business process and data objects, in addition to verifying the objects stored in the database.

Finally, *J4* is an extension of *C2* in which the model (*FGM*) has been enlarged to include *KPIs*, *Key Result Indicators (KRIs)*, *goals*, and *sub-goals*, among *input data* for the *BPM*. Thanks to this extension, the strategic plans are better covered by the *FGMs*, and the concepts are properly defined for the business experts.

Table 1.2 summarizes which type of decision is tackled in each proposal.

	J1	**C1**	**C2**	**P1**	**P2**	**C3**	**C4**	**J2**	**J3**	**J4**
IDD	✓			✓	✓	✓	✓	✓	✓	
RD		✓		✓		✓	✓		✓	
GD			✓							✓

TABLE 1.2: Context of the contributions

As explained above, Table 1.3 collects a set of collaborations developed in the context of this dissertation. Those contributions are related to *BPM*, but they are not totally aligned to decision-making improvements, since they are: exploratory, derived from the main contributions (C-C2); collaborations with other researchers (C-J1 and C-C1); or work derived from projects with other organisations (C-J2).

ID	Year	Type	Status	Title & Authors & Publisher
C-J1	2015	JA	P	Compliance validation and diagnosis of business data constraints in business processes at runtime. *María Teresa Gómez-López, Rafael M. Gasca and José Miguel Pérez-Álvarez.* Information Systems 48: 26-43 (2015). Impact index 1.456. (Computer Science, Information Systems, 46/139, **Q2**)
C-C1	2016	CWP	P	Guiding the Creation of Choreographed Processes with Multiple Instances Based on Data Models. *María Teresa Gómez-López, José Miguel Pérez-Álvarez, Angel Jesús Varela-Vaca and Rafael M. Gasca.* Business Process Management Workshops 2016 [**CORE C**]
C-J2	2016	JA	P	Developing the prototype AndaLAND for agriculture soil and water assessment in climate change scenarios. *M. Fernández-Boyano, D. Tabernero-Pérez, S. Alonso-Herrero, José Miguel Pérez-Álvarez, F. J. Blanco-Velázquez, M. Anaya-Romero and J. E. Fernández-Luque.* Spanish Journal of Soil Science, [S.l.], v. 6, n. 1, mar. 2016
C-C2	2017	CWP	A	An Architecture for Querying Business Process, Business Process Instances, and Business Data Models. *María Teresa Gómez-López, Antonia M. Reina Quintero, Luisa Parody, José Miguel Pérez-Álvarez and Manfred Reichert.* Business Process Management Workshops 2017 [**CORE C**]

TABLE 1.3: Collaboration contributions

***C-J1* proposes** the validation and diagnosis of *BDCs* in business processes at runtime. In this case, the variables involved in the *BDCs* can be variables from the dataflow of the business process or from external storage, therefore this *DSS* acts for *IDD*. The validation and diagnosis process is automated using *CP* techniques, to permit the detection and identification of possibly unsatisfied *BDC*, even if the data involved in these constraints is not all instantiated, and therefore possible errors can be detected in advance. In order to automate the queries needed to extract information from the data stored, in this contribution, a method to extract the tuples involved is proposed.

The problem of helping in the design of choreographed *BPMs* is addressed in **the contribution *C-C1***. By using a non-choreographed *BPM* and the data model as input to discover the relationships between the suggested *BPMs*, this *DSS* suggests the points at which the original process has to be choreographed.

Proposal *C-J2* is a case study for agriculture soil and water assessment. In this contribution, a *DSS* is proposed for the recommendation of the best method to irrigate an area, including quantity of water and frequency of irrigation. Each irrigation method can be modelled by using a *BPM*, and the quantity of water and frequency of irrigation can be modelled as input parameters of those *BPMs*. Therefore, this *DSS* proposes the business process to execute, and the best input variables to use in its execution, to achieve the objectives of the organisation. In that case, the objective of the organisation is to consume as little water as possible, while ensuring that the plants are well watered.

An improvement of *PIQL*, which proposes the integration of the data model, process model and process instance in the same query, is presented in **contribution *C*-*C2***. This proposal uses the *PIQL* presented in *C1* to be combined with information concerning the process model and the data stored in a single query.

1.5 Thesis Context

The candidate has developed this research activity as member of the IDEA Research Group[1] belonging to TIC-134 of the University of Seville, headed by María Teresa Gómez-López, the thesis advisor.

During the development of this thesis, the candidate has been involved in the following research projects:

- **SEQUOIA:** SUPPORT INTELLIGENT DECISIONS FOR BUSINESS PROCESSES REQUIREMENTS BASED ON BIG DATA AND MULTIPLE INSTANCES
  - **Duration:** 3 years (Jan-2016 – Dec-2018)
  - **Financier:** Ministry of Science and Technology of Spain
  - **Reference:** TIN2015-63502-C3-2-R
  - **Description:** Recent years have seen a spectacular increase in the volume and range of information available. A wide variety of data sources, from traditional structured data to Open Data, social networks, sensors and mobile devices, can provide more information on organisational environments, thus improving strategic decision-making. This phenomenon, known as Big Data, was forecast to generate a revenue of 15 billion Euros in 2016. Big Data, however, presents us with as many challenges and problems as it does expectations and potential. Guaranteed return on investment in Big Data exists, yet several studies show that projects in this field have a high failure rate. Institutions and public bodies earmark huge amounts of resources towards solving problems inherent to Big Data. Big Data management has several special features; most experts accept that these may be described as the 5 Vs (Volume, Velocity, Variety, Veracity, Value); they call for technological advances that do not yet exist and provide endless opportunities for research, the results of which would bring about tangible benefits for society. At present, the main solutions and approaches are focusing on providing solutions for distributed processing and the storage of massive quantities of data (based on NoSQL databases and/or Hadoop systems) and/or the application of statistical techniques and artificial intelligence in particular domains in an effort to extract knowledge from such huge volumes of data. While these approaches generate encouraging results, the selection and management of Big Data sources suffers today from a methodological and global approach that could exploit economies of scale and apply Big Data to various domains, thereby offering business opportunities to SMEs and entrepreneurs. The main objective of the coordinated SEQUOIA project is to contribute models, methods and software tools to allow organisations to take on Big Data projects and maximise their chances of success. By

[1] `http://www.idea.us.es/`

involving a systematic and methodical way of seeing how to incorporate Big Data into the daily decision-making process, it optimises the synergy between the different approaches of Business Engineering, Software Engineering and Data Engineering. The University of Seville will develop models and tools for improving the design and execution of the business processes which generate and use Big Data.

- **Clean Sky 2:** A-24 One step beyond on automated testing technologies
  - **Duration:** From July to December 2016
  - **Financier:** Airbus Space & Defence
  - **Description:** Analysis of software for the capture and exploitation of data generated by testing in the assembly of aircraft in Airbus Space & Defence. From this analysis, certain improvements are needed and future actions are derived.
- **Wonder:** Blind platform for issue replacement and delivery reasignment for the logistic sector
  - **Duration:** From January to July 2015
  - **Financier:** Ontime, Integral Logistic
  - **Description:** A web-based platform for the administration of subscriptions, Parcel-issue management, *Radio Frequency Identification (RFID)*, label management and delivery assignment for the logistics sector. The project consists of a web-based platform that will be associated with a database of *RFID* tags, where different users can (1) log in to report information about incidents produced by a labelled package with a *RFID* Tag; (2) administer and manage licences, users, and organisation identities; (3) insert and verify new *RFID* Tags; (4) receive, monitor and replace issues related to the labelled packages; (5) access a call-centre to report and manage incident solutions.

The following research stay has been carried out:

- **Center:** Xerox Research Center Europe (XRCE)
- **Location:** Grenoble (France)
- **Period:** From 12 January 2017 to 12 June 2017 (5 month in total).
- **Observations:** From 13w March to 12 June 2017 remotely from Seville.
- **Results:** The publications *P1*, *P2*, *C3* and *C4* presented in Table 1.1 were developed in the context of this research stay.

1.6 Roadmap: Structure of the Thesis

In this section, the structure of the dissertation is explained. First of all, there are five main parts in this document: Preface (I), Background (II), State of the art (III), Contributions (IV), and Conclusions & Future Work (V):

- **Part I Preface**: Chapter 1 introduces the problem, context and the motivation.

- **Part II Background**: A general concept overview is presented regarding the main elements required for a better understanding of this dissertation. This part consists of five chapters:
  - Chapter 2 shows what a business plan is, and its main components, oriented towards being understood by a computer scientist.
  - Chapter 3 collects the main concepts about *BPMs*, and presents the background to business process verification, validation and performance techniques. The use of *Business Processs (BPs)* is the mechanism that we propose to integrate the *DSSs* that support the strategic plans of the companies, therefore those basic concepts are essential for the comprehension of the proposals of this dissertation.
  - Chapter 4 shows the basic concepts of the new *Object Management Group (OMG)* standard, *Decision Model and Notation (DMN)*, which is one of the fundamental components used in this dissertation for many of the proposals.
  - Chapter 5 presents the main concepts and definitions regarding the *CP* paradigm, which is used as the base for the implementation and automation of most of the contributions provided in this dissertation.
  - Chapter 6 presents the main concepts about *DSSs*, their differences to similar systems, their usual components, and concepts of the decision-making process. The use of *DSSs* to implement strategic plans constitutes the main proposal of this dissertation.
- **Part III State of the art**: This part contains Chapter 7. In order to reveal the previous contributions to this topic, a *Systematic Literature Review (SLR)* has been carried out.
- **Part IV Contributions**: This is the main part of this dissertation, since it includes the proposals. As explained above, we have identified types of decisions made by users. In this dissertation, we propose *DSSs* that help towards making decisions for each of these types. For this reason, this part is divided into three subparts:
  - Subpart A collects the proposals for *Routing instances*. This subpart contains the Chapter 8 which presents our proposals for *RDs*. There are two key proposals in this chapter: the first is a proposal to extract information regarding the current status of the system, based on a language called *PIQL*; and the second, the *DSS* to *RD*, is based on the integration of this extracted information into *DMN* tables, which enables routing the business process instances in accordance with the strategic plans.
  - Subpart B exposes the proposals for *Assigning value to variable*. This subpart contains two chapters:
    - Chapter 9 is a proposal to verify that the information regarding former instances, stored in the database, is valid in accordance with the business process model, and therefore can be used to extract patterns for recommendations.
    - Chapter 10 proposes a *DSS* for *IDD*, in which the information of former instances is taken into account to automatically extract knowledge that will be used to offer better recommendations to the decision makers.

- Subpart C exposes the proposals *Choosing the process to execute*. This subpart contains Chapter 11 which describes our proposal for *GDs*. There are three key proposals in this chapter. The first proposal involves the modelling of the knowledge of business experts, by using *FGM*. The second proposal includes the validation of this *FGM* by using former instances. The third proposal is a *DSS* based on the simulation of this *FGM* to perform a what-if analysis that helps decision makers to decide which action is the best to perform.

- **Part V Conclusions & Future Work**: In this section, the conclusions of this dissertation are drawn. Finally, a set of ideas to continue this line of work is presented.

Part II

Background

Chapter 2

Business Plans

A business plan is a well known element in management science. This chapter exposes, in a simple way, what is a business plan, why this document is important for the companies and why every company has one. The aim of this chapter is not to explain the details of business plans in depth, but only to clarify that every constraint, business activity, business process model or business policy is described in a document that establishes a clear direction of a company. One of the main objectives of this dissertation is to use the business plan, and to provide business experts with a set of methodologies and tools to ensure that the politics and strategies defined in business plans are fulfilled in real scenarios.

A business plan is a description, in a clear and suitable manner, about how a company works and what are the objectives that must be achieved in the future. It is included in a set of documents that describes a roadmap of the business, outlines goals and details on how to achieve those goals. It should not merely aim to emphasize the strengths of the company, but it is better to offer a realistic portrait of its problems, risks, and obstacles. In addition, appropriate solutions should be proposed and discussed in detail [106].

The business plan is a very useful tool for the companies, which allows: (1) detection of errors and performance of correct planning, even before making any investment; (2) projection of results, so that in case the expected goals are not obtained, it proposes and asses alternative plans in order to obtain a more realistic context; and (3) tackling of possible risks and problems in advance.

A business plan is also a mechanism used by managers to get funding. Companies use business plans as an instrument to convince potential investors interested in their business. Furthermore, it is more feasible that investors decide to trust in a project that clearly exposes all facets of the proposal and shows its attractiveness in the forecast of the economic and financial status of the business, together with the viability and profitability.

Although two different businesses are never identical nor alike, but good business plans always contain a number of common themes [40]. They “tell a story” and explain how a business should achieve its objectives in a coherent, consistent and cohesive manner. The “story” must be focused on the needs of the customers. The plan must identify the market, its growth prospects, the target customers and the main competitors. It must be based upon a credible set of assumptions and should identify the supposition to which the success of the business is most sensitive. It should also identify the risks faced by the business, the potential downsides and the actions that should be considered to mitigate the risks [40].

Therefore, there is not a fixed structure of a business plan document, but frequently business plans incorporate these parts: *Executive summary*, *Operations plan*, *Financial plan*, *Marketing plan*, *Strategic plan* and *Human Resources plan* [122]. The two

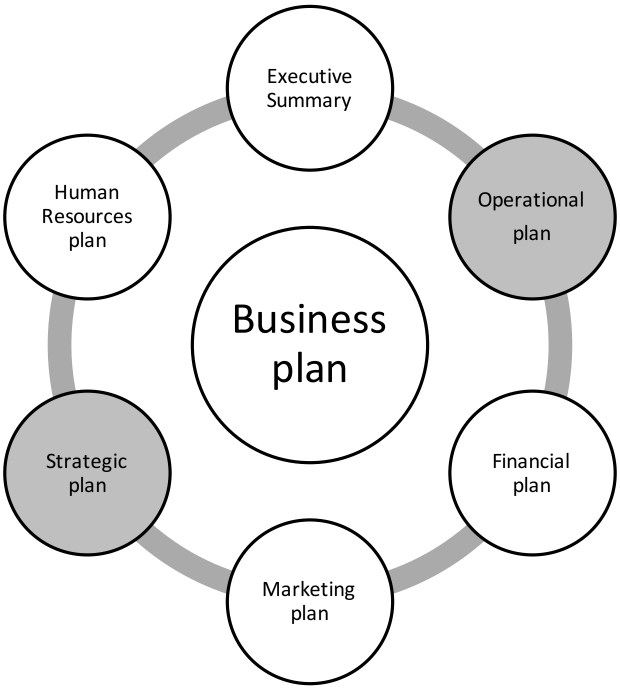


FIGURE 2.1: Parts of a business plan

main parts in which this dissertation is centred (Operational and Strategic plans) are marked in Figure 2.1.

In order to provide a general overview, those parts are detailed in following sections.

2.1 Executive summary

The executive summary compiles the essential statements and conclusions of the business plan in a very concise form. For most of the readers, the executive summary presents the most important sections of the business plan, because:

- It ensures a quick introduction into the main topics
- It gives a short overview of the enterprise
- It provides the core statements and conclusions of the enterprise strategy and success factors

The idea of the executive summary is a one-page statement, where it is summed up the essence of the business plan, by including answers to the questions: Who?, What?, Where?, When?, Why?, How?

In conclusion, the executive summary summarizes the content and purpose of the complete business plan. It is a concise statement about the business.

2.2 Operational plan

Operational plans describe the processes and resources that are used to produce the highest quality products or services as efficiently as possible.

Business operations typically include four key areas:

- Where the business is carried out (physically and online)
- The tools you need to execute the operations
- Who will do the operations
- The activities and the relation between them to carry out the business, including quality control and improvement systems

An operational plan is important because it describes thoroughly how is the everyday life of the company, which could include: the standardization of products or services; the clarification of where to get the necessary resources; the description about how to use those resources efficiently; and also, the explanation of how to define the most critical resources required. These advantages reduce risks where possible, and prepare contingency plans where necessary.

2.3 Financial plan

Financial planning is essential for every company, and it has to be also reflected in the business plan. The basic information that a financial plan has to contain can be represented graphically in Figure 2.2 [122].

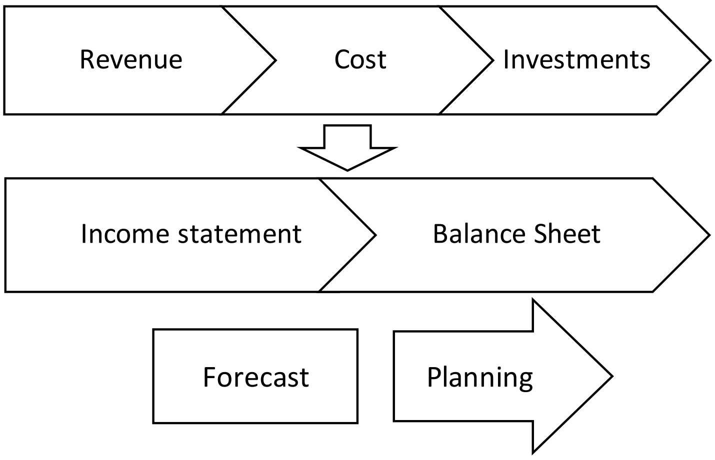


FIGURE 2.2: Basic information contained in a financial plan

The **revenue** is the evaluated amount of the products and services that the company sells. This data is taken from the marketing plan (Subsection 2.4). The **investments** represent the capital required for production. This can include properties, buildings, machinery, as well as financial investments like shares, but also immaterial investments such as computer software. The **costs** include all the remaining expenses which are necessary to keep your company running: salaries, wages, office supplies, information processing, telecommunication, etc.

The *income statements* represent the results of the business activities, while **balance sheets** sum up the financial activities of the business at a key date (often coinciding with the end of the calendar year, Dec 31). Both, *income statements* and *balance sheets*, can be calculated by using the last information.

Finally, financial planning also includes **forecast** and performs a **planning** for the financial situation in the future. This allows business managers to estimate how could be the situation in the future.

2.4 Marketing plan

A central aspect of any business plan is the marketing plan. Marketing differs from selling in as much as marketing has a customer rather than product focus. It means that in marketing plans customers are: analyzed, categorized, even their needs are studied in order to know how they are covered by the product or services that the company offers, etc.

In a marketing plan, business managers try to provide a response to questions, such as:

- What market segment need to be tackled by the business?
- How the offered products cover the detected needed?
- Who could the products be bough?
- Why can customers buy the products or services?
- Who makes the buying decision?
- How much are the customers willing to pay for the product or service offered by the company?
- Where can the customers buy the product or service?

2.5 Strategic plan

The strategic plan determines the direction and objectives for the organizations, devising goals and objectives and identifying a range of strategies to achieve those goals. The strategic plan is a general guide for the management of the organization according to the priorities and goals of stakeholders. Therefore, the direction defined in those strategic plans is called *the right direction*, and every department of the organization has to work in concordance with this *right direction*.

Figure 2.3 shows graphically a life-cycle of the strategic plan. The start point is the definition of the goals and objectives that the company wants to achieve. In order to have a clear vision of the capacities of the company, it is convenient to do a SWOT analysis [28]. This analysis aims to identify the key internal and external factors seen as important to achieve the objectives and is useful to define the final strategy to implement.

The strategic plans also define a set of indicators that represent the status of the company. Those indicators are needed to evaluate and know whether the company is working aligned to the defined strategy or not.

There are different types of indicators (e.g., measures, *Key Process Indicators (KPIs)*, *Key Result Indicators (KRIs)*), which represent known formulas for measuring business activities with unknown targets or thresholds. *KRIs* are indicators that directly correlates with the satisfaction of a goal or *KPIs*, that measures the performance of key activities and initiatives that are measured by *KRIs*.

Once the board and executive team analyses the evolution of the indicators, they are able to decide if it is necessary to redefine the strategy and how.

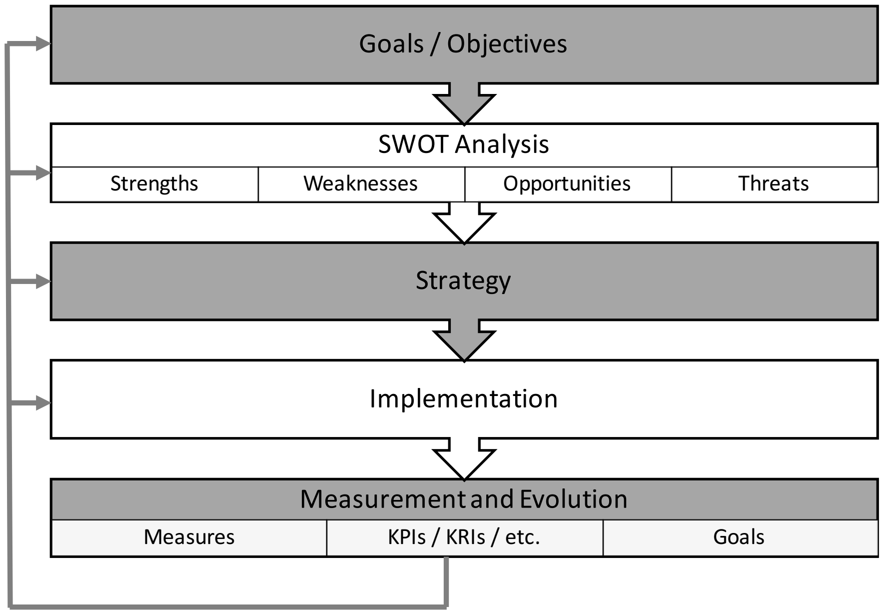


FIGURE 2.3: Typical strategic plan life-cycle

2.6 Human Resources plan

All businesses depend on their staff to succeed [40]. Human resources is extremely important, especially those who make decisions in the company. The human resources planning model is a method to ascertain if the company has enough and right employees to carry out its goals.

The human resources planning model encompasses three key elements, which include: the prediction of the employees needed by the company, the analysis of whether the supply of potential employees meets the demand, and the learning of how to balance the supply and demand of employees.

Chapter 3

Business Process Management

Business Process Management (BPM) is a key element for understanding the proposals in this dissertation, due to our contribution tackles *Decision Support Systems (DSSs)* in the context of the companies that use business processes for their daily activities. For this reason, in this chapter, the basics are presented.

As exposed in Section 2.2, operational plans describe the set of activities that are necessary to perform and to build products or services offered by the companies, and describing the everyday life of the company. However, operational plans are just a set of detailed documents that a company needs to implement in order to perform its goals, being the *BPM* a mechanism to achieve them.

BPM is focused on providing support to operational plans. To this end, Business Process Model consists of a set of ordered activities that should be executed (see Definition 3.1.1). *BPM* defines a complete life-cycle of ***BPs! (BPs!)***, which covers from the design to the optimization.

The remainder of this Chapter in structured as follows: basic concepts are presented in Section 3.1, the life-cycle defined for *BPM* is shown in Section 3.2, the existing perspectives to model a *Business Process (BP)* are presented in Section 3.3, and eventually Section 3.4 exposes the concept of *Process-Aware Information System (PAIS)*.

3.1 Basic concepts

A process in a company can be defined as a set of activities executed in a coordinated way to achieve a particular goal. Within the business scope, a process can be defined as a set of activities to help an organization for achieving a goal which provides a value for the company, and which is defined in its business plan. A business process (cf. Definition 3.1.1) is a particular type of process that describes the activities of an organization. One of the main objectives of business processes is to coordinate, within a model, the activities that form the operations defined in the business plan of the company.

Definition 3.1.1 *A BP consists of a set of activities that are performed in coordination in an organizational and technical environment. These activities jointly carry out a business goal [145].*

In order to use and manage *BPs*, business experts need to specify the *BPs* through *BP* models (cf. Definition 3.1.2) by using a modelling language. The selection of an adequate graphical method has become a major issue for both academic researchers and business professionals, since each individual process modelling method has its own characteristics. As a consequence, there are many research efforts dedicated to improve the modelling methods. In [64], a comparison of these major graphical process modelling methods is presented.

Definition 3.1.2 *A BP model consists of capturing which activities, events and states constitute the underlying business process [145]. Specifically, this is the set of activities and the execution constraints between them.*

The modelling of the business processes plays a vital role in the overall management of *BPs*. In recent years, Business Process Management (cf. Definition 3.1.3) has evolved as keystone of the *Information Technology (IT)* industry. Business Process Management has emerged as an evolution of the traditional *Workflow Management (WfM)* [3]. Moreover, Business Process Management is continuously evolving in order to improve the quality and effectiveness of *BPs*.

Definition 3.1.3 *BPM is an approach that includes concepts, methods, and techniques to support the design, administration, configuration, enactment and analysis of business processes [5, 145].*

Traditionally, ***BPs!****s* were carried out manually based on staff knowledge, company regulations and the resources that were available at the company. Currently, companies can achieve added benefits if they use software systems to coordinate the activities involved in their *BPs*. *BPM* allows organizations to ensure that *BPs* are executed efficiently, and that they generate information that can be used in their improvements. This improvement is attained through the information that is obtained from the daily execution of processes, which in turns indicates where potential inefficiencies can be identified and later optimized. To this end, it is necessary to have the appropriate software (cf. Definition 3.1.4) that provides the necessary support for *BPM*.

Definition 3.1.4 *A Business Process Management System (BPMS) is a generic software system that is driven by explicit process representations to coordinate the enactment of business processes [145].*

3.2 Business Process Management Life-cycle

BPM is orchestrated through a life-cycle as shown in Figure 3.1. The life-cycle of *BPM* to support ***BPs!****s* has four phases:

1. The requirements are extracted from the operational plans of the company, the business processes are identified, reviewed, validated and presented as process models in the process *Design and Analysis* phase.
2. The designs are developed and configured in a software system in the *System Configuration* phase.
3. During the *Enactment* phase, the process is executed by using the system configuration in the way prescribed by the process model. More specifically, an instance of a *BP* represents a specific case in the operational business execution of an organization.
4. Finally, in the *Diagnosis* phase, the operational process is analysed to identify problems in order to improve the process. This phase might even provide a diagnosis with the aim of proposing a solution to detected problems.

The BPM life-cycle is focused on the design of *BP* models, and the subsequent diagnosis of errors in the execution of these *BPs*. The creation of complete business process models is a fundamental prerequisite for organizations for the successful completion of the life-cycle and to engage the model in a *BPMS*.

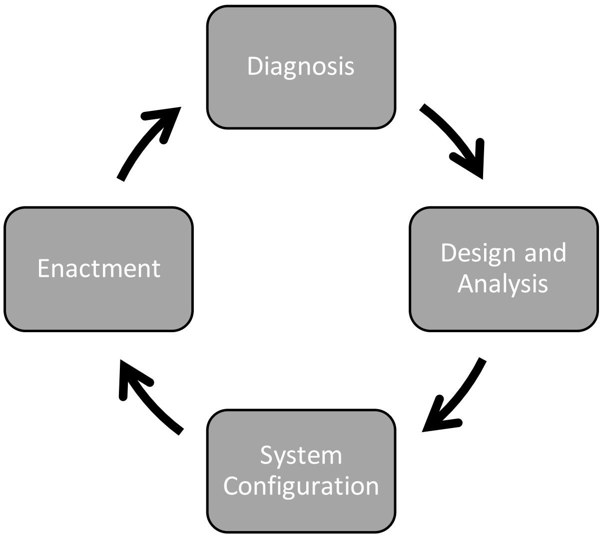


FIGURE 3.1: *BPM* life-cycle

3.3 Business Process Perspectives

According to Weske [145], there are two main perspectives in the development of a business process in *BPM*:

1. **Operational business process**, which defines the activities and their relationships, but neglects the implementation aspects of the business process.
2. **Implemented business process**, which retains information of the execution of activities, and of the technical and organizational environment in which they will be executed.

Operational business processes are specified by *BP* models (cf. Definition 3.1.2). In general, business process models must also permit the incorporation of various perspectives, which can be represented in various diagrams. The diagrams must show the rules, goals, objectives of the business and not only relationships, but also interactions [24]. A great part of the success of the modelling is the capacity to express the needs of the business, as well as to have a notation in which these needs can be described. Furthermore, the inclusion of several perspectives in *BP* models enables a more complete and successful execution of *BPs* to be carried out. In contrast, the *BP* models increase the workload and the complexity of reading comprehension if the perspectives are not clearly separated.

However, despite the fact that it is not an easy task, the business process, the environment features, and the intended use of the model must be taken into account to make a successful choice of an approach and/or notation [19]. Both Weske [145] and van der Aalst [2] differentiate between the most commonly used perspectives in operational business processes:

- *Functional Perspective* is the description of the set of activities to be performed in a *BP*.
- *Control-flow Perspective* refers to the order in which the activities are performed within a *BP*. Along with the functional perspective, these form the basis of *BP* models. This perspective represents the basic framework, which is then enriched with the other perspectives.

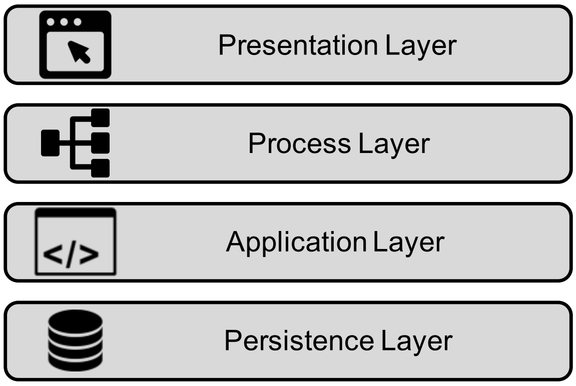


FIGURE 3.2: *PAIS* framework architecture [142].

- *Data-flow Perspective* includes the set of data used and consumed by the activities during the execution of a *BP*.
- *Time Perspective* refers to the set of temporal constraints to be considered during the execution of a *BP*, e.g., the duration of the business process activities and deadline constraints.
- *Resource Perspective* focuses on the people, roles, organisational units and any other entities of the arrangement models of a company that are involved in a *BP*.
- *Performance Perspective* establishes the process performance indicators to evaluate the performance and effectiveness of a *BP*.

For the developments, examples and proposals done within this dissertation, Functional, Control-flow and Data-flow Perspectives have been used, the adaptation to the rest of the perspective is set up as a future work.

3.4 Process-Aware Information System

In order to facilitate the specification and enactment of *BPs*, Dumas et al. introduced the concept of *PAIS*, henceforth referred to as *PAIS* [33]. This is "a software that manages and executes operational processes involving people, applications, and/or information sources on the basis of process models". In this way, the *PAIS* framework and *BPs* are strongly linked.

This architecture can be viewed as a 4-tier system, as shown in Figure 3.2:

- *Persistence Layer* enables the necessary support for a database management system to maintain the data persistence.
- *Application Layer* is responsible for storing the application codes and implementations of the various functionalities of the activities. These implementations can be shared by different organizations.
- *Process Layer* runs the process logic. In particular, it contains the schema and complete specification of the process model which is used for the process execution.
- *Presentation Layer* provides different build- and run-time tools for customers, e.g., a process template editor and an application program interface that enables the different components to be monitored.

The different layers are four parallel and independent systems per se, which can be simultaneously hosted in several machines, running different and independent applications. This independence is broken from the point of view of the exchanged data, since the layers are in continuous communication exchanging data in order to provide a needed functionality. In addition, the different layers ensure that any change (for example, in an application service which provides a particular functionality to a process step) triggers no other different changes in the Process Layer. It may be even possible to state that the interfaces remain stable [142]. Currently, a change in the execution order of activities and the addition of new activities in the Process Layer can be performed without modifying the implementation of any other application service.

Business Process Management Systems

A *BPMS* is a type of *PAIS*, which increases the effectiveness, performance, and agility in the day-to-day operations of the business. ***BPMSs!s*** ***(BPMSs!s)*** have been widely adopted by leading organizations, and can increase the business's productivity, agility and profitability.

There is a large number of commercial ***BPMSs!s*** that companies can integrate in order to support their *BPs*. The world's *IT* leading research and advisory company, Gartner^{TM}[1], has defined the following nine critical capacities [44] of a *BPMS*:

- **Interaction Management:** The ability to orchestrate multiple types of activities and interactions at runtime to support the work that people, systems and "things" do to produce specific business outcomes.
- **High-Productivity App Authoring:** Enables citizen and *IT* developers to build a process-centric application, quickly and easily. Applications built on the platform use a metadata model to manage the complete life-cycle of business processes and manipulate data related to the process.
- **Monitoring and Business Alignment:** *BPMS* platforms support the module of *Business Activity Monitoring (BAM)*, to continuously track the state of process instances, cases and other behaviors in near real time.
- **Rules and Decision Management:** Software facilities (e.g., inference engines, recommendation engines and decision management capabilities) that provide guidance for making human or automated operational decisions according to business directives or policy statements.
- **Analytics:** It applies logic and statistics techniques to data to provide insights for making better decisions. A *BPMS* may incorporate, or have connections to, predictive analytics, such as scoring services, prescriptive analytics or optimization engines.
- **Interoperability:** Adapter development tools to enable the interoperation with both external application services and systems. Such services and systems include custom and commercial-off-the-shelf packaged applications and cloud-based *Software as a Service (SaaS)* applications and their databases.
- **Intelligent Mobility:** The ability to access applications from a variety of mobile devices, including smartphones and tablets. As well as providing access

[1] http://www.gartner.com

from anywhere, the platform optimizes the mobile device's native capabilities, including its camera and other sensors.

- **Process Discovery and Optimization:** The capabilities of the platform include the discovering and optimization behaviours of processes, tasks and policies. This must include both analyzing past execution history and simulating proposed behaviors.

- **Context and Behavior History:** The maintenance of an archival history of the events instantiated in *BPMS* that have occurred during the process under control. These events may include process events, decisions, collaboration or other activities. The *BPMS* may also manage other kinds of data context (from external applications, databases or event streams) to enhance the intelligence and decisions made by the system.

Note that **decision management** is a considered crucial capacity by Gartner^{TM}, and the general proposal of this dissertation is to take advantage of this capacity, proposing a *DSSs* to assist decisions aligned to the strategic plans of companies. For this reason, we consider that our proposal is aligned to the industrial needs.

On the other hand, Gartner^{TM} has evaluated a set of commercial ***BPMSs!*** by using two criteria: the ability to execute and the completeness of Gartner^{TM} vision. The ability to execute measures the quality and effectiveness of the processes, systems, methods or procedures that enable *IT* providers to be competitive. Gartner^{TM} vision includes the analysis of the most important ***BPMSs!*** in accordance with the 9 crucial capacities described above. More details about how this comparison has been carried out can be found in [44].

The results of this comparison are graphically represented in the Magic Quadrant depicted in Figure 3.3. As shown, several vendors have been included in the Gartner^{TM} vision, such as IBM^{TM} or Oracle^{TM}.

FIGURE 3.3: Gartner^{TM} Magic Quadrant for Intelligent *BPMS* [44]

Chapter 4

Decision Model and Notation (DMN)

Business processes can include mechanisms to make decisions during each instance. The output of the decision might be used to route *Business Process Instances (BPIs)* in which the decision has been made, or as input of another task. Figure 4.1 presents an example that includes two decision tasks, "*Decide action*" and "*Decide amount*". *Decide action* is a decision task whose output is used to route the *BPI*, in this case to choose the concrete marketing action to perform. As can be seen, there are two alternatives: *mailing* (send one email to all customers) and *publicity* (invest in online publicity to reach new customers). If *mailing* alternative is taken, task *Send mails* is executed and an email is deliver to each customer. If *publicity* alternative is taken, the task *Decide amount* is executed, and its output is used as input of the following task. In the example, the output of *Decide amount* is the concrete amount to invest, that will be used in the task *Invest* to request the inversion to the supplier.

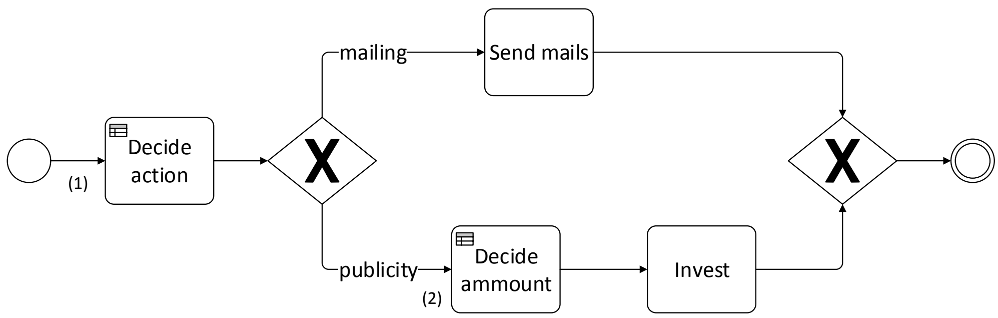


FIGURE 4.1: *BP* to make a marketing action

Therefore, we can distinct two types of decisions in the business process of the example: decisions to route the *BPI* or **route decisions** (1 in Figure 4.1) and **value assignment decisions** to stablish values to variables (2 in Figure 4.1) [144].

- **Route decisions:** Decisions that impact on the sequence flow executed for each instance. In this kind of decision, the decision output will determine the branch that is executed. As can be seen in decision (1) of Figure 4.1, the output of the decision task *Decide action* will determinate if branch *mailing* or branch *publicity* is executed. The use of these route decisions produces simpler business processes due to eliminates unnecessary gateways and scripting activities [12, 67].

- **Assign values decisions:** Those decisions are oriented to decide the value of a variable. For instance, in the example of Figure 4.1 (2), once the decision of the task *Decide amount* is executed, the amount is setted.

DMN is relatively a new standard managed by *Object Management Group (OMG)*[1], for describing and executing the decision logic, embedding them into decision tasks. The first version of *DMN* standard date from September 2015, and latest from June 2016. The purpose is to provide the constructs that are needed to model decisions so that organizational decision making can be readily depicted in diagrams, accurately defined by business analysts, and (optionally) automated [98].

4.1 Overview

The intention of *OMG* with *DMN* is to provide a third perspective: The *Decision Requirements Diagram (DRD)*, forming a bridge between *Business Process Managements (BPMs)* and *Decision Logic Models (DLMs)* [98]:

- *BPMs* will define tasks within business processes where decision-making is required to occur.
- *DRDs* will define the decisions to be made in those tasks, their interrelationships, and their requirements for decision logic.
- Decision logic will define the required decisions in sufficient details to allow validation and/or automation.

Bringing together *DRDs* and *DLMs*, they can provide a complete decision model which complements a *BPMs* by specifying in detail the decision-making carried out in process tasks. The relationships between these three aspects of modeling are shown in Figure 4.2.

This combination has the following advantages [30]:

- **Focused discovery:** By focusing on decisions and processes independently, the discovery processes is easier. Different stakeholders are involved in the process and the decisions within it, so separate models often work better. Because each model separately is simpler than the combined model, the discovery and modelling activities are easier to manage and complete successfully. Decision models link the tasks in a process to the business rules that will be required as well as to the organizations and business metrics that matter. All these make the discovery process more efficient.
- **Improved visibility and flexibility:** *DMN* structures and manages the business rules that a process requires, gathering them into a coherent model at each decision point in the process. This makes easier to find the right rules to change and allows the rules (decision) to be changed independently of the process improving flexibility. Because of the decision models are linked to business metrics, organizations get visibility into how their rules impact their business performance through the model.
- **Greater analytic agility:** *DMN* provides a model of the decision making in a process and this allows the impact of analytic models to be clearly expressed, allowing increasingly advanced analytics to be integrated into a process.

[1] `http://www.omg.org`

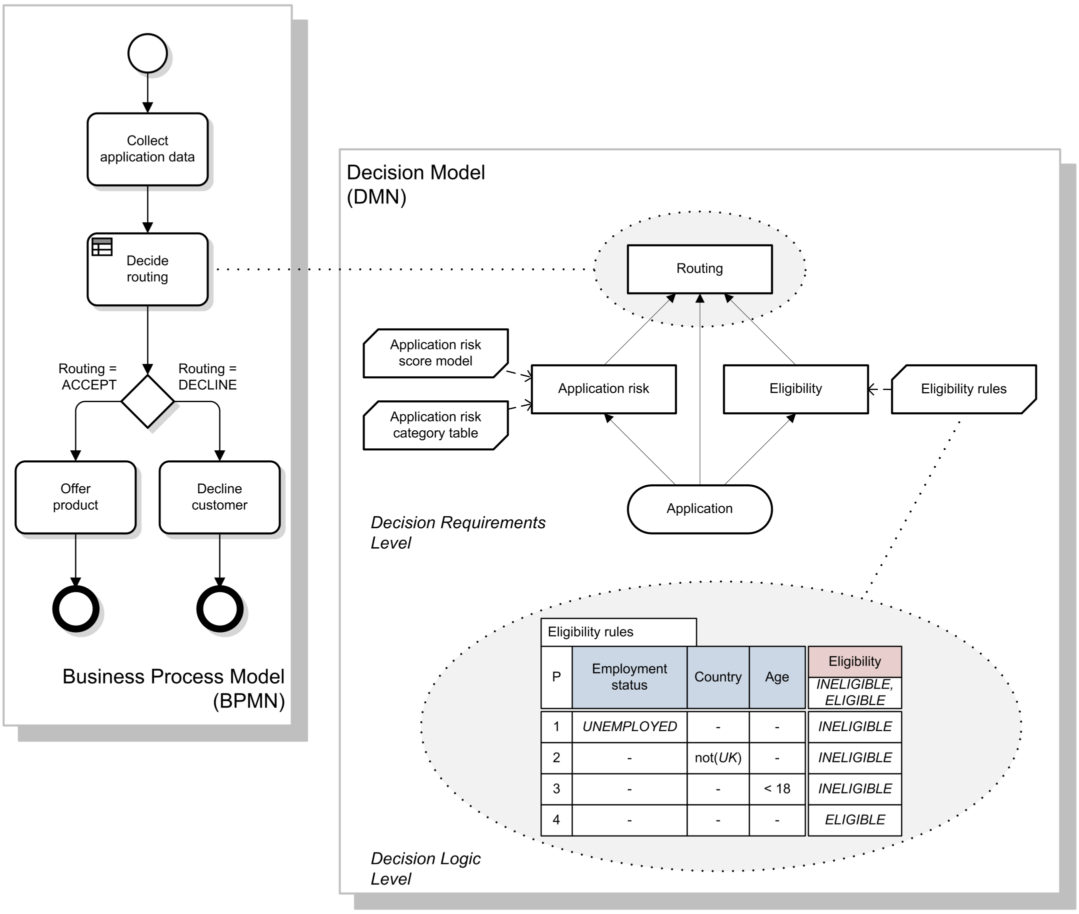


FIGURE 4.2: Aspects of modeling

In addition, *DMN* defines a business-oriented executable expression language called *Friendly Enough Expression Language (FEEL)* (see Figure 4.3). This language is used in decision tables and literal expressions, a tabular boxed expression format for defining more complex decision logic without programming [126].

4.2 Decision Table

A decision table is a tabular representation of a set of related input and output expressions, organized into rules indicating which output entry applies to a specific set of input entries. The decision table contains all (and only) the inputs required to determine the output. Moreover, a complete table contains all possible combinations of input values (all the rules).

As can be seen in Figure 4.4, a decision table consists of:

- **An information item name:** the name of an *Information Item*, if any, for which the decision table is its value expression. This will usually be the name of the Decision or Business Knowledge Model for which the decision table provides the decision logic.
- **An output label**, which can be any text to describe the output of the decision table. The result of a decision table must be referenced using the information item name in another expression, not the output label.

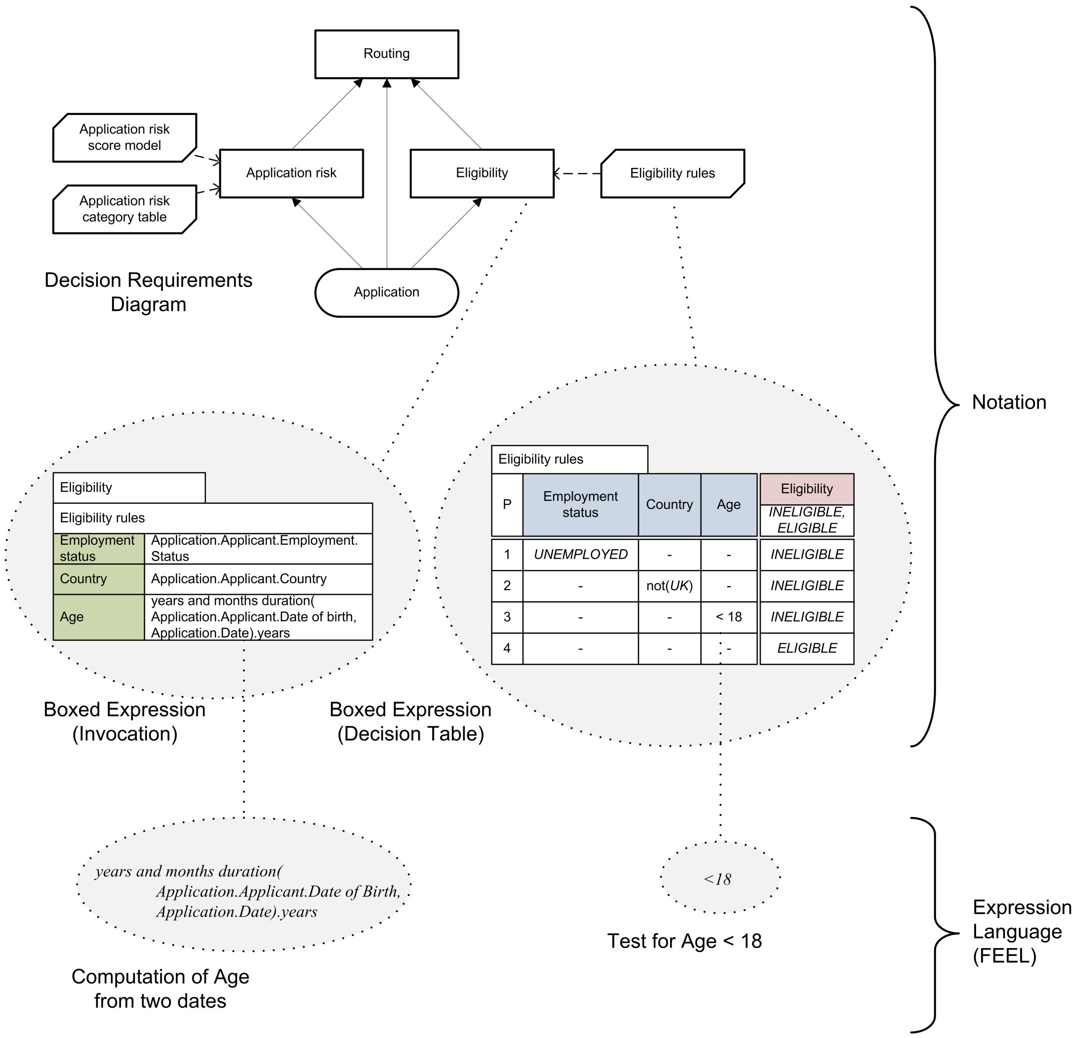


FIGURE 4.3: *DMN* constructs

- **A set of inputs** (zero or more). Each input is made of an input expression and a number of input entries. The specification of input expression and all input entries are referred to as the input clause.
- **A set of outputs** (one or more). A single output has no name, only a value. Two or more outputs are called output components. Each output component must be named. Each output (component) shall specify an output entry for each rule. The specification of output component name (if multiple outputs) and all output entries are referred to as an output clause.
- **A list of rules** (one or more) in rows, where each rule is composed of the specific input entries and output entries. As can be seen in Figure 4.3, the expressions used to specify the conditions in the inputs is *FEEL*. More information about *FEEL* can be seen in Subsection 4.4.

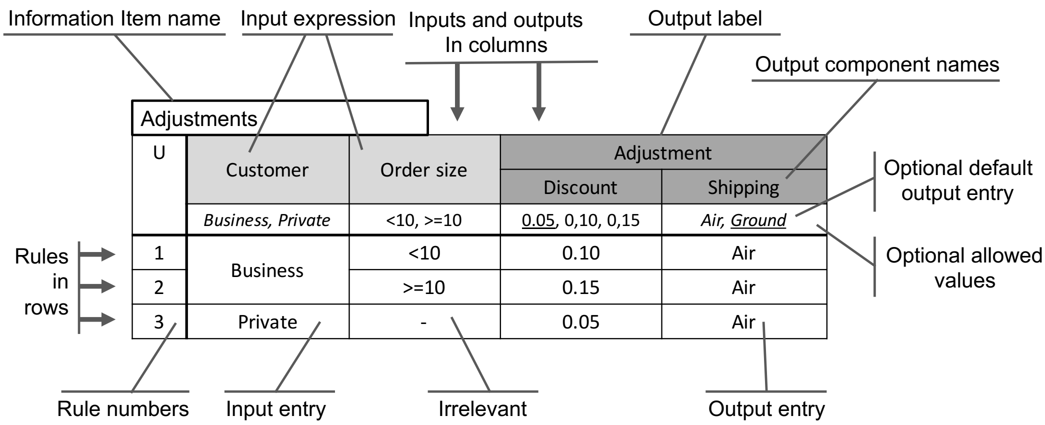


FIGURE 4.4: Decision table with horizontal orientation and multiple output components

The decision table shown in Figure 4.4 has a horizontal orientation, where rules are modelled as rows. *DMN* standard also allow vertical orientation, where rules are modelled as columns. If the rules are expressed as rows, the columns are clauses, and vice versa.

4.3 Hit Policy

A hit policy specifies how many rules of a decision table can be satisfied and which of the satisfied rules are included in the decision table result. Decision tables normally have several rules and by default, rules do not overlap. If rules overlap, meaning that more than one rule may match a given set of input values, the hit policy indicator is required in order to recognize the table type and unambiguously understand the decision logic. The hit policy can be used to check correctness at design-time [98].

The hit policy specifies what the result of the decision table is in cases of overlapping rules, i.e. when more than one rule matches the input data. For clarity, the hit policy is summarized using a single character in a particular decision table cell. In horizontal tables, as shown in Figure 4.4, this is the top-left cell, and in vertical tables this is the bottom-left cell. The set of possible hit policies are: Unique (U), Any (A), Priority (P), First (F), Collect (C), Output order (O) and Rule order (R).

The hit policies Unique, Any and First are single hit policies due to they always return a maximum of one satisfied rule, meanwhile, Rule Order and Collect hit policies are multiple hit policies, due to multiple rules can be satisfied.

The behaviour for single hit policies is:

1. **Unique:** no overlap is possible and all rules are disjoint. Only a single rule can be matched. This is the option by default.
2. **Any:** there may be overlap, but all of the matching rules show equal output entries for each output, so any match can be used.
3. **Priority:** multiple rules can match, with different output entries. This policy returns the matching rule with the highest output priority. Output priorities are specified in the ordered list of output values, in decreasing order of priority.
4. **First:** multiple rules can match, with different output entries. The first hit by rule order is returned. This is still a common usage, because it resolves inconsistencies by forcing the first hit.

The behaviour for multiple hit policies is:

1. **Output order:** returns all hits in decreasing output priority order. Output priorities are specified in the ordered list of output values in decreasing order of priority.
2. **Rule order:** returns all hits in rule order.
3. **Collect:** returns all hits in arbitrary order. An operator (+, <, >, #) can be added to apply a simple function to the outputs. If no operator is present, the result is the list of all the output entries. Collect operators behaviours are:
   (a) + (sum): the result of the decision table is the sum of all the distinct outputs.
   (b) < (min): the result of the decision table is the smallest value of all the outputs.
   (c) > (max): the result of the decision table is the largest value of all the outputs.
   (d) # (count): the result of the decision table is the number of distinct outputs.

Therefore, hit policies will determinate how the output is.

4.4 *FEEL*

As have been shown in Subsection 4.2, *FEEL* is the expression language that *OMG* proposes in the *DMN* standard, to specify the conditions of the inputs of the rules in decisions tables.

FEEL has the following features:

- Side-effect free
- Simple data model with numbers, dates, strings, lists, and contexts

- Simple syntax designed for a wide audience
- Three-valued logic (true, false, null) based on *Structured Query Language (SQL)* and *Predictive Model Markup Language (PMML)* [57]

The concrete expressions that can be built by using *FEEL* can be shown in [98].

Chapter 5

Constraint Programming

The analysis to discover the alignment between the objectives of an organization specified in its business plan, and the real behaviour of a company, brings about the analysis of a large number of restrictions and data. Additionally, the verification of the data that organizations maintain in data stores, according to their own business processes, implies the modelling and analysis of the correctness according to the states in which the data objects can stay.

In order to perform those analyses, *Constraint Programming (CP)* paradigm has been used in this dissertation as Artificial Intelligence technique. *CP* is a declarative model that describes the relation between variables and constraints to find values that satisfy the defined restrictions. *CP* is able to analyse the business plan and the real values of the variables.

CP includes many advantages: it is a very mature area that has been applied to a wide variety of problems related to optimization, and to those with high level of complexity; it uses propagation techniques to reduce the search space efficiently; there are numerous tools and algorithms available to model and solve problems; it permits an easy implementation of the business rules using a wide range of constraints, such as implication constraints, disjunctive constraints, reified constraints, global constraints, and channelling constraints. The basic concepts and search algorithms used in the *CP* paradigm are explained in the following sections.

5.1 Constraint Programming Concepts

CP is based on the resolution of *Constraint Satisfaction Problems (CSPs)*, which are problems where an assignment of values to variables must be found in order to satisfy a set of constraints. A large number of problems in Artificial Intelligence and other areas of Computer Science can be seen as special cases of *CSPs*. Examples include scheduling, temporal reasoning, graph problems, and configuration problems.

In general, a *CSP* (cf. Definition 5.1.1) is composed of a set of variables, a domain for each of them, and a set of constraints. Each constraint is defined over a subset of the original set of variables and limits the combinations of values that the variables in this subset can take. The goal is to find one assignment to the variables such that the assignment satisfies all constraints. In certain types of problems, the goal is to find all such assignments [74].

Definition 5.1.1 *A CSP consists of the tuple* $\langle V, D, C\rangle$*, where V is a set of n variables* $v_1, v_2, \ldots, v_n$ *whose values are taken from finite, discrete domains* $D_{v_1}, D_{v_2}, \ldots, D_{v_n}$ *respectively, and C is a set of constraints on their values. The constraint* $c_k(x_{k_1}, \ldots, x_{k_n})$ *is a predicate that is defined on the Cartesian product* $D_{k_1} \times \cdots \times D_{k_n}$*. This predicate is true iff the value assignment of these variables satisfies the constraint* c_k*.*

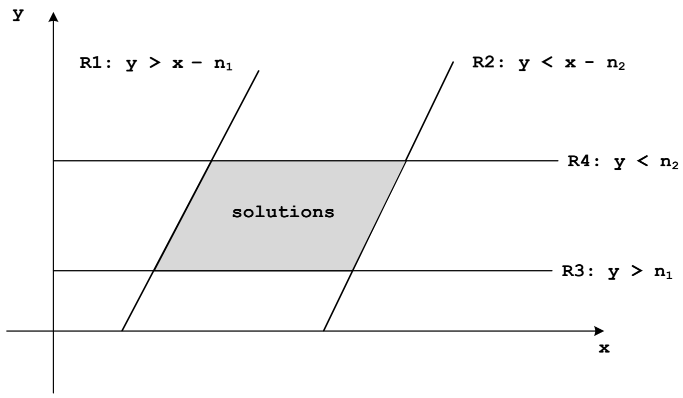


FIGURE 5.1: Sample graphic solutions of a *CSP*

The search for solutions for a *CSP* is based on the instantiation concept. An assignment of a variable, or instantiation, is a variable-value pair (x, a) which represents the assignment of the value a to the variable x. An instantiation of a set of variables is a tuple of ordered pairs, where each sorted pair (x, a) assigns the value a to the variable x. A tuple $\langle(x_1, a_1), \ldots, (x_i, a_i)\rangle$ is consistent if it satisfies all the constraints formed by variables of the tuple.

A solution of a *CSP* is an assignment of values to all the variables where all constraints must be satisfied. Hence a **solution** is a consistent tuple which contains values for all the variables of the problem. A partial solution is a consistent tuple which contains some of the variables of the problem. A problem is consistent if at least one solution exists, i.e., there is a consistent tuple. In Figure 5.1, there is a graphic which represents the space of solutions of a *CSP* that must satisfy four constraints ($R1$, $R2$, $R3$, and $R4$), and therefore the space of solutions is restricted to the grey-highlighted rectangle. The possible solutions of *x* and *y* are all the possible values found in the grey zone.

Finding the solutions of a *CSP* consists mainly of two phases: Consistency analysis and Search.

CSP Consistency

CSP solvers are based on the observation that if the domain for any variable in the *CSP* is empty, then the *CSP* is unsatisfiable. The idea behind each of these solvers is to transform the *CSP* into an equivalent *CSP* but one in which the domains of the variables are decreased. If any of the domains becomes empty, then this *CSP*, and hence the original *CSP*, are unsatisfiable. The solvers are said to be "consistency based" if the propagated information about allowable domain values form one variable to another until the domains are "consistent" with the constraints.

In order to reduce the search time of solution, the *CSP* algorithms are used to start with the process elimination of the inconsistent values of the domains. This implies that values that cannot satisfy the constraints of the model are eliminated from the possible sets of solutions, thereby drastically reducing the number of combinations.

One of the main difficulties in *CSP* resolution is the appearance of local inconsistencies. Local inconsistencies are values of the variables that cannot take part in the solution because they do not satisfy any consistency property. Therefore, if any consistency property is enforced, then all the values that are inconsistent attending to the property can be removed. However, it can be possible that certain values that are consistent with regard to a property are inconsistent regarding to another property at the same time. Global consistency implies that all values that cannot take part in a solution can be removed. The constraints of a *CSP* generate local inconsistencies because they are combined. If the search algorithm fails to store these inconsistencies, it will waste time and effort striving to carry out instantiations which have already been tested.

CSP Search Algorithms

Various approaches to solving *CSPs* have been developed, a number of which use constraint propagation to simplify the original problem. Others use backtracking to directly search for possible solutions, although most of them are a combination of both these techniques.

The techniques used in constraint satisfaction depend on the kind of considered constraints. Constraints are often used on a finite domain, to the point that *CSPs* are typically identified with problems based on constraints on a finite domain. Such problems are usually solved via techniques that combine propagation and searches, in a particular form of backtracking and local searcher. Constraint propagation is another method used on such problems; the majority of which remain incomplete. In general, they can solve the problem or prove it unsatisfiable, but not always. Constraint propagation methods are also used in conjunction with searches to make a given problem simpler to solve. Other kinds of constraints considered are those regarding real or rational numbers; solving problems on these constraints is performed via variable elimination or the simplex algorithm [85].

The search techniques to find solutions to a *CSP* are normally based on search algorithms, such as backtracking and exhaustive search. These ones strive to find a solution through the space of possible assignments of values to the variables, if it exists, or to prove that the problem has no solution, and hence they are known as complete algorithms. The incomplete algorithms, such as local searches, do not guarantee to find a solution, but they are widely used in optimization problems due to their great efficiency and the high cost that a complete search requires. Numerous complete search algorithms have been developed.

When solving a *CSP*, it is necessary to assign values to variables that satisfy a set of constraints. In real applications, problems are often over-constrained and have no solution. In order to solve these problems, several extensions of the model have been proposed, where weak constraints (which indicate preferences, not obligation) are allowed with different semantics, such as priorities, preferences, costs, and probabilities.

5.2 *Constraint Optimization Problems (COPs)*

Sometimes, the constraint problems are not only interested in the satisfiability of a set of constraints but also they want to find the "best" solution to the constraint problem. There are often numerous solutions to a *CSP*, which can mean that a user is interested in only a few of them, or only in a specific one. In general, if the user is just interested in an specific solution, the space of solutions can be reduced to a subset of the possible solutions. Finding the "best" solution for a set of constraints is called an *optimization problem* [85]. This requires a way of specifying which solutions are better than others. The usual way of doing this is by giving an objective function that has to be optimized.

Definition 5.2.1 *A COP consists of the tuple $\langle V, D, C, O\rangle$, where an objective function O is included in a CSP defined by the tuple $\langle V, D, C\rangle$. The objective function implies maximizing or minimizing a variable that can represent a numerical combination of others by means of a function.*

Optimization problems do not necessarily have a single optimal solution. For example, considering the constraints $\{X + Y \leq 4, X + Y = Z\}$ together with the objective function $maximize(Z)$. Any solution of the constraint $X + Y = 4$ is an optimal solution to this optimization problem.

COP Search Algorithms

As occurs with *CSP* search algorithms, the methods used to solve optimization problems depend on the specific problem types. Optimization problems can be categorized according to several criteria. Depending on the type of functions involved, there are linear and non-linear optimization problems (polynomial, algebraic, transcendental, ...). A solver could be applied to find any solution to the *CSP*, and then a constraint, which excludes solutions that are not better than this solution, could be added to the problem. The new *CSP* is solved recursively, giving rise to a solution which is closer to the optimum. This process can be repeated until the augmented *CSP* is unsatisfied, in which case the optimal solution is the last found solution.

One of the algorithms most widely used in practice is Dantzig's simplex algorithm [85]. However, constraint optimization can be solved by branch and bound algorithms, which are better known and whose use is more common. These are backtracking algorithms that store the best solution found during execution and use it to avoid repeating part of the search. More precisely, whenever the algorithm encounters a partial solution that cannot be extended to form a better solution than that stored, then the algorithm backtracks, instead of trying to extend this solution. The efficiency of these algorithms depends on how the best solution that can be obtained from extending a partial solution is evaluated. Indeed, if the algorithm can backtrack from a partial solution, then part of the search is skipped.

5.3 Evaluation Complexity of *CSP*

The complexity of *CSPs* has been analysed in great depth over recent decades [26], and depends on two parameters: the width of the graph and the order parameter. On one hand, the width of the graph represents the relation between the constraints, where the tractability in *CSPs* is due to the structure of the constraint network, and where the tree-structured *CSPs* have polynomial complexity (linear with respect to the number of variables, and quadratic with respect to the cardinal of the domain of the variables). On the other hand, the order parameter, defined as the ratio of the number of forbidden tuples to the total number of possible combinations, determines the partition of the problem space into under-constrained, over-constrained and just-constrained problems. In the first two cases, the problems are scalable, but in just-constrained problems, a significant increase in the solving cost could occur and scalability is not possible [134] (Figure 5.2).

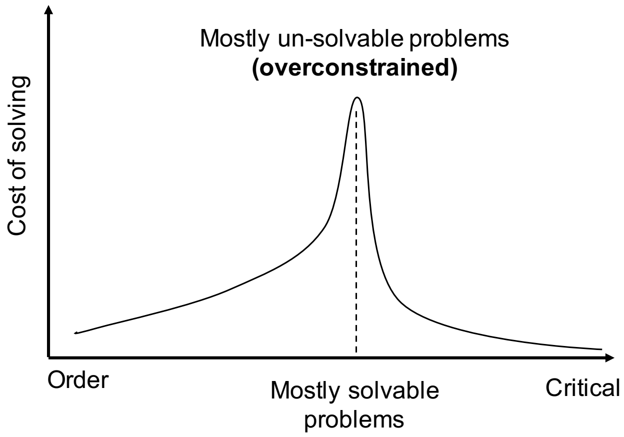


FIGURE 5.2: Graphic sample of complexity of a *CSP* resolution [26]

For these reasons, no affirmation concerning the efficiency or scalability in a generic way can be given by *CSPs* and *COPs*, since it depends on the type and number of constraints defined with numerical variables, and therefore the evaluation time depends on the specific problem.

Chapter 6

Decision Support Systems (DSSs)

A *DSS* is an interactive application, that compiles, combines and analyses raw data, documents, and fundamentals of social science to help in the decision process. It applies science, mathematics, managerial science, and personal knowledge (of decision makers), with the objective of identifying problems and determining their solutions. The techniques employed facilitate optimal decision-making, increase the effectiveness of the decisions, support decision makers (but do not replace them), and improve the effectiveness of directors in decision-making.

This dissertation proposes the use of *DSSs*, in order to help decision makers to reach decisions aligned to the business strategy that the *Board and Executive Team (BET)* defined in its Business Plans (see Section 2). For this reason, this chapter aims to outline history of *DSSs*, the decision-making processes, and the common components of a *DSS*.

6.1 Context

Decision Support Systems (DSSs) constitute a class of computerized information systems that support decision-making activities. The history of the implementation of these systems begins in the mid-1960s [112] with the development of minicomputers, timeshare operating systems, and distributed computing.

For companies, *DSSs* play an essential role in the decision-making process, since they help to capture important indicators that are fundamental to maintaining the correct direction of the company to achieve its objectives. These systems also contribute towards radical and strategic decisions. The advantages of the *DSSs* include:

- An increase in the productivity, understanding, and speed
- The ability to analyse different types of information which reduces problem complexity
- The ability to handle former data and compare it with current data
- The ability to be integrated with other systems
- The ability to produce a selection of alternative decisions in a short time
- A decrease in the possibility of any bias that normally occurs deliberately or accidentally through interventions [38]
- Provision of speedy and accurate answers that help in making major decisions [147]

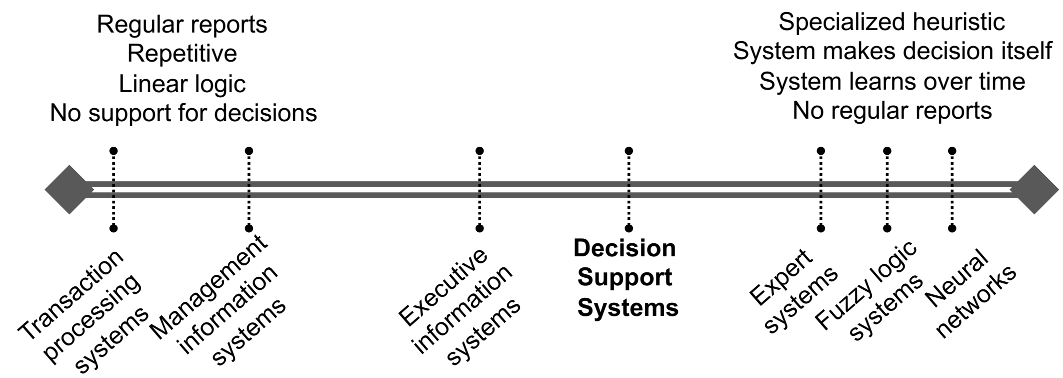


FIGURE 6.1: Types of Information System Managers [121]

The main disadvantage of *DSS* is that it uses former data obtained from previous situations in the company. If this information is inaccurate, then the derived deduction is incorrect. However, data used by companies used to come from different sources, such as a *Business Process Management Systems (BPMSs)*, *ECMS*, *Customer Relationship Managements (CRMs)*, and *Enterprise Resourcing Plannings (ERPs)*.

The first architecture of *DSS* proposed by [128] was composed of: (1) a model-based management system; (2) a data-based management system; and (3) a human computer interface.

Sorted in terms of their capacity of abstraction, the information system products available are illustrated in Figure 6.1. In this diagram, the conventional The *Management Information System (MIS)* and *Transaction Processing System (TPS)* are shown on the far left. Management Information Systems tend to be slow, and are not analysis-oriented. These systems tend to be used for the retrieval or extraction of information to be integrated and for the production of reports. Thanks to these reports, the managers receive information that is useful in decision-making. For this reason, the decisions that managers make while employing *MISs* are normally routine, structural, and anticipated decisions. However, *MISs* are not good for decision support.

In order to develop systems of a more usable nature, in the 1990s the *DSSs* were enriched with techniques rooted in Artificial Intelligence. In particular, the introduction of knowledge into the architecture previously described brings about the capacity of reasoning by the systems [79]. Those systems were called *Expert Systems (ESs)* and are represented on the right-hand side of Figure 6.1. *ESs* attempt to reproduce the logic of an expert human for the purposes of making a particular decision. The systems generally process a set of heuristics that are believed to mimic that logic. They are good at supporting decisions, but only those decisions that have already been programmed into the processes.

In between systems that fail to support decisions and those that make decisions by themselves, we can find *DSSs* and *Executive Information Systems (EISs)*. These two types of systems allow decision-makers to select what they want, both in terms of information and how it is presented. These systems strive to consider and process poorly structured data and underspecified problems. They provide flexible mechanisms for the retrieval and analysis of data, and tools that help in understanding the problems, opportunities, and possible solutions.

For example, an *MIS* is able to provide a profit/loss report that is aggregated by item and month, thereby delegating the responsibility of the detection of possible problems or deviations to the user. A *DSS*, on the other hand, could store the profit for later analysis and detection of problems or deviations. Moreover, *DSSs* allow, for instance, decisions to be made regarding individual products, groups of related products, and products in a particular region.

6.2 Decision making

In its most simplistic sense, a decision is a choice between the alternatives available. The decision itself can be seen as the result of the process of the consideration of facts and judgments that lead to a specific course of action. Members of an organization can consider the facts, their knowledge and what is suspected, with the objective of selecting the alternative action that is most likely to bring a good outcome for the company. The spectrum of decisions is wide: there are simple and well-structured decisions, but there are also complex decisions in which related knowledge remains unavailable.

The tools to support simple decisions tend to use a set of input variables that represents the scope of the decision, and, based on this scope, a decision is returned. Those decisions can be seen as a bijective function, in which a given scope always returns the same decision. On the other hand, complex decisions are usually unique and hard to formulate. Complex decisions often have no single correct answer and may not even have a right answer. Generally, *DSSs* are not employed to support the first type of decisions (well-structured and easy problems); they tend to be used for the second type of decisions (poorly structured and poorly understood problems) and when neither the solution nor the approaches to solving the problem are well understood [121].

Herbert A. Simon developed the model for decision-making [127] that can be seen graphically in Figure 6.2. This model is formed of three steps: intelligence, design, and choice. In the intelligence phase, the problem is identified, and the information concerning the problem is collected. In the design phase, several possible solutions are developed, while the final choice phase consists of choosing the final solution from among those obtained in the design phase.

The steps in which the *DSSs* can help to decision makers include:

- Identifying and defining the problem or opportunity: This includes detecting the problem or opportunity, and helping to split the problem or opportunity into terms of organizational objectives and constraints
- Identifying those actions that would address the problem or seize the opportunity
- Collecting appropriate information or accessing appropriate models that generate that information, such as predictive models
- Analysing data, and determining how the data is actionable. Proposing solutions to the problems or methods in order to address the opportunities
- Monitoring the results of the choice and assessing the decision in terms of the process and outcome

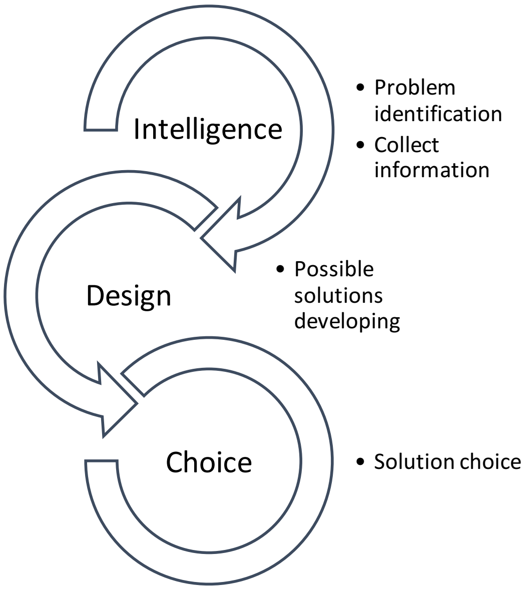


FIGURE 6.2: Decision making model

6.3 Components

The components of a typical *DSS* are:

- Data management: Data, factors or characteristics to analyse
- Knowledge: Model/knowledge management
- User interface

The following subsections analyse thorough these components.

Data management

This component performs the function of managing the information that *DSSs* need. This information can come from two different sources:

- **Organizational information:** As mentioned before, organizations employed systems such as *BPMSs*, *ECMS*, *CRMs* and/or *ERPs*. This information can be used by the *DSS*. This information can sometimes be copied and prepared in external databases, in order to reduce time when it needs to be processed.
- **External information:** This information is not part of the organization, but it is crucial for the decision process. This information can be, for instance, the traffic flow, in the case of deciding between whether to drive a car or ride a motorbike to pick up a package in transport companies.

The characteristics of the useful information for a *DSS* can be sorted into 12 categories, defined in terms of the choice context, the decision maker, and the decision environment under consideration:

- Timeliness

- Sufficiency level of detail or aggregation
- Understandability
- Freedom from bias
- Decision relevance
- Comparability
- Reliability
- Redundancy
- Cost efficiency
- Quantifiability
- Appropriateness of format

Knowledge

This refers to the information that a *DSS* uses as its working basis and is commonly represented by mathematical models to which techniques can be applied, such as:

- **Statistical techniques:** These contain a wide range of statistical functions, such as mean, median, mode, deviations etc. These models are employed to establish relationships between the occurrences of an event and various factors related to that event. It can, for example, relate sale of a product for different areas, income, season, or other factors. In addition to statistical functions, they contain software that can analyse series of data to project future outcomes.

- **Sensitivity Analysis techniques:** These are used to provide answers to what-if situations that occur frequently in an organization. During the analysis, the value of one variable is changed repeatedly and resulting changes on other variables are observed. The sale of a product, for example, is affected by different factors such as price, expenses on advertisements, number of sales staff, and productions. Using a sensitivity model, the price of the product can be changed (increased or decreased) repeatedly to ascertain the sensitivity of different factors and their effect on sales volume.

- **Optimization Analysis techniques:** These are used to find optimum values for a target variable under given circumstances. They are widely used for making decisions related to the optimum utilization of resources in an organization. During optimization analysis, the values for one or more variables are changed repeatedly while bearing in mind the specific constraints, until the best values for the target variable are found. They can, for example, determine the highest level of production that can be achieved by varying job assignments to workers, but it must be kept in mind that certain workers are skilled and their job assignment cannot be changed.

- **Forecasting techniques:** These use various forecasting tools, including regression models, time-series analysis, and market research methods, to make statements regarding the future or predictions. They provide information that helps in analysing the business conditions and making future plans. These systems are widely used for forecasting sales.

- **Backward Analysis Sensitivity techniques:** Also known as goal-seeking analysis, this technique is exactly opposite to that applied in sensitivity analysis models. Instead of changing the value of the variable repeatedly to see how it affects other variables, goal-seeking analysis sets a target value for a variable and then repeatedly changes other variables until the target value is achieved. For instance, to increase the production level by 40 percent using this technique, there are two steps: the target value for the production level is set and the analysis of required changes in related factors is performed. As an example, the related factors can be: the amount of raw material, machinery, tools, and the number of employees.

User interface

This is an interactive graphical interface that facilitates the interaction between the *DSS* and its users. It displays the results (output) of the analysis in various forms, such as text, tables, charts, and graphics. Users can select the appropriate option to view the output in accordance with their requirements.

The *BET*, for example, may prefer to view comparative sales data in tabular form whereas an architect creating a design plan would be more interested in viewing the results of analysis in a graphical format. The current commercial decision support systems are implemented using Web-based interfaces, and provide certain special capabilities, such as better interactivity, ease in customization and personalization, and simplicity.

Part III

State Of the Art

Chapter 7

State of the Art

Capítulo susceptible de publicación en formato de artículo o libro.

Part IV

Contributions

Subpart A

Routing instances

As described in Section 1.2, this dissertation includes three *Research Questions (RQs)*. The general aims of these *RQs* are: to ascertain where decisions are made (*RQ*1); to investigate how these decisions can be improved and to propose a *Decision Support System (DSS)* to help users (*RQ*2); and to investigate how these elements can be introduced into real scenarios (*RQ*3).

In order to answer the *RQ*1, the *Systematic Literature Review (SLR)* shown in Section 7 was performed. After this *SLR*, the following points regarding the decisions made in business processes were identified: (1) the decisions made during the daily business affect the achievement of their objectives; (2) of the three types of decisions, one is concerning with choosing an execution alternative (*Route Decision (RD)*); (3) *RDs* enable the modeller to describe the set of possible alternatives by means of various executable branches, in accordance with data-flow values at the decision points at runtime.

Figure 7.10 illustrates the example used in this dissertation (which can be seen in Figure 7.7), where the *RD* has been isolated. As can be observed, the output of the decision task "*Decide discount*" will determinate whether the upper, middle, or lower branch is executed.

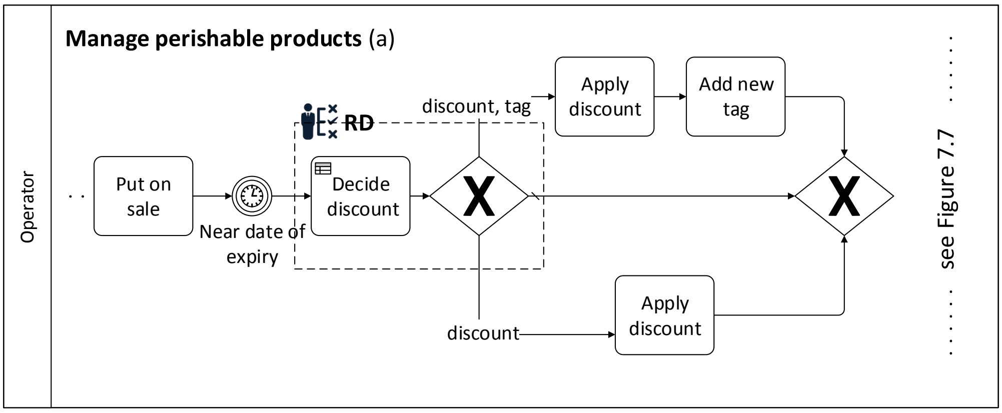


FIGURE 7.1: Example of routing instances

In Chapter 8, the *RQ*2 and *RQ*3 are tackled for the *RD*.

Chapter 8

Route Decisions (RDs)

Business Process Models (Ms) tend to include gateways for the combination of various branches that enable different activities to be executed in accordance with the value of a variable. This implies making an *RD*. Therefore, *RDs* are decisions that create and impact on the sequence flow of the activities executed during a *Business Process Instance (BPI)*, since when there are more than one possible branch to follow, these decisions determine the branch that should be executed.

8.1 Introduction

Decisions associated to *RDs* use the data that flow in the *BPI*, but there exist more important data during a process instance. *Business Process Management Systems (BPMSs)* generate and store information about their performance, such as the number of instances of a business process execution, the duration time of each activity, who has executed each activity, the resources involved, the frequency of each activity, and the number of unfinished instances. These measurements can be included in a dashboard using *Business Activity Monitoring (BAM)* or *Process Performance Measurement (PPM)* tools, were also *Business Intelligence (BI)* techniques can be applied [132], with the objective to be used by the *Board and Executive Teams (BETs)* of organisation to evaluate the status of the business, according to the goals defined in the strategic plans, and manually decide what to do. Unfortunately, after the *Systematic Literature Review (SLR)* that can be seen in Section 7, and to the best of our knowledge, there are no solutions that permit the incorporation of this information into *RDs*, allowing the automation of this task without human intervention.

The primary goal of *Decision Model and Notation (DMN)* is to provide a common notation that is readily understandable by all business users. Business analysts need to create initial decision requirements, meanwhile technical developers are responsible of automating the decisions and processes, and finally, business people manage and monitor those decisions. *DMN* creates a standardized bridge for the gap between the business decision design and implementation, and permits the inclusion of decision tasks into the process model. The way in which the data that flows in the process can influence the decisions has been the focus of the study of several papers and technologies, however, our contribution lies in the fact that we also consider the importance of including the performance data mentioned before, at runtime in the model.

Process Performance Indicators (PPIs) are highly related to the process instances that are being executed at any moment, and therefore the description of *PPIs* implies the description of the instance data, and the status of the instance affect to achieve the goals defined in the strategic plans of the companies. The incorporation of *PPIs* into the business process execution can be crucial: for example, when the assignment of a task to one particular person or another depends on the number of activities executed by each of them in the past, or when the time associated to a clock event depends on the number of instances that are being executed. For this reason, we have defined a *Process Instance Query Language (PIQL)* to extract the necessary information to build the *PPIs* and ascertain their values at run-time.

To illustrate this proposal, and answer the *RQ*3 of this dissertation, a real example about a platform for football bets, called Tutiplay^{TM} [136], is used. The example presents the necessity to incorporate information about the execution of other processes in order to improve the profits during the prognostic time, for example, by enlarging the open platform time to establish a bet for the most promising instances.

For these reasons, we consider that the execution of a process can be aligned with the objectives specified in the strategic plans, by incorporating information concerning the business execution, and therefore we wish to include data obtained from the business process performance into the decision rules executed at the decision points of the process. The incorporation of *PPIs* into the decision at run-time permits continuous improvements to be added, thereby building a more flexible and adaptable model. In particular, this incorporation provides a way to combine the process data and behaviour of various processes and instances at the same time. Unfortunately, the decision rules supported by commercial *BPMSs* fail to support the incorporation of this information both in the model and during the execution.

We propose an extension to the *DMN* to model *PPIs* and their introduction into the decision tables, thereby enriching the types of decisions and the managed data at decision points, and shielding the user from unnecessary details on how these *PPIs* are obtained. In order to extract the *PPIs*, we have defined a *PIQL* that allows business experts to describe the *PPIs*. The proposed business rule engine and a *Domain Specific Language (DSL)* are completed with an implementation of an entire framework that combines a set of mature technologies.

This proposal for *RDs* is organized as follows: Section 8.2 exposes the details of the real world example that illustrates the problem. Section 8.3 describes the necessary grammar and a *DSL* associated to decision points. Section 8.4 exposes how to take advantage of the previously described *DSL*, to build indicators. Section 8.5 explains the architecture of the solution. Finally, Section 8.6 shows an implementation of the described architecture and technologies.

8.2 Real world example

This illustrative example consists of a collaborative platform to play a football pool, called Tutiplay^{TM} [136]. Using the platform, the participants try to predict the outcomes of 14 football matches, where the alternatives are "1" to forecast the local team as the winner, "x" to draw, and "2" to forecast the visiting team as the winner. A forecast of all available matches is called a row, and a set of rows with a minimal of two rows composes a valid football pool ticket. This ticket is commonly known as a *quiniela*. Tutiplay^{TM} is a platform oriented towards allowing a set of people (normally friends) to forecast a *quiniela* betting ticket together. By using this platform, people can share a betting ticket, sharing the total price and winnings in the case of any gain. In each bet, each person fills out an independent row and lets the Tutiplay^{TM} platform collect all the rows together into a single betting ticket, and formalizes the bet using the lottery administration. In the case of economic reward, the platform also collects the winning, and divides the quantity between the participants. More than one bet can be opened to be forecast at the same time, and people can participate in more than one pool at the same time.

Figure 8.1 shows two business process models implemented to support the platform. The first model (*a. New bet creation*) shows how a bet is managed by the person who administers the platform, from the creation to the final formalization of the bets. The second model (*b. Forecast an outcome*) shows the steps that a player must follow to forecast a specific outcome.

As shown in Figure 8.1, the process to manage a bet (*a. New bet creation*), is divided into three parts.

In the first stage, the person who administrates the platform creates a new bet, and configures the parameters, such as *open time* (date from which users can forecast), *close time*, (date from which no more forecasts are allowed), and *extended time* witch is used to grant extra time, if necessary.

The second stage consists of monitoring the players' forecasts, and therefore starts when the bet is opened, and predictions are made by users. For each bet, the aim of the platform is to formalize as many forecasts as possible in order to maximise the profits. For this reason, the number of formalized forecasts can be considered as a *PPI* to be maximised. In order to improve the aforementioned *PPI*, three different actions can be executed, performed by means of the three condition flows shown in the process:

- **email:** consists of sending a reminder email to the people who have yet to make a forecast.
- **tweet:** consists of sending a tweet with the aim of alerting followers that they have yet to make a forecast. This tweet is not a personal reminder, like the email: it is tweeted with any content to produce an alert to connect players and followers.
- **time extension:** consists of extending the *open time*, thereby providing users with more time to make a forecast.

The *BET* have defined in the business plan of the company, some mechanism with the aim of improving the indicators, such as "number of forecasts", but not of worsening others. For example, if too many emails or tweets are sent, the risk of being considered a spammer at arises, with the consequence of losing players and followers. In that sense, in the case of the "email" branch, the strategic plan of Tutiplay^{TM} establish that it is not possible to send more than one reminder email for each bet, and it must be sent within 24 hours of closing time, if and only if at least 40% of the players have yet to make a forecast. In the strategic plan, about "tweet" action does not allow more than one tweet to be sent per 15 minutes. Moreover, the tweets are sent if the number of forecasts has not been incremented within the last hour. The "extended" alternative can be executed only once for each bet, and it will take place if, during the last 30 minutes before close time, at least 30 players are still forecasting.

As explained before, the presented *PPIs* enables the quality of the process to be measured in accordance with the number of finished instances. The *Tutiplay^{TM}* example needs to tailor each bet at runtime in accordance with to the value of this *PPI*, thereby rendering it unnecessary to redesign the model in accordance with to a *PPI* analysis. Therefore, the idea of the proposal needs to cover the instance adaptation in each case to improve the *PPI*. The adaptation of each case at runtime makes the model more flexible and agile. It does not contradict the improvement of the process redesign following the life-cycle proposed in [34], since this approach permits the

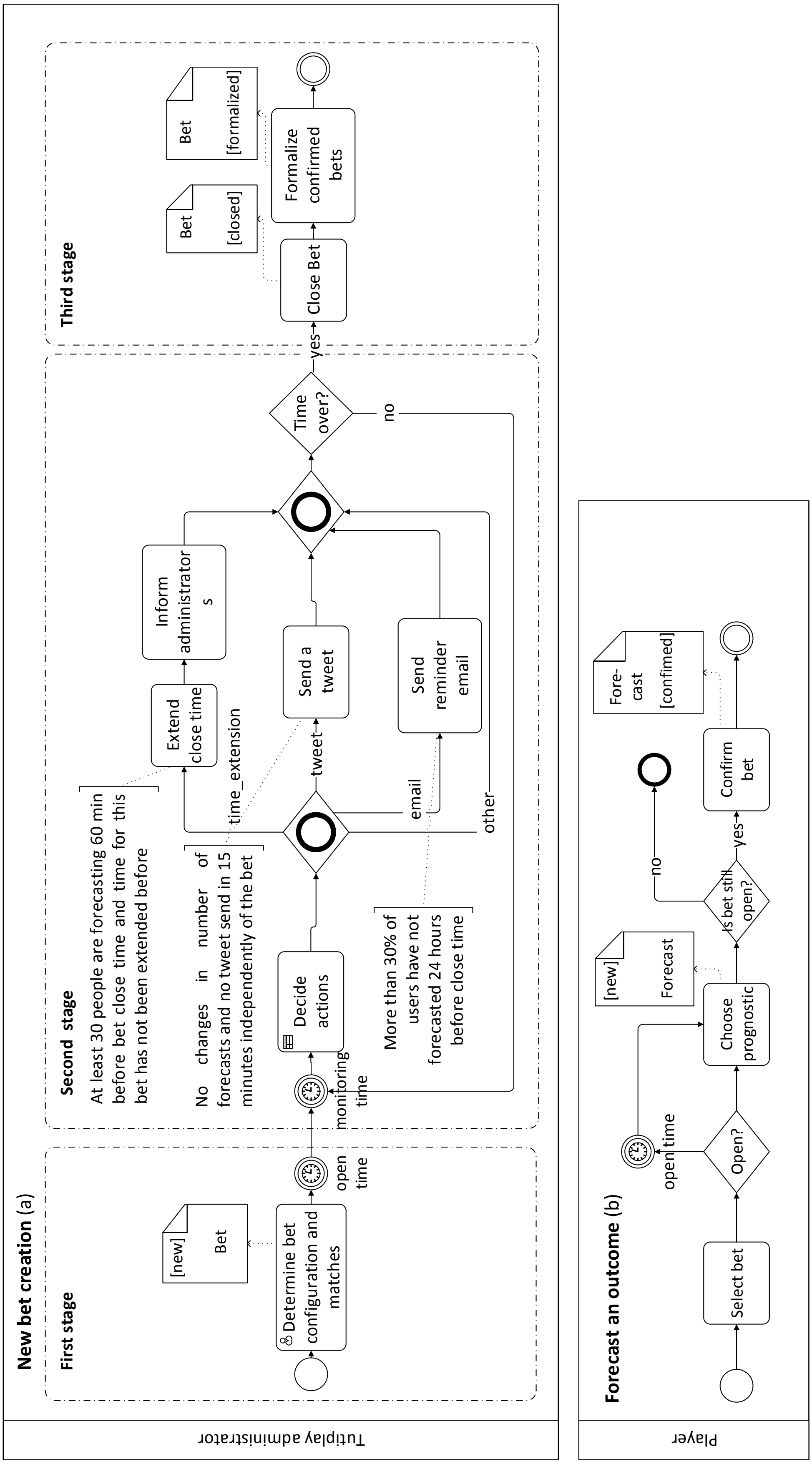


FIGURE 8.1: Tutiplay^{TM} business processes

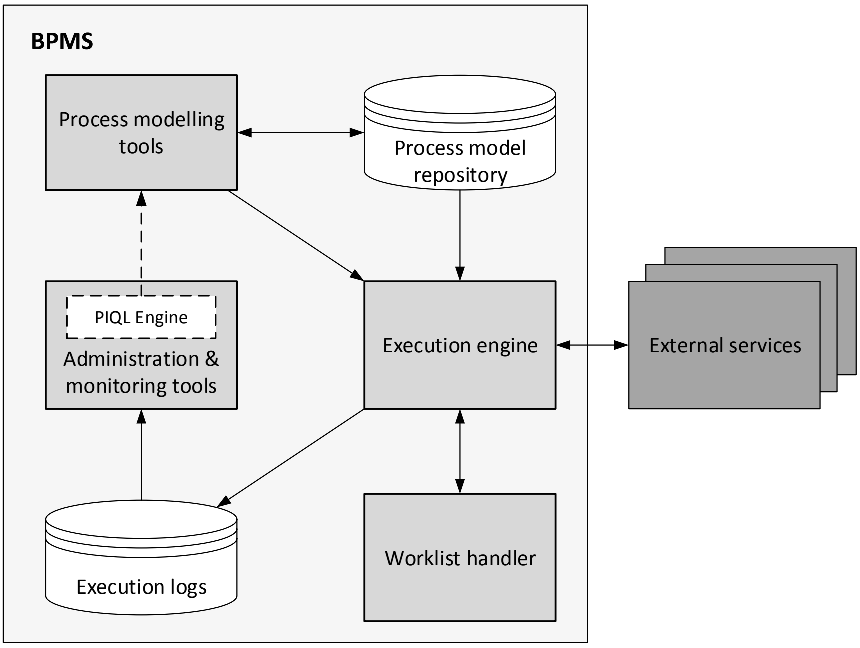


FIGURE 8.2: Proposed architecture of a *BPMS* extended to include *PIQL* Engine

deductions derived from business intelligence to be incorporated out design time, and each instance to be adapted to optimize the *PPIs* at runtime.

The third stage starts once the forecast time ends. At that moment the, forecast is closed, and the final tickets are printed and formalized in the lottery administration.

This process is a simplification of the complete model, where the process continues with the monitoring of bets, and, once all the matches are finalised, the platform manages the possible economic rewards.

On the other hand, process *(b. Forecast an outcome)* of Figure 8.2 describes how users access the platform to play. First of all, a bet is selected, in case there is any open bet. The task "choose prognostic" can then be performed for the participant to decide his/her prognostic. Once this task is finalised, a new *Forecast* object is created to store the forecast. In the case when the bet is still open, the user can confirm the forecast and the *Forecast* object is set to "forecast" state. Notice that not every participant completes the whole process at once; in real life the players can access to process several times to lay a bet (as many bets as they want). Frequently, users access the platform to inspect or predict certain matches, but not all matches. Most of the participants tend to wait near to the close time to confirm the prognostic. The bet is usually open for a week, and predictions can change depending on the news concerning football teams.

The architectures proposed for the current *BPMSs* present an isolation between the information of the execution logs (through administration and monitoring tools) and process modelling tools [34]. For this reason, it is not a minor task to incorporate the information, that is normally obtained in the monitoring phase, into the *M* (as is needed in the second stage of Process *New bet creation*), which needs to include the *PPI* values in the *RD* at runtime.

Various solutions are available to solve this problem, such as the creation of messages between the processes and local variables to store the necessary information, and storage of the information in a shared database. However, these solutions imply storing control information in the business logic, and creating new data-flow variables to ascertain the values of the *PPIs*. Hence, neither solution is sufficient according to the cohesion principles of software engineering, and they also imply an ad-hoc solution which is valid only for this specific issue, and is not enlarged to be included in other scenarios. For example, the action of "tweet" as advertising is related to the number of times that a tweet has been sent, that is, the number of times that the "send a tweet" task has been executed by any instance of the whole process. This inconvenience can also be solved by using a hard ad-hoc solution, for example, by using a global variable to model the number of times that a task has been executed in a period of time. Again, this solution also fails to solve the entire problem, since the "extended" alternative needs to know the number of live instances of the *Forecast an outcome* for a specific bet. The use of complex and ad-hoc methods are time consuming, and cannot be used in a general way, due to the necessary for specific implementations created by designer experts to transform the business decision policies into executable policies ones.

The following sections explain the proposed grammar designed to enlarge the description of the decision rules, and how these rules can be evaluated at instantiation time for each case. This is carried out using the so-called *Process Instance Query Expression (PIQE)*, which support the incorporation of *PPIs* into the *RD*.

8.3 Process Instance Query Language

In this section *PIQL* is presented, as a language that can select *BPI*. This language propose the use of *PIQL* that a engine has to interpret in order to extract the information from the system, this is: a database, a *BPMS*, *Enterprise Resourcing Planning (ERP)* or similar. *PIQL* is inspired in *A Process-Model Query Language (APQL)* [61] where the authors propose a language to select a model.

In order to formalize the expressions incorporated in the *PIQL*, we need to introduce the elements that can be included in the queries: *Process instance (PI)* and *Task Instance (TI)*.

BPI is described by the tuple ⟨*CaseId*, *Process_Name*, *Start*, *End*, *Cancelled*, *Who*, *List Of Global Data*⟩, whose attributes are:

- *CaseId* is the identification that describes the instance in an univocal way. It is assigned by the *BPMS* when an instance is created.
- *Process_Name* is the name of the process model.
- *Start* is the date where the instance has started.
- *End* is the date where the instance has finished, or *null* otherwise.
- *Cancelled* is the date where the instance has been cancelled, or *null* otherwise.
- *Who* has started the execution of the instance.
- *List Of Global Data* represents the global variables specific for each *M*, that can be interesting to be known out of it during each instantiation.

TI represents the tasks executed for each instance, and each *TI* is described by the tuple ⟨*CaseId*, *Task_Name*, *Process_Name*, *Start*, *End*, *Cancelled*, *Who*⟩, whose attributes are:

- *CaseId* is the identification that describes the instance in an univocal way. It is assigned by the BPMS when an instance is created.
- *Task_Name* is the name of the task.
- *Process_Name* is the name of the M associated to the activity.
- *Start* is the date where the task has started, or *null* otherwise.
- *End* is the date where the task has finished, or *null* otherwise.
- *Cancelled* is the date where the execution of the task has been cancelled, or *null* otherwise.
- *Who* has started the execution of the task in this instance.

By using Set theory over *BPI* and *TI*, and by applying filters over the attributes of the tuple, it is possible to select:

- **Instances of Processes:** finished, unfinished, started by a specific user, started after or before a specific time, finished after or before a specific moment in time, that contains a specific variable with a determined value, etc.
- **Activities executed in a Process Instance:** started in a specific *BPI*, assigned to a specific user, finalised, not finalised, cancelled, started after or before a specific moment in time, finished after or before a specific moment in time, etc.

Based on the above description of PI and TI, certain predicates can be defined to select process or task instances in a determined status:

- *Processes or Tasks finalised*: $|\ \forall$ i $\in \{PI \cup TI\}$ | i.End $\neq$ *null*|
- *Process or Task not finalised*: $|\ \forall$ i $\in PI$ | i.End $=$ *null*|
- *Processes or Tasks started:* $|\ \forall$ i $\in \{PI \cup TI\}$ | i.End $=$ *null*)|
- *Processes or Tasks cancelled:* $|\ \forall$ i $\in \{PI \cup TI\}$ | i.Cancelled $\neq$ *null*|
- *Processes or Tasks not cancelled:* $|\ \forall$ i $\in \{PI \cup TI\}$ | i.Cancelled $=$ *null*|
- *Processes or Tasks executedBy who*: $|\ \forall$ i $\in \{PI \cup TI\}$ | i.Who $=$ *who*|
- *Processes or Tasks that start before date*: $|\ \forall$ i $\in \{PI \cup TI\}$ | i.Start $\geq$ *date*|
- *Processes or Tasks that end after date*: $|\ \forall$ i $\in \{PI \cup TI\}$ | i.End $\leq$ *date*|

Let *sp* be this set of process instances in a determined status, and *st* be the set of task instances belonging to the *sp* in a determined status.

Over *sp* and *st*, a set of operations can be applied. But the counting is not the only operation allowed:

- Operations over the set of *sp*:
  - *Count*: Count all instances of *sp*.
  - *Obtain the value of a variable of the data-flow*: In the case where only one instance satisfies the filter, it obtains the value of this specific variable of the data-flow of that instance.

  - *Obtain the average of values of a variable of the data-flow*: The average values of a variable that belongs to all instances that match a specific filter.
  - *Obtain the maximum value of a variable of the data-flow*: The maximum value of a specific variable of the data-flow, of all instances that match a specific filter
  - *Obtain the minimal value of a variable in data-flow*: The minimal value of a specific variable in data-flow, of all instances that match a specific filter.

- Operations over the set of *st*:
  - Count: Count every time that tasks *t* is executed.

The grammar of Listing 8.1 has been defined to describe the *PIQL* expressions. This grammar contains the most common elements of a grammar with numerical operations, extended with a special construction that allows the business expert to make queries over the environment where the process is running. When the *PIQL* expressions (*PIQE*) are evaluated at runtime, an Integer is obtained that represents the aggretagion operation over selected instances that match the specified criteria.

```
EXPR ≜ PIQE | Number
PIQE ≜ CONTEXT ListOfAttributes
CONTEXT ≜ AGGREGATION_OP? (P | T)
AGGREGATION_OP ≜ Count | Average | Maximum | Minimum
ListOfAttributes ≜ AttributeComp BOOLEAN_OP ListOfAttributes
AttributeComp ≜ Attribute COMPARATOR_OP Attribute
Attribute ≜ Constant | Variable | Numerical_Expression
Constant ≜ String | Number | Date | Boolean | Null |
```

LISTING 8.1: Grammar defined for *PIQL*

Different specific syntax can be used to describe the abstract grammar presented in Listing 8.1. In order to facilitate the description of the *PIQLs* by a business expert, we propose a *DSL* that is close to natural language. Table 8.1 shows the patterns allowed, which help the instantiation of the grammar previously presented. In addition, Table 8.2 shows the allowed predicates with their transformation into a *DSL* pattern. Predicates and separation words (such as **with**, or **that**) make the grammar more user-friendly to business experts.

By using *PIQL*, users can define *PIQE*, those *PIQL* are evaluated. However, in this thesis we do not use *PIQL* by themselves, we use *PIQE* to build other grammar, for instance, in Section 8.4 we expose how to use *PIQE* to build *PPIs*, and later, in Section 10.4 they will be used to build *Process-Observational Variables (POVars)*.

8.4 Using *PIQL* to define *PPIs*

Business Process Management (BPM) life-cycle [34] defines how to improve processing based on the knowledge of historical executions. This information is extracted from the *BPMSs* by using administration and monitoring tools as can be seen in Figure 8.2, and constitutes major support to the redesign phase. Since these improvements are carried out in a manual way, basic *BPMS* architecture includes administration and monitoring tools. However, these tools remain disconnected from the process modelling tools, since the business expert is who introduces the necessary modification into the model.

Grammar Component	**DSL Syntax**	
CONTEXT P (Context of Processes)	**Operation**	**DSL Syntax**
	Count	The number of instances of *processes*
	Attribute in data-flow	The value of *variable* of *process*
	The average of a variable in data-flow	The average value of *variable* of *process*
	The maximum value of a variable in data-flow	The maximum value of *variable* of *process*
	The minimum value of a variable in data-flow	The minimum value of *variable* of *process*
CONTEXT T (Context of Task)	The number of instances of tasks	
List of attributes (Attributes Defined)	**Attributes**	**DSL Syntax**
	idCase	*with a case id*
	Process_Name	*with a name*
	Task_Name	*with a name*
	Start	*with a start date*
	End	*with an end date*
	Cancelled	*cancelled*
	Who	*executed by the user*
ARITHMETIC_OP	**Operator**	**DSL Syntax**
	+	*plus*
	-	*minus*
	$\times$	*multiplied by*
	/	*divided by*
BOOLEAN_OP	**Operator**	**DSL Syntax**
	$\wedge$	*and*
	$\vee$	*or*
	$\neg$	*not*
COMP_OP	**Operator**	**DSL Syntax**
	$=$	*is equal to*
	$\neq$	*is not equal to*
	$<$	*is less than*
	$>$	*is greater than*
	$\leq$	*is less than or equal to*
	$\geq$	*is greater than or equal to*

TABLE 8.1: Component of the Concrete Grammar and their *DSL* representation

Predicated	Transformed pattern
are finalised	end date is not equal to Null
are not finalised	end date is equal to Null
are cancelled	cancelled is not equal to Null
are not cancelled	cancelled is equal to Null
executed by {name}	the user is equal to {name}
start before {date}	a start date is less than {date}
end before {date}	an end date is less than {date}
start after {date}	a start date is greater than {date}
end after {date}	an end date is greater than {date}

TABLE 8.2: Predicates allowed

To solve the isolation between the model and the *PPIs* generated for the process engine at run time, in this contribution we presents a proposal for the values of the *PPIs* at runtime to be used also into the *DMN* rules. This implies creating a union between the process modelling tool and the monitoring tool, as presented in Figure 8.2. This new module connects the data of the execution logs to the modelling phase by allowing the modeller to make queries for the evaluation of the status of the *BPMS* execution. This contribution is an improvement of the typical architecture of *BPMSs* [34].

The adaptation of the architecture facilitates *BET* the use of *PPIs* aligned in the process execution, and therefore aligned to the strategic plans. Also, we propose the use of *PIQEs* using a *PIQL*, to extract information about the process instances and *PPIs* with a defined grammar and a friendly *DSL*. A *PPI* can be described by using arithmetical combinations with the information extracted from the process instances. These expressions are a combination of one or more constants, variables, operators, and functions, with the peculiarity that a *PIQE* also includes the capacity to incorporate information on the instances of processes and information concerning the activities of various instances in more detail. The grammar of Listing 8.2 extend the grammar of Listing 8.1 to build *PPIs*. As can be seen is a very simple grammar where *PIQE* are used.

$$\text{PPI} \triangleq \text{PPI ARITHMETIC\_OP EXPR}$$

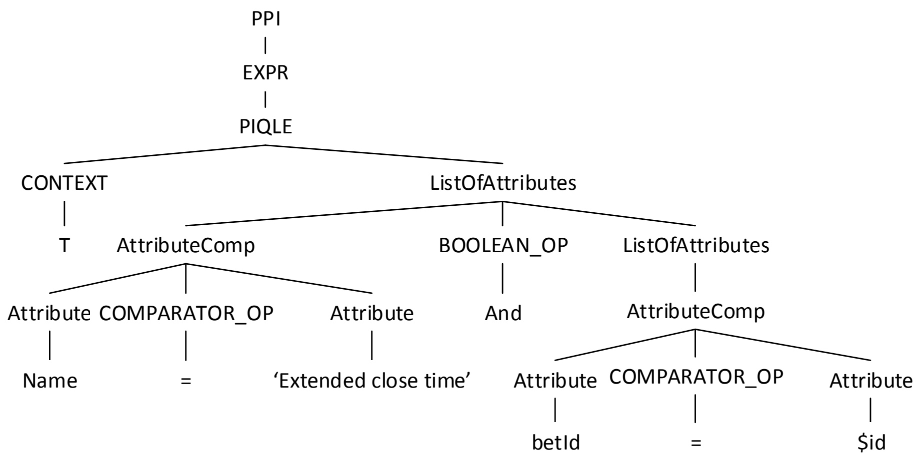
LISTING 8.2: Grammar defined for *PPI*

In order to illustrate the grammar presented above, Figure 8.3 shows three samples of the grammar trees, that have been generated following the examples shown in Section 8.5.

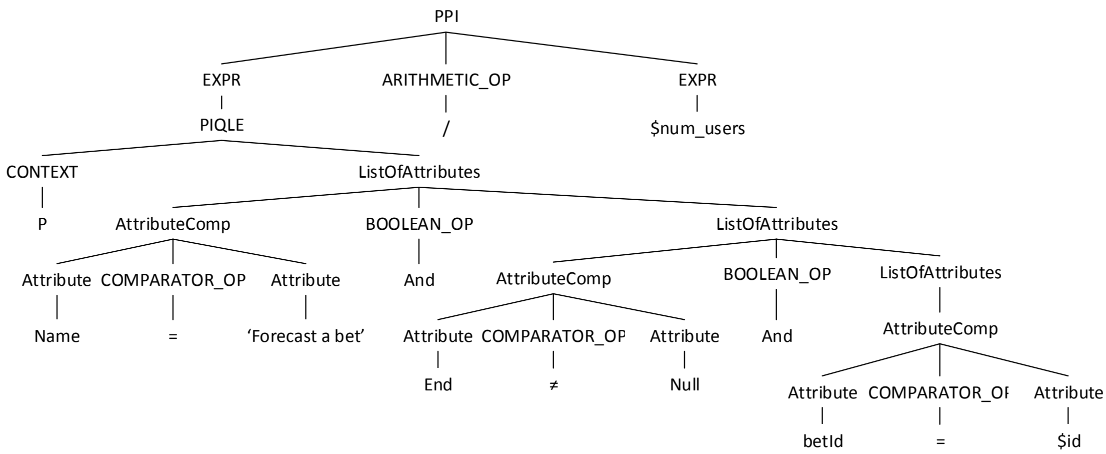
An application of this grammar is shown in the following section.

8.5 Process Aware Performance Indicators

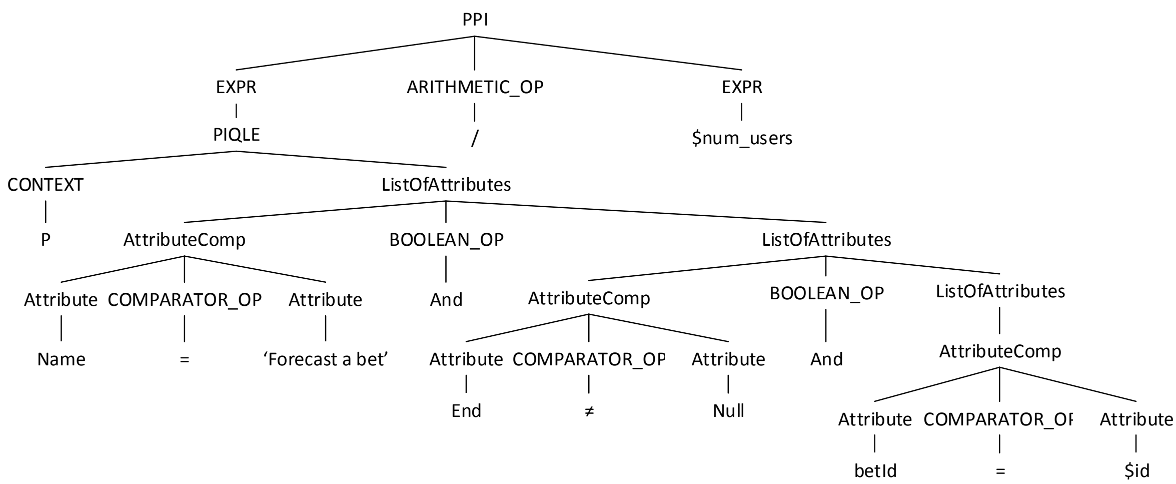
The definition of *PPIs* that uses the *DSL* described for the *PIQEs* facilitates the incorporation of the *PPIs* into the *M* by the *BET* of the company. We propose their incorporation as information for the evaluation of the business rules defined using the *DMN* standard [98], since it provides a human decision-making model. Since the primary goal of *DMN* is to provide a common notation that is readily understandable by all business users, a friendly *DSL* is crucial. If the information on the instances can be included easily in the decision of the process, then the *M* will be more adaptable and flexible to each instance.



(a) Executions of task 'send reminder mail' by bet



(b) Comparation of executions of process 'Forecast an outcome' with users in platform



(c) Executions of process 'Forecast an outcome' not finalised and related with a specific betId

FIGURE 8.3: Grammar trees

DMN provides a way to incorporate the decision rules into a decision task for routing the workflow in accordance with the evaluation of the decision. The basic element needed in this thesis have been introduced in Section 4, and more details can be found in the *Object Management Group (OMG)* specification [98]. Following we just details the points extended by this proposal, to be enlarged to support the incorporation of *PIQEs* into the decisions:

- **Decision table** defines a set of input variables used to make the decisions. In the standard, these variables are obtained from the data-flow. In our proposal, input variables can include *PPIs* related to process instance information. The grammar of the description of the variables is enlarged by using the *PIQEs* described above.
- **Business knowledge model** denotes a function encapsulating business knowledge (such as business rules, a decision table, or an analytic model). In our case, we use the tables to describe the business rules extracted from the strategic plans of the company, thereby relating the obtained output (email, tweet and time_extension) in concordance with the input values (emails_bet, percentage_finalised_forecast_bet and tweet_after_15min). As we mentioned in Section 4.4, the expressions permitted in business knowledge tables is *Friendly Enough Expression Language (FEEL)*.

In order to illustrate the use of the grammar and the syntax of the *DSL* proposed, Figure 8.4 shows the *DMN* applied to the Tutiplay^{TM} example. *PIQEs* are used as input values and are defined in the Decision table (Figure 8.4.a), and the decision rules are included in the table of Decision knowledge (Figure 8.4.b), which are obtained by means of a transformation from each *PIQE* into a specific value. The Decision table and business knowledge are associated to the task "Decide action" of Figure 8.1.

The decisions described in the business knowledge are stored in a database and associated with an identifier, called *Decision Identifier*. When a decision is made, the business rule task requests the evaluation of the business rules by using this identifier, together with other input data needed by the engine to evaluate the associated *PIQE*, such as *Case id* and information from the data-flow. Once the rules have been evaluated, the decision result is returned to the decision task. This task is responsible for the incorporation of the results into the data-flow of the process, such as putting it into the data-flow in order to route the process execution.

The way in which the *PIQEs* are evaluated in the decision process is detailed in the following subsection.

Decision-Process Architecture

Figure 8.5 shows the proposed architecture (denoted as *DMN* Extension) that uses the *PIQEs* obtained from a *BPMS*.

The *DMN* Extension is formed of two modules to support the description and evaluation of the *PIQEs*:

- **PIQE Engine Module** evaluates then *PIQEs* by using data received from invocation and data extracted from the *BPMS*. This is one of our proposals in the paper.
- **DMN Engine Module** evaluates the *DMN* rules. In Figure 8.5, this module is marked with *, since some *BPMSs* contain this engine and can be used as a

Decide action	
Decide action rules	
emails_bet	**The number of instances** of task 'Send reminder mail' **with** betId equal to $id
percent_finalized_forecast_bet	**(The number of instances** of process 'Forecast an outcomet' **that** are finalized and Id is equal to $id) divided by $num_users
tweet_after_15min	**The number** of instances of task 'send a tweet' that started before $current_time minus 900
forecasts_in_60min_by_bet	**The number of instances of process** Forecast an outcomet' **that** are finalized and betId equal to $id - **The number of instances** of process 'Forecast an outcomet' **that** end before $current_time minus 60 and betId equal to $id
extensions_by_bet	**The number of instances** of task 'Extend close time' **with** betId equal to $id
people_forecasting_by_bet	**The number of instances** of process 'Forecast an outcomet' **that** are not finalized and Id is equal to $id
date_to_close	$currentTime minus $close_time

(a) Decision about Actions

Decide action rules										
CI	emails_bet	percent_finalized_forecast_bet	tweet_after_15min	forecasts_in_60min_by_bet	extensions_by_bet	people_forecasting_by_bet	date_to_close	email	tweet	time_extension
								X,-	X,-	X,-
1	0	< 0.6	-	-	-	-	-	X	-	-
2	-	-	0	0	-	-	-	-	X	-
3	-	-	-	-	0	> 30	< date(00:30)	-	-	X

(b) Action Rules about Actions

FIGURE 8.4: *DMN* Model applied to Tutiplay^{TM} example

part of the *BPM* services, although, as started earlier they do not support the inclusion of the *PPIs*.

The sequence of steps shown in Figure 8.5 that are executed to evaluate a decision routing, and involve the *PPIs* includes: (1) when a decision needs to be made, the business task calls the engine to communicate the identifier of decision to select the decision rules involved and the required data-flow of the instance, such as the case_id; (2) the decision process starts by managing the *PIQE* contained within the *DMN* decision table, and evaluates the *PIQEs* in accordance with the information obtained from the *BPMS*, if necessary; (3) once the *PIQE* Engine Module has the *PIQEs* resolved, then the business knowledge is evaluated and the output that represents the decision taken is communicated to the *PIQE* Engine Module, and finally; (5) to route the execution, these variables are incorporated into the process data-flow.

8.6 Implementation of the proposal

In order to enable the incorporation of the decision concerning *PPIs* described by using *PIQL* in a real scenario, the architecture of Figure 8.5 is implemented. This implementation uses commercial tools, with a set of combined technologies presented in Figure 8.6.

The *BPMS* is implemented using *Camunda*^{TM}, since this is an open-source platform that includes other components necessary to conform the proposed architecture, such as the workflow, the business process management, the *DMN* evaluator, and the storage of logs for every process. *Camunda*^{TM} also includes a set of *Application Programming Interfaces (APIs)*, used to extract the *PPI* values.

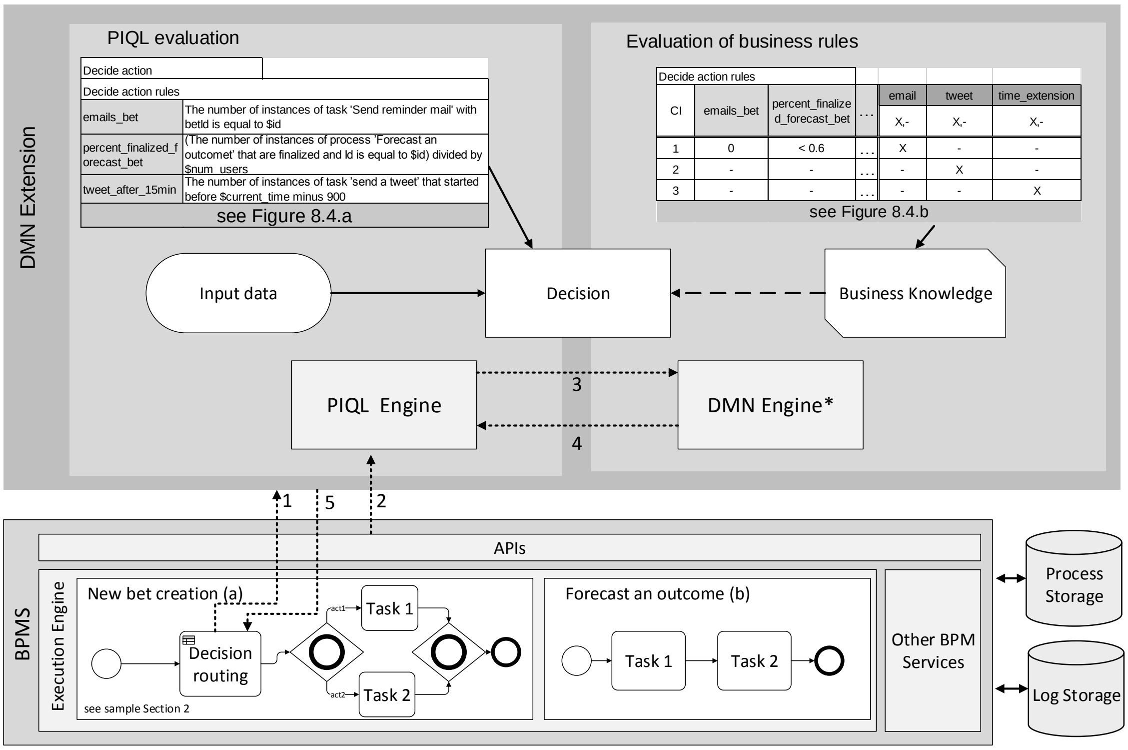


FIGURE 8.5: Decision-Process Architecture

In order to allow the communication between *Camunda*^{TM} and our *DMN* Extension, an application that uses a model-view-controller framework has been developed. This communication is established from the business rule tasks into the *BPMS* (which makes the request) to the *DMN* Extension, by means of a *Representational State Transfer (REST) API*. We have used *Jersey* to implement this "*REST* Layer", and *json* is used as the data exchange format. The requests are managed by the "controller" layer, which uses the "*DMN* Extension" to solve the requests. The "*DMN* Extension" consists of a "*PIQE* Engine Module" that solves the process instance expressions, and a "*DMN* Engine Module" to evaluate the decision rules. To manage *PIQEs*, the "*PIQE* grammar helpers" have been developed, and due to the importance of this module, more details are included in Section 8.6.

On the other hand, "*PIQL* Engine Module" needs to access the status of the *BPMS* to obtain information for the evaluation of the *PIQEs*. This is performed by using the *REST API* offered by *Camunda*^{TM}, and the *json* files are used as the exchange format. To evaluate the decision rules described in the business knowledge, the implementation of *Camunda*^{TM} has also been used.

Another important part of any model-view-controller application is the "*Data Access Object (DAO)* Layer". In this case, this component helps to store the business knowledge. We have chosen *Hibernate* to implement the object relational management in the "*DAO* Layer".

In order to allow users to handle the business knowledge easily, the 'Business Knowledge Modeller' has been included by taking the advantage of the architecture revealed herein. This module implements a web application by using *HyperText Markup Language (HTML)*, *Cascading Style Sheets (CSS)*, *Javascript* and *AngularJS*.

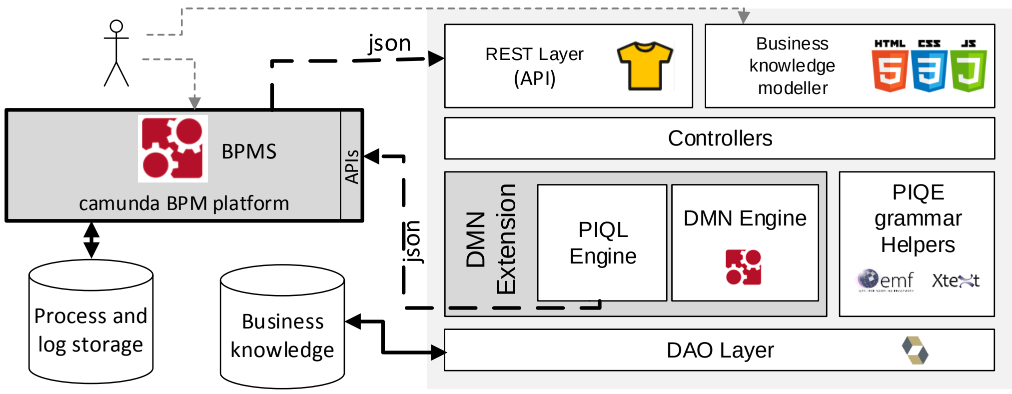


FIGURE 8.6: Architecture with the technologies

Grammar Implementation

In order to transform the *PPIs* described by means of the *PIQL* as shown in Section 8.3, the module called "*PIQL* grammar helpers" is developed. The two main technologies used employed the *Eclipse Modelling Framework (EMF)* [129] to model the grammar, and *xText* [150] to instantiate the grammar trees from a text. *xText* is an open-source framework for the development of programming languages and domain-specific languages, with features to describe the grammar and the parsing from the model description as an EMF model via text-to-model transformation. This component has been developed by means of an external module, to provide its usability for external modules that need it.

"*PIQL* Engine" is responsible for the resolution of the *PIQEs*, and, to this end, is based on an *EMF* model and uses external *APIs*. In our case, the "*PIQL* Engine" uses *Camunda history service*, which in turn, uses *Camunda REST APIs*. To obtain the *EMF* model instances, "*PIQL* Engine Module" uses "*PIQL* grammar helpers".

The business knowledge modeller module also uses "*PIQL* grammar Helpers" internally to validate the syntax of *PIQEs* introduced by the user. *xText* also contains methods to validate the grammar semantically, thereby facilitating the adaptation of the *PIQE* grammar to the *DMN* standard.

8.7 Conclusions

This contribution proposes an extension of the *DMN* standard, which allows business experts to automatize the decision-making processes, aligned with the strategic plans of the company, by taking into account the *PPIs* extracted from this document. To this end, we propose the use of *PIQLs* that permits the extraction of information from the instances and from tasks executed in the instances. This information, related to the *PPIs* of the process, is incorporated in the decision knowledge through the *PIQEs*. The extraction of *PPIs* and alignment with the process decisions have been completed with the definition of an architecture and the implementation of a framework, where a set of technologies has been combined to produce an usable solution. In order to validate our proposal, a real example has been used where the incorporation of the *PPIs* in the decisions is fundamental.

Thanks to our proposal, *BETs* can automate the decision-making processes, and this decision process is aligned to the strategic plans of the company, therefore the business instances become more agile and adaptative. Furthermore, the use of *PIQEs* enables business experts to include who, when and what instances are being executed at any moment.

Subpart B

Assigning value to variable

As described in Section 1.2, this dissertation includes three *Research Questions (RQs)*. The general aims of these *RQs* are: to ascertain where decisions are made (*RQ*1); to investigate how these decisions can be improved and to propose a *Decision Support System (DSS)* to help users (*RQ*2); and to investigate how these elements can be introduced into real scenarios (*RQ*3).

In order to answer the *RQ*1, the *Systematic Literature Review (SLR)* shown in Section 7 was performed. After this *SLR*, the following points regarding the decisions made in business processes were identified: (1) the decisions made during the daily business affect the achievement of their objectives; (2) from among these three types of decisions, one is concerned with deciding the value of a specific variable (called *Input Data Decision (IDD)*); and (3) *IDDs* are usually mapped into a business process as tasks where input data must be introduced, and they are sometimes associated with human decisions. In this subpart *RQ*2 and *RQ*3 are tackled for *IDD*.

IDDs are decisions that consist of **setting s specific value for variables introduced as input data in the business processes of an organisation**. The variable that needs to be set can represent resource allocation (decide the number of resources to use [77]), or configuration (decide values to execute some processes [47]). Therefore, the specific value assigned to a variable also **needs to be aligned to the strategic plans** of the company, since one wrong value can cause the *Business Process Instance (BPI)* to finalise incorrectly according to the objectives defined in the strategic plans of the company. Figure 8.7 shows this situation, by using the illustrative example used in this dissertation (shown in Figure 7.7), in with the *IDDs* have been isolated.

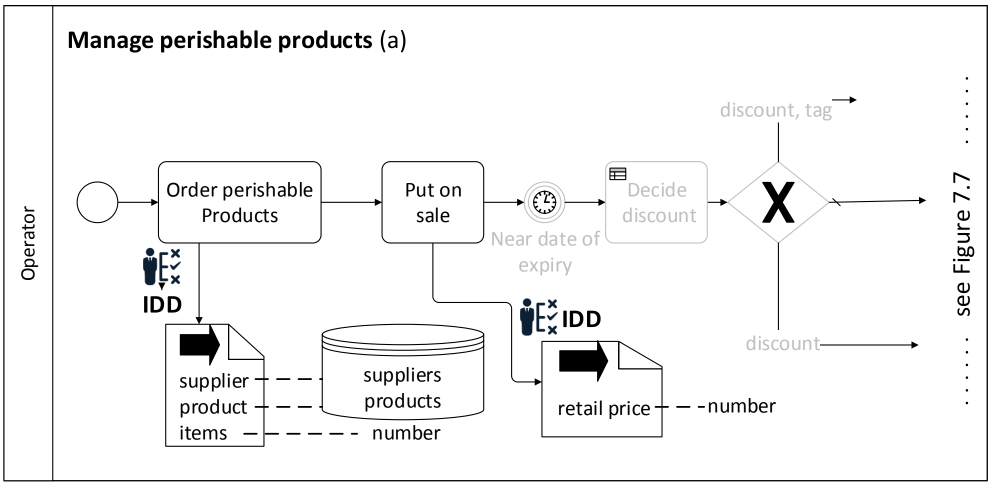


FIGURE 8.7: Example of assigning value to variable

In the figure, these types of decisions are marked with the tag **IDD**. As can be seen, in the task "*Order perishable products*", a user has to choose the value for "*supplier*" (from a set of suppliers available), the value for "*product*" (from a set of products available), and also for "*items*" (a number that represents the number of items to order). Furthermore, in the task "*Put on sale*" the user has to decide the "*retail price*" for customers.

Imagine that the *Board and Executive Team (BET)* of the company in the strategic plans of this supermarket has established that the goal of the company is to have the greatest income possible, but that the principal objective is that the **balance must be positive** or zero, that is, it cannot run at a loss. Furthermore, in the strategic plans, the calculation of the profits is specified:

- Expenses are calculated by multiplying the number of decreased items ordered by the price of the product.
- The income from sales at normal prices are calculated by multiplying the number of items sold at the normal price by the price.
- The income from sales with 25% discount is calculated by multiplying the number of items sold with 25% discount by the price with a 25% discount.
- The income from sales with 50% discount are calculated by multiplying the number of items sold with 50% discount by the price with a 50% discount.
- The total income is calculated by adding together the income with normal sales, sales with a 25% discount, and sales with the 50% discount.

Derived from this complexity, the person that must decide the value of the input data (variables of the data flow) outlines above is faced difficulties: if too many items are bought, then some will be left unsold; if the retail price is too low, then profits are reduced; and, if the retail price is too high, the number of products sold could decrease, thereby reducing the profits. As can be observed, **the values of the variables** determine whether the *BPI* will end up better or worse, that is, with higher or lower profits. Moreover if the **instance finalises correctly**, the balance must be positive.

On the one hand, to face the *RQ*2 (that is, to help users choose the values more aligned with the strategic plans) our proposal for *IDDs* is to create a *DSS* based on the analysis of previous instances. Thanks to this analysis, it is possible to understand the behaviour of the *BPIs*, and to use this information to suggest the best values based on the previous experiences. On the other hand, to face the *RQ*3 (that is, to integrate the *DSS* in real scenarios) two real examples have been used, where we encountered issues that have to be faced. On analysing the real example, however where we certain challenges were uncovered that have to be tackled before the *DSS* could be built:

- The information regarding former instances are usually stored in databases. Sometimes organisations do not use a *Business Process Management System (BPMS)*, but instead develop ad-hoc systems.
- It is common that organisations re-design their *Business Process (BP)* model that works as a *BPMS*, for many reasons. This situation can mean that an older *BPI* fails to match the new *BP* model, even if a *BPMS* is used.

For these reasons, **the information extracted from the database has to be validated**. Erroneous data can lead to erroneous extracted knowledge, and therefore unsuitable suggestions.

Finally, when the problem of using legacy data is solved, then the *DSS* regarding input data decisions can be incorporated. Furthermore, the common way for the users to set these variables, is by using forms, and for this reason the best alternative to the integration of a *DSS* that helps users to set the values for these variables under decision is by suggesting the values on those forms.

In this subpart, a proposal for data object verification in accordance with *BP* models and data model is described in Chapter 9. Once the data objects are verified, the methodology proposed for decision-making support of *BP* regarding input data based on previous instances is presented in Chapter 10.

Chapter 9

Data Object Verification

Capítulo susceptible de publicación en formato de artículo, libro o patente.

Chapter 10

Input Data Decision

Capítulo susceptible de publicación en formato de artículo, libro o patente.

Subpart C

Choosing the process to execute

As described in Section 1.2, this dissertation includes three *Research Questions (RQs)*. The general aims of these *RQs* are: to ascertain where decisions are made (*RQ*1); to investigate how these decisions can be improved and to propose a *Decision Support System (DSS)* to help users (*RQ*2); and to investigate how these elements can be introduced into real scenarios (*RQ*3).

In order to answer the *RQ*1, the *Systematic Literature Review (SLR)* shown in Section 7 was performed. After this *SLR*, the following points regarding the decisions made in business processes were identified: (1) the decisions made during the daily business affect the achievement of their objectives; (2) there are three types of decisions, one of which is concerning with choosing the process to execute, in order to maintain the right direction established in the business plans (called *Governance Decision (GD)*); and (3) the execution of certain business processes can stimulate several indicators of the business. *GDs* are related to the selection of the best process to execute in each case, with the aim of maintaining the direction established in the strategic plans.

An example can be seen in Figure 10.12, which is the same as illustrative example used in this dissertation (shown in Figure 7.7), but where **GD** has been isolated. As can be seen, there are three business processes represented in this figure:

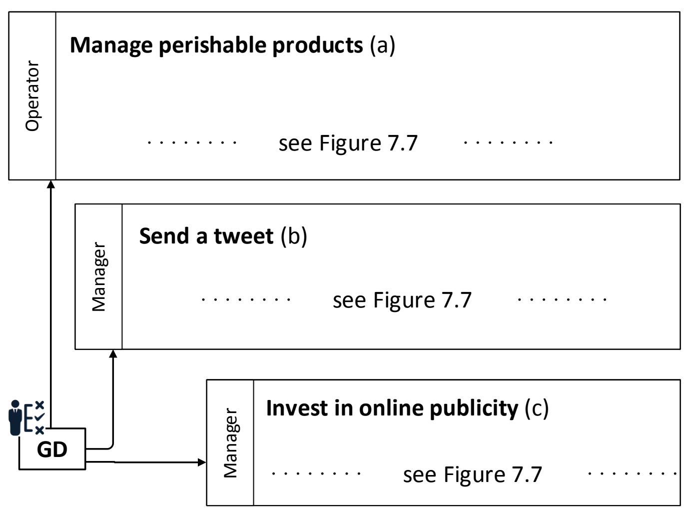


FIGURE 10.1: Example of choosing the process to execute

- First process, *Manage perishable products (a)* consists of ordering products and putting them on sale. This is a basic process for the company, since it is oriented towards the implementation of the operations of the company.
- Second process, *Send a tweet (b)*, consists of publishing information in social networks. This process is oriented towards reaching possible customers by

publishing a new tweet on social networks. It is not related to the implementation of the operations of the company itself, but it does contribute towards increasing the number of customers.

- Third process, *Invest in online publicity (c)*, consists of spending money in publicity. As in the previous process, this does not implement the operations of the company itself. This process is oriented towards reaching new customers, and therefore to increase the sales. The difference between this and the previous one is that this process has more power to reach new customers, but it decreases the global earning since the process is not free.

The choice as to which process to execute to reach the objectives of the company and to maintain it aligned to the strategic plans is a *GD*. In Chapter 11, *RQ*2 and *RQ*3 are tackled for this type of decision.

Chapter 11

Governance Decision (GD)

Capítulo susceptible de publicación en formato de artículo, libro o patente.

Part V

Conclusions & Future Work

Chapter 12

Final Remarks

The **direction of a company** is **defined** by *Board and Executive Teams (BETs)* in business plans. A complete business plan depicts all and each one aspect of a company. In other words, the business plan of a company can be considered as a picture that describes the present and future of the company.

The two most important components of a business plan are the **operational plan**, and the **strategic plan**. The first collects all the activities that can be performed in the company to develop the products or services that the company offers. The second **specifies the direction and objectives of the company**, by devising goals and objectives and identifying a range of strategies to achieve those goals.

Overall, **companies have to act in alignment with the direction established** in the business plan. However, sometimes this is not straightforward, since decisions are made **by people** who usually take into account their local knowledge of the company, their previous experiences, and even intuition. This intuition is not necessary a bad thing, but more objective decisions should be made to maximise the achievement of the objectives. **The creation of tools, methodologies, and mechanisms to help business experts make decisions aligned with the direction established by the company in the strategic plans is therefore crucial.**

The capacity to help in the decision-making process is considered by Gartner^{TM} as a crucial capacity for these systems that support the operations of the company [44], called *Business Process Management Systems (BPMSs)*. In this dissertation, we propose the use of *Decision Support Systems (DSSs)* to help users to make decisions aligned with the direction specified in strategic plans.

We are interested in business-process-driven organisations, and through a *Systematic Literature Review (SLR)* as shown in Chapter 7, we have detected three types of decisions made within *Business Processs (BPs)*: ***Route Decisions (RDs), Input Data Decisions (IDDs),* and *Governance Decisions (GDs)*.**

The central contributions of this dissertation are these three *DSSs*, each associated to a type of decision. In Chapter 8, we propose a *DSS* for *RDs*, in Chapters 9 and 10 we propose a *DSS* for *IDDs*, and, finally, in Chapter 11, we propose a *DSS* for *GDs*.

- **The *DSS* for *RDs*** is based on the necessity of routing the *Business Process Instances (BPIs)*, and employs not only the local information of the instances, but also the general status of the organisation, that is, decisions aware of *BPIs*. To solve this issue, we propose two elements: the first element is a language that functions as an engine to extract the status of the organisation, called *Process Instance Query Language (PIQL)*; and the second element is the capacity to introduce the variables (*Process Performance Indicators (PPIs)*) defined by using the *PIQL* in *Decision Model and Notation (DMN)* tables.

Thanks to this proposal, *BETs* can automate the decision-making process, and this decision process is aligned to the strategic plans of the company, therefore the business instances become more agile and adaptive.

- **The *DSS* for *IDD*** is based on the necessity to help users make decisions when they introduce values of variables in *BPIs*. These values can be related to resources, configurations, etc., and can affect the correctness of the finalisation of the *BPI*, in accordance with the strategic plans.

  We propose the analysis of former instances to extract the behaviour of the variables involved. Combining this knowledge, we can provide better recommendations. Furthermore, we propose the use of the *Comparable Instance (CI)* instead of all former instances. A *CI* is the set of former instances considered similar to the instance in which the decision has to be made, and hence, the extracted knowledge is aligned to the instance under decision.

  Related to the *DSS*, we detected the necessity for the validation of the information in the data store. Former instances are stored from the first time that the process has been deployed and executed, but the business process model can be changed. Since the information used to be stored by external systems, the information can therefore become misaligned to the current business process models, due to the deductions being performed by an incorrect *DSS*.

  To solve this issue, we propose a methodology to validate the business objects (former instances) stored in databases, based on defining a set of statuses to which the business objects can belong, and the business process models can then be annotated with those statuses. The statuses are validated through the business process model, and the stored business objects are also validated to ensure that compliances with the business process model.

- **The *DSS* for *GD*** helps users in the decision regarding which process to execute. The direction and goals of the company are specified in the strategic plans, however, which is the best action to perform (*BP* to execute), in order to reach those goals? in order to solve this problem, we face three issues: first, to model the knowledge of the business experts, regarding how the company works; second, to contrast this knowledge with the former instances stored in databases, in order to validate them; and third, to offer a *DSS* based on what-if analysis in order to predict the status of the company if an action is performed, that helps decision makers make better decisions.

  An adaptation of a *Fuzzy Governance Map (FGM)* is proposed for the modelling of the knowledge of business experts. The advantage of using *FGMs* is that it is possible to relate the various actions to be performed in the company with how these actions may affect indicators, goals, and sub-goals.

  On the other hand, we propose the partial modelling of *FGM*. Each business expert can model only his/her part of the knowledge. Therefore, every *FGM* is joined with the data of the company. Previous of this process, a single *FGM* is obtained, and this *FGM* is validated by business experts and the real data of former instances of the company.

  This last proposal involves the capacity of predicting the future status of the company when business processes are executed, by using the current status, and the *FGM*.

> Thanks to this *DSS*, decision makers can simulate the consequences of performing actions before the actions are executed, and hence they can made better and wll-documented decisions.

The *DSSs* and related proposals carried out in the context of this dissertation have been extracted from **real-world companies**, and we have used real-world examples to illustrate the proposals. Moreover, certain **scientific publications** and **patents** have been performed to publish partial results; these publications and the type of decisions with which they are related are set out in Section 1.4.

It should be borne in mind that although the *DSSs* proposed in this dissertation do not ensure the fulfillment of a strategic plan, they do indeed help. First of all, the strategic plan is part of a business plan, in which not only goals and objectives are specified. It can also be relevant to include information about how to use other types of resources, such as physical location of stores, and the protocol to employ when attending to a customer in a store. However, these aspects remain outside the scope of this dissertation, and hence the fully strategic plans cannot be supported here. On the other hand, there are certain factors that cannot be taken into account, such as market trends and the actions of competitors.

However the *DSSs* and techniques proposed in this dissertation improve four aspects: (1) they help organisations make better decisions, based on the global status of the company, and what has happened in the past; (2) they ensure that the decisions made are aligned to the strategic plans, and hence nobody involved in the organisation makes decisions misaligned to the goals defined by the company; (3) they take advantage of the information stored in databases, which otherwise would not be exploited for the improvement the company; and (4) they take advantage of the knowledge of the people that have been working in the company, who know how the company really works.

Chapter 13

Direction of Future Work

This dissertation proposes three *Decision Support Systems (DSSs)* that help business experts make decisions aligned with the direction established by the company. For the development of these *DSSs*, various sub-objectives have also been achieved in this dissertation: the improvement of the language that enables the extraction of information on both current and former instances, *Process Instance Query Language (PIQL)*, and the upgrade involving the incorporation of external data into the *Business Process (BP)* to be used in the decisions and validation of their use.

During the research/building phase of these proposals, and during the meetings maintained with the people responsible for the companies, both improvements and future work have appeared, which include the following:

Related to the proposal of the *PIQL*, we consider the following future research:

- **Enrich the selectors:** Multiple applications have been found for *PIQL*, such as the creation of dashboards by business experts, and its use by *Business Intelligence (BI)* tools. For some of these new applications, more expressiveness is needed. For this reason, as future work, we consider that the enrichment of the information that can be included as variables into the *PIQL* sentences to be of particular interest. In the same way, other dimensions can be considered, such as the use of resources, execution time, business load, and security aspects.

- **Integrated data sources:** Business data is managed by means of business processes during process instances. Both business processes and business data models are isolated from the viewpoint of the data extraction and business inference. The current version of *PIQL* only queries *Business Process Instances (BPIs)* (current and former), however the data stored is strongly related to the life-cycle of business data objects that flow during an instance, and these need to be aligned with the business process model. Since these three aspects cannot be combined, we therefore consider it interesting to define a SQL-like language that integrates business process, business data, and business process instances into the same query.

  The publication C6 of Table 1.1 provides initial research in this direction.

Regarding the future work related to the *Input Data Decision (IDD)*, we consider four areas where our work could be more helpful: (1) through the improvement of the mechanism to ascertain the behaviour of the business and its observational variables; (2) through enriching the model with further dimensions; (3) through assistance in reaching the optimization of the strategic plans, not only in terms of their satisfiability; and (4) through including uncertainty and non-controlled external factors.

- Focusing on (1), it would also be interesting to apply data-mining techniques in order to **discover new relations between the *Process-Observational Variables (POVars)***. We regard these techniques as potentially useful in understanding the behaviour between *POVars*. This knowledge can contribute towards understanding how the business evolves, and can also facilitate improvements in the decision-making process by making better recommendations to decision makers.

- Regarding (2), **input data in a *BP*** sometimes belongs to enumerate domains. An example is, of this is supplier from a list of possible suppliers, where this selection sets other variables, such as *price* and *quality*. In the contribution carried out in this way, we work with a range of values of *Decision Variables (DVars)*, and the decision-maker is allowed to make this selection. For the future, as part of the information of the *DSS*, we would like to provide the features that enable external constraints, related to services, to be considered.

- Related to (3), strategic plans usually include objectives, such as "increase profits". This issue can easily be addressed in our proposal, with very simple modifications and a single-objective search in the structure of the proposed *Constraint Satisfaction Problems (CSPs)*. However, we found that business experts need **multi-objective searches** since they usually want to optimize a set of variables, but also want to maintain or reduce other variables, for instance "increase profits while maintaining service quality". This is no trivial task, and for this reason we plan to address multi-objective optimization in future work.

- Regarding (4), the possibility of **including external and uncertain factors** can be included, such as market trends, risks, and actions of competitors that can affect the business. The business plans also consider these concepts, and for this reason, the development of a module to forecast these elements and its support in the decision-making process may prove to be very interesting specially as regards improving the support of strategic plans.

Regarding the methodology presented for the integration of data objects to verify and incorporate external data into a *BP*, we suggest the following possible improvements:

- An extension of the *Domain Specific Language (DSL)* to define the states of the business objects, in order to obtain more expressiveness and to enrich the capacities in the description of the data object states. The use of *PIQL* to describe the states of the business objects can also be studied, together with the usability of defined dynamic states.

- The applicability of the status definition and annotation in the business process models for migrations. Companies that have have no *Business Process Management System (BPMS)* and want to incorporate one, or companies that are using a *BPMS* and want to use another, have to migrate the information to continue exploiting it. We consider that the approach employed for the validation of the business objects can be extended to include the automatic migration of a legacy system to a *BPMS*.

- Related to last point, the execution time of a *BPI* is often too long, and we have detected companies in which the average execution time of a *BPI* is approximately 3 years. When these companies want to incorporate a *BPMS* or want to migrate to a different *BPMS*, the migration is not the only challenge: the processes that were active in the old system have to continue active at the same status in the new system. We think that our approach, combined with simulation techniques, can be applied to solve this issue.

- With the objective of creating a more industrial application, the inclusion of an analysis of the relation between data entities with different cardinalities in the same verification process must be tackled. Currently, relationships between entities of data objects remain unsupported. Although this characteristic remains unnecessary for research and for the demonstration of the methodology, it is needed for industrial environments.

Regarding the *Fuzzy Governance Map (FGM)*, we propose the following future work:

- The incorporation of *BI* techniques to discover relationships between *BP* executions and indicators. Currently there are techniques to validate the relationship, but none exits to discover new relationships. Not only can the discovery of new relationships improve the *FGM*, but it can also provide a better understanding of the company by the business experts.
- Related to the previous point, the viability of incorporating *BI* techniques to discover new nodes could also be studied.
- In the study of the factors that can affect the *FGM*, those factors can act as a trigger to reverify the *FGM* and rediscover new relationships that make the model dynamic and adaptable.
- As proposed for *IDD*, external factors, such as market tends, actions of competitors that can affect the business, and risks can all be included in the *FGM*.

Finally, it should be pointed out that the *DSSs*, methodologies, and techniques proposed in this dissertation have been tested in isolation and with static data sets, provided by the companies whose examples have been used. It could prove interesting, however, to integrate all three *DSSs*, and to test the performance and applicability in real time and with a continuous flow of data. Furthermore split tests could be performed in order to evaluate the recommendations proposed for the *DSSs* working.

Part VI

Appendices

Appendix A

List of Abbreviations

A	Activity
API	Application Programming Interface
APQL	A Process-Model Query Language
BAM	Business Activity Monitoring
BC	Business Constraint
BDC	Business Data Constraint
BE	Business Expert
BET	Board and Executive Team
BI	Business Intelligence
BPA	Business Process Administration
BPC	Business Process Compliance
BPSDL	Business Process State Definition Language
BPI	Business Process Instance
BN	Bayesian Network
BP	Business Process
BPM	Business Process Management
BPMN	Business Process Model and Notation
BPMS	Business Process Management System
BRG	Business Rule Group
CI	Comparable Instance
CRM	Customer Relationship Management
CM	Conceptual Modelling
CN	Collaborative Network
COP	Constraint Optimization Problem
CP	Constraint Programming

CPM Corporate Performance Management

CSP Constraint Satisfaction Problem

CSS Cascading Style Sheets

D Dictionary

DAO Data Access Object

DirP Director Process

DLM Decision Logic Model

DMN Decision Model and Notation

DO Data Object

DPoint Decision Point

DRD Decision Requirements Diagram

DSL Domain Specific Language

DSS Decision Support System

DVar Decision Variable

ECMS Enterprise Content Management System

EIS Executive Information System

EK Expert Knowledge

EMF Eclipse Modelling Framework

ERP Enterprise Resourcing Planning

ES Expert System

FEEL Friendly Enough Expression Language

FGM Fuzzy Governance Map

FI Former Instance

GD Governance Decision

HTML HyperText Markup Language

IDD Input Data Decision

IT Information Technology

IUD Instance Under Decision

KPI Key Process Indicator

KRI Key Result Indicator

M Business Process Model

MIS Management Information System

NDP Non-Director Process

NFI Non-former Instance

OMG Object Management Group

ORM Object-Relational Mapping

PAIS Process-Aware Information System

PI Process instance

PIQE Process Instance Query Expression

PIQL Process Instance Query Language

PMML Predictive Model Markup Language

PPI Process Performance Indicator

PPM Process Performance Measurement

POVar Process-Observational Variable

RD Route Decision

REST Representational State Transfer

RFID Radio Frequency Identification

RQ Research Question

S Status

SaaS Software as a Service

SQL Structured Query Language

SLA Service Level Agreement

SLR Systematic Literature Review

TI Task Instance

TPS Transaction Processing System

UML Unified Modeling Language

URN User Requirements Notation

WfM Workflow Management

YAWL Yet Another Workflow Language

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