UNIVERSITA' DEGLI STUDI DI PADOVA

Dipartimento di Ingegneria Industriale (DII)

Dipartimento di Tecnica e Gestione dei Sistemi Industriali (DTG)

Corso di Laurea in Ingegneria Meccanica

A Decision Support System for the Strategic Planning in the Automotive Industry

Relatore:
Prof.ssa Daria Battini

Laureando:
Stefano Vitali, 1146571

Anno Accademico 2017/2018

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Abstract

Making decisions in the industrial field is a very complex and crucial task, and over the years many models, methods and tools have been developed to help decision makers. The absence of a publication that analyses the decision-making process models made by scholars over the years and proposes an overall model, the large number of methods and tools to support its steps, and the need to create a decision support system that helps the managers of a leading automotive company in strategic planning are the motivations that gave birth to this master thesis. The creation of the model and the framework developed to help the decision makers in choosing the methods and tools best suited for their needs is based on a profound study of literature, enriched by the contribution of experts. Finally, the results obtained were tested with a case study related to the above mentioned decision support system.

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List of abbreviations

NAME	ABBREVIATION
Advanced Tool	[AT]
Analytic Hierarchy Process	AHP
Analytic Network Process	ANP
Benefits, Opportunities, Costs, Risks	BOCR
Binary Decision Diagram	BDD
Casual Loop Diagram	CLD
Data Envelopment Analysis	DEA
Data Handling	[DH]
Decision Maker	DM
Decision-Making Process	DMP
Decision Support System	DSS
DEVelopment	DEV
ELimination Et Choix Traduisant la REalité	ELECTRE
Fuzzy Cognitive Map	FCM
IDentification	ID
IMPlementation	IMP
Interactive Data Visualization	IDV
Multi-Attribute Utility Theory	MAUT
Multi-Criteria Decision-Making	MCDM
Original Equipment Manufacturer	OEM
Preference Ranking Organization METHod for Enrichment of Evaluations	PROMETHEE
Problem Structuring Method	PSM
	[PSM]
Quality Function Deployment	QFD
Research Question	RQ

REVision	REV
Soft System Methodology	SSM
Start of Production	SoP
STatistics	[ST]
Strategic Decision-Making Process	SDMP
Strengths, Weaknesses, Opportunities, Threats	SWOT
Technique for Order of Preference by Similarity to Ideal Solution	TOPSIS
VISualization	[VIS]
Weighted Sum Method	WSM

CHAPTER 1

Introduction

Abstract: In this chapter, the work developed in the thesis is introduced, reporting the related characteristics and problems. The author exposes some of the key concepts of the work, with a brief historical contextualization, to allow the reader to frame the problem to be addressed. At the same time discusses the choices take to analyse and solve the objective of the thesis (this topic is exposed more extensively in Chapter 3). Then, the motivations that justified the choice of the Thesis topic and the Research Question around which all the work was structured are shown.

In the current world scenario the competitiveness, the survival and the long-term success of a company derives first of all from a correct Strategic planning which, according to Chandler's (1962) definition, corresponds to the determination of the basic long-term goals and objectives of an enterprise, and the adoption of courses of action for carrying out these goals. Therefore, the decisions taken at this stage are going to influence the company's structure and competitiveness for many years: as an example, in the automotive world this planning is carried out 5 years in advance of the introduction of a new model and will define the company's capability to produce the latter for the next 12 years (Fleischmann et al., 2006).

To understand how to correctly process this type of decision, it is necessary to start from the "basic" process that is the Decision-Making Process (DMP). The scholars began to take an interest in the study of DMP in the early 1900s. The first to propose a model of DMP was Dewey in 1933, followed by many others as Simon (1960) and Mintzberg (1976), just to name a few. All these scholars have identified a series of phases and steps that compose the DMP, whose purpose is to indicate how to make a decision (Nutt, 2008).

In the light of increasingly complex decisions, as for instance reported by Fleischmann et al. (2006), Grünig and Kühn (2017) and Marugán et al. (2017), it is no surprise that an entire stream of literature is studying decision-making theory. Various perspectives have been taken to deepen our understanding of decision-making, including e.g. processes, methodologies, tools and influence factors. However, only few publications can be found that combine the knowledge of these various perspectives. The author claim that the combination of these various perspectives is necessary to help practitioners to design better decision support systems: the DMP can involve a large number of variables, increasing the complexity and difficulty of qualitative and quantitative analysis (Marugán et al., 2017). For this reason since the 1970s (Holsapple, 1977) professionals and scholars have started designing systems to aid decision-makers in choosing between several alternatives and, consequently, to help the decision-maker to decide what alternative is the best (Talluri et al., 2013; Suzuki and Dai 2013; Rezaei 2015; Marugán et al., 2017). These systems, called "Decision Support Systems" (DSS), "can be defined as computer-based information systems that are designed to support any or all phases of the decision-making process" (Mora et al., 2012) and represent fundamental systems for the management of many phases of industrial production, from the short-term planning (e.g. Scheduling) to the long-term planning (e.g. plant allocation).

The creation of a DSS starts from the correct choice of the methods and the tools to implement in it: as reported by Poh (1998) "the large number of available methods posed an additional level of complexity to unfamiliar designers who were unable to determine the most effective method or methods for any given specific problem." The reader can deduce that the design of a DSS is very complex and can take a long time, especially if the developer does not have a thorough knowledge of all the methods and tools that can be used.

The thesis research activities are motivated by the growing DSSs relevance and a case study in which a DSS has to be developed. This DSS is meant to help practitioners in the strategic planning of the automotive industry, when dealing with the question of when to introduced new vehicles to the market. In this problem a variety of different decisions have to be taken, for instance when to launch a new vehicle, what resources to use and which assets (e.g. platforms, engines) to share among the products to be introduced. In the author's case company it is well known that these decisions are strongly linked to a multi objective decision making problem, i.e. the decisions are linked to contradictory objectives. While a decision may be good for one objective, it might lead to an infeasible schedule from another perspective. The purpose of the DSS is to help practitioners to find a feasible schedule, which optimally balances the various company objectives. To this end, the following Research Question was formulated:

RQ: *"How to design a Decision Support System (DSS) that helps practitioners in the automotive industry with the planning of new vehicle introductions?"*

Making such a system for a car manufacturer poses a further challenge: the automotive world requires special attention because the strategic planning is complicated by market trends, currently markets increasing dynamics and globalization of the supply chain, including sales markets, production sites, and suppliers. Furthermore, competition forces car manufacturers to launch new car models frequently to provide new functions for customers, new concepts and so on (Fleischmann et al., 2006). For these reasons, it is essential that a DSS for this sector allows a constant "maintenance" of the managed data, as adaptations during implementation become necessary to align resource allocation plans with an evolving set of available information (Klingebiel and De Meyer, 2013).

This thesis is structured as follows. The next section reports a brief overview of what is present in the literature regarding DMPs, methods and tools to support it, influence factors, and DSSs. Then, section 3 shows the methodology with which the work was carried out, while in section 4 the obtained results and the case study are described. In the final part of the thesis, section 5, the results are discussed, conclusions are drawn, the author explains how this work can be useful to other professionals and finally the main limitations that have been identified are exposed.

CHAPTER 2

Analysis of the Literature

Abstract: The main purpose of this review is to give a brief overview of the current state of literature regarding the DMP, methods and tools to support it, the factors that influence it and the DSS already designed. Furthermore, some considerations relating to the automotive sector are reported.

Keywords: Overview, Decision-Making Process, Method, Tool.

The DMP and the DSSs have been extensively studied in the literature but, as can be seen in Table 2.1, there is no publication that fully covers the topic and that, alongside all the various steps, presents the various methods and tools that can be implemented to design a DSS. In addition, the literature presents DMP models that are very solid and very mentioned (Mintzberg et al., 1976; Simon, 1977) but that need to be updated, as the environment in which modern companies operate is much more complex and dynamic than when these models were made. These needs and some proposals to improve these models have been identified in recent literature, such as Schmidt et al. (2015), Marttunen et al. (2017) and Marugán et al. (2017).

Publications on methods to support DMP are very numerous, but as they relate to specific methods, no publication has been found proposing methods to support the entire DMP.

The search for papers that treated the tools, however, was more difficult. These publications, in addition to being much more limited in number, are related to DMP steps, situations and problems that are very specific.

The papers related to the influence factors are many but often related to psychological aspects that are not of interest in this thesis, however it was possible to identify a sufficient number of publications that treated the influencing factors considered important for the definition of a DMP model (some examples are reported below).

With this literature analysis it was also possible to frame the problem and its context. Starting from the concept of "decision": the result of human conscious activities aiming at choosing a course of action for attaining one or more established objectives (Filip, 2017). This series of actions composes the DMP that, as indicated by Nutt (2008), consists of "action-taking steps indicating how to make a decision". These steps can be carried out with the help of methods and tools. A method is a systematic procedure carried out according to a pre-established order and plan in view of the goal to be achieved; this procedure requires a set of pre-established inputs that will be processed to obtain the information for which the method has been defined. Very common are the Multi-Attribute Decision Making methods (e.g. ELECTRE, TOPSIS, AHP): procedures that specifies how attribute information is to be processed in order to arrive at a choice (Rao 2008). A tool is a system developed to make possible / improve the visualization, analysis and management of data and information, in order to facilitate the understanding of the phenomena that underlie these data and information. An example of very complex and useful tools in this field are Data Mining tools: tools that apply modeling techniques to data in order to build models or find other patterns / regularities (Provost and Fawcett, 2013). Methods and tools become increasingly necessary as the complexity of the decision increases. The Decision Maker (DM), to obtain good results, must use them following the right methodologies: indications on how to use all the usable supports in the correct way. In addition, numerous influence factors (everything that may change the DMP conduct) such as the operating scenarios uncertainty (Klingebiel and De Meyer, 2013), the strategic decision-making characteristics, the external environment, the firm characteristics and so on (Shepherd and Rudd, 2014) must be taken into account in order to proceed in a responsible way to the development of the DMP.

Table 2.1
Overview of the topics covered in the literature.

Publication	P	M	T	I
The New Science of Management Decisions (Simon, 1960)	●			
A behavioral theory of the firm (Cyert and March, 1963)	●			
The Structure of "Unstructured" Decision Processes (Mintzberg et al., 1976)	●			
The New Science of Management Decisions. Revised Edition (Simon, 1977)	●			
The Decision-Making Process for Strategic Adaptation (Ronchi, 1980)	●			◐
Strategic decision processes: comprehensiveness and performance in an industry with an unstable environment (Fredrickson, 1984)	◐			○
Strategic Decision Making (Eisenhardt and Zbaracki, 1992)	◐			●
DSS for multiobjective project scheduling (Slowinski, 1994)		◐		
Personal and Structural Determinants of the Pace of Strategic Decision Making (Wally and Baum, 1994)	◐			◐
Strategic Decision Making (Schwenk, 1995)	○			●
Tentative guidelines to help choosing an appropriate MCDA method (Goutuoni et al., 1997)	○	●		
Tentative guidelines to help choosing an appropriate MCDA method (Guitouni and Martel, 1998)	◐	●		
A knowledge-based guidance system for multi-attribute decision making (Poh, 1998)		●		
Intelligent Multicriteria Decision Support: Overview and Perspectives (Siskos and Spyridakos, 1999)		●		
A Decision Support System for the Seller's Return Problem in the Product Line Design (Alexouda and Paparrizos, 2000)		◐		
RODOS: Decision Support for Nuclear Emergencies (Bartzis et al., 2000)	○	◐	◐	
DSS for the Evaluation of National IT Infrastructure Investments: A Study of Cable Television in Greece (Giaglis et al., 2000)		◐		◐
A prototype decision support system for strategic planning under uncertainty (Koutsoukis et al., 2000)	○	◐		
Decision Making under Various Types of Uncertainty (Yager, 2000)		◐		
Multi-Criteria Decision Making Methods: A Comparative Study (Triantaphyllou, 2000)		◐	●	
Past, Present, and Future of Decision Support Technology (Shim et al., 2002)	◐	◐	○	
Problem structuring methods in action (Mingers and Rosenhead, 2004)	○	◐		
Strategic Decision-Making Processes: BEYOND THE EFFICIENCY-CONSENSUS TRADE-OFF (Roberto, 2004)	○			●
Decision Making – The Analytic Hierarchy and Network Processes (AHP/ANP) (Saaty, 2004)		●		
The Strategic Decision-Making Process in Organizations (Janczak, 2005)	◐			●
A list-based compact representation for large decision tables management (Fernandez del Pozo et al., 2005)			◐	
Strategic Planning of BMW's Global Production Network (Fleischmann et al., 2006)		◐		◐

Visual Representation: Implications for Decision Making (Lurie and Mason, 2007)			◐	
A Multicriteria Decision Support System for Housing Evaluation (Natividade-Jesus et al., 2007)		◐	◐	
On the concept of decision aiding process (Tsoukiàs, 2007)	◐			
The Decision-Making Process in a Complex Situation (Bennet et al., 2008)	●			○
Evaluating flexible manufacturing systems using a combined multiple attribute decision making method (Rao, 2008)		◐		
Information Visualization for Decision Support (Zhu and Chen, 2008)			●	
Theoretical tools for understanding and aiding dynamic decision making (Busemeyer and Pleskac, 2009)	○		●	
An Optimization-Model-Based Interactive Decision Support System for Regional Energy Management Systems Planning under Uncertainty (Cai et al., 2009)		◐		
A model for fuzzy multiple attribute group decision making and fuzzy simulation algorithm (Zeng, 2009)			●	
A framework for dynamic multiple-criteria decision making (Campanella and Ribeiro, 2010)		●		
A fuzzy multi-atribute decision-making method under risk with unknown attribute weights (Han and Liu, 2011)	○	◐		
A Strategy for Using Multicriteria Analysis in Decision-Making (Munier, 2011)	◐	●		
Aggregate production planning in the automotive industry with special consideration of workforce flexibility (Sillekens et al., 2011)		○		○
Multiple criteria decision making (MCDM) methods in economics: an overview (Zavadskas and Turskis, 2011)	○	◐		
Problem structuring methods 'in the Dock': Arguing the case for Soft OR (Ackermann, 2012)		●	●	
Are Groups More Rational than Individuals? A Review of Interactive Decision Making in Groups (Kugler et al., 2012)	○			○
An agent-based fuzzy cognitive map approach to the strategic marketing planning for industrial firms (Lee et al., 2013)		◐	○	
Application of multi-criteria decision analysis in design of sustainable environmental management system framework (Khalili and Duecker, 2013)		◐		
Becoming Aware of the Unknown: Decision Making During the Implementation of a Strategic Initiative (Klingebiel and De Meyer, 2013)	○			●
Supplier Rationalization: A Sourcing Decision Model (Talluri et al., 2013)		●		
A Decision-Support System for the Design and Management of Warehousing Systems (Accorsi et al., 2014)		○	◐	
Making sense of complex data visualization (Janvrin, 2014)			●	
Integrating Multicriteria Evaluation and Data Visualization as a Problem Structuring Approach to Support Territorial Transformation Projects (Lami et al., 2014)		◐	○	
Pre-launch new product demand forecasting using the Bass model: A statistical and machine learning-based approach (Lee et al., 2014)		◐	○	
The Influence of Context on the Strategic Decision-Making Process: A Review of the Literature (Shepherd and Rudd, 2014)	●			●
Aiding to Decide: Concepts and Issues (Bouyssou et al. 2015)	●	◐		
Decision support system framework for performance based evaluation and ranking system of carry and forward agents (Karthik et al., 2015)		◐		

MADM method considering attribute aspirations with an application to selection of wastewater treatment technologies (Gao et al., 2015)		◐		
Decision Support System and Multi-Criteria Decision Aid: A State of the Art and Perspectives (Razmak and Aouni, 2015)		●		
Best-worst Multi-criteria Decision-making Method (Rezaei, 2015)		●		
Decision-making process for Product Planning of Product-Service Systems (Schmidt et al., 2015)	◐	●		
Thinking About Entrepreneurial Decision Making: Review and Research Agenda (Shepherd et al., 2015)	○			◐
Collaborative Problem Structuring Using MARVEL (Veldhuis et al., 2015)	○	●		
From process control to supply chain management: An overview of integrated decision making strategies (Dias and Ierapetritou, 2017)	○	◐		○
Computer - Supported Collaborative Decision - Making (Filip et al., 2017)	◐	●		
Solving Complex Decision Problems: A Heuristic Process (Grünig and Kühn, 2017)	◐	●		
Structuring Problems for Multi-Criteria Decision Analysis in Practice: A Literature Review of Method Combinations (Marttunen et al., 2017)		●		
Optimal decision-making via binary decision diagrams for investments under a risky environment (Marugán et al., 2017)	◐	○	●	
A systematic literature review and critical assessment of model-driven decision support for IT outsourcing (Rajaeian et al., 2017)		◐		
A Review on Decision-Making Methods in Engineering Design for the Automotive Industry (Renzi et al., 2017)		●		
Multi-criteria weighted decision making for operational maintenance processes (Dhanisetty et al., 2018)	○	◐	◐	
Strategic advice for decision-making under conflict based on observed behavior (Garcia et al., 2018)			●	
Practical Decision Making using Super Decisions v3: An Introduction to the Analytic Hierarchy Process (Mu and Pereyra-Rojas, 2018)		◐		
An approach for robust decision making rule generation: Solving transport and logistics decision making problems (Petrovic' et al., 2018)		◐		
A simulated annealing algorithm for the capacitated vehicle routing problem with two-dimensional loading constraints (Wei et al., 2018)		◐		
THIS THESIS	●	●	●	●
Legend	P = Decision-Making Process; M = Method; T = Tools; I = Influence Factors			

The analysis of the literature relating to the automotive sector (not reported in table 2.1) has highlighted a general lack of publications concerning the Strategic DMP and how to support it. Moreover, systems to help DMs in strategic planning, even in German industries, world leaders and technologically advanced, are still little used. Recent publications, such as Becker et al. (2017), report that a fundamental phase of strategic planning as the "ramp-up planning at a German car manufacturer is done in sequential steps and is characterised by much manual effort".

This is a further push both to develop a framework that helps the professionals of this sector to develop this type of systems both to create the concept related to the RQ and to explain how it was obtained, with the hope that these indications will help those interested in developing a DSS for long-term planning in a cars company.

CHAPTER 3

Methodology

Abstract: This thesis project was developed following the methodology illustrated in the following chapter. The author has carried out four main tasks to reach the final objective: a literary review, the study of the DMP and DSSs structure, the creation of a Framework to help professionals who develop DSSs, and finally the test of this Framework, making a DSS concept for a long-term planning task in a major worldwide Automotive Company.

Keywords: Review Methodology, DMP model, Framework.

3.1 Introduction to the chapter

As reported in the introduction and topic overview, DSSs are increasingly important and required by companies, which need to help the DMs make the best possible decisions. The development of many DSSs and the methods to build them, however, was not accompanied by a parallel update of the DMP models and, above all, the new methods and tools, developed to support specific DMP steps, were not contextualized within the whole DMP. For these reasons, it was decided to start from the principle, i.e. from the DMP, and only then proceed with the study of the methods and tools to support the phases, and the DSS.

Before answering the RQ and proceeding with the case study, the author has carried out an extensive literary review, whose purpose was to find information to meet the following points:

- Define in the most complete way what are the steps of the DMP;

- Study which are the most efficient and most used methods and tools to support these steps in a DSS;
- Analyse the DSSs already presented in the literature and the publications related to their architecture to obtain useful information for the implementation of the DSS described in the introduction.

Thanks to this literature review a great deal of information has been collected, which have been selected, analysed and processed. First of all, all data relating to the DMP have been analysed and aligned. Then a model, that takes into account both historical models and modern needs, has been developed. This study made it possible to understand what were the characteristics, the problems and the needs related to each step: keeping that in mind, the author has researched and studied the best methods and tools to support the various steps.

At this point the DMP model that had been developed was partly modified, to make it more suitable for the real purpose of the thesis, i.e. the development of a DSS. This operation has not distorted the DMP but, on the contrary, has made it closer to what is its natural application in practice. The final results of this first work are shown in section 4.2.

After studying the DMP and identifying methods and tools to support it, the author has been able to create a framework that presents, according to the DMP phases, methods and tools to support it and, therefore, to design a DSS. Along with this framework, guidelines have been created to help the DMs in choosing which of the various methods and tools to implement (see section 4.3).

The specific DSS concept (see section 4.4) for strategic planning in the automotive industry has been designed starting from what has been described so far and from information obtained from further publications related to the characteristics and problems of this specific sector.

The framework and the DSS concept were then subjected to the analysis of professionals involved in Strategic Planning in a major German automotive company.

3.2 Literature Review Methodology

The research of the articles was carried out using the Scopus database, following methods and settings typical of the sector, such as Kampen et al. (2012) and Andriolo et al. (2014). The first of these two publications was taken as a model for the setting of table 3.1 and figure 3.1, that schematically show the review process described below.

The keywords related to the objects under analysis were crossed with those related to the area of interest. Specifically, the following search terms were applied, as can also be seen in Table 3.1: '("Decision-Making Process" OR "Decision-Making Processes" OR DMP) AND (Steps OR Strategic OR Planning OR "Production Plan")', '("Decision Support System" OR DSS) AND (Strategic OR Planning OR "Production Plan" OR Automotive OR Implementation OR Visualization OR Framework)'.

Table 3.1
Keywords used in the primary search.

Primary keywords → Objects under analysis	Secondary keywords → Area of interest
Decision-Making Process Decision-Making Processes DMP	Steps Strategic Planning Production Plan
Decision Support System DSS	Strategic Planning Production Plan Automotive Implementation Visualization Framework

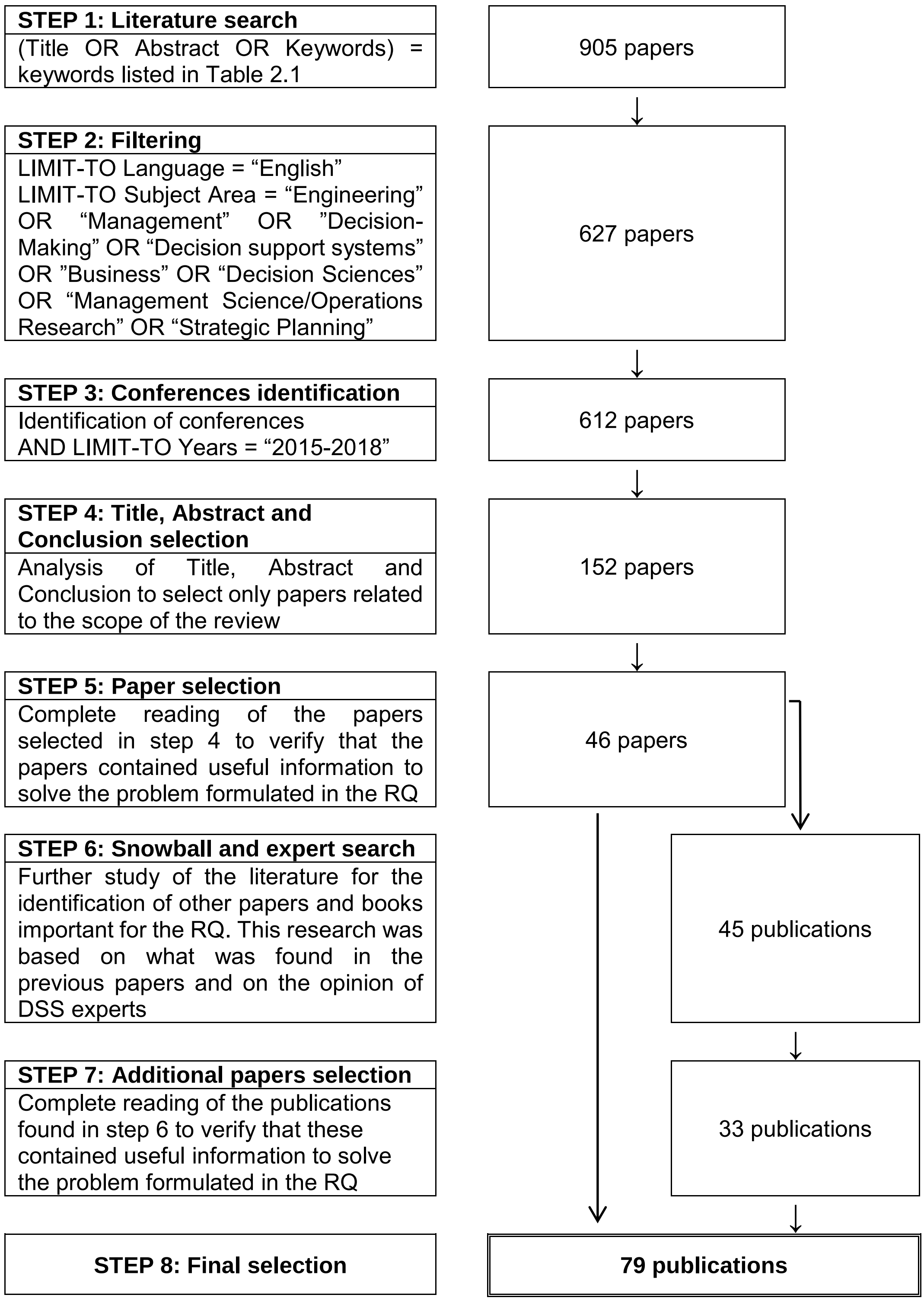
All articles containing at least one combination of keywords (primary + secondary) in the title or in the abstract or in the keywords were considered.

The research was limited only to publications in English language. Then, to focus the research on the areas of interest the following filters were applied: "Engineering", "Management", "Decision-Making", "Decision support systems", "Business", "Decision Sciences", "Management Science/Operations Research" and "Strategic Planning". No restrictions on the publication year were imposed. Conferences older than 3 year have been ignored. After this initial selection process, 627 publications were identified.

First of all, the papers were selected on the basis of the title, then the abstract and the conclusions of the remaining publication were analysed. After this selection, 152 papers remained, which were then read completely, leading to the identification of 46 papers.

The information acquired in the study of these papers and the indications of some DSS experts has led to the identification of 45 other publications (including several specific books), of which 33 were included in the literature review.

Figure 3.1
Review Methodology.



Thanks to this analysis, a total of 79 publications were identified as the basis on which to build the thesis.

3.3 Structuring the DMP model

The bibliographic research was initially focused on the identification of papers containing the "historical" models (e.g. Simon, 1960; Mintzberg et al., 1976; Fredrickson, 1984), i.e. those already widely discussed and considered valid (albeit with their own limitations) by the scientific community, then the papers in which these models are criticized and where there are notes on how to improve some parts were selected (e.g. Schwenk, 1995; Marugán et al., 2017). Finally, the publications related to methods, tools and DDSs (e.g. Schmidt et al., 2015; Marttunen et al., 2017) were considered, from which the author obtained other useful information to adapt his DMP model to the architecture of a well-structured DSS.

After analysing the DMP models developed in the past, it was necessary first of all to align the various concepts to obtain an initial model completely based on the models already proposed and validated over the years. Then, the indications and ideas drawn from all the other selected publications were collected and revised in order to develop some changes to be made to the initial DMP model. The goal sought in this phase was to create a DMP model that, in addition to being based on concepts well known in the literature, also take into account the exigencies of modern industries and is suitable to be supported in a DSS.

3.4 Developing the Framework

The development of the framework started by analysing the various DMP steps to understand how a method or tool could support them. Moreover, this study has allowed to expand the literature analysis in a targeted way, in order to identify the best methods and tools developed specifically for one of the steps.

The search for methods and tools was conducted in two ways. The author has searched all those publications (papers and books) that dealt from a theoretical point of view methods and tools (in this category the paper reviews are included). Since it is not possible, for reasons of time, to analyse all the literature identified, the most important publications (considered as such in the literature, taking into consideration the importance of the authors and the impact factor of the publications) and those published by the developers of the methods and tools have been selected. In parallel, papers relating to DSSs were studied. In this way it was possible to understand which methods and tools were actually used and make an initial selection, discarding those methods and tools that have proved to be inefficient (because they are too expensive from a computational point of view) or too weak to give satisfactory results. Also in this case, it was not possible to study all the DSSs present in the literature, those papers that describe well-known DSSs (due to their importance or efficiency) or with a high rate of innovation have been chosen.

In addition to the initial selection described above, the methods were further selected by discarding those that did not appear in method reviews, tools reviews and specialist books. To avoid excluding innovative methods and tools, which have not yet become established in the DMP science, these have been evaluated on the basis of their already present applications and how these have been evaluated by scholars.

In order to create the Framework, the identified methods and tools have been categorized according to the DMP phase they can support and the typology to which they belong (visualization, optimization, multi criteria decision-making methods and so on). The choice to present to the reader a framework in which for each phase are inserted more methods and tools is due to the fact that there is no method or tool that is the best. This problem is well known in the literature, as reported by Guitouni and Martel (1997) "Despite the development of a large number of refined multicriterion decision aid (MCDA) methods, none can be considered as the "super method"' appropriate to all decision making situations". Furthermore, often the methods with the best results in terms of proposed solutions are not implementable when the complexity of the problem under analysis is high. As an example, Sillekens (2011) noted that a mixed integer linear programming approach requires excessive computational time if it is used to solve a problem of aggregate production planning of flowshop production lines in the automotive industry, and for this reason a heuristic approach is indicated as preferable.

In conclusion, according to the specific problem, the DM must use the methods and tools that better adapt (in terms of functioning and output quality).

In a series of meetings with some experts of a major German automotive company interested in this Framework, the author discussed the motivations for which the methods and tools have been chosen, and established how to structure it to make it quick to read and understand.

Finally, the knowledge acquired in the study presented above has been reworked and condensed into short guidelines that help the DM to understand the functions and the potentialities for which each method and tool is suitable to support a specific DMP phase and, therefore, which of these to implement in a specific DSS. Section 4.3 shows these guidelines for the corresponding methods and tools.

3.5 Case Study

The framework was applied and tested with a case study provided by a major German automotive company. The problem consists in planning two strategic choices (scheduling SoP and EoP of each vehicle, each variant and each engine, and assigning engines to vehicles) according to three objectives (timing goals, sales goals, and CO_2 capacity limit goals). According to this information (described in greater detail in section 4.4), the author used the framework to identify which methods and tools to use to implement a DSS that meets the requirements indicated, justifying the made choices.

Then, the results were discussed with a DSS expert in order to validate what was obtained.

CHAPTER 4

Results

Abstract: This chapter describes the results of the research work and the practical application made in this thesis project. As anticipated in chapter 3, the research started with the study of the DMP and with the development of a cutting-edge model, which is followed by the creation of a framework that presents methods and tools to support the entire DMP. On this theoretical basis, the author then designed a DSS concept for strategic planning in a major German automotive company.

Keywords: Decision-Making Process, Phases, Steps, Methods, Tools, Framework, Guidelines, Automotive, Case Study.

4.1 Overview of the Chapter

The chapter is structured as follows. Section 4.2 presents the DMP model developed by the author. At the beginning of the section the selected bibliographic sources are reported, described and commented; then the DMP model is exposed. Section 4.3 shows the Framework designed to help professionals who want to develop a DSS: in this diagram are indicated the methods and tools to support the various phases of the DMP, accompanied by short guidelines to help the understanding of the potentials and of the application limits. The DSS concept is described in section 4.4, starting from the problem and then presenting the developed solution.

4.2 The Decision-Making Process (DMP)

As already said, the DMP consists of a series of phases and steps. It normally implies allocating the necessary resources and it is the result of processing information and knowledge that is performed by a DM (or a group of DMs) who is empowered to make the choice and is accountable for the quality of the solution adopted to solve a particular problem or situation. Time constraints, the shortage of adequate data, the prohibitive costs of information collecting and processing or even the lack of confidence in the results provided by not well explained computerized procedures may lead the DM to accept a suboptimal solution, instead of running for an optimal one (Filip, 2017).

Each type of situation requires a suitable DMP, which takes into account not only the characteristics of the problem to be solved but also those of the external environment in which the problem is placed.

By focusing on the modern industry problems, it is important to stress that the external environment is extremely dynamic and can lead to huge changes in a short time. For these reasons, the DMP is not linear but interactive, and provides for the need to re-evaluate the made choices, in order to keep the process update: only in this way it is possible to obtain valid, implementable and effective solutions.

When carrying out the DMP, the "time" factor and how the events are temporally linked must always be taken into account. In this regard, it is good to remember that the DM must consider the information in their time validity window; otherwise, they are useless and can lead to completely incorrect solutions.

Another responsibility of the DM is to create models that are representative of the phenomena in a realistic way. The various assumptions must be corrected as unrealistic or approximate assumptions result in unsatisfactory solutions.

Furthermore, a correct DMP requires a correct analysis of the problem and of everything that surrounds it: several levels of analysis must be carried out, inside and outside the company (in case the DMP concerns the industrial world). The DM can choose, depending on the situation, whether to perform a holistic or reductionist analysis (Bennet and Bennet, 2008).

As mentioned above, during the DMP can happen many events that can disrupt the course of actions: it is essential to understand what are the causes of these events in order to understand how to respond to these changes. These causes can be single, multiple sequential or multiple simultaneous. The DM must identify the real patterns behind things and understand what can be influenced, what can be controlled and what cannot. It is also essential to understand if an event is a problem in itself or the symptom of another problem.

When making a decision it is always good to try to understand what the consequences are and how the situation will evolve in the future.

4.2.1 The STRATEGIC Decision-Making Process (SDMP)

The Strategic DMP is a type of DMP that deals with the planning of actions essential for the competitiveness and survival of a company. For this reason, it has specific features to be taken into account in the implementation of the DMP model (Papadakis et al., 1998; Elbanna, 2006; Shepherd and Rudd, 2014). The most important is that, since it is a long-term planning, the SDMP must be able to process information that will change several times, both during the process itself and after identifying the best solution to implement. For these reasons, it must be designed in such a way as to be “maintained": it must be possible to update the data on which the options are processed in such a way that the latter are always consistent with the objectives and the industrial reality.

The SDMP begins with the strategic issue diagnosis (Schwen, 1995), in which all the factors related to planning are analyzed. This phase is very important because ignoring a factor in these preliminary steps could compromise the entire SDMP.

Among the most important factors, all customer requests must be identified and considered, bearing in mind that they could change over time (it is important to provide flexibility reserves).

The decisions taken at high levels (senior management) gradually influence all the underlying levels, which, in turn, will push up feedback on the effectiveness of the chosen solutions: these feedbacks are of great importance to improve the SDMP and therefore, the latter must be able to accept and process them.

4.2.2 Sources and Macro-Phases definition

To develop a DMP model that was based on a solid foundation, many of the phases, steps and routines developed in the literature were taken into consideration and analyzed. Alongside the need to have a model that is reliable and as complete as possible, the author considered that it was appropriate to try to take a step forward, considering some of the major needs of modern DMP (reliability of solutions, dynamism and subjection to sudden changes) and considering that nowadays often this process is supported by DSS. With this idea in mind the author has tried to develop the model in such a way that it can be used to effectively break down the problems and understand how to deal with them. A further step forward was made with the Framework (section 4.3) which, alongside the various steps, suggests some methods and tools to support them.

This part of the thesis was based on the sources reported in this paragraph. In table 4.1 is indicated the degree of detail with which each of the four macro-phases is analysed by every sources. As will be explained below, the model consists of four macro-phases, arranged sequentially: identification (ID), development (DEV), implementation (IMP) and revision (REV). This representation is useful to the reader as it allows to identify very quickly which are the sources that deepen a particular part of the DMP or which, for example, give a global analysis: in this way it is possible to focus the attention only on publications relating to the topic of interest. The sources are arranged in table 4.1 starting from those that deal in more detail with the first macro-phases up to those that concentrate on the last ones. The table shows that the scholars have deepened more the DEVELOPMENT phase, while little attention was paid to that of REVISION.

In table 4.2 the steps defined / analysed by the selected sources are reported in a systematic way. The representation purpose is to report the steps without any manipulation, to allow the reader to identify which sources have treated the various steps (the DMP processing is reported in paragraph 4.2.3). The steps are listed sequentially to make the representation clear; as it will be underlined also later, the various steps within the macro-phases do not follow each other sequentially. As it is clearly visible there is a lot of "white space" and no source has all the steps: this is due to the fact that in many publications some steps have been collapsed within more generic steps (this has often occurred in the case of the "Situation diagnosis") and some steps (such as "Authorization" and "Identifying uncertainties") are defined and treated specifically by few sources.

Below, after explaining how the author defined the four macro-phases, the contents of each source are analysed, grouping the sources in such a way that both the order in which they are shown in the table and the point of view with which the concepts are treated (purely theoretical or more focused on the methods used to support the steps) is followed.

Table 4.1
Contents available in the sources.

Source	Macro - Phases			
	ID	DEV	IMP	REV
A Strategy for Using Multicriteria Analysis in Decision-Making **(Munier, 2011)**	●	●	⊙	Ø
Structuring Problems for Multi-Criteria Decision Analysis in Practice: A Literature Review of Method Combinations **(Marttunen et al., 2017)**	◐	●	Ø	Ø
On the concept of decision aiding process **(Tsoukiàs, 2007)**	◐	◐	●	Ø
Multi-Criteria Decision Making Methods: A Comparative Study **(Triantaphyllou, 2000)**	⊙	◐	Ø	Ø
Optimal decision-making via binary decision diagrams for investments under a risky environment **(Marugán et al., 2017)**	⊙	◐	⊙	Ø
Personal and Structural Determinants of the Pace of Strategic Decision Making **(Wally and Baum, 1994)**	○	◐	⊙	Ø
A behavioral theory of the firm **(Cyert and March, 1963)**	○	◐	⊙	Ø
The New Science of Management Decisions **(Simon, 1960)**	◐	◐	◐	◐
Intelligent Multicriteria Decision Support: Overview and Perspectives **(Siskos and Spyridakos, 1999)**	⊙	●	◐	⊙
Strategic decision processes: comprehensiveness and performance in an industry with an unstable environment **(Fredrickson, 1984)**	○	◐	◐	Ø
The Structure of "Unstructured" Decision Processes **(Mintzberg et al., 1976)**	⊙	◐	◐	⊙
Past, Present, and Future of Decision Support Technology **(Shim et al., 2002)**	○	◐	◐	⊙
Are Groups More Rational than Individuals? A Review of Interactive Decision Making in Groups **(Kugler et al., 2012)**	○	Ø	○	Ø
Rodos: Decision Support for Nuclear Emergencies **(Bartzis et al., 2000)**	○	Ø	⊙	Ø
Strategic Decision Making **(Eisenhardt and Zbaracki, 1992)**	○	⊙	⊙	⊙
Strategic Decision Making **(Schwenk, 1995)**	⊙	◐	⊙	◐
Solving Complex Decision Problems: A Heuristic Process. Springer Berlin Heidelberg **(Grünig and Kühn, 2017)**	◐	⊙	Ø	●
Decision-making process for Product Planning of Product-Service Systems **(Schmidt et al., 2015)**	○	Ø	Ø	●
The Decision-Making Process for Strategic Adaptation **(Ronchi,1980)**	⊙	◐	◐	●

Ø NO Information → ○ → ⊙ → ◐ → ● COMPLETE Analysis

Table 4.2
Steps and sources.

	IDENTIFICATION					DEVELOPMENT				IMPLEMENTATION				REVISION		
	Problem formulation and objective setting	Identification of external and internal factors	Assigning weights to the factors	Identifying/modelling criteria	Situation diagnosis	Identification and generation of alternative solutions	Identifying uncertainties	Determining decision action consequences	Alternatives evaluation	Explanation	Selection	Authorization	Implementation	Update of the situation (objective)	Comparison with the previous situation (objective)	Return to earlier phases
Simon (1960)	X				X	X			X		X		X *		X *	X *
Cyert and March (1963)	X					X			X		X					
Mintzberg et al. (1976)	X				X	X			X		X	X				X
Ronchi (1980)	X				X	X			X		X		X	X	X	X
Fredrickson (1984)					X	X			X		X		X			
Eisenhardt and Zbaracki (1992)					X	X					X					X
Wally and Baum (1994)					X	X			X		X					
Schwenk (1995)	X				X	X			X		X			X		X
Siskos and Spyridakos (1999)	X			X		X		X	X	X			X	X		
Bartzis et al. (2000)					X					X						
Triantaphyllou (2000)	X			X		X			X							
Shim et al. (2002)	X					X			X		X		X			X
Tsoukiàs (2007)	X			X	X		X		X	X	X		X			
Munier (2011)	X	X		X	X	X		X	X		X					
Kugler et al. (2012)					X						X					
Schmidt et al. (2015)					X									X	X	X
Grünig and Kühn (2017)	X			X **	X	X		X	X		X			X	X	X
Marttunen et al. (2017)		X	X	X		X	X		X							
Marugán et al. (2017)	X	X				X	X		X		X					

The first three phases were defined on the basis of Mintzberg et al. (1976)'s work: for the first two was used the same name reported in the paper, while the third (called "selection" in the paper) was named "IMPLEMENTATION" to make it more coherent with all the other publications and because it is the thesis author's opinion that this name is more exhaustive. This does not imply any incongruity because even in the Mintzberg's scheme the implementation of the chosen solution is carried out in this phase. The last phase has been defined very accurately in Ronchi (1980)'s paper, in which it is referred to as "Adaptation". In subsequent publications, however, this name has not been used and often the sources report the need to "revise" the DMP, for these reasons the author of the thesis has preferred to use the term "REVISION". Even in this case there is no inconsistency because the adaptation process can be considered as a type of revision.

In the table, some cells are marked with asterisks, whose meaning is as follows:

* → These three steps were introduced in the Simon's Revised Edition of 1977

** → In Grünig and Kühn (2017), this step is placed in the development phase, after the "Identification and generation of alternative solutions".

The factors identification and weights assignment steps are explicitly reported only in a few sources as they are often assimilated in the diagnosis phase: even in this thesis this choice was made and they were indicated as situation diagnosis sub-steps. The same speech is valid for the "Determining decision action consequences" step, which is often inserted in the alternatives evaluation step. In this case, however, the thesis author preferred to keep the two steps well separated as they are supported by different tools / methods.

It is interesting to note that the identification / modelling of the criteria is a step that has become relevant in the literature once the DSS have started having great importance.

The authorization step is reported only in Mintzberg's DMP: given the considerable importance of this publication and in light of the fact that modern companies are structured and with well-defined hierarchies, this step is considered fundamental for the DMP and, therefore, has been included in this thesis.

The selected sources will now be briefly commented.

Munier	**(2011)**
Marttunen et al.	**(2017)**

These two papers pay great attention to how to identify the problem to be faced, to define the right objectives and to provide the information to the next macro-phase of development. For this purpose, methods belonging to the Problem Structuring Methods (PSM) family are typically used (they will be extensively discussed in section 4.3).

The first step to start the DMP is to clearly define the objectives and all the actors involved in the process (DM, stakeholders ...). All the (often-contradictory) objectives must be taken into consideration in order to solve the real problem in analysis, trying to minimize its approximation. At the same time it is fundamental to analyse the context in which the problem to be solved was born and, therefore, in which the DMP will take shape and act: in this step the external and internal factors must be identified and the relative weights assigned to each of these factors. Once the objectives have been set and the situation has been clarified, it is necessary to establish the conditions for achieving the selected goals. In light of all the existing constraints, the right criteria must be identify and developed in order to evaluate the various options that will be taken into consideration and their consequences. In some cases, it is necessary to establish thresholds that limit the values assumed by certain parameters (this operation is often required when methods such as Mathematical Programming are used).

In order for the DMP to proceed successfully, it is necessary that the information collected and provided to the DM in this first macro-phase is as complete and correct as possible. The type of information processed is not purely technical, but all data relating to the effect and impact of the DMP on the society, the economy, the environment and so on must also be considered. Such data could be expressed through opinions or forecasts of experts of the most disparate sectors: the DM must be able to evaluate and consider in the DMP all the various types of information that come to it.

Once this macro-phase is finished, it would be opportune to consider all the steps again, to verify that all the necessary information has been collected, that every aspect has been considered, studied and discussed. If some gaps are found it is advisable to fill them before proceeding with the second macro-phase.

The sources then go on to study the next phase, that of DEVELOPMENT. Marttunen et al. (2017) tackles the problem from a very technical point of view, focusing on the usable methods and tools (which are not the subject of this section) while the other source adopt a more theoretical approach, discussed below.

Given the enormous amount of data that the DM now has to manage, it is first necessary to process and present them in such a way that they can be used and manipulated effectively.

Carefully defined the situation and gathered all the necessary information (IDENTIFICATION phase), it is possible to move on to the DEVELOPMENT phase. The first step consists in identifying and / or developing various alternative solutions to the problem. Some of them may already be ready to be evaluated while others may require work to be defined. Regardless of how they are obtained, they must then be evaluated and ranked, taking into account any established thresholds. This operation is carried out using the previously identified / modelled criteria. Since each criterion has a different influence, it may be necessary to assign a weight to each of them.

In the ranking of the alternatives it is important to determine what consequences they have on the system: a solution could modify the system to such an extent that it is no longer the best solution or even makes its application impossible. The selection process therefore requires a series of recursive analyses to take into account the influence of the solutions on the whole system.

Tsoukiàs (2007) and Bouyssou et al. (2015)

These two publications were considered as a single source as they deal with the Decision Aiding Process (DAP), which presents some slight differences with respect to the DMP. Despite this, very useful information concerning DMP has been derived from these two papers. Moreover, in the opinion of the author of this thesis, the two papers can be seen as complementary because the second is based on the concepts of the first, expanding and enriching the treatment.

The DAP is theoretically constituted by the following four steps:

- a representation of the problem situation;
- a problem formulation;
- an evaluation model;
- a final recommendation.

Depending on the type of situation to be faced, all four or only a few can be developed.

The way these steps work is similar to the one set out above, the contribution given by this source to this work is related to the evaluation models of alternatives (set of criteria, techniques, methods and tools) and to uncertainty. The choice of the model influences the proposed solutions as each model works differently and, consequently, generates and / or classifies the alternatives in a different way. It is also necessary to validate the chosen models, if possible: conceptual validation (verify the suitability of the concepts used), logical validation (verify the logical consistency of the model), experimental validation (verify the results using experimental data), and operational validation (verify the implementation and use of the model in everyday life).

Bouyssou et al. (2015) indicate among the various factors to be taken into account in the DEVELOPMENT phase also the uncertainty, suggesting to associate to each information considered in the process the corresponding uncertainty distribution, to make the representation as faithful as possible to reality.

Triantaphyllou (2000)
Siskos and Spyridakos (1999)
Shim et al. (2002)
Bartzis et al. (2000)

These four sources treat the DMP in an extremely focused manner to the DSSs: the various steps taken into consideration are exposed in the light of their implementation in the DSSs, showing how it is possible to implement the DMP in a DSS. From these four papers it is possible to obtain ideas and technical information useful for the development of a DSS.

Marugán et al. (2017)

The DMP can also be classified according to the degree of completeness of the information. There are three cases:

- DMP under certainty: this scenario implies that the decision-maker has a complete information about the problem (the causes, consequences and all the variables of the problem are known);
- DMP under risk: a risk environment is considered when some of the information available is stochastic;
- DMP under uncertainty: the decision-maker has not a complete information of the problem, or part of the information is missing.

Each of the three types of DMP listed above must be managed by adopting special measures and methods. The source under analysis presents a method to manage the DMP under risk. Obviously, in reality, DMP under certainty does not exist because it is impossible to perfectly define a problem and the situation in which it must be managed; however, in some situations it is possible or necessary to resort to this approximation.

Wally and Baum (1994)
Cyert and March (1963)
Simon (1960) and Simon (1977)
Fredrickson (1984)

These sources (together with Mintzberg et al., 1976, which is treated separately to be able to present its model in more detail) are the historical foundations upon which all the study of the DMP is based until today. Although with slight differences, all provide a substantially sequential model, which is composed of the following steps: problem formulation and objective setting, situation diagnosis, identification and generation of feasible alternative solutions, alternatives evaluation, selection, and integration.

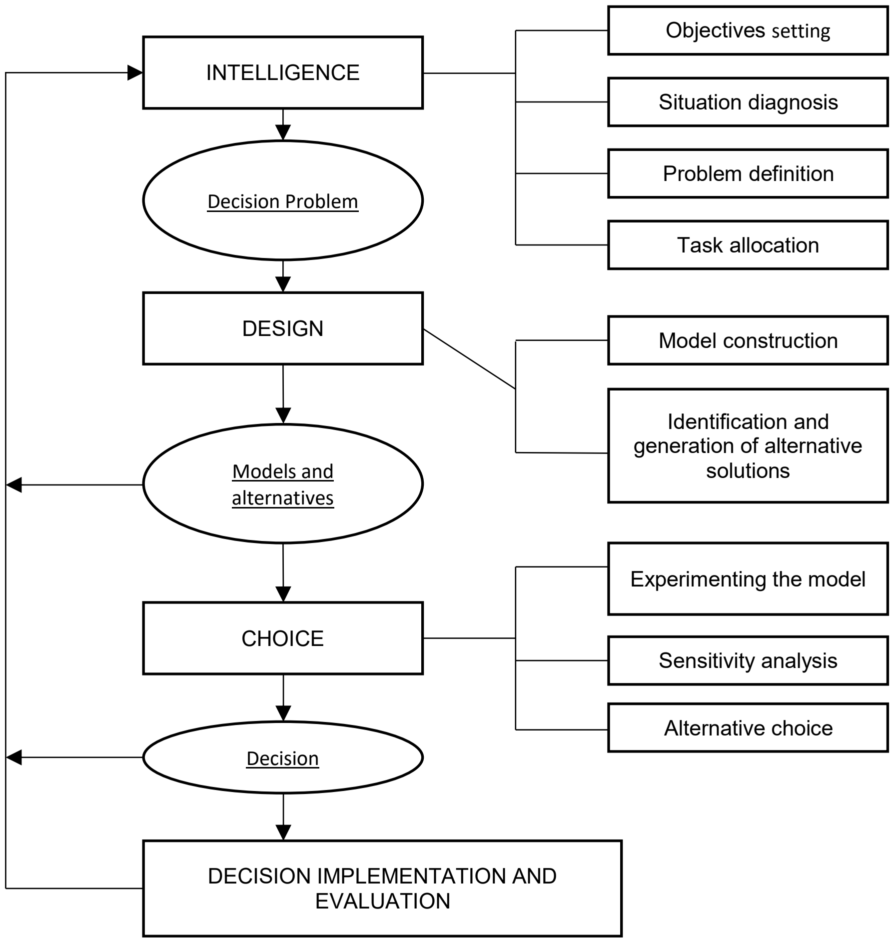
Simon (1977), who's results are schematically reported in figure 4.1, was one of the first scholars to highlight the need to consider the changes in the environment during DMP development and the effects of DMP decision on the process itself.

Mintzberg et al. (1976)

This publication, which is listed among "some of the most recognized papers on strategic decision making" (Rauch et al., 2014), presents a model that in addition to being constantly cited (according to Google Scholar appears to have been mentioned more than 2000 times in the last eight years) is recognized as the model from which some of recent DMP models have been obtained (Maitland and Sammartino, 2015).

The proposed model consists of three phases in sequence, each of which is composed of steps and subroutines (both in sequence and in parallel), as can be seen in Figure 4.2.

Figure 4.1
Simon's DMP scheme.



1) <u>THE IDENTIFICATION PHASE</u>

- The Decision Recognition Routine: Opportunities, problems, and crises are recognized and evoke decisional activity;
- The Diagnosis Routine: Information relevant to opportunities, problems, and crises is collected and problems are more clearly identified.

In this phase INTERNAL or POLITICAL interruptions may take place: they are usually due to disagreement related to the type of problem to be addressed and how to solve it.

2) <u>THE DEVELOPMENT PHASE</u>

- The Search Routine: DMs identify all ready-made alternatives;
- The Design Routine: Ready-made solutions which have been identified are modified to fit the particular problem or new solutions are designed.

3) <u>THE SELECTION PHASE</u>

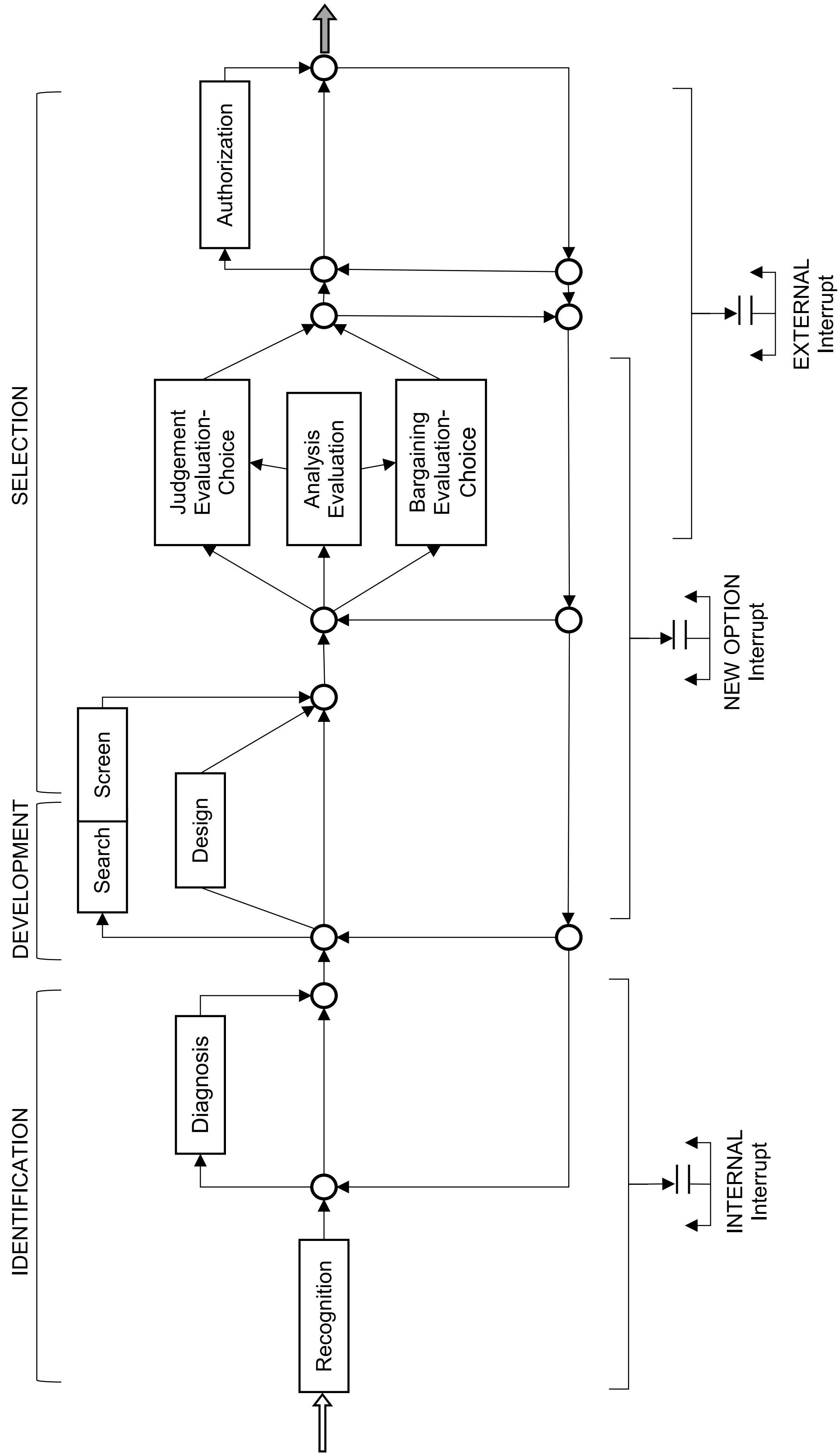
- The Screen Routine: This routine is activated when the search routine identifies more alternatives than can be intensively evaluated. Alternatives are quickly scanned and the most obviously infeasible are eliminated;
- The Evaluation-Choice Routine: An alternative is chosen either through a process of analysis and judgment or a process of bargaining among decision makers;
- The Authorization Routine: When the individual making the decision does not have the authority to commit the organization to a course of action, the decision must move up the organizational hierarchy until it reaches a level at which the necessary authority resides.

In the development and selection phases two types of interruptions can arise: NEW OPTION interruptions and EXTERNAL interruptions. The former usually occur in the final part of the development phase or in the selection phase and concern the emergence of new options that can be used in the DMP: this involves the need to go back to the design phase or, in the simplest case, to select or reject immediately the new option. The second type, on the other hand, occurs during the selection phase when entities or external difficulties block the presumption of the DMP: it may be necessary to go back to the design phase and completely redefine all the solutions.

Depending on the type of situation to be faced, some phases or subroutines may or must be skipped: the model is quite general and can be adapted to almost all the problems to be challenged.

The possibility to go back and update the DMP parameters during the latter, makes the model very flexible and able to work effectively in situations where maintenance is required during and after the DMP.

Figure 4.2
Mintzberg's DMP scheme.



The first three macro-phases in the model developed in this thesis are directly linked to the three phases proposed in this source, expanding and modifying the contents to make them more current and adapt them to a subsequent implementation in a DSS. In particular, the author of the thesis considered it appropriate to add the REVISION macro-phase, responsible for updating all the objectives and parameters at the end of the process and the comparison with the data taken into consideration at the beginning and during the first three phases.

Kugler et al. (2012)
Eisenhardt and Zbaracki (1992)
Schwenk (1995)

These three sources recall the classic models already discussed and add marginal contributions to them.

The most interesting study is provided by Schwenk (1995), who introduces the Strategic Issue Diagnosis. This operation is the one that starts the SDMP, going to influence the whole process. The author emphasizes the importance of promptly identifying the new conditions created by environmental change and understand how these changes affect strategic decisions over time.

Grünig and Kühn (2017)

This book deals with the DMP that must be implemented to solve complex decisions. To effectively deal with this kind of situation, it is advisable to follow systematic procedures with clear and defined methods and rules, making the process as transparent and clear as possible. This last necessity is due to the fact that in this way the process can be understood and analysed also by external people who, therefore, can identify errors or inconsistencies in the process. Other indications are those typical of each DMP that is to base the process on complete and objective information and proceed always focusing on the goals.

This source proposes to resolve complex decisions using a heuristic approach. Sub-problems can be dealt with a sequential or a parallel manner depending on the characteristics of the problem and its decomposition into sub-problems. Each sub-problem must be studied keeping in mind its boundary conditions which, therefore, must be defined with precision in the decomposition phase of the problem. In this way the acceptability of the solutions found is guaranteed (as they respect the links of each sub-problem).

Schmidt et al.	**(2015)**
Ronchi	**(1980)**

These two papers deal extensively with the last macro-phase of the DMP: that of revising and updating the whole process.

The adaptation of the planning process to environmental changes is, in fact, a necessary condition to obtain implementable solutions. The need to undertake an adaptive action is due to events that modify the equilibrium situation in which the DMP started: problems or opportunities. Not all adaptive actions can be put into practice because, in the initial phase of the DMP, are placed constraints that, as already said several times, affect the DMP throughout its development. It is therefore important to consider immediately the possibility of having to take corrective action, and to prepare the DMP parameters in such a way as to have reserves of flexibility.

Designing the DMP in such a way that the DM can updates the values of the various parameters allows, moreover, to update the planning with the last requests of the customers, as they vary. This means that the planning is consistent with the demands of the market and, therefore, increases the competitiveness of the company.

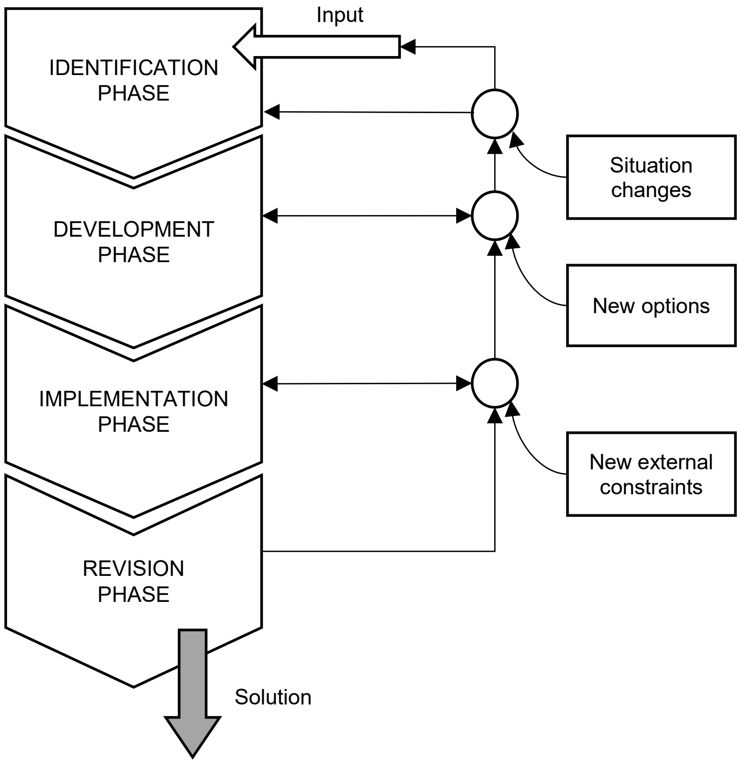
In conclusion, the DMP becomes an iterative process in which the objectives are constantly reviewed to keep the proposed solutions coherent with reality and competitive.

4.2.3 Results of the study: the proposed DMP model

This section presents the DMP model developed by the author.

As can be seen in figure 4.3 (that represents the model in its most aggregated form), the model consists of four macro-phases, arranged sequentially. It is adaptable to almost all problems and situations to be addressed with a DMP because, according to need, it is possible to skip one or more phases or one or more steps. Moreover, it allows the DM to return to the previous phases during the process and to take corrective actions. The right part of the diagram shows that the information processed in one phase can change the previous phase.

Figure 4.3
Aggregate DMP Model.



Furthermore, the external environment may involve the need to review some of the phases due to changes in the situation in which the DMP is developed and / or the emergence of new options (new technologies or new possibilities for the company) and / or external constraints (which may be political or related to company problems).

Now the various macro-phases will then be presented in detail

IDENTIFICATION PHASE

The fundamental steps of this phase is the problem identification and the objectives setting: these start all the DMP and delineates the physiognomy of the whole process, so of all the subsequent steps.

Table 4.3
Identification phase.

Main steps	Sub-Steps
Problem formulation	Objective setting
	Identification of influence factors
	Assigning weights to the factors
	Identification of constraints
Data preparation	Data collection
	Data filtering
	Check data quality
Criteria definition	Criteria evaluation
	Assigning weights to the criteria

In this first step all the actors involved in the process (DMs, stakeholders ...) must be defined, also indicating the responsibilities of each one, so that it is possible to trace who managed the various steps during the process (in the event that it is necessary to ask for explanations or correct what was done) and to quickly identify who to contact to obtain the authorizations. Then the objectives must be defined carefully, compatibly with the aspirations and available resources. Often the objectives are contradictory.

Then the DM need to do a diagnosis of the situation, collecting all the information required to define in the most complete and real way the context of the problem to be solved: this analysis identifies and imposes constraints within which to develop the DMP and highlights the first critical issues and opportunities to be addressed later. The DM must identify, catalogue and report all the factors (internal to the company and related to the external environment) that influence the process and must assign (manually or using support methods and tools) a weight to each factor: in this way preferences can be oriented according to the previously defined objectives. The priority is to represent the situation as coherently as possible with reality.

In order to evaluate the various alternatives that will be found and / or developed in the next macro - phase, criteria are necessary: rules that establish the conditions for achieving the planned goals. Together with them, it is sometimes required to define some thresholds to limit the values that can be assumed by the parameters (usually this operation is mandatory when using Mathematical Programming). The criteria identification / modeling can be done even after defining all the alternatives available to the DM (as suggested by some publications e.g. Grünig and Kühn, 2017) however, it is the author's opinion that defining the selection criteria in parallel with the definition of objectives and to the analysis of the situation, allows a more contextualized and therefore precise choice. In addition, grouping all the steps related to the representation of the problem in its entirety in this first phase, allows to implement the DMP more effectively in a DSS as the DM will enter all this data at the beginning in a screen (or more linked screens), effectively displaying what will then be processed. The selection of criteria is very complex and has been widely dealt with in the literature. The main requirements for a correct choice are the following (Keeney and Raiffa,1999; Filip, 2017):

- Completeness: the criteria must cover all relevant aspects that determine a choice;

- Non-Redundancy: certain aspects must be reflected by no more than one evaluation criterion;
- Operability: the criteria should be comprehensible by all persons involved in decision making and allowing the measurement or qualitative evaluation of the merit of the alternatives;
- Workable size: there should be a reasonable trade-off between the desire to consider all relevant aspects and the need to operate with a manageable set of criteria.

Finally, all the information collected must be checked to verify that they are congruent with each other and that the problem to be addressed and the context in which it is born is described in its entirety. If some gaps are found it is advisable to fill them before proceeding with the second macro-phase.

In recent years, the amount of information that a DM has to manage has increased enormously: production monitoring, online information sharing, and so on, involve a continuous and massive flow of information that needs to be stored and then used for proceed with the DMP. Despite this data abundance is positive as it allows a detailed and updated description of reality, often many of them are redundant or superfluous: it is necessary to filter the data that comes in input to the development phase. This step is not reported in Table 4.2 as it is not explicitly reported by the studied sources. However, all the latest DSS-related publications report the need to perform this step. In order to propose a DMP model that is mindful to current needs, the author inserted this step and considered it at all effects a part of the DMP.

In conclusion, the purpose of this macro – phase (whose steps are shown in table 4.3) is to gather all the information required for performing the DMP. This information must be clear and complete as much as possible; the DM must be able to manage not only technical information, but also opinions and forecasts of experts of the most disparate sectors, data relating to the effect and impact of the DMP on the society, the economy, the environment and so on.

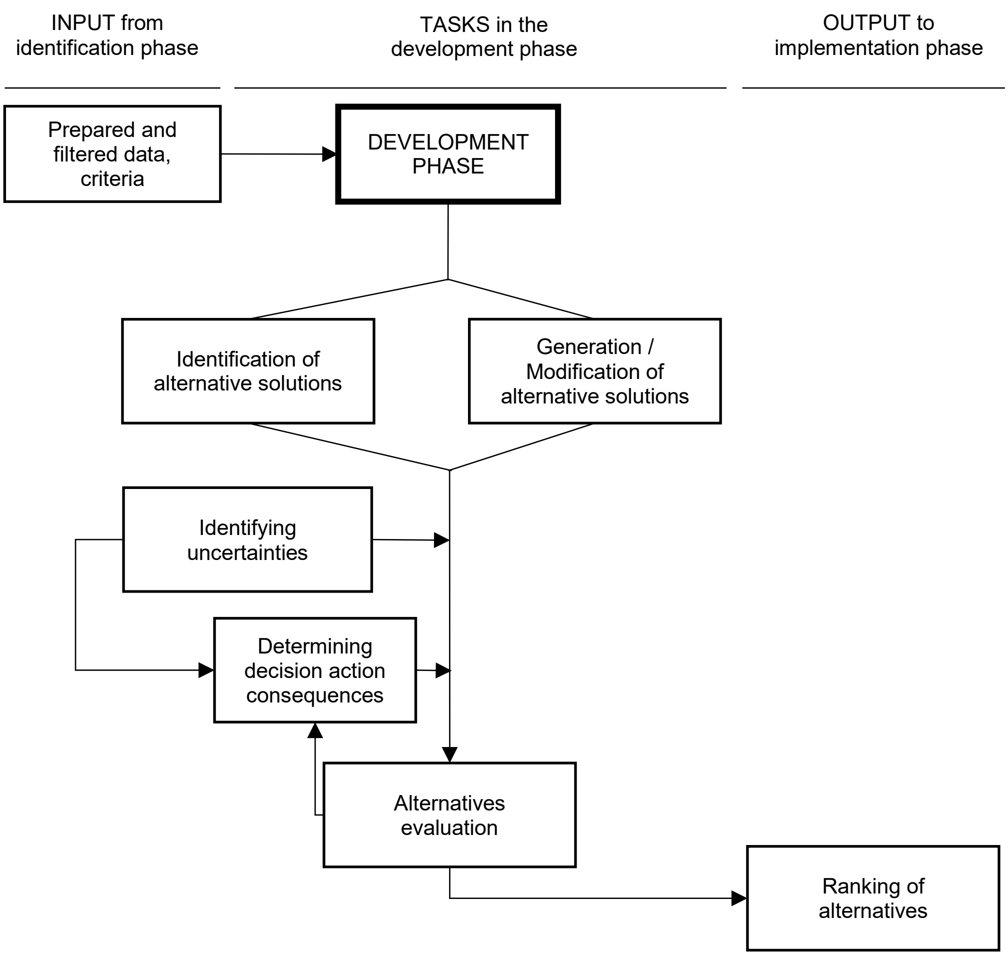
DEVELOPMENT PHASE

Once the data and information have been collected and prepared, the DM can proceed with the development of the solutions of the problem, acting in three ways:

- Ready-made alternatives to the specific case already exist. The DM must stores and pass them to the next step.

- There are valid alternatives to similar problems, which can be adapted to the DMP in place. In this case, the DM must study these solutions and modify them.
- Create completely specific solutions.

Figure 4.4
Development phase.



In some cases, the ready-made alternatives can be very numerous, so the DM will eliminate the less effective ones and those that do not respect all the constraints of the problem and will memorize only some of the alternatives initially found. If the problem to be solved is very complex, can be convenient or necessary to subdivide it into sub-problems to be studied separately (depending on the situation, the sub-problems can be studied sequentially or in parallel). For each sub-problem the validity constraints must be defined and the development and implementation process must be applied. Finally, the various solutions must be combined together to define the solution to the initial problem.

Before commenting on the alternative evaluation step, the author considers it appropriate to stress the importance of uncertainty in the process. As already pointed out by Gotzes (2009), uncertainty is a key issue in many decision problems and ignoring randomness can easily lead to inferior or even infeasible decisions. Any data, be it a number or an opinion or any other type of information, can not be completely certain but is always associated with uncertainty. Ignoring this fact can be very dangerous! For this reason it would be advisable for any data considered in the DMP to be accompanied by its probability distribution and its degree of uncertainty. The uncertainties will then be combined and each alternative will be associated with the relative uncertainty. This information first indicates how a possible solution is solid, then it must be taken into account when the various alternatives are compared and when the consequences of each individual alternative are determined. Since it is impossible to consider the uncertainties of all data, the author recommends considering the degree of uncertainty of the most important data (those directly related to the definition of the problem and those relating to the most influential parameters of the environment).

After the DM has decided how to handle the uncertainty of the parameters, he / she must determine the consequences of the various alternatives. At first, especially if the number of alternatives is high, this calculation / forecast can be made considering only some of the main parameters, to identify the solutions that are most incompatible with the decision environment. After the alternative evaluation step and, therefore, after the alternatives have been ranked, this step must be redone with precision. Only the consequences of some alternatives, those that are more convenient to solve the problem, will be studied. In this way it is possible to verify that they are actually implementable. Then, a second ranking can be made that takes into account also the consequences that each solution entails and how them could modify the system. Indeed, some solutions could modify the system to such an extent that they are no longer the best solutions or even that their application become impossible. In the worst case, this step could highlight the fact that all the alternatives are not applicable, making necessary either the development of new alternatives or even the change of initial objectives. This eventuality could happened even in the case in which is not possible to find or develop any solution or if the uncertainty is so great to request a new definition of the problem and / or to collect the information again.

The conclusive step of this macro-phase, after which the information will be transferred to the implementation phase, is that of the alternatives evaluation. All the various alternatives arriving at this point should be evaluated and ranked, using the criteria previously identified / modelled and taking into account the values thresholds. Since each criterion has a different influence, it may be necessary to assign a weight to each of them, in order to guide the DMP along the desired direction.

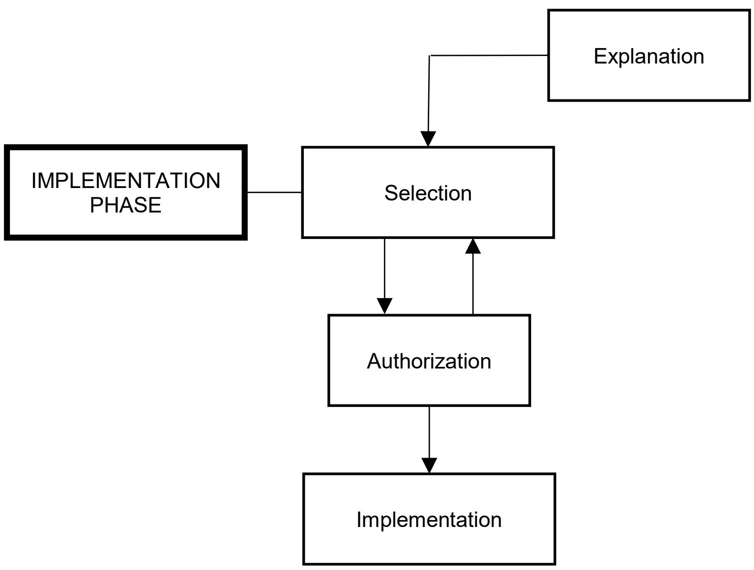
At the end of this phase a list of possible alternatives (all of which can be implemented) should have been drawn up; the various solutions are ordered from best to worst and passed to the next phase (as can be seen in the OUTPUT to the implementation phase zone of figure 4.4).

It is important that the classification process is carried out in a transparent way, so that an external observer can understand how the alternatives have been ranked.

IMPLEMENTATION PHASE

The input of this macro - phase is the ranking of the alternatives: now the best solution must be chosen and implemented.

Figure 4.5
Implementation phase.



The selection step is very complex, especially when the selection is made by a group of people and not by a single DM. In this step, in fact, it is not possible to choose mechanically the "highest ranking" solution because the DMs must first understand how the ranking was obtained (as will be shown in the next sections each method involves different results and this fact is to be taken into account). Then all the requisites necessary for the practical implementation of the solutions must be verified (some of these parameters have already been considered in the previous phase, but these too must be re-evaluated to verify that they are respected at the time of implementation). This process is usually multistage and iterative. Initially the DMs discard all the solutions that are the worst in the ranking, then evaluate all the remaining options several times, excluding from time to time those that are the least effective. If the selection is made by a group of DMs, in addition to analysing and judging the solutions, a further operation is necessary: the bargaining. In fact, each DM will have different opinions on the alternative as he / she has a different way of thinking and may prefer one objective to another. Bargaining usually takes a long time and is carried out with meetings. The needed time is greatly reduced if among the DMs there is one that has more decision-making power than the others have and, therefore, can impose his / her decision or can influence that of others.

The selection can be supported by the explanation step: the latter is extremely important, especially if this macro - phase concerns multiple DMs, with different degrees of competence. Its purpose is to provide information, as complete as possible, on alternatives and how they have been ranked. In this way the DMs can make a choice that is aware and in the light of all the details (the people responsible for carrying out the identification phase could be different from those that make the selection). Moreover, if the DMs have different skills, this allows to create a common knowledge base thanks to which the time required for bargaining could be considerably reduced.

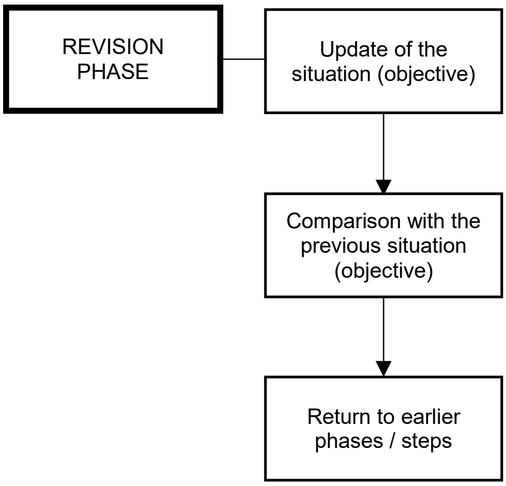
Since in companies there is a hierarchy of control, before implementing the chosen solution, it is often necessary to request authorization from the people in charge of the control. In this step the chosen solutions can be blocked, requiring the DMs to provide new ones.

It is possible that, in the end, no solution is authorized: in this case, it will be necessary to go back to the previous phases to develop new alternatives or even take drastic actions such as changing the objectives.

REVISION PHASE

After choosing and implementing a solution, it is advisable to check how this solution actually changes the initial situation and if this involves changing some initial objectives. The final verification of the objectives is always opportune because during the DMP these could be changed.

Figure 4.6
Revision phase.



If the DM detects changes, due to the implemented solution or external factors, he /she has to compare the new situation with the initial one, from which the DMP has started. In this way the DM can understand if he / she has to restart the DMP (if the situation and objectives have changed considerably) or modify what has already been done (if the changes are small and manageable) or confirm the solution already implemented.

At this point, the DM will have to decide whether to return to a previous phase or step or to conclude the DMP by ratifying what has already been done.

4.3 Supporting the Decision-Making Process

Various methods and tools can support the DMP steps. As already stated in Chapter 3, there is no method or tool that is the best, for this reason scholars have created (and are still creating) methods and tools to help the DMs in the DMP phases according to the problem they are facing.

To make the exposition as clear and comprehensible as possible, the methods and tools have been grouped and organized according to the DMP macro-phases they can support: the Framework is structured according to the Aggregate DMP Model, in such a way as to provide a linear and concise representation. It is the author's opinion that considering the DMP in its aggregate form does not make the exposure less exhaustive; rather, it is necessary to grasp the key aspects of the various methods and tools, and give them a clear place within the DMP.

To get a more detailed understanding of DMP, the reader is invited to view section 4.2.

In each section, the steps related to the phase of interest are shown. Compared to the DMP model, the steps are also rearranged in such a way as to be presented in a sequential form. Next to some steps are shown the tools that can be directly used to support it. Each method is numbered with the same number of steps that it can support; next to some methods are indicated the tools that can be used to apply those methods. The tools are identified with capital letters.

To understand the function, the potentialities and the application limits of each method and tool, there are guidelines for each of them: according to the specific situation and following the reported guidelines, the DM should be able to identify and use the methods and tools that are most suited for solving his / her problem.

In the following, in order not to make the guidelines dispersive, the term DM has been used to indicate indistinctly the decision maker, professional who design a DSS and the user of the DSS. Moreover the term has always been used in the singular but it can also indicate groups of DMs, professionals and users.

4.3.1 Sensitivity analysis

Sensitivity analysis is not a DMP step but it is a mandatory task to do when supporting the DMP with a DSS, indeed performing the sensitivity analysis is essential for checking the consistency of final rankings: it "permits to find out how the solution changes (how sensible it is), regarding the variation of some parameters" (Munier, 2011). Petrovic´ et al. (2018) adds that "Criteria weights are often one of the greatest contributors to the uncertainties in solving DMPs using MCDM methods. Therefore, it is very important to explore the influence of criteria weights variations to ranking orders obtained according to the selected MCDM methods and the proposed approach.” For these reasons, some methods and tools, that allow the DM to carry out this analysis correctly, have been inserted into the Framework.

4.3.2 Methods, Tools and Guidelines

This section shows all the chosen methods and tools, with the respective guidelines. The description of the operation of each method and tool is not the purpose of this work: the knowledge deepening of the chosen methods will be a reader's task.

The Framework, without the guidelines to be more streamlined and quickly interpretable, has been reported in Appendix A. The structure of this scheme was perfected through a series of meetings with experts of a major German automotive company for whom it was designed.

The labels prefixed to the name of some methods and tools have the meaning described in table 4.5. Given the length of the framework with the guidelines, to facilitate the reader in identifying the phases, each of them has been framed with a different colour (see table 4.4); in addition, the tools are boxed with a single line and the methods with a double line.

Table 4.4
Phases – Colour.

PHASES	COLOURS
Identification	(black)
Development	(red)
Implementation	(green)
Revision	(light blue)

Table 4.5
Meaning of the labels used in the Framework.

CATEGORY	LABEL	MEANING (PURPOSE)
DATA HANDLING	[DH]	Manage and interpret data.
VISUALIZATION	[VIS]	Visually presenting information and data to make interpretation easier.
STATISTICS	[ST]	Ability to manage the uncertainty and variability of the processed data.
PSM	[PSM]	Methods created to identify, interpret and model a problem or situation.
ADVANCED TOOL	[AT]	Tool, whose structure is well defined, composed of methods and tools.

IDENTIFICATION PHASE

1. Problem formulation {C, D, E, F, G, H, I, K, L, M}
   1.1. Objectives setting
   1.2. Identification of influence factors {A, D, J}
      1.2.1. Assigning weights to the factors {D, J}
   1.3. Identification of constraints
2. Data preparation
   2.1. Data collection
   2.2. Data filtering
   2.3. Check data quality {B}
3. Criteria definition
   3.1. Criteria evaluation
   3.2. Assigning weights to the criteria {D, J}

METHODS

<u>Methods i, ii, iii and iv can support steps 1, 1.1, 1.2 and 1.3.</u>

i. [PSM] Soft System Methodology (SSM) {C, E, F, G}
   - This method can be used to identify and structure problems. It is particularly useful if the system / situation is complex.

ii. [PSM] Strategic Options Development and Analysis (SODA) {E, F, G}
   - This method can be used to structure and study in detail complex problems that affect more people (even with different skills). The result of applying this method is an exhaustive model of the problem or situation in which it arises.

iii. [PSM] Strategic Choice Approach {E, F, G}
   - The DM can use this method when the problem under analysis affects more people with different skills and points of view of the situation, and when there are many sources of uncertainty. This method has been designed for Collaborative DMP and its application can be long as it is required that all the various actors progress simultaneously in small steps.

iv. MARVEL {E, F, G}
   - MARVEL is a method used to explore a problematic situation and its dynamic response to events or interventions: the DM, in addition to structuring the problem to be addressed, can understand how the system surrounding the problem works. This recently developed method integrates simulation in collaborative problem structuring.

<u>Method v can support steps 1, 1.1, 1.2 and 1.2.1.</u>

v. Quality Function Deployment (QFD)
   - The DM can use this method to identify and quantify numerically which are the parameters of greatest interest from customers.

   1.2.1. Monte Carlo simulation
   - A Monte Carlo simulation can be implemented in the identification phase to help the DM calibrate the factors weights.

3.2. Monte Carlo simulation
   - A Monte Carlo simulation can be implemented in the identification phase to help the DM calibrate the criteria weights.

TOOLS

A. [DH] [AT] Data mining
   - Data mining are tools that discover patterns and hidden rules in data sets. It allows to obtain information and knowledge that help the DM in identifying the problems and the behaviour of the system under analysis.

B. [DH] [AT] Database Management Systems
   - These systems allow the DM to create, store, read and manage data in a database. It is a fundamental tool to effectively enable the interaction between DM and database. Furthermore, it establishes which data can be accessed and modified by the various users (if there are more than one).

C. [DH] CATWOE
   - CATWOE is a simple tool that helps to identify problems and objectives of a business (it is usually used for companies). It is based on the global consideration of the actors and of the system in which the DM wants to act.

D. [DH] Strengths, Weaknesses, Opportunities, Threats analysis (SWOT)
   - SWOT analysis, through the identification of internal (strengths and weaknesses of the company) and external factors (opportunities and threats offered by the environment) helps the DM to establish the objectives in a compatible way with the environment in which it operates.

E. [VIS] Decision Tree
   - With a Decision Tree, the DM can represent in an orderly manner: a model, the problem under analysis (and the influence on the various parts of the system), the alternatives in analysis (and their consequences)... In other words, this tool allows a clear representation that, besides favouring the understanding of the DM, makes easier to translate problems, models, options to a mathematical formulation. This tool is indicated to represent hierarchical structures.

F. [VIS] Network Diagram
   - The aims and benefits of this tool are similar to those of the Decision Tree but it is used when the DM has to analyse and represent a network structure. This tool is very powerful if inserted into an IDV.

G. [VIS] Casual Loop Diagram (CLD)

- This type of diagram allows the DM to give a clear representation of how the variables that come into play in a system are connected to each other. This tool is very effective if the number of variables is not too high, in fact, if the system is characterized by many parameters then the representation could be very complex and difficult to read.

H. [VIS] Binary Decision Diagram (BDD)

- This tool is used to represent the internal relations of a system. This tool admits only the representation of Boolean functions and, usually, is the most suitable tool to represent them as it makes the visualization compact and clear.

I. [VIS] Fuzzy Cognitive Map (FCM)

- FCMs are the most suitable tools to represent complex systems, models and problems. They allow a quick translation of the information into a matrix form, which can be processed later. These tools are very powerful if inserted into an IDV as this translation can be completely automated.

J. [VIS] Pareto plots

- The DM can use these diagrams to identify which factors are most influential. This is particularly useful for understanding how to deal with problems and to have a clear situation analysis (the DM can obtain useful information on where to focus his / her attention).

K. [ST] [VIS] Bayesian network

- This tool is used to represent complex uncertain situations to find the joint distribution of the underlying events. It visualizes the relationships among the variables of a system, associating to each of them its own probability function. The DM can use this tool to represent problems and systems taking into account uncertainty. It is a directed and acyclic graph.

L. [ST] [VIS] Markov network

- A Markov network has the same purpose as a Bayesian network, but is used when the system variables are unidirectional. It is an undirected graph, moreover it can be cyclic or acyclic depending on the situation in which it is used.

M. [ST] [VIS] Graph model

- This tool is used to visualize the conditional dependencies among the variables of a system. The DM can use it to create statistical models, especially when some of the variables are random variables.

N. [DH] [VIS] [AT] Interactive Data Visualization (IDV)

- The DM through an IDV can directly display and edit diagrams and plots. This allows, therefore, both to insert (by moving, inserting links, assigning labels ...) and to obtain (by selecting and reading the parts of representation of interest) information in a very rapid way.

DEVELOPMENT PHASE

4. Generation of alternative solutions
    4.1. Identification of ready-make solutions {C}
    4.2. Modification of already made solutions
    4.3. Definition of new solutions
5. Alternatives evaluation {A, B}
    5.1. Identifying uncertainties
    5.2. Determining decision action consequences {C}
6. Ranking of the alternatives

METHODS

4.3. Bayesian inference

- The DM can implement a Bayesian inference method in a DSS to allow it to propose new solutions and improve the evaluation of the alternatives already developed, as new information becomes available. Furthermore, it can be used to improve prediction models of the decision action consequences.

4.3. Birnbaum-cost measure method

- This method was developed specifically for the DMP under risk (some of the information is stochastic). It can be used to solve complex problems (requires a lower computational effort than the "classical" optimization methods) as resources allocation and planning optimisation. The results proposed by this method, however, are approximate and, therefore, the obtainment of the optimal solution is not guaranteed.

4.3. Mathematical optimization (programming) {E, F}

- Mathematical programming studies the methods for finding the maximum and / or minimum points of a mathematical function. In order to use these methods as support for DMP, it is first necessary to translate the problem into a mathematical model, depending on the type of problem there will be some more suitable methods and others that will not be effective. The greatest limitation for the application of these methods is the great computational effort that they require as the complexity of the problem increases: for this reason sometimes it is not possible to calculate the exact solution but the DM must look for an approximate solution (usually using heuristic methods).

5. Data Envelopment Analysis (DEA)

- With this method it is possible to quantify the efficiency of production units (especially indicated for the evaluation of Decision Making Units) and to quantify the production frontiers. This information is important to generate viable solutions and to evaluate the feasibility and the goodness of the alternatives in analysis.

5.2. Agent-based simulation

- With an Agent-based Simulation the DM can model the dynamics of a complex system and study how the "actors" behave according to the available alternatives. "Actors" means the various entities that have a role (active or passive) in the system.

5.2. Monte Carlo simulation

- The DM can implement a Monte Carlo simulation to perform different “what-if” scenarios in order to analyse the sensitivity of final rankings to the changes in criteria weights.

5.2. Bayesian inference

- The DM can implement a Bayesian inference method in a DSS to allow it to propose new solutions and improve the evaluation of the alternatives already developed, as new information becomes available. Furthermore, it can be used to improve prediction models of the decision action consequences.

6. Multi-Criteria Decision-Making Methods (MCDM)
   - The MCDM methods evaluate the different alternatives using criteria (usually conflicting criteria because the objectives are conflicting): through these, the DM can structure its preferences. These methods require a lower computational power than mathematical programming. Many methods belonging to this category have been developed and the most efficient and used ones are shown below. There is no method that is better than the others and for this reason the author has highlighted some key features that the DM must consider to choose the MCDM method to be implemented:

     a) Ranking mode;
     b) Type of input information;
     c) Uncertainty degree;
     d) Compensation degree*.

     *A method is compensatory if admits a compensation between the different evaluations: this means that a good performance on one criterion can easily counterbalance a poor one on another. This feature is not allowed in some DMPs.

- Weighted Sum Method (WSM)
  - a) Direct rating – b) Cardinal – c) Deterministic – d) Compensatory.
  - Simple and easy to implement.

- Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)
  - a) Direct rating – b) Cardinal – c) Deterministic – d) Compensatory.

- Analytic Hierarchy Process (AHP) - Analytic Network Process (ANP)
  - a) Pairwise comparison – b) Cardinal – c) Deterministic / with uncertainty – d) Compensatory.
  - This method works similar to how humans make decisions and it is based on a linguistic scale (often used also in other MCDM methods to define criteria weights) so it is easy to understand. For this reason it is very suitable for Collaborative (Group) DSS.

- ELimination Et Choix Traduisant la REalité (ELECTRE)
  - a) Pairwise comparison – b) Ordinal / cardinal / mixed –

c) Deterministic – d) Partially compensatory.

- PROMETHEE
  - a) Pairwise comparison – b) Ordinal / cardinal / mixed – c) Deterministic – d) Partially compensatory.
- Multi-Attribute Utility Theory (MAUT)
  - a) Tradeoffs & lotteries – b) Cardinal – c) With uncertainty – d) Partially compensatory.
- SIMUS Method
  - a) Direct rating – b) Cardinal – c) Deterministic / with uncertainty – d) Partially compensatory.

TOOLS

A. [VIS] Radar charts
- This tool is very useful as it allows to visualize and quantify (by calculating the area) the goodness of the alternatives in analysis. It is usable for this purpose if each objective / feature can be represented on a one-dimensional axis. It also allows to quickly compare alternatives, matching the polygons shapes.

B. [VIS] Decision tree
- This tool is limited to short time horizons because the branches in the tree grow in number very fast with extensions of the decision horizon. If the problem under analysis is simple, the DM can directly use a decision tree to define and evaluate the solutions and for the next selection step.

C. [AT] Neural network
- The DM can implement a neural network to predict and study the evolution of the system as the available alternatives vary. In addition, neural networks can be used to recognize the problem in analysis and to suggest a solution. However, their effective functioning envisage a long phase of "learning".

D. [VIS] Pareto plot
- Pareto plots are useful tools to illustrate the effect of criteria weights in the final rankings, in this phase they are used as sensitivity analysis tools.

E. Exact solution

F. Heuristics (Approximate solution)

- Heuristics are defined as methods developed to solve problems quickly and sufficiently satisfactorily. With these techniques, in fact, there is no guarantee of obtaining optimal solutions but just an approximated one. The DM can be forced to use these methods if the problem under analysis is too complex to find an exact solution with optimization methods or if he / she needs to obtain solutions in a short time.

IMPLEMENTATION PHASE

7. Selection {A, B, E, F}
   7.1. Explanation {D}
   7.2. Authorization
8. Implementation

TOOLS

A. [VIS] Radar charts

- If the alternatives can be represented with these graphs, the DM can select the best alternative by calculating the polygon area. Moreover, he / she can quickly understand the characteristics of the options (represented by the shape of the polygon).

B. [VIS] Decision Tree

- If the problem under analysis is simple, the DM can directly use a decision tree to select the best solution.

C. [DH] [VIS] [AT] Interactive Data Visualization (IDV)

- The implementation of an IDV is important to allow the DM to explore the results obtained in the previous development phase. This is strongly recommended in Collaborative (Group) DSSs to ensure that the various DMs can explore and understand what has been done. Through an interface of this type, moreover, the DMs can select the option they deem best and the authorization officers can give the necessary authorizations.

D. [DH] [VIS] Decision tables

- The decision tables are used to provide information to the DM and form a knowledge database that is fundamental for the explanation step. Its implementation requires a big effort (both for entering information and for the memory required to store them) but makes the DSS much more effective as it allows all DMs to have a common knowledge base.

E. [DH] Benefits, Opportunities, Costs, Risks analysis (BOCR)

- If the problem is simple and the options are not many, the DM can evaluate the alternatives quickly through this simple framework.

F. [AT] Neural network

- A neural network can be designed to recognize the problem in analysis and to suggest the best solution to solve it (among the various alternatives known by the network). In order to make this tool effective, an initial phase of "learning" is necessary, which it is not always possible to complete in the industrial reality.

REVISION PHASE

9. Update
    9.1. New objectives?
    9.2. Check the situation statement {A, B, C}
10. Comparison {A, B}
    10.1. Evaluate the difference between old and new goals
    10.2. Compare the new situation with the previous one
11. Return to earlier phases / steps

TOOLS

A. [VIS] Radar charts

- The DM can represent the system by reporting the value of the main parameters on a radar charts. By doing this before and after the DMP, he / she can compare the system state once the chosen solution has been implemented.

B. [VIS] Network diagram

- This tool allows the DM to represent the final status of the system, highlighting all the links between the various parameters. Very useful when the studied problem concerns the sharing of resources and / or components.

C. [VIS] Pareto plots

- The parameters of greatest influence can be strongly highlighted by this type of graph, allowing the DM to understand how the implemented solution modifies the system and whether the mechanisms that regulate the system have changed.

D. [DH] [VIS] [AT] Interactive Data Visualization (IDV)

- Also in this phase, to design an effective DSS it is necessary to implement an IDV, so that the DM can analyse in detail and compare the proposed data and graphical representations.

4.3.3 Optimization models

If the DM chooses to use mathematical optimization to generate solutions to the problem, depending on the characteristics of the latter, a specific type of model must be created, to whom corresponds a type of programming. Below are the most used.

a. Linear programming

- Used when problem and system are modelled with linear functions and the constraints of the objective function are linear. Very used in Operational Research (OR) because many industrial problems are represented with linear functions.

b. Mixed integer programming

- Some of the variables can only take integer values.

c. Interval linear programming

- This is a method for decision making under uncertainty. The uncertain parameters are expressed as intervals without any distributional information: this allows interval information to be directly transferred into the optimization process and resulting solution, making the model more robust and light.

d. Non-linear programming

- Used if the problem and / or the system and / or the constraints of the objective function are modelled with non-linear functions.

e. Stochastic programming

- This is a method for decision making under uncertainty. Some or all parameters are associated with their probability distribution.

f. Dynamic programming

- The DM can implement this method to solve complex problems. Dynamic programming involves the division of the original complex problem into simpler sub-problems to solve in a recursive way: the optimal solutions to the sub-problems are then used to find the optimal solution of the whole problem. This method is applicable only if the solutions of the sub-problems can be combined in a final solution to the original problem.

4.4 Case Study: A DSS for the Automotive Industry

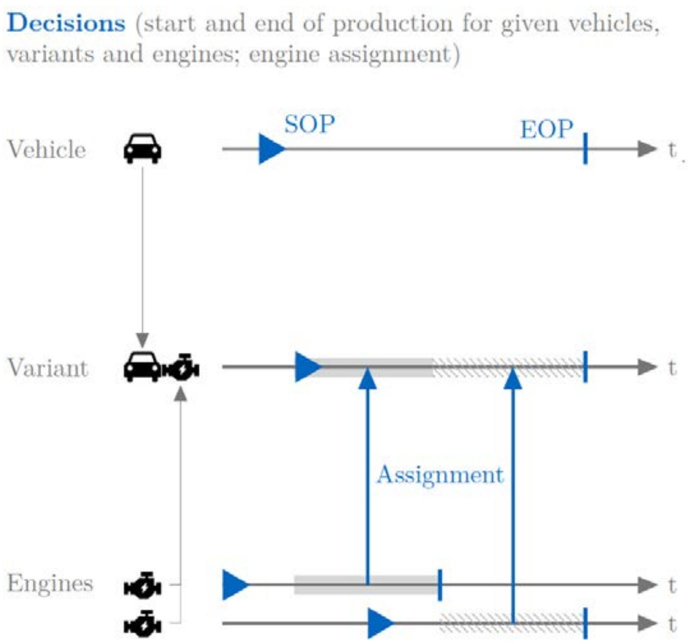
This section shows the Case Study carried out to test the Framework developed in the thesis. After an initial introduction that contextualizes the problem under analysis, the author's proposal for the development of the required DSS is reported.

4.4.1 Introduction

The practical application of the contents of sections 4.2 and 4.3 consists in the realization of a DSS concept, specifically designed to help the DMs operating in a major German car manufacturer in planning the introductions of new vehicles. This task is part of strategic planning, whose importance has already been highlighted.

The problem to be faced was presented in Bersch et al. (2018) and involves the timing of the Start of Productions (SoPs) and End of Productions (EoPs) of each vehicle, each variant and each engine. A variant of a vehicle is defined by the combination of a vehicle (type) and an engine (type), where due to interface specifications several engines can be assigned to a vehicle. In addition, engines have to be assigned to vehicles in order to create variants. There is also a start and finish time for the engine assignment for two reasons. First, start and finish of variants are decisions in the DSS. Second, different engines can be assigned to the same variant at different times. The decisions to be taken and the goals of the DSS are represented in figure 4.7 and figure 4.8, taken from Bersch et al. (2018).

Figure 4.7
Decisions to be taken.



For these decisions, a planning horizon of three successive but overlapping vehicle generations is considered, although some vehicles of the first of these three generations are being produced already, hence, only the EoP of these vehicles is still a decision. However, also these vehicles have to be considered, since on the one hand, they partly determine the demand of specific resources and on the other hand, time windows of future SoPs and EoPs are influenced. Furthermore, due to the length of the planning horizon, vehicle introductions are planned for more than 15 years, while vehicle variants are only planned for the next couple of years.

As just underlined, the decision to be taken have an impact on many goals, which represent the objectives of different business units but can only be evaluated on a corporate level.

In this case study three main objectives in the planning of product introductions were considered: timing goals, sales goals and CO2 capacity limit goals.

Timing goals are focusing on the cost side in development and production, hence they have a company internal perspective. Based on the company's experience with previous projects, some vehicle projects should be scheduled with a specific temporal distance in order to be developed efficiently. For instance, consider two vehicles A and B, with A being a lead vehicle and B its derivative. Compared to A, B has only minor changes like a different shape of the trunk (e.g. estate derived from sedan). In this case, there should be a minimum distance between A and B, since this allows to have a mature solution concept for the lead vehicle before transferring this concept to the derivative. At the same time, there should be a maximum distance between A and B, so that the technology of the derivative is still state of the art at its market launch without further changes. By targeting for a desired temporal distance between the two vehicles, the company minimizes the developing effort. Another example of timing goals is to minimize exceptions from a targeted limit of simultaneous SoPs per product line.

To effectively schedule the SoP of a vehicle, it is necessary to keep in mind that this "moment" is preceded by a series of preparatory phases (module planning, plant testing and so on) and that before reaching the full-production there is a phase called "ramp-up", during which the production rate is increased until the target rate is reached. Simultaneously with this phase the ramp-down of the old models occurs (there is a period of time in which both new and old models are produced). Terwiesch and Xu (2004) defined the production ramp-up as “the period of time during which a manufacturing process is scaled up from a small laboratory-like environment to high-volume production”. This phase is delicate since many problems arise in connection with the start of mass production (e.g. because of engineering changes and compatibility problems) and, consequently, the productive potentials of the plants are constrained and limited (Al-Aomar, 2006). Therefore, the scheduling of vehicles SoPs must be such as to make the ramp-up and full-production as easy as possible, with the aim of stressing the production plants as little as possible. The correct use of the production plants is very important since overloading the production / assembly lines can result in stops that spread backwards throughout the logistic chain (Fredriksson, 2006).

Taken together, these timing goals reflect the company's experience on how to minimize peaks in the necessary production effort and thereby minimize development costs. The challenge is to fulfill all timing goals while deviations from the average development capacity $\bar{u}$ are to be minimized. Obviously, this goal can be directly influenced by shifting SoPs.

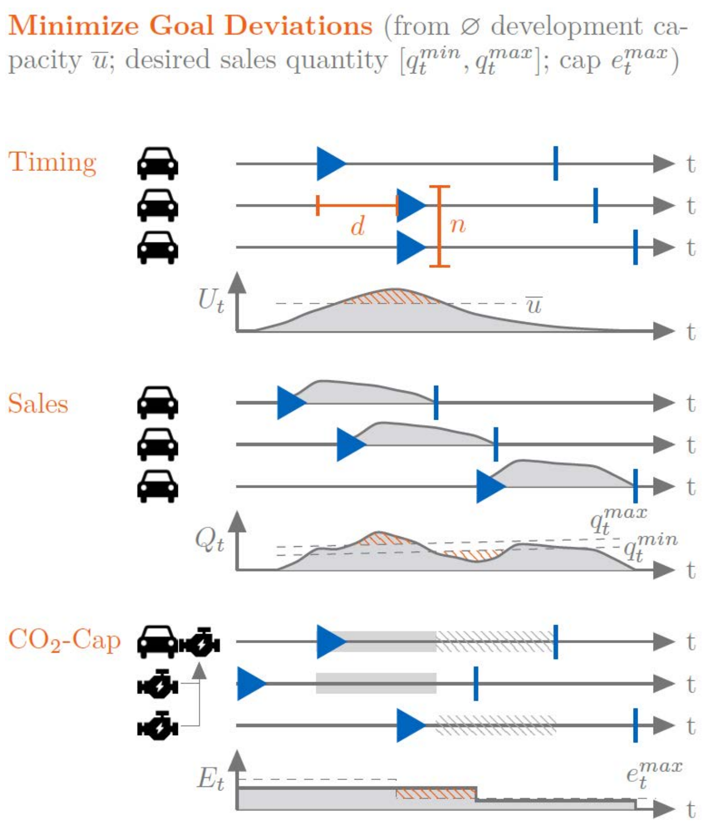
Targeted sales quantities obviously have a direct impact on the company's revenue. At the same time, assuming vehicles are produced immediately before sales, they also influence the resource demand for production capacities. Considering both, resource demand for production and revenue from sales at the same time, it is aimed for constant, smoothly (i.e. with small variance) growing sales. This way, cost for overtime and idle time of resources is minimized while smooth revenue growth is obtained. As illustrated in figure 4.9 sales of each vehicle follows a typical sales function. Towards the end of the production lifecycle, customer demand for the product decreases. Hence, sales depends on the SoP and EoP of each vehicle.

The last goal is dealing with an external perspective, in this case regulatory issues regarding the CO2 limit imposed by the European Parliament (2009). Original Equipment Manufacturers (OEMs) in the automotive industry have to ensure that the sales volume weighted average of CO2 emission is below a certain cap-limit. The latter depends on the average weight of sold cars, where the limit increases with increasing average weight. For an average vehicle weight of 1372 kg the limit is 130 g CO2 / km. Taking into account the lifecycle of sales, the limit depends on decisions outlined above as well as on the assignment of engines to vehicles.

In summary, all objectives discussed above are directly or indirectly influenced by SoP- and EoP-decisions as well as the engine assignment decision. Furthermore, since projects are linked via several constraints, e.g. resource demand or engine assignment, the problem cannot be decomposed into individual sub-problems.

Now two made assumptions are reported. First, we assume that the decision on the engine assigned to a vehicle does not have an impact on the value for the customer, as long as the customer receives state of the art technology. That is, neither sales nor revenues are impacted by this decision. Second, we assume that each variant follows a typical sales curve, which depends on both, SoP and EoP. Typically, companies in the automotive industry have substantial knowledge in deriving these sales functions from SoP and EoP. With this assumption, sales becomes a parameter depending on SoP and EoP.

Figure 4.8
Goal deviations.



At this point, the reader understood the importance of correct planning and the motivations that are pushing automotive companies to invest resources in the design of DSSs that help managers and engineers in these decisions.

Given the context and the purposes of the DSS, below an additional requested feature is reported. The DSS will be used by different professionals, with different degrees and fields of expertise: it is, therefore, a Collaborative (Group) DSS, i.e. a DSS designed in such a way as to allow more people to enter, read and manipulate information, depending on their work task. For now, the evaluation of alternatives (in the development phase) will not be collective.

4.4.2 Application of the Framework

The application of the Framework is subdivided into four sub-sections, each of which is related to a phase of the DMP. The choice of methods and tools was carried out considering the tasks that the requested DSS must perform and comparing them with the DMP steps reported in the Framework. This allowed the system to be broken down into the sub-tasks to be carried out to arrive at the final result: once the various sub-tasks have been ordered, the relative methods and tools that could support them have been identified. The choice between the various proposed methods and tools was carried out by checking which ones were best suited to the specific case, based on the indications provided by the guidelines.

4.4.2.1 Identification phase

First of all it is useful to check what steps to support in this phase for this specific application. The problem and the objectives to be achieved are well known, so the use of PSMs or any tool related to the identification of the problem are not required. Being long-term planning there are not large amounts of data to analyse or large databases to consult, moreover, dealing with strategic planning it is assumed that the data are of high quality. The criteria have already been selected too. For these reasons in this initial phase will be implemented only tools that allow the DMs to structure the problem within the DSS and to enter and manage the information. Since this is a Collaborative DSS it is fundamental that these operations can be done in a simple, fast and intuitive way: it is therefore necessary to implement an IDV at this stage and also in those of implementation and revision.

The IDV will interact with the following visualization tools:

- Network Diagram: enter vehicles and engines within the DSS. In this phase the first connections can be assigned (i.e. define some variants), known for design or sales needs. This tool allows a clear representation of the sharing of modules, a typical network structure, and allows the DM to have at a glance the overview of vehicles and engines and the sharing of engines between the variants. The effectiveness of this tool could decrease if the number of vehicles and engines that the DM wants to consider at the same time is high, in this case the various connections could be difficult to follow.

- Decision Tree: define the time intervals within which to schedule the various vehicle projects (vehicles derived from a main project). Enter the aggregate sales forecasts of the various vehicles. The tree structure is typical of derivative vehicles, which represent the branches that start from the main project. With a representation of this type, it is easy to understand the company offer to the market (the more vehicles there are, the more options the company offers to the customer) and identify which vehicles are the most critical to manage (those with more "branches"). The DM will be able to enter data regarding the various vehicles (listed above above) by selecting the various branches. It is the opinion of the author that in this way it is also possible to verify the congruence of the inserted scheduling intervals, by checking the overlap of the intervals.
- Fuzzy Cognitive Map: define (quantitatively) the main production requirements and constraints for vehicles and engines, inserting the requested key productive resources by the various modules. In addition to facilitating the understanding of the distribution of resources, through the observation of the various links, allows the DM to enter this information intuitively (established a "connection" then he / she must assigned the corresponding need) and, in the subsequent stages, the calculation of the necessary resources (which will be compared with those available). It is advisable to indicate only the key resources for two reasons: since long-term planning is only the need of these resources to be calculated (De Toni et al. 2013), moreover, increasing the number of elements to be represented, the insertion of data is less easy and the representation becomes more difficult to be interpreted.

4.4.2.2 Development phase

This phase requires the development of two results: the creation of variants (assignment of engines to vehicles) and the scheduling of vehicles, variants, and engines.

For the first purpose, an MCDM method can be implemented that, according to a series of parameters, can indicate which are the best variants to offer to the market. Since CO_2 emission limits can not be exceeded, it is important that the chosen method is not totally compensatory, to avoid considering as positive the solutions that have good performances regarding the other parameters but do not respect the imposed emissions limits. The method chosen to rank the alternatives is PROMETHEE II, which can process ordinal, cardinal and mixed information. The relative importance of criteria (assigning weights to criteria) can be evaluated using AHP, using the combination of AHP - PROMETHEE II methods, which is already widely used and effective for this type of problem, as reported by Renzi et al. (2017).

For scheduling the various SoPs and EoPs, an algorithm is required that optimizes the objectives set out in the introduction to this section. Given the statistical nature of both the sales curves and the functions describing the ramp-up and ramp-down phases, it may be convenient to apply interval programming. In this way, the DM can analyse the variability of the proposed salutation taking into account the uncertainty related to these parameters. To verify the feasibility of the proposed schedule, an agent-based simulation could be implemented in the DSS, with which to forecast how the plants and the supply chain will be stressed.

4.4.2.3 Implementation phase

The way to proceed in this phase is linear: the DM must evaluate the information coming from the previous phase, understand it, request the necessary authorizations and implement the solutions that it considers best.

In order to choose and implement the best solution, the DM must be able to explore and fully understand the alternatives proposed. To meet these needs two tools are useful: IDV and decision tables. These latter allow the DM to understand how the ranking of alternatives was made and what are the various constraints and requests that led to obtaining the proposed schedule, providing textual indications. The main downside is that they require a lot of work to be implemented. A further tool that can be used to graphically represent the characteristics of the proposed solutions are radar charts, which show information on the axes such as production costs, CO_2 emissions and other parameters of interest. These are particularly interesting because their shape allows a quick understanding of the properties of the solutions and allows a quick comparison between them: it is sufficient to compare the shapes to have at a glance an evaluation of the main differences.

The IDV can also be used to unlock the permissions needed to proceed with the implementation. However, this step depends on the company's internal policies.

4.4.2.4 Revision phase

At the end of the implementation phase, the DMs will have established the timing in which to start with the ramp-ups of the new models and the ramp-downs of the old ones, the SoPs and EoPs of the engines, and the various assignment of the engines to the models. This planning, being of long-term, is such that a lot of time will pass between the establishment of the dates and the actual beginning of the phases: in this period of time some of the parameters included in the DSS will change (e.g. CO_2 emissions limits). For this reason, it will be necessary to gradually update these parameters and monitor the situation in the revision phase: are the goals of the company always the same? How the external environment is changing? Are there any new market trends or new laws? These are some of the questions that the DM must keep in mind.

To better support this phase, the implemented tools must be able to allow the DMs to understand how the situation is modifying and how these changes affect what has already been established. Then, after comparing the new situation with the initial one, depending on the extent of the changes, the DM will decide whether to confirm the schedule or change it, returning to earlier phases.

Also in this case an IDV will allow to interact quickly and effectively with the data.

The tools chosen to help the DMs in reviewing and interpreting the changes are:

- Network diagram: Give a global view of the sharing of engines between the various vehicles. Including the production plants in this diagram and showing where motors and vehicles are made could give a clear vision of the solidity of the production and suppliers networks (the more "connections" and the more solid the production or supply of a module, because if a stop occurs in a plant or supplier there are others that can make up for this lack and continue to provide the modules in the required numbers). As already anticipated in the identification phase, this tool allows the DM to have an overview of the sharing of the modules, allowing him / her to quickly understand which are the most used.
- Pareto plots: show how much the vehicles ramp-ups stress the various production plants, this allows an immediate representation of the flexibility reserves of the various plants (it is sufficient to report the level relative to the maximum production capacity and check its distance from the first column of the diagram). Another Pareto plot can represent the CO_2 emissions of the various vehicles, in such a way as to indicate which are the ones to which the greatest attention should be paid.

4.4.2.5 Case Study conclusions

Having identified the methods and tools to compose the DSS, all that remains is trying to implement it and verify the implementability of what is indicated. The Framework not only allows this identification, but also makes the DMs reflecting on the way to proceed with the steps in such a way as not to neglect any passage.

The scheme proposed in this thesis can not guarantee the effective implementation of what it presents in specific cases to be addressed but always allows to have indications that can be precise (in the case in which the methods and tools identified are actually appropriate for the case in question) or rough (if methods and tools do not meet the requirements of the DM): passing from steps to the following lines the DM can guess what is the way to direct his research and get a DSS that meets its requirements.

CHAPTER 5

Conclusions

Abstract: This is the final chapter of the thesis, in which the obtained results are discussed and the conclusions of the work are drawn. The author also indicates what are the limitations and how this work could be improved with future research and applications.

5.1 Discussion of results

The developed DMP model has the function of making understand what is the way to proceed to establish decisions that are solid and competitive, regardless of the area in which the DM is operating.

In the world scenario characterized by the need to make critical and complex decisions in a short time, the need to support DMs with methods and tools that make the DMP steps faster and easier to play is continuously increasing. For these reasons, the DSSs are continuing to spread more and more.

With this thesis, the author hope to provide a new framework that will act as a bridge between the DMP steps and all the various methods, techniques and tools that have been developed over the years to support them. Given the increasing importance of DSSs, it is important to provide a framework that immediately allows the identification of the most suitable methods and tools to support the various steps; this implies that the design will be faster and more aware. To achieve this goal, the contribution made by some DSS experts operating in a major German automotive company was fundamental, as they provided indications on how to structure the work to make it effective and user-friendly.

The holistic approach with which the thesis has been developed will allow both professionals and those approaching the DSSs world to understand the complexity of these systems and have guidelines that help to unravel in this discipline. Understanding all the various problems that come into play will allow them to proceed with order in the implementation and to limit the errors that can be made in the development of a DSS.

A Case Study allowed to test the framework practically, verifying the topicality and competitiveness of the methods and tools it contains.

5.2 Limitations and future research

Given the big number of papers related to DSSs made for industrial management it was not possible to analyze them all, due to temporal constraints. The author has chosen which papers to study according to the following criteria:

- priority was given to the DSS related to the automotive world and strategic planning;
- no publications describing DSSs partially or not in a clear way were considered. This is due to the fact that some reviews of DSSs, which present the same information, have been identified and studying: considering also the individual papers would have been redundant;
- priority was given to those papers that present a complex and / or innovative DSS, i.e. those publication in which in addition to the evaluation part of the alternatives, much attention was given to the part of visualization and interaction with the user and in those in which more methods are combined to maximize performance and efficiency.

The author is aware that due to this selection may have been omitted some publications that could have made a tangible contribution to this thesis. In addition to this limitation, it must be emphasized that the work is based on an academic literature concerning many industrial fields (to be sure to create a framework that is solid and at state of the art) and for this reason there is no guarantee that all the methods and tools reported are actually implementable in the specific context of the reader. The provided guidelines also have the task of helping the reader to eliminate methods and tools that are not suitable for his / her applications.

In the light of the foregoing, first of all it is important that many experts will analyze and put into practice what is shown in this thesis, to understand its actual potentiality.

Considering the great work done in this field it will be appropriate to consider this thesis as a work in continuous development, by updating the various methods and tools as they are proposed by scholars and tested in industrial applications.

In conclusion, the author hopes that, when this work does not meet the needs of those who consult it, it can give the inspiration and useful indications on how to proceed. Later this new information collected by the reader should be included in the framework to make it more and more complete.

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	IDENTIFICATION	DEVELOPMENT	IMPLEMENTATION	REVISION
Steps	1. Problem formulation {C, D, E, F, G, H, I, K, L, M} 1.1. Objectives setting 1.2. Identification of influence factors {A, D, J} 1.2.1. Assigning weights to the factors {D, J} 1.3. Identification of constraints 2. Data preparation 2.1. Data collection 2.2. Data filtering 2.3. Check data quality {B} 3. Criteria definition 3.1. Criteria evaluation 3.2. Assigning weights to the criteria {D, J}	4. Generation of alternative solutions 4.1. Identification of ready-make solutions {C} 4.2. Modification of already made solutions 4.3. Definition of new solutions 5. Alternatives evaluation {A, B} 5.1. Identifying uncertainties 5.2. Determining decision action consequences {C} 6. Ranking of the alternatives	7. Selection {A, B, E, F} 7.1. Explanation {D} 7.2. Authorization 8. Implementation	9. Update 9.1. New objectives? 9.2. Check the situation statement {A, B, C} 10. Comparison {A, B} 10.1. Evaluate the difference between old and new goals 10.2. Compare the new situation with the previous one 11. Return to earlier phases / steps
Methods	1 – 1.1 – 1.2 – 1.3 i. Soft System Methodology (SSM) {C, E, F, G} ii. Strategic Options Development and Analysis (SODA) {E, F, G} iii. Strategic Choice Approach {E, F, G} iv. MARVEL {E, F, G} 1 – 1.1 – 1.2 – 1.2.1 v. Quality Function Deployment (QFD) 1.2.1. Monte Carlo simulation 3.2. Monte Carlo simulation	4.3. Bayesian inference 4.3. Birnbaum-cost measure method 4.3. Mathematical optimization (programming) {E, F} 5. Data Envelopment Analysis (DEA) 5.2. Agent-based simulation 5.2. Monte Carlo simulation 5.2. Bayesian inference 6. Multi Criteria Decision-Making Methods ➢ Weighted Sum Method (WSM) ➢ TOPSIS ➢ AHP (ANP) ➢ ELECTRE ➢ PROMETHEE ➢ Multi-Attribute Utility Theory (MAUT) ➢ SIMUS Method		
Tools	A. [DH] [AT] Data mining B. [DH] [AT] Database Management Systems C. [DH] CATWOE D. [DH] Strengths, Weaknesses, Opportunities, Threats analysis (SWOT) E. [VIS] Decision Tree F. [VIS] Network Diagram G. [VIS] Casual Loop Diagram (CLD) H. [VIS] Binary Decision Diagram (BDD) I. [VIS] Fuzzy Cognitive Map (FCM) J. [VIS] Pareto plots K. [ST] [VIS] Bayesian network L. [ST] [VIS] Markov network M. [ST] [VIS] Graph model N. [DH] [VIS] [AT] Interactive Data Visualization (IDV)	A. [VIS] Radar charts B. [VIS] Decision tree C. [AT] Neural network D. [VIS] Pareto plots E. Exact solution F. Heuristics (Approximate solution)	A. [VIS] Radar charts B. [VIS] Decision Tree C. [DH] [VIS] [AT] Interactive Data Visualization (IDV) D. [DH] [VIS] Decision tables E. [DH] Benefits, Opportunities, Costs, Risks analysis (BOCR) F. [AT] Neural network	A. [VIS] Radar charts B. [VIS] Network diagram C. [VIS] Pareto plots D. [DH] [VIS] [AT] Interactive Data Visualization (IDV)
Legend	[DH] = DATA HANDLING; [VIS] = VISUALIZATION; [ST] = STATISTICS; [AT] = ADVANCED TOOLS			

APPENDIX B

Riassunto esteso

Abstract: In questa appendice è riportato il riassunto esteso in lingua italiana.

Per garantire la sopravvivenza e la competitività delle aziende nella realtà industriale moderna è di fondamentale importanza elaborare una corretta pianificazione strategica, che corrisponde alla definizione degli obiettivi di lungo termine e delle modalità e risorse necessarie per raggiungerli (Chandler's, 1962). Le decisioni prese in questa fase vanno a delineare la struttura e la competitività dell'azienda per molti anni; a titolo di esempio può essere preso in considerazione il mondo dell'automotive nel quale solitamente l'introduzione dei nuovi modelli è pianificata 5 anni in anticipo e definisce a grandi linee la capacità produttiva di questi ultimi per i successivi 12 anni (Fleischmann et al., 2006).

Data la grande complessità ed importanza del processo con cui vengono prese queste decisioni (DMP) negli anni sono stati svolti molti studi riguardanti sia il processo stesso, e come condurlo in modo efficace e corretto, sia metodi e strumenti per supportarlo. Questi metodi e strumenti sono spesso di difficile utilizzo (soprattutto al complicarsi degli scenari e delle decisioni da prendere) e, per questo motivo, negli anni hanno raggiunto un'importanza sempre maggiore i "Decision Support Systems" (DSS), cioè software che implementano metodi e strumenti creati dagli studiosi per aiutare manager ed ingegneri nel processo decisionale.

L'importanza e la complessità di questi sistemi, il gran numero di metodi e strumenti disponibili (ognuno dei quali risponde a determinate richieste ed è applicabile a particolari situazioni) e la necessità di una delle maggiori aziende al mondo produttrici di automobili di sviluppare un DSS per la pianificazione dell'introduzione nel mercato dei nuovi modelli hanno fornito le motivazioni per lo sviluppo di questa tesi, la cui principale Research Question è la seguente:

RQ: *"How to design a Decision Support System (DSS) that helps practitioners in the automotive industry with the planning of new vehicle introductions?"*

Questo DSS, oltre a dover trattare un problema con obiettivi contrastanti (una decisione buona per un obiettivo potrebbe portare ad una schedulazione impossibile per altri obiettivi) come accede per quasi la totalità delle decisioni da prendere nel mondo industriale, deve tenere conto anche di una serie di problematiche tipiche dell'industria automobilistica, quali andamenti del mercato particolarmente turbolenti e la globalizzazione dei siti produttivi, di vendita ed assistenza.

Lo sviluppo della tesi è stato effettuato svolgendo le seguenti fasi: è stata condotta un'estesa revisione della letteratura per definire nel modo più completo possibile il DMP, trovare i metodi e gli strumenti elaborati dagli studiosi negli anni e analizzare i DSS più rilevanti progettati negli anni; è stato elaborato e proposto un modello di DMP, è stato progettato uno strumento per aiutare gli sviluppatori di DSS nella scelta corretta di metodi e strumenti ed infine è stato realizzato un concept di DSS che rispondesse alla RQ.

L'analisi della letteratura ha messo in luce la mancanza di un modello di DMP moderno e che risponda con efficacia alle necessità delle aziende moderne, per questo motivo il primo risultato di questa tesi è stato quello di allineare i vari modelli presentati in passato e di proporre un modello che oltre ad avere delle solide basi, sia anche attento alle esigenze attuali (sezione 4.2). Questo modello presenta quattro macro-fasi (identificazione, sviluppo, implementazione e revisione) all'interno delle quali vanno condotti degli steps. La struttura di questo modello va adattata alla particolare situazione in cui viene impiegato.

Lo strumento per aiutare gli sviluppatori di DSS (sezione 4.3) contiene tutti i vari metodi e strumenti identificati dall'autore della tesi e li mette in relazione coi singoli steps che possono supportare, fornendo inoltre delle linee guida che spiegano le caratteristiche e le limitazioni principali di ogni metodo e strumento: in tal modo analizzando il modello di DMP proposto (e adattato al caso specifico in esame) è possibile identificare subito quali metodi e strumento possono essere implementati per realizzare un DSS che sia solido ed efficiente. Sono inoltre trattate alcune delle caratteristiche e delle criticità comuni a tutti i DSS.

Il case study (sezione 4.4) è relativo alla creazione di un concept che descriva in che modo strutturare un DSS relativo ad un aspetto della pianificazione a lungo termine nel settore dell'automotive: l'introduzione dei nuovi veicoli. Questo DSS non è relativo al solo aspetto "commerciale", cioè non va solo a schedulare quando lanciare nel mercato i nuovi modelli ma affronta il problema da una prospettiva molto più ampia e cioè tenendo conto della fase di ramp-up e ramp-down dei modelli negli impianti, la comunanza dei moduli, l'andamento delle vendite e le emissioni di CO_2. Gli output di questo DSS sono tre: la definizione delle varianti (abbinamento carrozzeria + motore), la produzione dei motori e l'inizio e la fine produzione dei veicoli.

Oltre agli obiettivi già esposti, una delle speranze dell'autore è quella di fornire, con questa tesi, una sorta di ponte tra la realtà accademica, volta alla creazione di metodi e strumenti efficienti ed innovativi, e la realtà industriale, nella quale è importante ottenere decisioni implementabili, efficienti ed in tempi brevi. Tramite lo schema realizzato dall'autore la sviluppo di un DSS potrà essere svolto in modo molto più veloce, schematico e, soprattutto, limitando la possibilità di incappare in errori. Data la vastità dell'argomento l'autore è consapevole della possibilità di aver omesso pubblicazioni rilevanti nella fase della revisione letteraria, inoltre, il gran lavoro che gli studiosi continuano a svolgere in questo campo è tale per cui questa tesi non va considerata come un lavoro concluso ma sarebbe opportuno continuare ad integrare i nuovi metodi e strumenti man mano che vengono progettati e che ne viene dimostrata l'efficacia.