POLITECNICO DI TORINO

Master of Science in Automotive Engineering

MASTER’S DEGREE THESIS

Pietro Penna

POLITECNICO DI TORINO

Master of Science in Automotive Engineering

Management of Industrial Processes

Project Portfolio Management

A Case Study in Punch Torino

Developed in:

Supervisor:
Professor Paolo Chiabert

Candidate:
Pietro Penna

December 2021

INTRODUCTION

The car industry started as a niche craft production by specialized workshops and coachbuilders. It was Henry Ford who shifted the balance towards standardized mass production. The economic principle on which it is based is economies of scale; from Henry Ford onwards, all industrial policies are always geared towards absorbing fixed costs. The automotive industry is now facing an unprecedented slump in demand but above all an intensification of emissions regulations by the world's major governments.

Automotive manufacturers are operating under capacity utilization with markets fragmented into small niches and increasingly demanding in terms of quality and technological content. As a result of differing emission regulations, two trends are emerging: on the one hand, the need to produce new-generation, fuel-efficient, and environmentally friendly cars for rigid markets in rich countries; on the other hand, the need to produce low-cost cars for low-motorization markets. In this globalizing scenario, technological innovation is becoming a strategic imperative for companies capable of changing the dynamics of creating competitive advantage. To maintain competitiveness, companies need to continuously invest in technological projects. However, the constraints placed on the exploitation of resources require their strategic allocation to subsets of projects that are more accredited, i.e. with a higher probability of success. A variety of decision-making tools can be applied to select the optimal set of projects upstream in the portfolio management process.

The scope of this thesis is powertrain technology, in particular, it aims to provide a perspective of what are the most representative and well-known approaches of project selection within portfolio management. An application case developed in collaboration with the New Business Development team within Punch Torino has as an object a potential improvement of the project portfolio management process, applying the abovementioned techniques to a real case of project selection, providing prioritization of R&D projects.

1. An Overview of the Automotive Sector

The automotive industry has played a key role in the global economy since its inception. In 2020, more than 78 million motor vehicles, including cars and commercial vehicles, were produced worldwide (Figure 1-1), making this manufacturing sector the first in the world in terms of turnover. The automotive industry includes industries associated with the production, wholesale trade, retail trade, and maintenance of motor vehicles, and it has always been the leading manufacturing industry in each nation, according to its size in terms of workers and turnover, but also in terms of all the businesses associated with it, starting with raw materials.

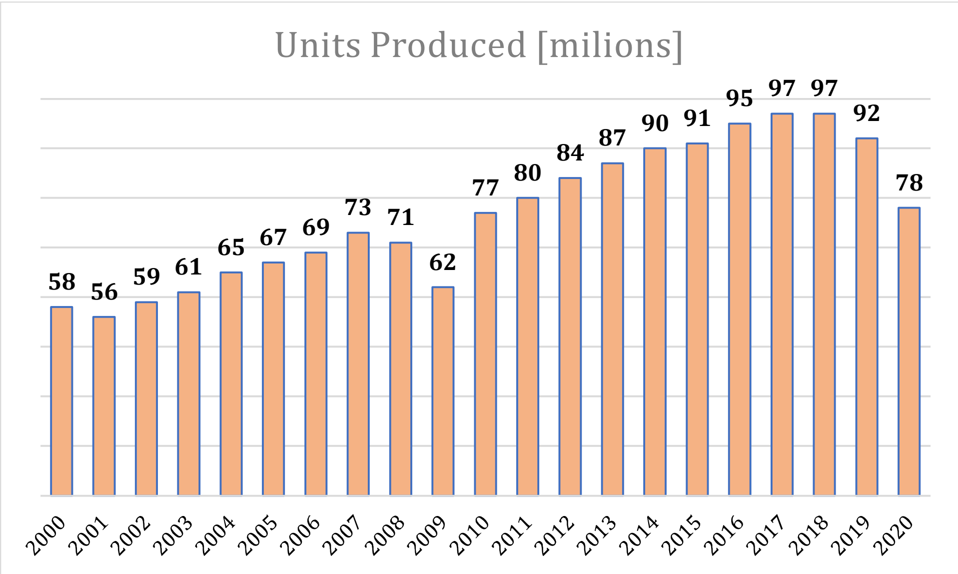

Figure 1-1: Worldwide Motor Vehicle Production 2000-2020[1]

The companies active in the automotive sector that is responsible for the assembly and production of motor vehicles are the OEMs (Original Equipment Manufacturers). At the beginning of the car industry's life, many companies had to leave the market, even among those who had most influenced the evolution of 4-wheelers with their aesthetic or mechanical innovations. The set of countries that

[1] Source: https://www.statista.com/statistics/262747/worldwide-automobile-production-since-2000/

make up the largest automotive markets and are home to the car manufacturers responsible for most of the vehicles produced in the world, are Europe, Japan, and the United States, as can be seen in Table 1-1.

Industrial Group	Nation	Vehicles
Toyota Group	Japan	9.3 milion
Volkswagen AG	Germany	9.1 milion
Renault – Nissan – Mitsubishi Alliance	France / Japan	7.8 milion
General Motors	U.S.A.	6.8 milion
Hyundai - Kia	South Korea	6.4 milion
Stellantis	Italy / U.S.A.	6.3 milion

Table 1-1: World's Largest Automakers in Terms of Units Produced in 2020[2]

The Chinese, Russian and Indian industries are also beginning to enter the global car market, although their production is still very limited and mainly oriented towards the assembly of products under license or the construction of models intended mainly for their domestic market.

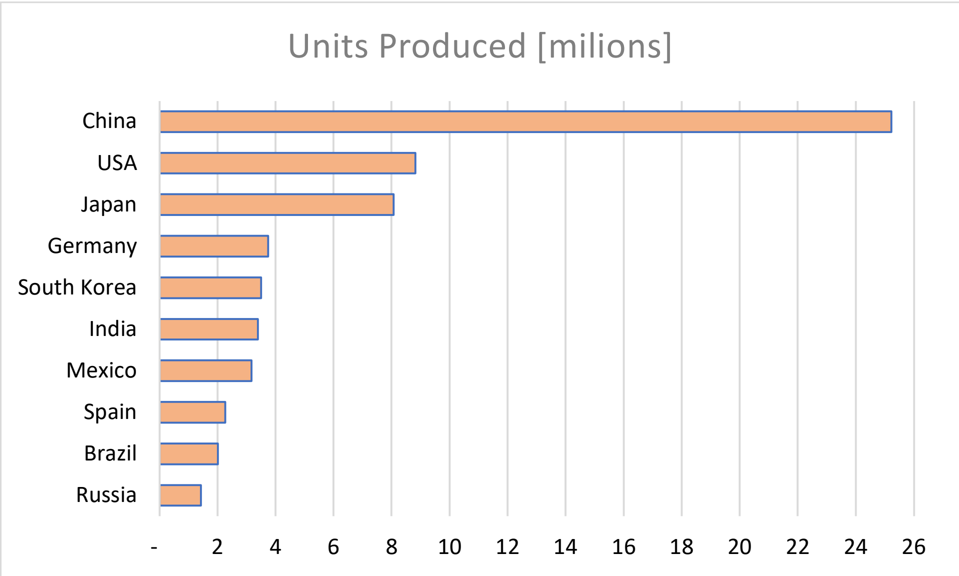

Figure 1-2: Worldwide Motor Vehicle Production 2020[3]

[2] Source: https://en.wikipedia.org/wiki/List_of_manufacturers_by_motor_vehicle_production
[3] Source: https://www.oica.net/category/production-statistics/2020-statistics/

The automotive industry is essential to the world economy, employing many skilled workers and providing a vital boost to knowledge and innovation. It is where the largest private investment is made, particularly in research and development (R&D), reaching 85 billion every year (source: OICA), to bring to market a range of models incorporating increasingly innovative and, above all, sustainable technologies. It also makes a significant contribution to the gross domestic product (GDP) of the globe. Building, assembling, and equipping almost 80 million vehicles employs around 10 million people, representing 5% of total manufacturing employment worldwide. It is also estimated that each 'direct auto job' supports at least another 5 indirect jobs in the community: there are thus more than 50 million jobs thanks to the automotive sector. Cars are built using goods from a variety of industries, including steel, iron, aluminium, glass, plastics, textiles, electronics, rubber, and more (the industry is the largest purchaser of these materials in the US). The car manufacturing industry is considered to be highly *capital and labour-intensive*, and in many countries, a large proportion of production is exported. The main sources of cost to produce and sell cars are labour (while machines and robots are playing a greater role in vehicle production, there are still substantial labour costs in car design and engineering), materials, and advertising (car manufacturers spend billions of euros each year on print and broadcast advertising and have spent large sums of money on market research to anticipate consumer trends and preferences).

1.1. THE MAIN HISTORICAL STAGES

The evolution of the automotive sector has been influenced by various innovations in fuel consumption, production methods, as well as changes in markets, suppliers, and company structures. Since its inception, the automotive industry has been characterised by significant phases of structural evolution that have led to major changes in products, manufacturing methods, but also in the theoretical principles behind them, as well as in the concept of the car itself. Initially, the car was born in European machine shops as a luxury good. The year 1913 marked an important date for the world economy: Henry Ford introduced the assembly line and conveyor belt to his company, hand in hand with the victory of the petrol engine. The first car with an electric starter was introduced in the same year. These were not purely technological developments: the theory of Taylorism introduced new standards of productivity, partly redefining the role of the worker, and opening up human and social issues. On the one hand, the new working class rebelled against these dynamics by coining the derogatory term 'Fordism', and on the other hand, the first step was taken towards the mass production of cars that could be affordable for the lower classes. The crucial process innovations implemented by Henry Ford and later by Alfred P. Sloan at General Motors (the introduction of a multi-divisional structure) made it possible to achieve economies of scale by lowering production costs, thus favouring the evolution of the car into a mass production good. In the United States, during the first two decades of the 20th century, there were a multitude of car manufacturers, which by the end of the 1920s had been reduced to just three major producers: **General Motors Company**, **Ford Motor Company**, and **Chrysler Corporation**. These three large companies enjoyed significant advantages over the smaller companies because of their financial strength, which guaranteed great advantages in marketing, production, and technological innovation until the 1980s. In the same years, several companies in the sector emerged (notably **Volkswagen** and **Mercedes** in Europe) and some car manufacturers started to acquire other companies and attempt to expand into foreign markets. During the Second World War, most production facilities were adapted to the production of weapons and military vehicles. The world's major economies, especially in Europe and the Far East, were destroyed and this fact encouraged the emergence of new strategies and more efficient production methods, as **Toyota** did, paving the way for **lean manufacturing**. Between the 1950s and 1960s, several technological innovations, such as fiberglass bodies and higher fuel compression ratios, improved vehicle performance as well as comfort and, above all, safety. In addition, the 1970s were characterised by strict environmental regulations that led to the development of technologies capable of reducing polluting emissions, such as the catalytic converter. 1964 was an important date for the US market: US President Lyndon B. Johnson signed legislation introducing a 25% tariff on imported pick-ups. This tariff has remained in force to this day and has guaranteed American manufacturers' dominance in this market segment: Ford's F series has been the best-selling vehicle in the USA for years, with records of over 900 thousand units in 2005-2005. Finally, the 1980s saw the rise of Japanese manufacturers, with the gradual spread of the production methods they had developed and the beginning of the decline of the three big American companies. *Toyotism* did not have the revolutionary effects of Fordism, but it did change consumer expectations and forced manufacturers to change their strategies and organisational systems. The basic idea of this philosophy is to maintain a continuous flow of the production process that adapts to changes in demand. It is a production system that guarantees continuous and perfect symmetry between the supply of goods produced and the demand coming from the market. The Japanese model, using **just in time** (**JIT**), tends to release products in short and differentiated series, continuously adapting them according to fluctuations in demand; it is, therefore, the market that drives production. European and American OEMs have had to adapt to the practices introduced by the Japanese: since the 1990s, the average lifespan of the models produced has fallen sharply compared to twenty years earlier, while the average number of models launched per year by each manufacturer has increased dramatically, along with the quality of the products and the percentage of work carried out by external suppliers. The major car manufacturers have started assembling vehicles all over the world.

The sector has been characterised by numerous acquisitions and mergers of multinational companies on different fronts and for often heterogeneous reasons over the last thirty years (a merger with the aim of market expansion, the case of Renault - Nissan, companies similar in terms of products operating in different territories), or collaboration agreements between two or more companies that aim to carry out a joint project involving the synergic use of resources provided by each individual participating company, but also a fair sharing of the risks linked to the investment itself or a fair distribution of possible losses or profits. These contractual forms are called Joint Ventures. The most important ones that have taken place in recent years are: GM - FIAT (2000) to share platforms and engines, and therefore R&D costs; GM and a Russian manufacturer (AvtoVAZ) to bring an SUV to the Russian market; Peugeot - Citroën and Toyota to build a new car in Kolin in the Czech Republic. The logic of the merger is therefore as follows: to make agreements between complementary companies that will make it possible to expand the markets served (with a good balance between developed markets and those taking off), the market segments (from low-cost to premium cars) and the fuels. Market research conducted by KPMG in the field of statistics on a sample of 200 executives from among the most influential companies in the sector confirms the willingness of automakers to conclude joint venture agreements or simple strategic alliances to find the resources needed to support R&D (31%), followed by self-financing (26%) and bank debts (18%), as illustrated in Figure 1-3.

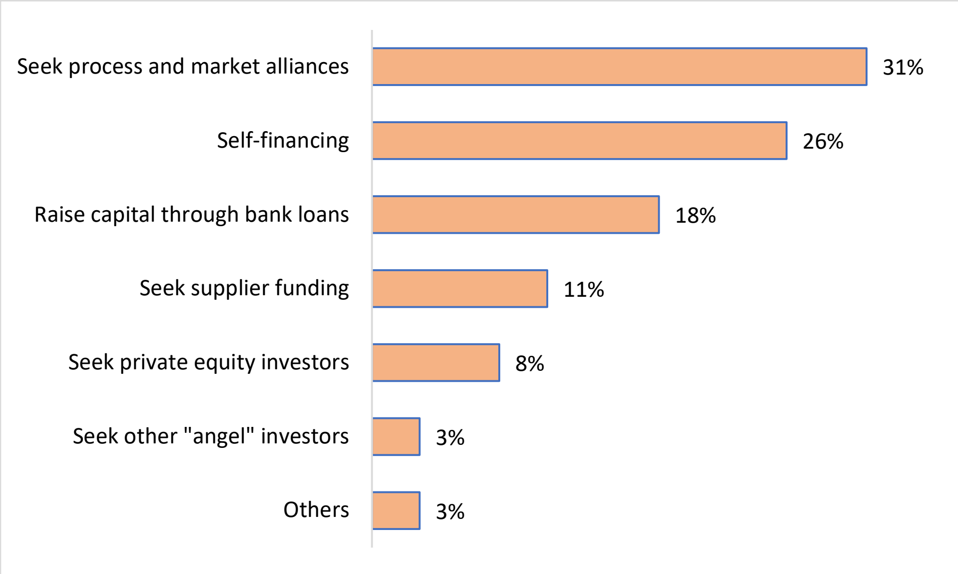

Figure 1-3: The research conducted by KPMG demonstrates the willingness of manufacturers to collaborate and create strategic alliances to find the necessary resources to keep R&D activity alive. This is followed by self-financing, debt to the bank, other financial intermediaries, venture capital, and finally through private investment[4]

In addition, strong global expansion and internalisation have given the major car manufacturers a greater ability to infiltrate new markets quickly and cost-effectively, and the range of products on offer to consumers has increased. The economy is becoming global due to four major processes: financial globalisation, the liberalisation of international trade, and the emergence of newly industrialised countries, as well as a drastic reduction in distances thanks to new means of communication. In this scenario, the main car manufacturers choose to relocate some production sites to different regions or countries with more favourable conditions

[4] Source: KPMG's 2011 Global Auto Executive Survey

(especially lower labour costs) and define their sales strategies and investments on a global scale. After lean production, the strategic focus of companies shifted to how they organise their supply systems, which saw the relationships between companies and the characteristics of their interactions change, first with the introduction of JIT techniques, through the integrated supply, and finally with outsourcing strategies geared towards modular outsourcing[5].

1.2. THE VEHICLE DEMAND CHARACTERISTICS

Europe, the United States, and Japan: these three geographical areas have characterised the global automotive system since the 1970s and represent the regions that make up the largest automotive markets and are home to the car manufacturers responsible for the majority of vehicles produced worldwide. Since the 1990s there has been a reversal of this trend: these large markets have become mature and car manufacturers have been looking at other trade areas such as China, Brazil, India, and Mexico where there are favourable conditions for the growing demand for vehicles. So, the car market is indeed a growth market, but it is a market in which, while the countries where the historic manufacturing companies are rooted are still those with the greatest production in absolute terms, the growth rates indicate a progressive shift of the production axis towards the countries of South-East Asia. The **BRIC** markets (**Brazil**, **Russia**, **India,** and **China**) represent the reference points for the sector's growth, given their low motorisation rate (Figure 1-4), a high number of inhabitants, and therefore very low levels of per capita car ownership.

[5] The main feature of the integrated supply chain product essentially concerns the extension of the range of services entrusted to the supplier, whose role "is no longer that of making parts to the customer's design but that of supplying complex entities, being responsible for the development, design, quality and reliability of the systems themselves" (Bianchi, Enrietti, 1999, 16-17). The new profile of the supplying company is expressed in two different directions; on the one hand the supplying company becomes an integrator to the system, responsible for the sub-systems of the final product, its design and industrialisation, the interchange with the various manufacturers specialised in the production of the single parts and must take charge of the whole logistical dimension of this management. On the other hand, it becomes a supplier of modules, i.e. it undertakes to supply the final company with 'pre-assembled' modules which will then be sent to the company and assembled into the final product.

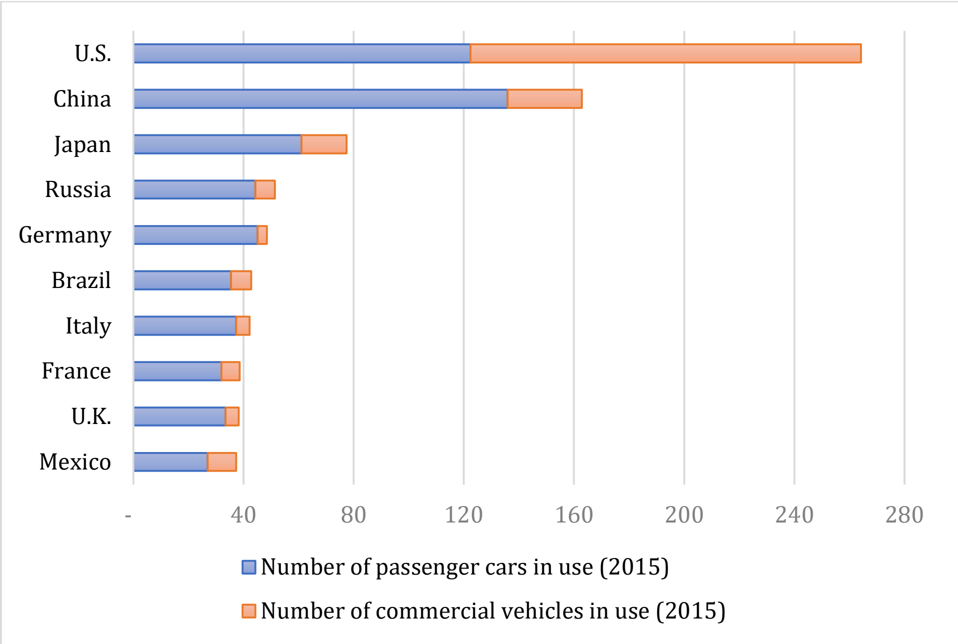

Figure 1-4: Number of Vehicles in Use by Country (in Thousands of Units) (2015)[6]

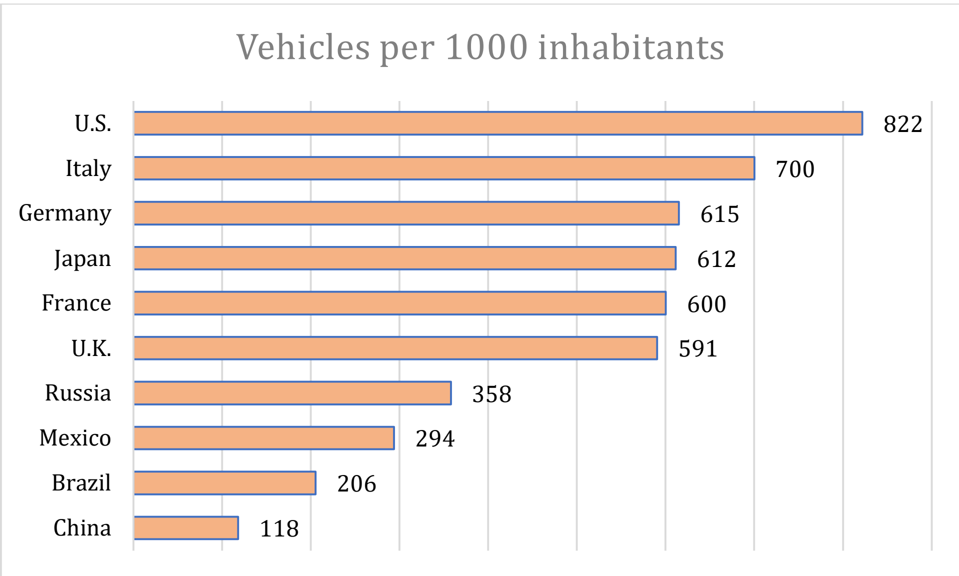

Figure 1-5: Number of Vehicles Per 1000 Inhabitants (2015)[7]

Countless factors explain the differences, including marked differences in the structure of demand for motor vehicles in different macro-areas. The nature of

[6] Source: Organisation Internationale des Constructeurs d'Automobiles (OICA)
[7] Source: Number of vehicles (OICA), 2015 population (Wikipedia)

demand for motor vehicles is influenced by a combination of socio-cultural factors, local conditions, and tax regimes which, despite globalisation, remain closely divided.

In the **USA**, larger cars continue to prevail (fewer than in the 1980s and 1990s), especially SUVs (Sport Utility Vehicles) and CUVs (Crossover Utility Vehicles), normally equipped with V6 petrol engines and automatic traction, while the market share of diesel and hybrid engines remains very low, with the latter growing in recent years especially in regions such as California or large metropolises. In western **Europe**, cars with a smaller size, fuel consumption, and engine capacity, typically with manual drive and increasingly with diesel engines, prevail (the market share stands at 50% for both engines, with petrol increasing also because of the rise in hybrid vehicles, which are predominantly petrol-powered but remain a niche market). Firstly, these different demand patterns are due to local conditions (smaller roads in Europe and longer journeys in the USA), but also to tax regimes, i.e. higher fuel costs in Europe and stricter emission limits.

In emerging countries, the same factors influence the nature of demand for motor vehicles. In **South America**, and particularly in Brazil, demand for small cars with petrol engines prevails as they benefit from significant tax breaks. They are also leaders in the use of alternative fuels (such as ethanol). However, the use of diesel engines remains prevalent in the field of commercial vehicles, mainly due to the lower cost of the fuel itself and the greater reliability of the engines (larger size linked to lower consumption, with engines tending to be more durable). The **Asian** market is quite different, with fast-developing countries (such as China and South Korea) implementing emissions' standards in line with the European and American ones, investing in electrification (Japan is the leading country from this point of view, especially for what concerns the hybrid vehicles), and others more similar to the South American ones, such as India and the Middle Eastern ones (the same applies to Russia). The main challenges for some African and Asian governments in the future concern regulations on pollutant emissions in line with Europe and the United States.

The three factors which have led to a series of changes in the demand for motor vehicles, in the strategies of the OEMs, and in the relationships between them are the following:

- Instability and fluctuations in oil prices,
- A greater focus on the environment, eco-innovations, and the promotion of sustainable transport,
- The role of the BRICs.

A significant trend in recent years, as a consequence of the points listed above, has been the growth of sales in the lower segments. This trend has long roots in Europe, in fact, since the beginning of the 1990s, there has been a clear upward trend in sales of small cars, a trend that first accelerated in 2006 and a second stronger one in 2009, to cover 44.7% of registered cars. During the same period in Europe, sales of 'low-medium cars fell to 29.7% and of 'high-medium cars to 15.1%, and there was a modest fluctuation in premium models between 10 and 15% of registered cars, which are the segment with the highest economic returns[8]. This significant increase in the sales volumes of small cars has lowered the profit margins of some car manufacturers operating mainly in these segments (Hyundai, Peugeot, Opel, etc.), while groups operating in the high-end segment such as Mercedes or BMW, whose sales prices are much higher, are less exposed.

Population growth and economic development have damaged the state of the environment around the world, and this has become a widespread phenomenon in recent years. North America and Europe are increasingly concerned about climate change (China has recently come into the picture) and the role that man-made greenhouse gas emissions play in global warming. Emissions from the world's most advanced economies grew by 5% between 2000 and 2007, a tenth of the increase recorded during the same period in the developing world. The transport sector is one of the sectors that contribute most to the increase in atmospheric pollutant emissions, and strong attention is paid to transport at a global level and by individual countries to comply with the Kyoto Protocol. In 1991, the European Union issued a series of directives on pollutant emissions from vehicles, forcing car manufacturers to make significant changes to engine architecture to be able to market vehicles in the EU. Based on these directives, five categories of vehicles have been identified (Euro 1, 2, 3,

[8] "La situazione dell'industria automobilistica nel mondo all'inizio del 2010, Un Rapporto a cura di Francesco Garibaldo per la Provincia di Torino". Bologna, 2010.

4, 5, 6 and Euro I, II, III, IV, V, VI for commercial vehicles); the abbreviation Euro followed by a number indicates the standards introduced periodically by the European Community with increasingly stringent limits for CO2 emissions measured in g/km for civil vehicles and g/kWh for commercial vehicles. However, the European Union is not alone on the road to limits on car emissions, but it has the US administration at its side: new models of cars and light transport vehicles marketed in the USA from 2012 will have to guarantee fuel savings of around 5% per year.

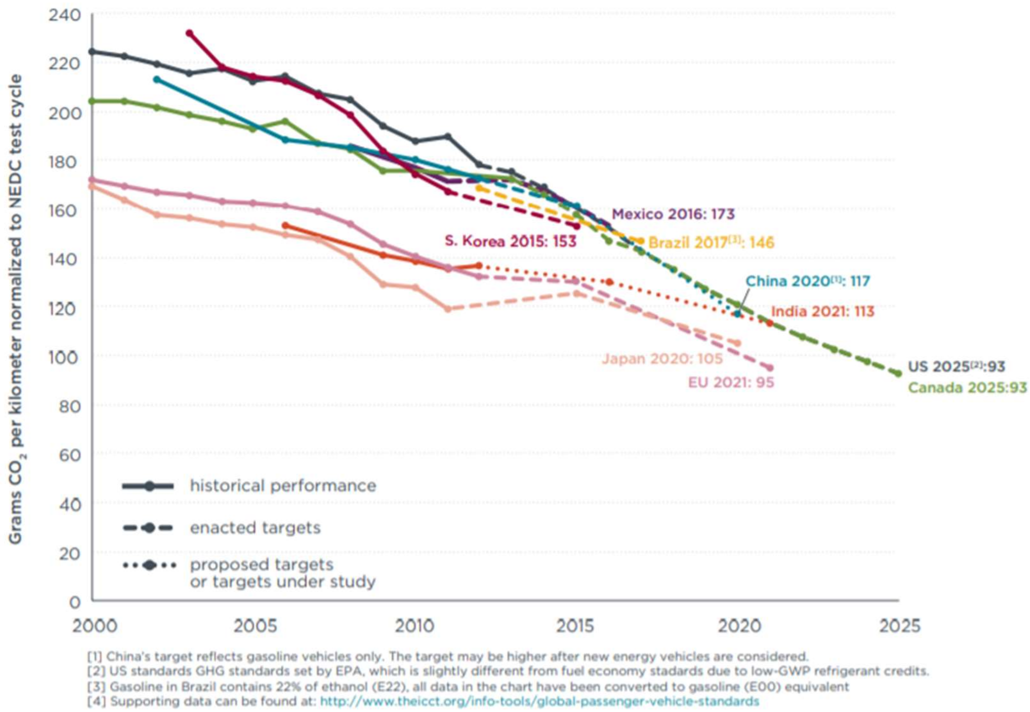

Figure 1-6: Comparison of CO2 Regulations for Passenger Cars, in Terms of NEDC gCO2/km[9]

The regulations for CO2 standards that have been introduced and will be intensified in the coming years force car manufacturers to renew their car fleets, on the one hand, thus encouraging innovation and the search for more efficient and environmentally friendly solutions, and on the other hand avoid risky collapses in car sales: customers are forced to replace their cars if they do not meet the requirements of the new regulations. The new technologies in the field of powertrain developed by

[9] Source: International Council for Clean Transportation (ICCT), 2014

OEMs that have made it possible to achieve excellent performance in terms of reducing pollutant emissions, refer to technical optimizations made to mature architectures, such as traditional internal combustion engines, or to so-called hybrid technologies (a vehicle equipped with two propulsion systems, (a vehicle equipped with two propulsion systems, such as an electric motor coupled to the traditional combustion engine), up to completely innovative technologies, such as electric cars or hydrogen cars, which are much less polluting than traditional engines, but have much higher development costs (with the former becoming increasingly popular in the global market, also thanks to a decrease in the development costs of batteries and an improved range, as shown in Figure 1-7).

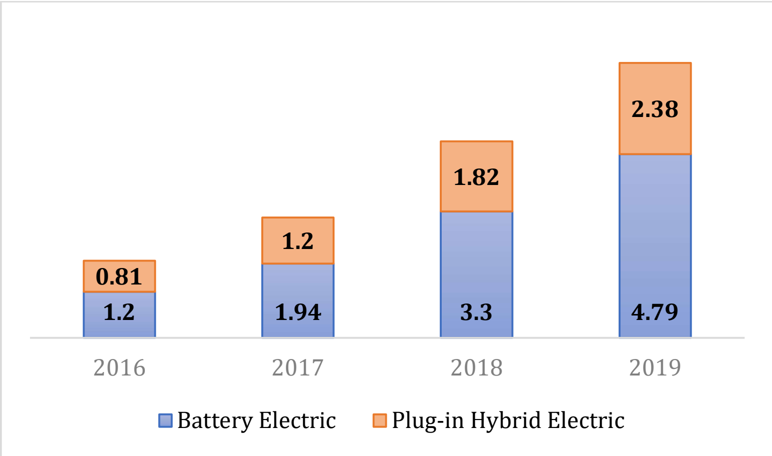

Figure 1-7: Number of Electric Vehicles in Use Worldwide (In Million Units)[10]

[10] https://www.statista.com/statistics/1101415/number-of-electric-vehicles-by-type/

2. PUNCH Torino

PUNCH Torino is the core company that allows the PUNCH Group to lead the engineering of innovative propulsion systems and control solutions, based on the unique combined expertise of developing, producing, and integrating proven technologies, systems, and processes towards turnkey solutions[11].

PUNCH Torino vision and values:

"We provide our partners with innovative engineering solutions and affordable products for a sustainable mobility, building our excellence around people"

Figure 2-1: The Turin Engineering Centre

The story of the engineering Centre starts in 2005 becoming GM Powertrain Europe, after the divestiture of Fiat-GM Powertrain. The site has dramatically increased during the last decade, becoming a centre of excellence – General Motors Global Propulsion System – with its 700 employees from 12 different nations, and the offices located in the 'Cittadella Politecnica' (University Campus). The Centre was responsible for the design of diesel engines for the entire GM group and was also in charge of the design and development of the ECUs. In February 2020 Torino site has been acquired by the Belgian PUNCH Group, becoming PUNCH Torino.

[11] Source: https://www.punchtorino.com/

Today, PUNCH Torino's commitment focuses on the future of sustainability, with a shift towards green solutions, as demonstrated by the recent creation of a new company, PUNCH Hydrocells, for the research and development of hydrogen-related solutions. Diesel technology anyway still represents the company's core business, as demonstrated by its ongoing collaboration with General Motors on the development of new propulsion systems, combining performance with low emissions and high fuel economy, for all the major markets such as Europe, North America, Brazil, China, and Russia, both in the automotive and marine industry. The belief in the diesel technology is also demonstrated by the R&D effort of the Centre to investigate innovative solutions, as an additive manufacturing-enabled piston design, to improve engine-out emissions and thermal efficiency beyond Euro 6 (research conducted in cooperation with GM and Istituto Motori).

The company is structured in three main areas:

- **Engine Hardware**, responsible for the design and development of engines from concept to serial production, leveraging a wide cross-functional skillset. It includes the departments of:
  - *Design and Release of Components*, responsible for CAD/CAM design, digital mock-up, materials engineering, additive manufacturing.
  - *Computer-Aided Engineering* (*CAE*) department that deals with structural and NVH analysis, Computational Fluid Dynamics (CFD), and system analysis.
  - *Development, Calibration, and Validation* whose target is to optimize the engine performance and emissions with specific testing activities, and finally assess and validate the engine hardware.
  - *Engineering Quality*
  - *Cost Engineering and Benchmarking*, to evaluate the competitiveness of components and products, by analysing products and strategies of competitors.
  - *Advanced Engineering*, is responsible to develop new technologies and integrate them into new products, by exploiting a mix of expertise in most of the engineering areas.

- **Controls**, responsible for the design and development of controls algorithms, On-Board Diagnostic (OBD) in compliance to major markets regulations, and finally for the design, integration, testing (SIL[12], HIL[13], V-ECU[14]), and software production release. The controls department is also responsible for the electronic hardware design, analysis, and validation. Recently, the *Data Analytics* team has been introduced; it combines Artificial Intelligence and Data Science skills to improve OEMs' needs in product quality, implementing technologies such as fleet management, field data analysis, predictive maintenance, etc.
- **Testing and Labs**. The Centre is equipped with 19 Firing High Dynamic Test Cells with climatic, barometric, and NVH capability designed for testing activities oriented to engine calibration, validation, hardware development, combustion R&D, and ECU development. In addition, chassis dyno activities are carried out on 2WD roller benches to provide coast down procedures, durability cycles, road load simulations, and other activities.

  The facility is also structured to guarantee a wide set of component testing activities to support the propulsion systems development with data analysis and benchmarking studies, such as airflow benches for ducts, valves, and turbos, and hydraulic benches for fuel pumps and injectors.

[12] Software-in-the-loop (SIL) refers to techniques for testing electronic control units using full software emulation of the system for which they are intended.
[13] Hardware-in-the-loop (HIL) refers to techniques for testing electronic control units by connecting them to special benches that more or less fully reproduce the electrical and electronic system they are intended for.
[14] Virtual HW ECU in the loop (V-ECU). The goal is to frontload the testing process by enabling software teams to create and run their software tests before the actual ECU hardware is available. Higher quality tests, higher quality software and a more streamlined "in-the-loop" flow is the intended outcome of this solution.

3. The Investigation Field

The following chapter is dedicated to investigating the *Project Portfolio Management* background, by analysing the project's main characteristics, the processes that lead to the definition of the portfolio, and the relative key roles involved, and the most popular selection techniques present in the literature. The chapter also includes a brief section of the Agile techniques, applied to portfolio management.

3.1. PROJECT PORTFOLIO MANAGEMENT

The project portfolio analysis and planning had seen its growth in the 1990s, as business portfolio planning did in the two previous decades. Some of the new criteria addressed in the process of portfolio selection included (and still do) the organization's objectives and priorities, financial benefits, intangible benefits, availability of resources, and risk levels[15].

In the modern globalized context, technological innovation becomes a strategic imperative to gain a competitive advantage over the competitors. The strategies adopted define the company's approach to its competitors in terms of market and products, making it clear which opportunities are to be pursued. The main innovation strategies that can be adopted by a company include (Ulrich and Eppinger, 2000):

- <u>Technological Leadership</u>: to pursue this strategy, the company invests in research and development of new technologies, their application, and the development of new products.
- <u>Cost Leadership</u>: this strategy pursues the competitive advantage by reaching the best production efficiency, thanks to economy of scale, optimized production processes and management, and lower labour costs. Emphasis is given to the production.

[15] Schniederjans, Mark J., & Santhanam, Radhika (1993). A multi-objective constrained resource information system project selection method. European Journal of Operational Research.

- Focus on Clients: with this strategy the company's objective is to develop close relationships with its clients, evaluating their needs and preferences.
- Imitation: this organization follows the market's trends, leaving to its competitors the research of new products.

Strategic planning is the process through which businesses gain a competitive edge by defining medium/long-term goals and techniques for achieving them. On a secondary level, strategic planning is responsible for the coordination of the concerned company's divisions (such as R&D, marketing, finance, and so on) to guide them in the achievement of the strategic goals specified.

The link between the strategic planning and the operational activities is represented by ***portfolio management*** that, based on the strategic objectives identified by the top management, defines the project portfolio, meaning the set of projects considered more remunerative and aligned with the company's strategy.

To understand the role of portfolio management from the point of view of strategic planning it is necessary to refer to the *resource-based* approach, in which the company is defined, based on its resources (people but also physical assets like machinery, etc.) and on the organizational routines that link and activate these resources. Given that the routines describe both company's activities and knowledge, we will talk about *competencies*; when some competencies are particularly relevant inside the company, usually are referred to as *core competencies*. Those competencies that the enterprise actively manages to make them an integral part of their strategy are often called *capabilities*. It sometimes happens that these areas of excellence of the company turn into traps, and especially when the success factors change over time into constraints, making the company rigid, closed, and against change (Leonard-Barton, 1992). Finally, the *resource-based* view of a company presents it as a continuously changing and improving environment, seeking a better fit in the economic and technological context, re-organizing its sources and routines, and pursuing better profitability. These activities are called *dynamic capabilities*.

3.1.1. PROJECT PROPERTIES

In its broadest sense, a project can be defined as "a complex effort, usually less than three years in duration, made up of interrelated tasks, performed by various organizations, with a well-defined objective, schedule, and budget." A program is "a long-term undertaking which is usually made up of more than one project." A task is "a short-term effort (a few weeks to a few months) performed by one organization, which may combine with other tasks to form a project." The foregoing definitions are from Archibald (1992)[16].

A project portfolio is a collection of projects, and/or projects under one or more programs, that are carried out under the sponsorship and/or administration of an organization. As a result, these projects must compete for scarce resources (people, finances, time, etc.) available from the sponsor, because it is uncommon to have enough resources to carry out every project that is proposed and meets the organization's minimum requirements for certain criteria such as potential profitability, etc. This results in a need to select among available projects to meet the organization's objectives in some optimal manner, however that may be defined[17].

To have a better understanding of project portfolios is necessary a brief understanding of what are the attributes that characterize the projects, and the complexities that arise in the selection process[18].

Life Cycle - A project goes through a series of more-or-less well-defined phases, through a build-up in size and resource consumption until a peak activity value, after which starts to decline to reach its natural ending. The generic definition of project phases includes:

- Identification and Feasibility Analysis.

---

[16] Archibald, Russell D. (1992). Managing High-Technology Programs and Projects (Second Edition), New York, NY: Wiley.
[17] N.P. Archer, F. Ghasemzadeh (1996). Project Portfolio Selection Techniques: a review and a suggested integrated approach. Innovation Research Working Group, Woking Paper no.46.
[18] Meredith, Jack R., & Mantel, Samuel J., Jr. (1995). Project Management: A Managerial Approach (Third Ed.), New York, NY: Wiley.

- Planning. To plan a project means to forecast its evolution, so as to optimize the timing, the use of resources. The planning activity is about the identification of the physical elements forming the project (*schematization*), identification of the execution processes for each of the physical elements of the project and evaluation of the required quantities and resources, and the assignment of the executive responsibilities.
- Programming / Scheduling. Programming is the activity of assigning due dates and time constraints to all identified activities in order to define the *Project Plan*, which is the master document that describes the temporal deployment of the project's activities, based on the constraints coming from the resources' availability. Scheduling is the "core" of the programming phase: it generates the detailed project plan, by defining the project's calendar and assigning expected start and finish dates to the project, according to the activities' estimated duration, the sequencing, and possible constraints (*project milestones*). After having defined the project dates (under the hypothesis of infinite resource availability), it is necessary to compare *required resources* and *available resources*, taking into account possible priorities among the activities. Two criticalities may occur:
    - *Overload* when the required resources exceed the available,
    - *Underload* when the available resources exceed the required.

  Two are the *levelling* techniques:
    - **Fixed duration scheduling**: the total duration of the project cannot change, and the available resources must be increased
    - **Fixed resource scheduling**: the total amount of resources cannot be increased, meaning it is necessary to postpone the project's final deadline.
- Monitoring and Control. Monitoring is the activity of verification of the progress of the project activities, identification, and analysis of possible variations concerning planned performances. The control activity, on the other hand, consists of the actuation of the identified recovery actions. The control system of a project is a cyclic process: it enables to anticipate the consequences of past

events in order to plan recovery or response actions before that those consequences may occur.

- Budgeting is a process that develops in subsequent phases during the project: during the feasibility phase, a draft of the project's budget is defined and, after the go/no go approval, it is analysed and updated during the programming phase, according to the planned activities and the estimated efforts.

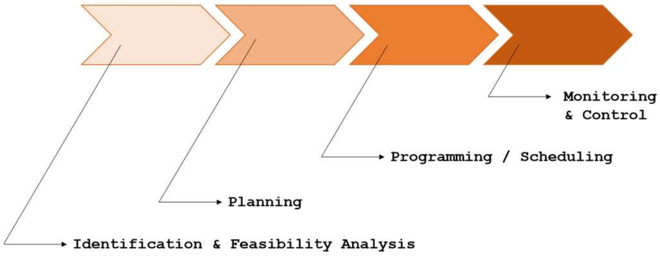

Figure 3.0 Project Phases During Its Life Cycle

Projects vary in size and complexity. No matter how large or small, simple or complex, all projects can be mapped to the following life cycle structure (see Figure 3-1).

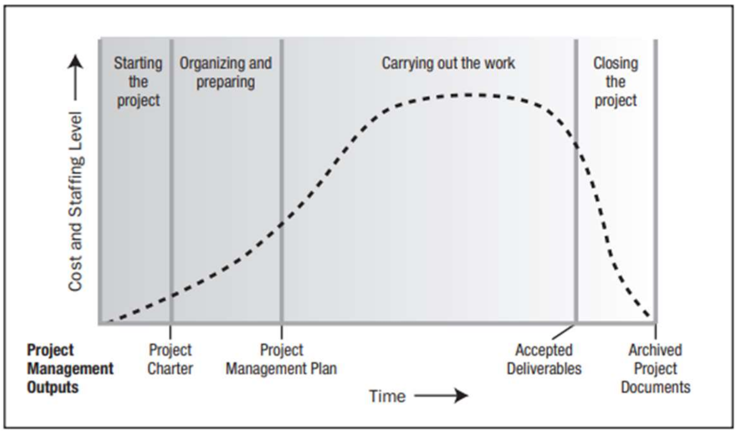

Figure 3-1 Typical Cost and Staffing Levels Across the Project Life Cycle[19]

This generic life cycle structure is often referred to when communicating with upper management or other entities less familiar with the details of the project. This high-

[19] Project Management Institute (2011). A guide to the Project Management Body of Knowledge (PMBOK guide). Project Management Institute.

level view can provide a common frame or reference for comparing projects (even if they are dissimilar in nature).

Interdependencies - In most organizations, it is usual to carry out several projects in parallel, and there is frequently an interaction between the project organization (i.e., R&D department) and other functional areas (i.e., marketing, production, finance) which have vested interest in the project; that is, a project can be carried out on the functional area's behalf, and/or it may consume resources which they control.

Uniqueness – Every project has some characteristics which are unique and require special attention in selecting it for inclusion in the development portfolio or requires some customization in the way it is managed if selected.

Conflict – Every project selected must compete for scarce resources and the attention of management at every phase of its life cycle; the amount and type of resources required, along with the management activity, depends upon the phase of the project.

Complexities - Many complexities can arise in the project's selection process, including:

- Multiple and often conflicting objectives (or criteria),
- Difficulties in determining the trade-offs among the various criteria. In this respect, organizations must be careful not to overemphasize, in establishing selection guidelines, internal policies, and budget controls; instead, is important to consider other non-tangible criteria (i.e., strategical objectives, that not always are remunerative),
- Additional complexities arise from the fact that some evaluation criteria are qualitative, thus based on the judgement of the stakeholders, making it difficult the comparison between different factors. Moreover, in the selection process, the risk associated with each project (both in the development phase and in the marketplace – commercial risk) must be considered, and there may be a large amount of uncertainty associated with both the risk level and the scoring of individual projects on each specific criterion. Uncertainty in estimating project

parameters tends to decline as the project moves from its early to later life cycle stages, while risk must be initially assessed and continuously monitored during the development phase.

- In addition to the difficulties linked with project objectives, often several constraints must be considered; among them, the most important ones include overall project budgets, scheduling, resources availability and capabilities, and the market.

Selection of, or adjustments to, a project portfolio is a continuous process that recurs at regular intervals. Projects previously included in the portfolio should also be re-evaluated at appropriate “milestones” and “gates”, in competition with new projects or projects not previously included in the portfolio and kept on hold.

3.1.2. PORTFOLIO MANAGEMENT

A first approach to project portfolio management dates back to the fifties when Harry Markowitz[20] laid the foundations of the modern theory of portfolio *Modern Portfolio Theory*. La MPT allows determining a specific mix of investments that will guarantee the highest level of profitability, keeping a low risk. In the beginning, the MPT was thought only for financial investments and, only in 1981, McFarlan[21] focuses his attention and his studies on a potential application of the MPT to IT (*Information Technology*) projects. In 1992 Wheelwright and Clark[22] developed a structure for the categorization of projects, called: *The Aggregate Project Plan* to map innovation projects based on the degree of novelty of production technologies. According to the authors, whose study was aimed at the realization of innovation activities, companies

[20] Markowitz’s study was based on the analysis of the process that generates the demand and supply of financial assets according to the risk/return ratio expressed by them. The basic principle that governs Markowitz’s theory is that to build an efficient portfolio it is necessary to identify a combination of securities such as to minimize the risk and maximize the overall return by compensating for the asynchronous performance of individual securities. To make that happen, the securities that make up the portfolio must be unrelated or, rather, not perfectly correlated (Markowitz H. Portfolio selection. J Financ 1952).

[21] McFarlan FW. Portfolio approach to information system. HBR 1981 (Sept-Oct): 142-151.

[22] Wheelwright SC, Clark KB. Creating project plans to focus product development. HBR 1992; 70(2): 67-83.

should build aggregate development plans of new products that consider the direct relationship between the degree of novelty of the project, risk, and profitability. As the first increases, in fact, the risk inherent in the project increases as well, both from a technical and commercial point of view. However, the greater the novelty of the project and its riskiness, the greater the expected return on the investment.

The **project management** discipline, initially born to manage complex activities at an operative level, gradually became a key competence for companies also at a strategic level. Thanks to a coordinated set (portfolio) of projects, companies carry out the continuous transformation of products and processes that are the basis of the research and the protection of their competitive advantage. The focus of the *project management* then is on the single projects, at an operative level, intending to manage and control the correct execution of such projects within the established time frame. At an upper level, the **program management** has the task to coordinate sets of interdependent projects (called programs) so that each of them has the right resources' allocation, making sure that the results obtained at the end of such programs are in fact usable downstream from either the ordinary operating activities or from other projects. Even if the *program management* is above the project management, it is not given decisions of a properly strategic nature. The objectives of a program are clearly more complex and articulated than those of a single project and usually consist in the execution of a business strategy. Above the program management, we finally find the **portfolio management**, whose job consists in the definition, selection, and addressing of the whole set of projects and programs that constitute the business's project activities. The aim here is strategic, as the portfolio management sets the objectives. For a better understanding of the differences between *project*, *program*, and *portfolio management* refer to table 3.0.

	PROJECTS	PROGRAMS	PORTFOLIOS
Scope	Restricted	Broad and subjected to variations	Oriented to business, follow corporate strategy
Change Management Policy	Avoided	Accepted and exploited	Continuously monitored
Performance Criteria	Project's completion according to time, cost, and result	ROI, benefits, and new capabilities brought to the company	Aggregate performance and impact on business
Organizational Relationships	Mainly with professional figures employed in the projects	With stakeholders and project managers	With top management and staff personnel
Required Competencies	Authoritativeness in operational tasks and team building ability	Political and strategical	Analysis and decision-making ability
Planning	Detailed realization, closely followed	Aggregate realization, continuously revised	Aggregate realization, continuously revised
Monitoring	Direct	Governance	Observation of results and performances of projects and programs

Table 3.0 Comparison Between Projects, Programs, And Portfolios[23]

A first key component of a company's *project portfolio* is then constituted by those projects that the organization undertakes to implement its strategic policies and actions, to modify them, on the technological and organizational components of the firm's *operations*. These projects' goal is to increment the company's capabilities to create value but, on the other hand, they will not directly add value since it will be created by the operations (i.e., the implementation of a new production line, the acquisition of a new production technology, etc.). At the same time, companies do not improve their capabilities just through projects whose deliverable is specifically constituted of a structural or organizational change. Companies prepare more operative projects (i.e., development of a new product) and, thanks to the new competencies learned, also these projects end up causing an organizational change, that can have strategic value. By noticing this, the firm's product development plan

[23] Cantamessa, M., Rafaele, C., Cobos, E. (2007). Il Project Management. Un approccio sistematico alla gestione dei progetti. s.l.: Isedi, 2007.

gains a fundamental role in the corporate strategy. From one side, it becomes the endpoint of the traditional hierarchical approach of strategy: the firm set a strategic direction, from which derives a set of projects, which in turn determine a change in company assets (material or knowledge) and, based on those assets, the company can develop new products. On the other side, the product's development plan turns into the starting point of an alternative approach[24]: the company identifies a strategic direction and implements a product development plan that is partially (and intentionally) not aligned with the organizational competencies; by engaging in such actions, the company expects to clash with its limits and to acquire, through a (or more) learning process, those missing assets. This means that, in practice, many of the operational projects (as the development of new technology, new product, or the entrance in a new market) acquire a value that goes beyond the economic return attributable to the same.

The project portfolio of a company will be constituted both by "change" projects, whose launch is due to the need to implement the business strategy and by operational ones, mostly linked to research and development activities, in which the strategic content related to change and knowledge gain may have, depending on the case, a more or less relevant role. This project portfolio will constitute in effect the link between the company's strategy and ordinary operational activities. It will be managed by the activities of **project portfolio management** based on the strategic objectives set by the top management and on the requests coming from the company's functions. The *portfolio management* will decide on the activation of these projects, observing their evolution and periodically deciding on their execution. The link between *portfolio management* and *operations* arises, in the first place, from the balance the company is required to find when planning between a *top-down* approach, in which the priority is the translation of the corporate's strategy into projects aimed at change, and a *bottom-up* approach, from which emerges the role of the company's functions in exposing their needs and ideas for change.

[24] As an example, Helfat C.E., Raubitschek R.S. (2000). Product Sequencing: Co-evolution of Knowledge, Capabilities and Products. "Strategic Management Journal", Vol.21 No.10, pp.961-79.

In the first case, the portfolio manager sets ex-ante the budget to be assigned to the different projects and for the realization of the single strategic actions. This approach requires a remarkable initial decision effort but allows budget management to be at least partially decentralized at the different company functions. In the second approach instead, the proposals come from below and the portfolio manager must implement a method to screen the projects, based on some relevant criteria, by evaluating the expected returns and the alignment with the company's strategy. In this approach, the manager always has a clear and detailed picture of the whole set of projects, but obliges him to a continuous decision-making process, dynamic and hard to follow. Moreover, it will be harder to communicate and implement a corporate strategy, which might also be far from the proposed projects. In business practice anyway, it is difficult to find pure systems such as *bottom-up* and *top-down*. Most of the companies have developed systems that can be defined as "hybrid", in which the planning activity is an articulated communication and negotiation process between the company's functions and decision-makers. In this decision process, the strategic-oriented initiatives will follow a *top-down* approach while all the others will be planned in a *bottom-up* one (Cantamessa et al., 2007).

Finally, in the *project portfolio management* context, it is good practice to devote adequate attention to the relationships with staff resources that can influence the effectiveness of the planning process and the subsequent translation into projects. In particular, are relevant the links with the following functions:

- **Administrative and Financial Bodies**. Projects portfolio constitutes a remarkable investment for companies. While planning, it is essential to understand the boundaries within a project that should be approved. The administrative body is essential in supporting an effective reporting action that helps to keep under observation the expenses and the returns achieved.
- **Human Resources**. Most of the time, the actuation of a portfolio's project is bound to the availability of human resources more than financial ones. It is not always possible in fact to guarantee an adequate means of resources with the required competencies to the projects, and as well it is difficult to find these resources outside the organization. Moreover, it is the responsibility of the

portfolio management functions to ensure that the simultaneous use of resources on routine projects and activities does not coordination problems or tensions inside the organization. Finally, the strategic value of the project portfolio makes it necessary the creation of an adequate information structure to communicate the status of the projects in the most widespread way within the company.

- **External Relationships.** The strategic nature of the projects portfolio makes it necessary to build an external communication strategy that updates the various stakeholders involved, such as clients, suppliers, public institutions, etc.
- **Marketing.** In the projects portfolio's management are frequently necessary marketing competencies: competitive benchmarking, market analysis, pricing strategies, and many others.

3.1.3. PROJECT PORTFOLIO PROCESS

The aggregate planning process of projects does not merely imply a decision on the launch of the single project but requires a modulation between different projects coherently with the company's strategy. For example, a company whose objective is to improve its competencies on an unexplored technology will allocate many resources on R&D projects. On the other hand, a company seeking the competitive advantage through diversification will set up its aggregate plan on multiple development projects, eventually rationalizing this effort through the introduction of "platform projects" to allow a common base technology for the different products' variants to be realized. A company to obtain a competitive advantage based on costs instead will invest in projects aimed at the development of production systems that guarantee low production costs and high volumes.

The absence of a systematic approach to portfolio management means that the number of projects tends to be elevated and chaotic since the lack of formal controls on the strategic coherence or the availability of resources makes it quite easy to start the projects, but the lack of ongoing formal controls makes it impossible to finish them. The absence of formalized criteria for the management of projects may also have technical consequences, as it prevents every project from having specific and clear objectives, synergically with other projects. Thus, "omnibus projects" will tend to take place in which, for example, the relatively limited objective to adapt a product for a new market might be associated with the one to develop and apply an innovative process technology, with the risk to accomplish none of the two.

According to the PMI standard (*Project Management Institute, 2011*)[25], the project portfolio management, therefore, consists of two main moments. The first is the activities that lead to the structuring of the portfolio itself, by individuating and approving the projects and the programs coherently with the company's strategy and with the available resources, supported by the *Aligning Process Group* which determines how components will be categorized, evaluated, selected for inclusion, and managed in the portfolio. The second instead is the monitoring and revision activities of the portfolio, supported by the *Monitoring and Controlling Process Group* which reviews performance indicators periodically for alignment with strategic objectives and verifies the benefits for the organization from the components of the portfolio. These two moments in turn are inserted between the activities for the formulation of the strategic plan and the execution of projects and programs. Based on the PMI's standards is possible to identify fourteen activities for this process (Table 3-1). There is a tight connection between the Portfolio Management Process Groups and the ongoing business process cycle of developing a business strategy, aligning projects and programs to that strategy, and monitoring the results of these decisions. Figure 3-2 shows the links between portfolio management processes, Process Groups, and the organization's strategic plan. The diagram illustrates:

- **The organization's strategic plan**: the decision base for any project portfolio management process and the basis for establishing the determining factors that will make each portfolio unique.
- **Portfolio management process**: a series of interrelated processes, from identifying and authorizing portfolio components to review the progress of

[25] Project Management Institute (2011). The Standard for Portfolio Management. Project Management Institute.

those components. These processes accommodate strategic plan changes by revisiting the aligning process.

Strategic Planning & Business Process Context	
Aligning Process Group	**Monitoring & Controlling Process Group**
➢ Identify components ➢ Categorize components ➢ Evaluate components ➢ Select components ➢ Analyze portfolio risks ➢ Analyze portfolio risks ➢ Prioritize components ➢ Develop portfolio risk responses ➢ Balance portfolio ➢ Communicate portfolio ➢ Authorize portfolio	➢ Monitor and control portfolio risks ➢ Review and report portfolio performance ➢ Monitor business strategy changes

Table 3-1: Portfolio Management Process Groups

The process flow diagram, Figure 3-2, provides a summary of the basic flow and interactions amongst Process Groups, strategic plan, and the project management process. A Process Group includes the constituent portfolio management processes that are linked by the respective inputs and outputs, where the result or outcome of one process becomes the input for the following one. Notice that Process Groups should not be thought of as portfolio management phases, that instead is a set of inter-related business management processes, supported by the Process Groups, performed to achieve a pre-specified result.

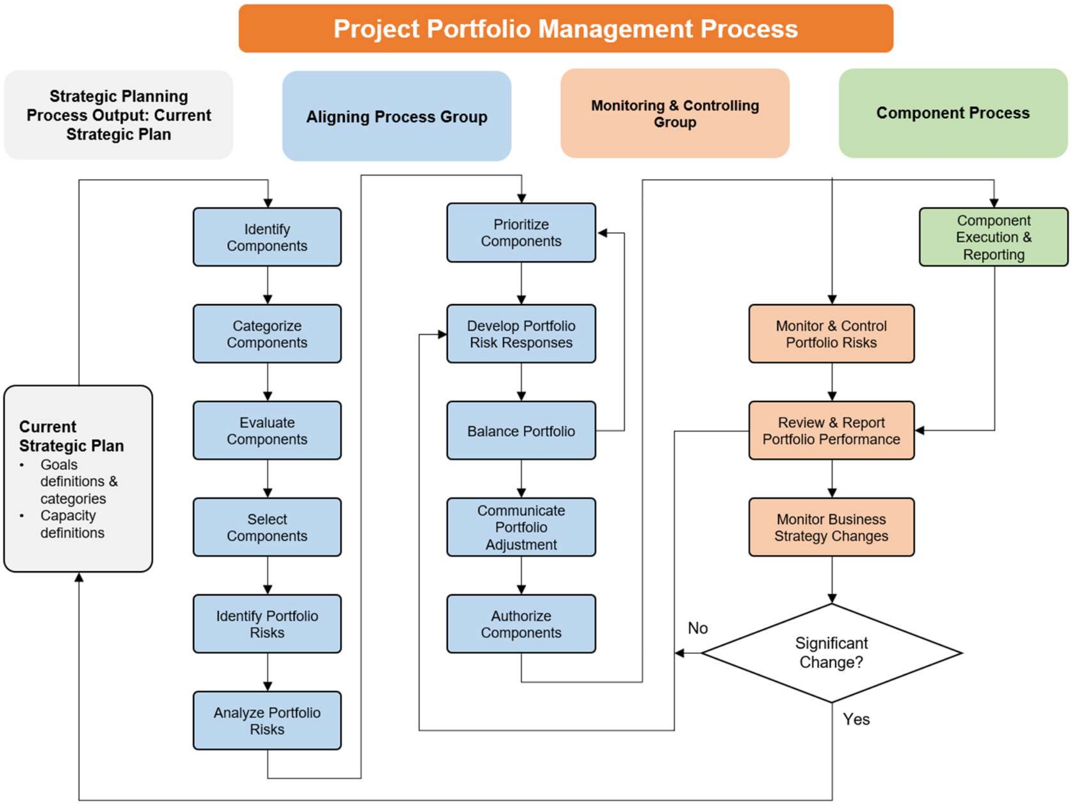

Figure 3-2: Portfolio Management Processes – High-Level Illustration

The following section will provide a brief overview of the main processes that constitute portfolio management, focusing mainly on the *categorization of components*.

Identification – is responsible for structuring and maintaining the register of the components (projects, programs, activities that constitute the portfolio). This register usually includes both the approved and ongoing projects and those that are being defined. The main part of this activity consists in defining a list of descriptive characteristics of each component, necessary to confront and choose them (i.e., component type – project or program –, the relationship with the company's strategy, strategic benefits, etc.).

Categorization – is responsible to create a taxonomy for the portfolio components and assigning each of them to the most appropriate category. This activity is essential because, when deciding whether take out a project or continue it, these must be compared with components with similar structural characteristics. To create homogeneous categories of components moreover allows performing top-down budgeting, with which the top management outlines the resources to be assigned to each category and leaves to the *portfolio managers* the task to identify and take out the best projects inside them. The categories are typically defined based on the nature of the project (development of a new product, investments of production systems, improvement of profitability, adaptation to regulations, organizational improvement, etc). As an example, a classification based on four types of projects (Figure 3-3), based on the innovation degree of the product's technology and of process's will be proposed (Clark and Wheelwright, 1992)[26]. **Clark** and **Wheelwright** identify four degrees of the novelty of the technology, both of product and production, that are:

- Radically new
- Next generation
- Capacity extension
- Marginal modification

Combined with the two relevant dimensions of project complexity a sixteen-quadrant matrix is obtained, in which they identify areas of coherence about new product development projects. The authors moreover identify two macro-areas of projects outside the abovementioned matrix. The first is constituted by the projects of "true" research and development, that do not yet have direct finalization of product or production process and are located outside the development process of the new product; the second one consists of R&D projects carried out in the form of an alliance and cooperation with other undertakings or research institutions. Clark and Wheelwright underline the importance of also highlighting this macro-category of projects; they argue that often, according to their empirical survey, projects carried out collaboratively are not considered in the overall policies of project aggregation and resource allocation, although these cannot be considered invariant concerning the contribution they make to the competitiveness of the company. Among the "true" R&D projects of a new product the authors distinguish, regardless of the mode

[26] Clark, K.B., Wheelwright, S.C. (1992). Managing the New Product and Process Development. New York: The Free Press, 1992.

(autonomous or collaborative), between *breakthrough*, *platform*, and *derivative* projects. The first class represents the innovation projects with the higher risk and expected profitability (advanced R&D and radical innovation). The expected design effort does not only concern the product's technology but also the manufacturing, thus for the company the effort for these projects is considerable. It probably represents a "forefather": the technological complexity is such as to induce to concentrate the resources on the achievement of precise technical objectives, postponing to a second phase, in which the product will also have demonstrated the validity of an idea on the market, the evaluations on upgrades of the product and processes. The **platform** projects instead are less complex aggregates for what concerns the depth of the single technologies employed, but more strategically relevant and important for marketing, due to the width of the final goal and for the number of competencies embedded. In fact, they bring together all the next-generation product development projects starting from a breakthrough and the resulting incremental product and process innovations. These projects represent therefore a long-term aggregate, finalized to the management of one (or more) generations of products and correlated production technologies, in the different market segments in which the product may find applications. Moreover, the consistency between product interventions and innovations in the production method allows maximising the efficiency of production and logistic processes, therefore generating greater margins and, ultimately, value. The last class of R&D projects, the **derivatives**, concerns the extensions of use of the family and production technology, the modifications, the marginal and progressive refinements to the product and process. Even if it cannot be considered marginal in terms of resources consumption inside the organization, and actually the share of design and development time dedicated to it is increasing the greater the company's innovative effort has been in the past, the strategic horizon of these projects is quite limited. Sometimes, in practice they are defined as *"continuous improvement"*, meaning that they guarantee the quality of product and process of the company, but with reactive behaviour and quick fixing of problems. The platform project represents a non-negligible investment; it allows to implement a series of derivative projects with a very low marginal cost. The overall R&D costs of the platform project and all its derivatives generally will be smaller than if each project had been carried out independently. This allows to realize in an economic way the differentiation strategy (Porter, 1980)[27], with a high degree of customization of the products to market segments or even to individual customers: in these cases, we speak of *mass customization*. Once the business strategy has been defined, it is fundamental to align the projects portfolio to it in an iterative way and solve the conflicts in the resources' allocation and portfolio balancing.

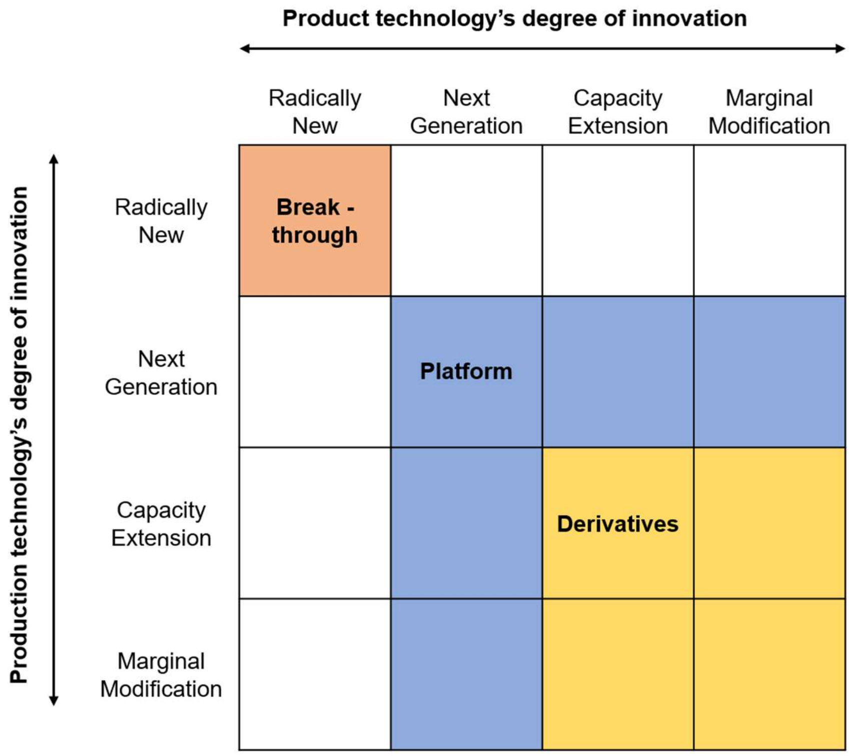

Figure 3-3: Wheelwright & Clark Aggregate Project Portfolio Framework

Evaluation – it is responsible to use the data gathered in the previous phases and potentially missing ones, to reach an objective opinion on each project; this opinion will be the input for the following phase of selection.

Selection – it is responsible to identify and produce a subset of organization's components worthy of pursuit based on the evaluation recommendations and the

[27] Porter, M. (1980). Competitive strategy: Techniques for analysing industries and competitors. New York: The Free Press, 1980.

organization's selection criteria (in the following chapter an overview of the main selection techniques will be provided).

Prioritization – it is responsible to assign, for each of the selected projects, a priority index that helps the decision-makers to make a definitive choice of inclusion or exclusion.

Balance – it is responsible to integrate the prioritization's phase with some wider considerations to support the next programs' authorization phase. This phase allows to find the right balance between the portfolio's components respecting all the constraints, starting from human and financial resources, always keeping in mind the strategic objectives. During this phase are identified the critical resources for which it will be possible the external sourcing or propose to the top management investment's recommendations.

Authorization – it consists in the formulation of the relevant decisions by the decision-makers, in their communication to the different stakeholders, and in the official assignment of the requested resources to the approved components.

3.2. PROJECT PORTFOLIO SELECTION TECHNIQUES

Many articles and books have been published on the subject of project evaluation and selection, covering well over a hundred different techniques (Cooper, 1993)[28]. These techniques appear to fall into two broad categories: *benefit measurement techniques* and *project selection/resource allocation techniques* (Baker and Freeland, 1975)[29]. Although some techniques fall into both categories, the first deals with the evaluation of individual projects on some basis (economic or otherwise), whereas the second deals with the development of project portfolios based on known evaluations of candidate projects.

---

[28] Cooper, Robert G. (1993). Winning At New Products (Second Ed.), Reading, MA: Addison-Wesley.
[29] Baker, N. R., & Freeland, J. (1975). Recent advances in R&D benefit measurement and project selection methods. Management Science, 21, 1 164-1175.

3.2.1. BENEFIT MEASURMENT TECHNIQUES

Benefit measurement techniques can be defined as systematic procedures for collecting and integrating subjective and objective benefit data. Baker and Freeland (1975) offer the following classification based on the thought processes imposed on the respondents, although a particular benefit measurement method may belong to more than one of these classifications.

COMPARATIVE APPROACHES – includes approaches such as *Q-sort* (Souder 1984)[30], a psychometric method for categorizing items based on the opinions of a group of people and eliciting group consensus on these categorizations, *Ranking* (Martino 1995: pairwise comparison, and the Analytical Hierarchy Procedure or AHP)[31], *Standard Gamble*[32], and *Successive Comparison* (Churchman & Ackoff 1954[33]; Pessemier & Baker 1971[34]). In these methods, the alternatives are first compared and then a set of project benefit measures, based on the stated preference, is computed. In general, once the projects have been arranged on a comparative scale, the decision-makers can work their way down the list, selecting projects until all available resources have been depleted. The majority of these techniques are simple to understand and apply, and they allow for the integration of quantitative and qualitative attributes. There are also some drawbacks, such as the difficulty to compare a large number of projects, the lack of explicit dependence to the risk, a rigid structure that obliges to repeat the process each time a project is added or deleted from the list, etc. The most famous and used between these approaches is the

---

[30] Souder, William E. (1984). Project Selection and Economic Appraisal, New York, NY: Van Nostrand Reinhold

[31] Martino, Joseph P. (1995). R&D Project Selection, New York, NY: Wiley.

[32] The standard gamble is a method based on the von Neumann–Morgenstern axioms of expected utility theory. It seeks to assess the 'utility' of a health state by observing people's willingness to accept a certain risk of death in order to avoid the state. A respondent is typically asked to consider a choice between two alternatives in a typical framing of the standard gamble. In alternative A, the person would live with certainty for the rest of his or her life with a specific health problem (the one for which the valuation is required). Alternative B is typically described as a risky treatment with two possible outcomes: life in optimal health with probability p or immediate death with probability (1-p). The standard gamble's measurement goal is to determine the probability of optimal health, p, at which the respondent is 'indifferent' between alternatives A and B, in other words, the point at which the two alternatives appear equally appealing.

[33] Churchman, C.W., & Ackoff, R.L. (1954), An approximate measure of value, Operations Research, 2

[34] Pessemier, E.A., & Baker, N.R. (1971). Project and program decisions in research and development, R & D Management, 2(1).

Analytical Hierarchy Process (**AHP**), developed by Thomas Saaty[35] in the 1970s, whose main use is to select a project from a list. The AHP method can be used to determine the cost/benefit ratio of a project whenever it is not possible to evaluate the pros and cons from just a financial point of view. In general, the method allows to prioritize programs/intervention strategies/projects etc., with the final goal to reach the objectives' success. The following steps are involved in AHP to solve a decision problem:

Step 1 – Establishing the decision hierarchy by decomposing the decision problem into a hierarchy of interconnected decision elements.
Step 2 – Gathering input data through pairwise comparisons of decision elements.
Step 3 – Estimate the relative weights of decision elements using the "eigenvalue" method.
Step 4 – Add the relevant weights of decision elements to produce a set of ratings for the decision alternatives.

The major advantages of AHP method are:

- It organizes the decision problem into stages that relate to a situational understanding: goals, criteria, sub-criteria, and alternatives. The decision-maker can focus on smaller sets of decisions by breaking the problem down into levels (Harker 1989)[36].
- Only two parameters are compared at a time; this enables analysts and decision-makers to better focus on, comprehend, and discuss issues.
- People frequently differ on some judgements, yet these disagreements usually have little or no impact on financial decisions; AHP enables sensitivity analysis, which reduces the rhetoric in discussions that frequently occur in group settings (Harker 1989).
- Handles qualitative as easily as quantitative factors.

[35] Saaty, Thomas L., Rogers, Paul C., & Pell, Ricardo. (1980). Portfolio selection through hierarchies, The Journal of Portfolio Management, 6(3), 1 6-21.
[36] Harker, Patrick T. (1989). The art and science of decision making: The Analytic Hierarchy Process. In Analytic Hierarchy Process: Applications And Studies (Golden,Bruce L., Wasil, dward A., & Harker Patrick T., Eds.).

- Commercial software (Expert Choice ®) is readily available.

Despite the logical and scientific foundations of AHP, the following disadvantages have appeared:

- Perhaps the most controversial issue is that relative ranking of alternatives might be altered by the addition of other alternatives.
- The AHP method's bounded 9-point scale[37] may produce results that are inconsistent with acknowledged coherence requirements; this problem is most severe with a large number of options, but it might exist also when there are only three (Murphy 1993)[38].
- The number of pairwise comparisons required of the decision-maker becomes demanding as the number of criteria and choices rises[39]. To address this issue in large-scale AHP issues, Saaty and Vargas created an alternative approach that performs fewer comparisons; if this method is employed, the analyst must weigh the robustness of the estimates against the speed of the procedure to choose how many comparisons to run (Kamenetzky 1982)[40].
- The AHP technique implicitly presupposes that evaluators' preferences are inconsistently expressed. Once a certain level of consistency is established through coherence tests, there should be no errors in the input data (Zahedi 1986)[41]; this is not the case in practice, because consistency checks are unlikely to prevent all random errors.

SCORING METHODS – these approaches[42] assume that a small set of criteria, such as cost, resources availability, technical success likelihood, etc., can be defined

[37] Generally, the evaluation scale for the comparison of the criteria *i* and *j* varies from 1 to 9, where 1 stands for *equally important* criteria, 9 means that *i* is *absolutely more important than j* and vice versa 1/9, with intermediates values for all the other degrees of relative importance. The criteria $a_{i,j}$ will populate the pairwise comparison matrix *A*, from which the eigenvalues are calculated.

[38] Murphy, Catherine Kuenz (1993). Limits on the analytic hierarchy process from its consistency index, European Journal of Operational Research, 65, 138-139.

[39] in a hierarchy with four levels and six possibilities on each level, for example, the decision-maker must do (4x6x5)/2 = 60 comparisons.

[40] Kamenetzky, Ricardo D. (1982). The relationship between the Analytic Hierarchy Process and the additive value function, Decision Sciences, 13, 702-71 2

[41] Zahedi, Fatemeh (1986). The Analytic Hierarchy Process - A survey of the method and its applications, Interfaces, 16(4), 96-108.

[42] Based on Martino, Joseph P. (1995). R&D Project Selection, New York, NY: Wiley.

and used to determine the attractiveness of each potential project. The scores are then combined (when various weights are adopted for each criterion the process is known as *Weighted Factor Scoring*, probably the most common scoring model) to produce an over benefit estimate of each project. Although the benefit measures are relative, projects can be added and deleted without affecting the overall scores; moreover, they allow the integration of both quantitative and qualitative criteria, with relatively simplicity. The main disadvantages of this technique pertain to the lack of explicit reference to risk, to the unwieldy and difficult evaluation of the weights; moreover, these techniques are not well suited when are present interdependencies between projects, in which the selection or not of a project influences the appeal of another.

BENEFIT CONTRIBUTION MODELS – with these methodologies, project benefit is measured in terms of contributions to a range of project or program objectives. Depending on the approach, the resulting metric may or may not be relative. Alternatives can be added or removed without affecting the benefit score of exiting options. Methods in this category include:

- **Economic Return** (Martino 1995; Remer et al 1993[43]): the main indicators to express the economic return of an investment used in the portfolio selection's activities are:
    - *Net Present Value* (*NPV*) – defined as the difference between the present value of cash inflows and the present value of cash outflows over a period of time. The NPV is the result of computations used to determine the present value of future stream of payments; if the NPV of a project or investment is positive, it signifies that the discounted present value of all future cash flows associated to that project or investment will be positive, and hence appealing.

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

[43] Remer, Donald S., Stokdyk, Scott B., & Van Oriel, Mike (1993). Survey of project evaluation techniques currently used in industry. International Journal of Production Economics 32, 103-1 15.

Where R_t is the net cash inflow-outflows during a single period t, i is the discount rate or return that could be earned in alternative investments, and t is the number of timer periods.

The economic analysis by means of NPV requires only future cash flows to be considered, as all costs already incurred, as well as revenues already assumed, cannot be influenced by the decision, and should therefore not influence it either. A very sensitive point in the economic evaluation of projects lies in the uncertainty associated with projects. Because of this, cash flows must be discounted at a rate that includes the project-specific risk. However, few cases (and companies) are really able to determine this value; in general companies use as interest rate the WACC (*Weighted Average Cost of Capital*), which is nothing else than the weighted average of the returns expected from the different sources of financing, and it is also the weighted average of the returns that the financial markets expect from the different financial activities existing at the company. It is therefore of little value for assessing individual projects, some of which will be less risky than the averages (and the WACC would lead to excessive discouragement of their activation), and conversely others will be riskier. To avoid this, corporate finance experts should therefore prepare a catalogue of typical discount rates for each project category and communicate them to the project portfolio management office.

- *Internal Rate of Return* (*IRR*) – in a discounted cash flow analysis, IRR is the discount rate that makes the NPV of all cash flows equal to zero. In other words, the IRR is the projected yearly rate of growth from an investment; in general, the higher the rate of return, the more favourable an investment is to make. IRR is consistent across different types of investment and, as such, may be used to rate several prospective investments or projects on a pretty equitable basis, and usually when comparing options with similar qualities, the one with the highest IRR is likely to be the best.

$$0 = NPV = \sum_{t=1}^{T} \frac{C_t}{(1+IRR)^t} - C_0$$

Where C_t is the net cash inflow during the period t, C_0 is the total initial investment costs.

- *Return on Investment* (*ROI*) – is a performance metric used to assess the efficiency or profitability of an investment (or compare several investments); it attempts to directly measure the amount of return on a certain investment in relation to the cost of the investment. The benefit (or return) of the investment is divided by the cost of the investment itself: the outcome is given as a percentage or ratio. Because ROI does not account for the holding duration or passage of time, it may overlook the opportunity costs of investing elsewhere.

$$ROI = \frac{Current\ Value\ of\ Investement - Cost\ of\ Investement}{Cost\ of\ Investment}$$

  Notice that *Current Value of Investment* refers to the proceeds obtained from the sale of the investment of interest.

- *Discounted Payback Period* – is a capital budgeting process used to determine a project's profitability. A discounted payback period expresses the number of years required to break even from undertaking the initial expenditure by discounting future cash flows and accounting for the time value of money. The metric is used to assess a project's viability and profitability: the shorter the payback period, the sooner a project or investment will create cash flows sufficient to cover the initial cost.
- *Expected Value* (*EV*) – is the predicted value of an investment at some point in the future. In statistic and probability analysis, the EV is calculated by multiplying each conceivable outcome by the likelihood that each outcome will occur and then summing all those values. By

estimating anticipated values, investors can select the scenario that is most likely to provide the desired result.

$$EV = \sum P(X_i) \times X_i$$

Scenario analysis[44] is one method for evaluating an investment opportunity's EV: it examines potential outcomes for a proposed investment using estimated probabilities and multivariate models. Scenario analysis also assists investors in determining whether they are taking on an adequate level of risk in relation to the expected outcome of the investment, usually based on the IRR or the NPV. The EV of a random variable is a measure of the variable's centre of distribution; essentially, the EV is the variable's long-term average value. An index often presented in literature is the so called *Expected Commercial Value* (*ECV*)[45]:

$$ECV = (NPV * P_c - C) * P_t - D$$

that correspond to the decision tree of Figure 3-4, where *NPV* is the *Net Present Value* already discussed, P_C is the probability of commercial success, P_t the probability of technical success, *C* the value of the investments necessary for production, and *D* the value of the R&D costs that the project will occur in the future.

[44] Scenario analysis is the process of calculating the expected value of a portfolio after a specified length of time, assuming specific changes in the values of the portfolio's assets or critical circumstances, such as an interest rate shift; is commonly used to estimate changes in the value of a portfolio in response to an unfavourable event, and it can also be used to investigate a theoretical worst-case scenario. Based on mathematical and statistical principles, provides a process for estimating shifts in the value of a portfolio based on the occurrence of various occurrences, referred to as scenarios, using the ideas of "what if" analysis, or sensitivity analysis. Sensitivity analysis simply examines how different values of an independent variable affect a dependent variable under different conditions. These evaluations can be used to measure the degree of risk involved in a specific investment in relation to a number of hypothetical occurrences ranging from highly probable to highly implausible.

[45] Cooper, R.G., Kleinschmidt, E.J. (1987). New Products: What Separates Winners from Losers. Journal of Product Innovation Management. 3, 1987, Vol. 4, p. 169-184.

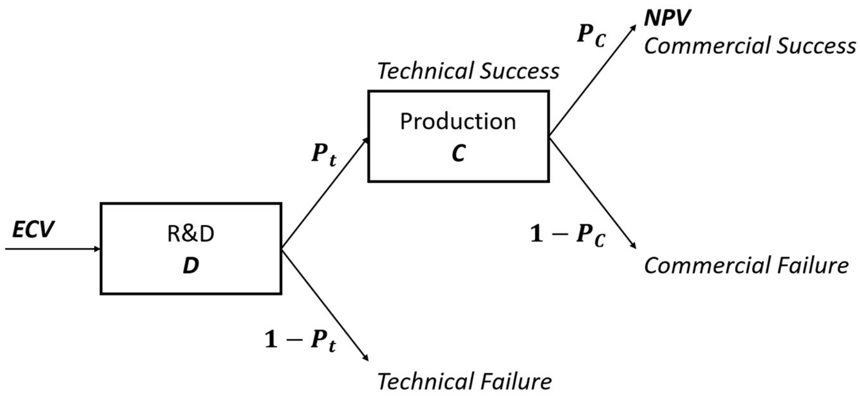

Figure 3-4: ***ECV*** **composition**

- **Cost-Benefit Analysis** (Canada & White 1980)[46]: these techniques entail calculating a benefit-to-cost ratio, with the inputs coming from present-value computations of both benefits and costs in order to translate them to the same time basis. Cost-benefit analysis originated as a decision-support methodology for choosing between different investment projects. it consists of comparing one or more investment proposals with the zero alternative, that is the hypothesis of leaving the situation unchanged: of all the alternatives, the one with the highest gain is chosen. The effects of a project are divided into two main groups: benefits, representing the positive effects, and costs, representing the negative effects for the intended objective. Costs and benefits are evaluated in monetary terms with regard to all quantities involved in the project, both those with a market value of their own and those without (such as time, quality, pollution, etc.); the latter are treated through the use of “shadow prices”. The limitation of this technique lies precisely in this monetary method of analysis according to which all goods or services must be valued on the market. Cost-benefit analysis, like any process of analysis, can be divided into a number of fundamental phases:

[46] Canada, John R., White, John A. (1980). Capital Investment Decision Analysis for Management and Engineering, Englewood Cliffs, N.J.: Prentice-Hall.

- Definition of alternatives: possible investment projects are defined, also defining the objective to be achieved by the implementation of a certain project.
- Definition of economic life and analysis horizon: the comparison and calculation of costs and benefits must be carried out within the project's life horizon, meaning that the analysis horizon must coincide with the project's economic life; however, as the economic life varies greatly depending on the type of project, a time horizon of 10-30 years is generally considered, also in order to be able to rely on reliable economic forecasts.
- Data collection: this is the longest and most delicate phase because data on demand, costs, benefits, and shadow prices have to be collected.
- Cost-Benefit calculations
- Ranking of alternatives: by calculating the NPV and IRR for each alternative, it is possible to rank the various investment projects.
- Sensitivity analysis: checking the robustness of the model set up, that is assessing the reliability of the results according to the choices made and any errors in estimates.

– **Risk Analysis**, including decision theory, Bayesian statistical theory/trees (Canada & White, 1980; Hess, 1993[47]; Martino 1995; Riggs et al, 1994[48]), and decision theory combined with influence diagram approaches (Krumm & Rolle, 1992; Rzasa, Faulkner, and Sousa, 1990).

MARKET RESEARCH APPROACHES - there are numerous market research methodologies that may be used to create data for estimating demand for new products or services based on concepts or prototypes that can be shown to potential customers to measure the product or service's potential market. Consumer panels, focus groups, perceptual mappings, and preference mapping are just a few of the techniques used. The advantage of this technique is related to the focus paid to market,

[47] Hess, Sidney W. (1993). Swinging on the branch of a tree: Project selection applications, Interfaces 23 (6), 5 - 12.
[48] Riggs, Jeffrey L., Brown, Sheila B., & Trueblood, Robert P. (1994). Integration of technical, cost, and schedule risks in project management, Computers & Operations Research,21 (5), 521 -533.

since any new product or service is propelled by the market; resources should not be squandered on developing products or services that are unlikely to be successful and moreover market demand and pricing estimates are critical in determining how much money may be allocated to development initiatives. On the other hand, these techniques are useful only for market-driven products and services and cannot be used for internally consumed products and services, such as information systems, unless the product or service being considered is similar to one already in the market, in which case the uncertainty in the forecasted customer acceptance rate will be extremely high.

3.2.2. PROJECT SELECTION/RESOURCE ALLOCATION TECHNIQUES

Although they can be utilized in some circumstances on their own, project selection/resource allocation approaches can be used to represent a second stage in portfolio selection, using inputs that can be the outputs of first stage benefit measurement methods. Several of these ideas have been proposed in the literature, and several will be briefly discussed below.

STRATEGIC PLANNING TOOLS - portfolio selection has a wide range of strategic ramifications. The best sources of related material are Hax & Majluf (1984[49] and 1996[50]), who explore a variety of strategy development methodologies, including the usage of portfolio matrices, which will be described more below. The goal of strategic planning is to provide long-term direction to the corporation as a whole and to each of its business components. Strategic planning, in general, aims to preserve a viable connection between the organization and its environment by explaining the firm's strengths and weaknesses in the context of environmental opportunities and dangers. The strategic planning effort is focused on developing a feasible set of alternatives for exploiting potentially advantageous situations or deactivating potentially explosive ones. The ultimate goal of this effort is to choose a plan of action

[49] Hax, Arnoldo C., & Majluf, Nicolas S. (1984). Strategic Management: An Integrative Perspective, Englewood Cliffs, N.J.: Prentice-Hall.
[50] Hax, Arnoldo C. & Majluf, Nicolas S. (1996). The Strategy Concept and Process: A Pragmatic Approach (Second Ed.), Upper Saddle River, N.J.: Prentice-Hall.

that ensures the long-term growth and profitability of the organization. Although day-to-day tasks are undoubtedly crucial and must not be overlooked if the firm is to function efficiently, managers should also be concerned with higher, though less immediate, levels of decision. Actions aimed at the strategic planning-intelligence stage of decision making are in charge of moulding the organization's future and have long-term repercussions affecting its eventual success or failure. Nonetheless, they do not receive their fair share of managerial attention because they lack a sense of urgency that necessitates quick action.

- **Cognitive Modelling or Policy Capturing** (Martino 1995; Schwartz & Vertinsky, 1977[51]). This is a strategy for analysing global decisions in order to determine the components (real decision processes) that went into them. There are two approaches: *decision replication* and *decision assessment*. The goal is to calibrate the decision-making process such that future decisions are consistent with previous ones. It allows for the examination of global decisions in order to comprehend how they were made, but on the other hand has the disadvantage that only previous judgments can be reviewed, and it takes a big number of them to receive the most advantage; moreover, these procedures are of limited utility in fresh situations.
- **Cluster Analysis** (Mathieu & Gibson, 1993)[52]: the study carried out by Mathieu and Gibson describes a decision support method to large-scale R&D planning. A quantitative model is employed, based on three analytical tools: 1) the interaction matrix, 2) hierarchical cluster analysis, and 3) the strategic planning matrix of the Boston Consulting Group (BCG). The model's results are used to calculate the number of R&D program areas, the technological focus of each R&D program area, and the relative distribution of resources to the R&D program areas. Traditional optimization strategies for R&D planning frequently produce solutions that do not consider the decision maker's judgment, expertise, and insight. The decision support approach proposed

[51] Schwartz, S.L., & Vertinsky, I. (1977). Multi-attribute investment decisions: A study of R&D project selection, Management Science, 24, 285-301.

[52] Matthieu, R.G., & Gibson, J.E. (1993). A methodology for large-scale R&D planning based on cluster analysis, IEEE Transactions on Engineering Management, 40(3), 283 -292.

supports, rather than replaces, the R&D planner's judgment through the use of a graphic representation of the relative position of technological clusters, as well as an interactive and iterative approach to issue solving. Cluster analysis is an exploratory statistical approach used to look for natural groups or clusters of items (in this example, system-level technologies) in data. Identifying groupings of items from a large data set necessitates a measure of closeness. There are several proximity metrics, and there is no agreement that one proximity measure is preferable to another. Two frequently utilized dissimilarity metrics, Euclidean distance[53] and the Jaccard coefficient[54], were chosen in this technique. Market share, rate of sales growth, market size, and cluster cohesion are the four key performance indexes used to assess the attractiveness of a technological cluster for policy support. Gibson[55] praised the Boston Consulting Group (BCG) with incorporating market share and sales growth metrics into a long-term strategic planning tool. It is crucial to note that the technique presented does not adhere to the typical BCG approach to long-term strategic planning, but rather applies the BCG matrix to large-scale R&D planning. According to Gibson, market share and rate of sales growth are "*remarkably sensitive predictive tools in strategic marketing*". Market size indicates the potential economic effect of technologies in a certain cluster. Finally, cluster cohesiveness is a measure of the synergy that exists between the system-level technologies in that cluster, as assessed by average cluster distance, (defined as the sample mean of the within-cluster dissimilarity values). The performance indices are best displayed, according to the authors, graphically in the form of a modified BCG matrix. Market share and average sales growth are represented on two dimensions of the matrix, whilst market size for each technological cluster is proportional to the circle's diameter and

---

[53] The Euclidean distance between system-level technologies Ti and Tj is defined as dTi,Tj=q=1n(xiq-xjq)2, where xiq is the q^{th} variable for the i^{th} technology.

[54] The Jaccard coefficient defines the dissimilarity between system-level technologies Ti and Tj by dTi,Tj=(b+c)(a+b+c) where *a* represents the number of variables for which xiq=1 and xjq=1, *b* is the number of variables for which xiq=1 and xjq=0, and *c* is the number of variables for which xiq=0 and xjq=1. It is worth noting that the Jaccard coefficient regards a 0-0 match as carrying no information for assessing the closeness of two objects.

[55] J. E. Gibson. Managing Research and Development. New York: Wiley, pp. 24-33, 1981

cluster cohesiveness is related to the thickness of the circle's circumference. Following the identification of high-performance technology clusters using the BCG matrix technique, the number of program areas, technological focus of these program areas, and relative distribution of resources to the program areas must be defined. The number of high-performing technological clusters identified via the BCG matrix analysis correlates to the number of program areas within the R&D program. The technological emphasis of the program area is formed by the features of the technologies inside the cluster as well as the main support technologies linked with each technology cluster. Finally, performance measures such as the market size linked with each technological cluster may be used to direct the relative distribution of funding to the various program areas. Furthermore, metrics of variety across program areas can be utilized to assess portfolio risk. Program areas that are vastly diverse in terms of technology have a greater level of total program risk.

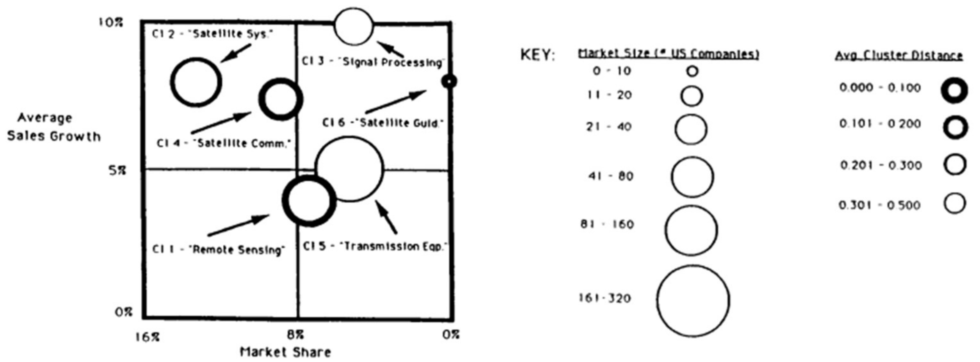

Figure 3-5: ***BCG Plot-Average Rate of Sales Growth v. Market Share for the Six Cluster Average Linkage/Euclidean Distance Solution presented by Mathieu and Gibson in their analysis***

The main disadvantage of this method is that only helps to find clusters of similar projects but does not help the selection of specific projects inside it. A strong point of the method is related to the assist it gives in maintaining the firm's strategic direction.

- **Portfolio Matrices**. Portfolio matrix approaches can be used to prioritize and allocate resources among competing projects. Several well-known consulting companies have pushed the adoption of these methodologies during the previous few decades. The Boston Consulting Group (BCG), McKinsey & Company, Strategies Decision Group (SDG), Arthur D. Little Corp. (to name a few) have all created well-known and commonly utilized portfolio matrix methodologies for project portfolio selection. Portfolio matrices are two-dimensional visual representations of all the projects being considered. In a portfolio matrix, one dimension usually reflects the chance of success and the other the economic value of the project, or more broadly, one represents the external elements impacting the business and the other the internal aspects defining the firm's strengths and weaknesses. The location of a project inside a matrix recommends the pursuit of a certain strategy in all such matrix techniques. The goal is for decision makers to be able to pick an appropriate mix of projects on the dimensions indicated by these approaches. The benefits of project portfolio matrices are the same regardless of the type of matrix display used:

- Portfolio matrices are well-organized, disciplined approaches that aid in the selection of a project portfolio.
- Managers frequently fail to employ a logical economic strategy. Portfolio matrices help managers make more sensible judgments than they would if they relied just on their intuition. Moreover, portfolio matrices provide information to decision makers in a "user-friendly" style, and they can be utilized in decision-making sessions by groups of managers.
- Portfolio matrices provide an overall view of all projects in progress on a single map, and they tend to impose strategic rigor in decision making. They also give a common lexicon to ease the sharing of ideas among decision makers.

The following are instead the key drawbacks of project portfolio matrices:

- Portfolio matrices' scope excludes other essential strategic problems.
- The employment of project names (e.g., cows, dogs, etc.) is popular in this method, and while they are appealing and simple to use, they may encourage decision makers to disregard profit maximization

(Armstrong & Brodie 1994)[56]. In addition, according to research, the BCG matrix methodology, like other matrix approaches, interferes with profit maximization (Hax & Majluf 1984). As a result, several researchers have warned against adopting matrix approaches under any circumstances unless evidence demonstrating they yield superior outcomes is produced (Armstrong & Brodie 1994).

- Excessive rigidity, which is inherent in these methodologies, may lead to mechanical thinking, which stifles rather than enhances creativity. Portfolio matrices can stifle really innovative thought when utilized by untrained decision makers (Hax & Majluf 1984), and portfolio matrices are sensitive to the operational definition of the dimensions, cut-off points, weighting system, and specific model used.

Growth Share (**BCG**) **Matrix** - A framework to assist firms in determining the priority (and resources) that they should assign to their various enterprises. It is also known as the Boston matrix, and it categorizes each of a firm's businesses into one of four categories; the categories were all given distinctive names – *cash cow*, *star*, *dog*, and *question mark* – which helped to push them into the collective consciousness of managers all over the world. The two axes of the matrix are relative market share (or the ability to generate cash) and growth (or the need for cash).

- *Cash cows* are businesses that have a high market share (and are therefore generating lots of cash) but low growth prospects (and therefore a low need for cash). They are often in mature industries that are about to fall into decline.
- *Stars* have high growth prospects and a high market share.
- *Question marks* have high growth prospects but a comparatively low market share (and have also been known as wild cats).
- *Dogs*, by deduction, are low on both growth prospects and market share.

[56] Armstrong, I.Scott, & Brodie, Roderick J. (1994). Effects of portfolio planning methods on decision making: Experimental results, International Journal of Research in Marketing, 1 1, 73-84.

Such an examination leads to the conclusion that surplus cash from a conglomerate's cash cows should be transferred to the stars and question marks, while the dogs should be closed down or sold off. In the end, question marks transform into either dogs or stars, while cash cows become so depleted of funds that they ultimately transform into dogs.

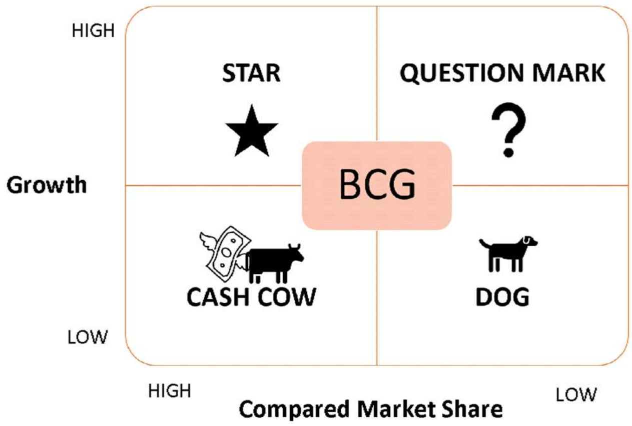

Figure 3-6: ***BCG Growth Share Matrix***

In Table 3-2 are reported the typical implications for strategic positioning linked to the different categories:

Business Category	**Market Share Thrust**	**Business Profitability**	**Investment Required**	**Net Cash Flow**
Stars	Hold/Increase	High	High	Around zero
Cash Cows	Hold	High	Low	Highly positive
Question Marks	Increase	None or negative	Very High	Highly negative
	Harvest/Divest	Low or negative	Disinvest	Positive
Dogs	Harvest/Divest	Low or negative	Disinvest	Positive

Table 3-2: Strategic Positioning implication for the BCG Matrix

The problem with this system is that categorizing firms in this manner might be self-fulfilling. Knowing you're working for a dog isn't especially motivating, however working for a well-known celebrity is. Furthermore, some businesses make incorrect assumptions about when industries are mature. This may lead individuals to believe that enterprises should be treated as cash cows when, in fact, they are stars. Consumer electronics was one such industry. Many considered it mature in the 1970s, but it recovered in the 1980s with the invention of the CD and VCR. Not before, however, several companies had abandoned their electronics divisions to the fate of the cash cow. The growth share matrix has been criticised for encouraging businesses to worry over market share. In a world where markets are becoming increasingly flexible, this can cause people to lose sight of the greater picture. If Lego, for example, viewed its market to be mechanical toys, it would overlook the reality that it competes for the attention of young boys with companies such as Nintendo.

GE McKinsey Matrix - Is a strategy tool that provides a systematic approach for multi-enterprise corporations to prioritize their investments across their business divisions. It assesses the business portfolio, gives additional strategic implications, and aids in the prioritization of investments. In the 1970s, General Electric was managing a vast and complex portfolio of unconnected products, and it was dissatisfied with the returns on its investments. Companies at the time typically depended on forecasts of future cash flows, future market growth, or other future projections to make investment decisions, which was an untrustworthy manner of allocating resources. As a result, GE engaged McKinsey & Co., and the nine-box framework was created. The nine-box matrix depicts the BU[57]s on its 9 cells, indicating whether the corporation should invest in a product, harvest/divest it, or conduct additional research on the product and invest in it if there are still some resources available. The BUs are evaluated on two axes: *industry attractiveness* and *competitive strength of a unit*.

- <u>Industry Attractiveness</u>: indicates how difficult or easy it will be for a company to compete and earn profits in the market. The more prosperous an industry is, the more appealing it is. Analysts should look at how an industry will evolve in the long run rather than in the near

[57] A business unit (BU) can be defined as an operating unit or a planning focus that sells a distinct set of products or services to an identifiable group of customers in competition with a well-defined set of competitors. The business unit is the level of analysis where most of the strategic planning effort is centred.

future when analysing industry attractiveness, because the investments required for the product usually need a long-term commitment.

- <u>Competitive Strength of a BU or Product</u>: The matrix analyses a business unit's or product's competitive strength against its rivals along the X axis. In other words, managers attempt to establish whether a business unit has a durable competitive advantage (or, at the very least, a temporary competitive advantage). If the company has a long-term competitive advantage, the next issue is, "How long will it last?"

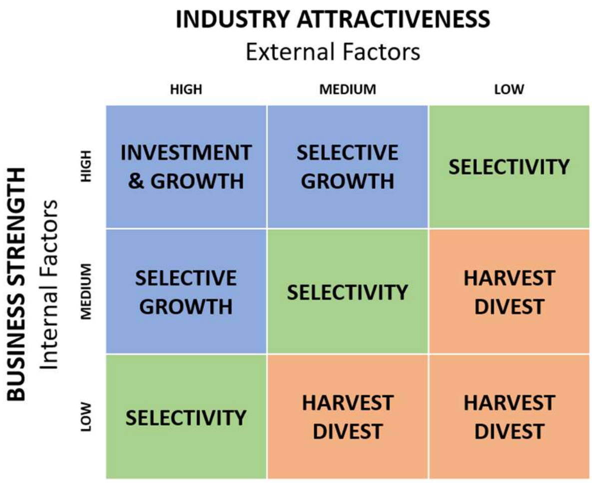

Figure 3-7: General layout of the McKinsey Matrix

The benefits of this strategy are found in the assistance it provides in prioritizing limited resources in order to get the best returns, the managers awareness on how their products or business units perform, the identification of strategic initiatives that the organization must take to improve the performance of its business portfolio. It is a more advanced business portfolio structure than the BCG matrix. On the other hand, it requires a consultant or a highly skilled individual to ascertain the industry's attractiveness and business unit strength as precisely as feasible, it is costly to carry out, and it does not consider potential synergies between two or more business units.

In Figure 3-8 are displayed the typical strategies to adopt based on the industry attractiveness – business strength level identified[58]:

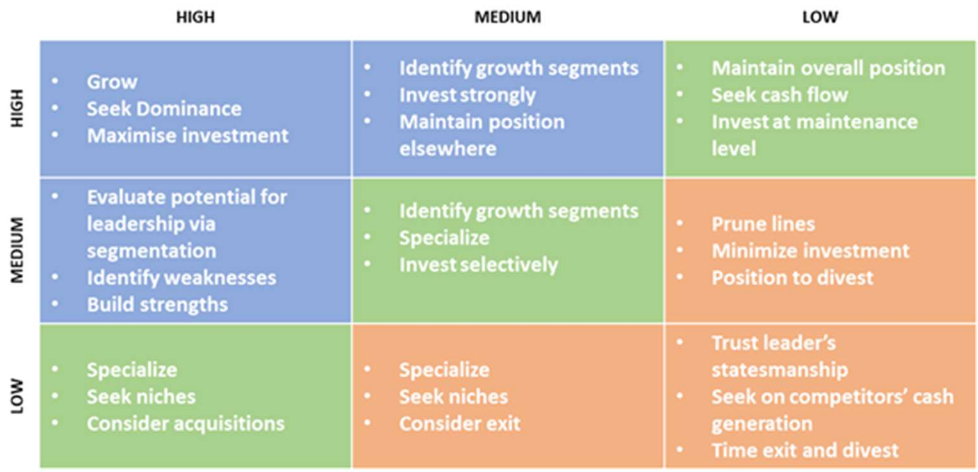

Figure 3-8: Common strategies to adopt according to the McKinsey Matrix

SDG Matrix – There are two aspects to the SDG portfolio matrix. The first dimension indicates the project's expected commercial value (Net Present Value or NPV) if technical success is achieved. The probability of technical success of the project is represented by the second dimension. The two factors described above are calculated for each candidate project and then plotted in a bubble diagram for all of the candidate projects. The size of the bubbles or circles represents the amount of financial resources dedicated to each project, therefore functioning as a third dimension, project size. A typical SDG matrix is depicted in Figure 3-9. Each quadrant in this diagram has its own name. These designations may differ depending on the country or company where the matrix is utilized, but the approach for a project falling into that quadrant should be the same because projects in the same category tend to have comparable features. The following are some common labels for SDG quadrants:

- *Pearl* – Highly attractive initiatives with a high commercial value as well as a high likelihood of technical success. Typical projects in this category

[58] In Chapter 4 is reported a deeper analysis on the use of the tool and the steps necessary for the construction of the matrix.

include identified innovative commercial applications and demonstrated technology advancement projects.

- *Bread* and *Butter* – Projects having a high technical success rate but a low commercial value. This category often includes evolutionary improvements in process or product, modest extensions of current technologies or applications, and minor projects. These initiatives are frequently required since they offer the cash flow that fuels the firm's activities.
- *Oyster* – Projects with a low chance of success but a high commercial value. This category is characterized by revolutionary commercial applications and unique technology advancement projects. To safeguard the firm's future, oysters must be bred to produce pearls.
- *White Elephant* – These projects have neither a high technical success rate nor a high commercial value. This category includes oysters that have been discovered to be commercially inflated, as well as bread and butter initiatives with overstated chances of success.

The decision rule could be to seek for as many pearls as possible, invest in oysters, try to limit the bread-and-butter ones (which are usually overabundant), and eliminate white elephants. The primary benefits of utilizing the SDG portfolio matrix are that it explicitly addresses technological risk (essential, especially for R&D) and that the model represents the project's commercial worth. In most cases, this is the primary reason for completing the project. On the contrary, the disadvantages of his method are related to the fact that the model offers no guidance on how many oysters and/or which ones to choose, or how many bread and butters and/or which ones to cut, and it assumes that all key resource absorption can be stated with a single index (financial). In fact, other vital resources, such as labour and technological resources, should be addressed as well. The SDG model takes solely the likelihood of technical success into account. Commercial success likelihood, which is an essential risk element and sometimes more critical, is overlooked; commercialization and R&D expenses are not reflected in the commercial value represented by NPV, therefore some adjustments in the definition of commercial value are required. Furthermore, the model does not explicitly account for the money and marketing expenditure necessary to capitalize on technological achievement. Finally, the SDG technique does not address the critical problem of project dependency. What should the decision maker do, for example, if one project is a pearl but another project that provides certain essential inputs to that project is a white elephant?

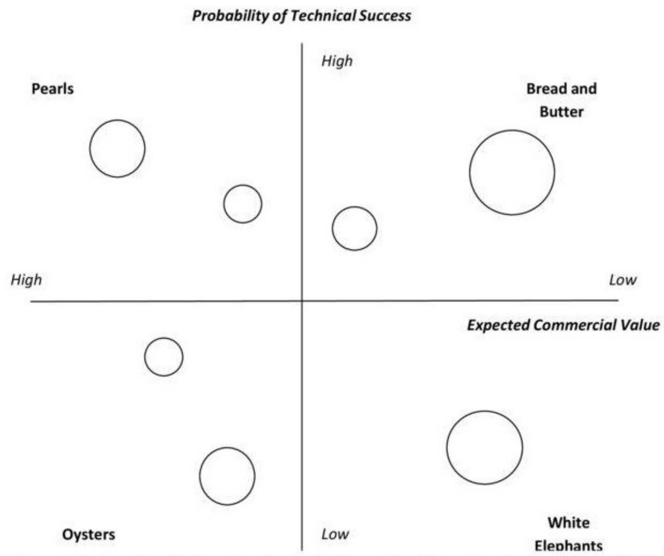

Figure 3-9: Strategic Decision Group (SDG) Portfolio Evaluation Matrix[59]

The Lifecycle (ADL) Matrix - The Arthur D. Little Strategic Condition Matrix, or ADL Matrix, is a portfolio management approach based on the Product Life Cycle (PLC). It was created in the 1980s by Arthur D. Little, Inc. (ADL), one of the most well-known consulting organizations, to assist a corporation in managing its collection of product businesses as a portfolio. The ADL matrix, like other portfolio planning matrices, represents a company's numerous enterprises in a 2-dimensional matrix. It is a systematic framework for considering strategies that are depending on the industry's life cycle. The ADL technique employs the aspects of environment evaluation and business-strength assessment i.e., Competitive Position and Industry Maturity. The environment assessment identifies the industry's life cycle, and the business

[59] Source: Robert G. Cooper, Winning at New Products: Accelerating the Process from Idea to Launch, second edition. Reading, MA: Addison-Wesley.

strength assessment categorizes the company's SBUs into one of five competitive positions, each of which is defined by four life cycle stages. The dimensions are combined to form a 5 (competitive positions) by 4 (life cycle phases) matrix (Figure 3-10).

Figure 3-10: The Lifecycle (ADL) Matrix

- *The Competitive Position*. Strategic activities and rival strategies determine a company's competitive position. Quality and competitive position strength are markers of a company's strength. The ADL matrix classifies each corporate section based on its position, which might be dominating, strong, favourable, tenable, or weak.

  Dominant – Dominant competitors are extremely uncommon. Dominance is frequently the product of a quasi-monopoly or fiercely protected technological leadership.

  Strong – Not every industry has a dominating or strong competition. Strong competitors can generally pursue their preferred strategy regardless of their opponents' movements.

  Favourable – Business line has a competitive edge in particular market categories. However, when industries are fragmented, with no competitors clearly standing out, the leaders tend to be in a favourable position, and as a result, market leaders have a decent degree of independence.

  Tenable – Specialization (geographical or project specialization) in a small or protected market segment may generally keep a tenable position lucrative.

Weak – weak competitors can be intrinsically too small to survive independently and profitable in the long term, given the competitive economics of their industry.

- *Industry Maturity*. The term "industry maturity" may easily be renamed "industry life cycle." Of course, not just industries, but also segments, should be evaluated here. Industry maturity is classified into four stages: embryonic, growing, mature, and aging.

  Embryonic – The first stage, which is distinguished by rapid market expansion, low competition, new technology, substantial investment, and high prices.

  Growth – The market continues to strengthen, revenues grow, there are few (if any) rivals, and the firm benefits from bringing a new product to market.

  Mature – The market is stable, there is a well-established customer base, market share is stable, there are many rivals, and effort is expended to differentiate from competitors.

  Aging – As demand declines, firms begin to exit the market, the battle for market share among surviving rivals becomes too expensive, and companies begin to exit or consolidate until the market is demise.

	EMBRYONIC	GROWTH	MATURE	AGING
DOMINANT	• All out Push for Share • Hold position	• Hold Position • Hold Share	• Hold Position • Grow with industry	• Hold Position
STRONG	• Attempt to improve position • All out Push for Share	• Attempt to improve position • Push for Share	• Hold Position • Grow with industry	• Hold Position or Harvest
FAVORABLE	• Selective or All out Push for Share • Selective attempt to improve position	• Attempt to improve position • Selective Push for Share	• Custodial or Maintenance • Find Niche and attempt to protect it	• Harvest or Phased withdrawal
TENABLE	• Selectively Push for position	• Find Niche and protect it	• Find Niche and hang-on or Phased withdrawal	• Phased withdrawal or abandon
WEAK	• Up or Out	• Turnaround or abandon	• Turnaround or Phased withdrawal	• Abandon

Figure 3-11: Strategic Positioning in terms of *Market Share*

	EMBRYONIC	GROWTH	MATURE	AGING
DOMINANT	• Invest slightly faster than the market dictates	• Invest to sustain growth rate (and pre-empt new competitors)	• Reinvest as necessary	• Reinvest as necessary
STRONG	• Invest as fast as market dictates	• Invest to improve growth rate (and improve position)	• Reinvest as necessary	• Minimum reinvestment or Maintenance
FAVORABLE	• Invest selectively	• Selective investment to improve position	• Minimum and/or selective reinvestment	• Minimum maintenance investment or Disinvest
TENABLE	• Invest (very selectively)	• Selective investment	• Minimum reinvestment or Disinvest	• Disinvest
WEAK	• Invest of Divest	• Invest or Divest	• Invest selectively or Disinvest	• Disinvest

Figure 3-12: Strategic Positioning in terms of *Investment Requirements*

	EMBRYONIC	GROWTH	MATURE	AGING
DOMINANT	• Probably profitable • Net Cash Borrower	• Profitable • Probably Net Cash Producer	• Profitable • Net Cash Producer	• Profitable • Net Cash Producer
STRONG	• May be unprofitable • Net Cash Borrower	• Probably Profitable • Probably Net Cash Borrower	• Profitable • Net Cash Producer	• Profitable • Net Cash Producer
FAVORABLE	• May be unprofitable • Net Cash Borrower	• Marginally Profitable • Net Cash Borrower	• Moderately Profitable • Net Cash Producer	• Moderately Profitable • Cash Flow Balance
TENABLE	• Unprofitable • Net Cash Borrower	• Unprofitable • Net Cash Borrower or Cash Flow Balance	• Minimally Profitable • Cash Flow Balance	• Minimally Profitable • Cash Flow Balance
WEAK	• Unprofitable • Net Cash Borrower	• Unprofitable • Net Cash Borrower or Cash Flow Balance	• Unprofitable • Possibly Net Cash Borrower or Producer	• Unprofitable (write-off)

Figure 3-13: Strategic Positioning in terms of *Profitability* and *Cash Flow*

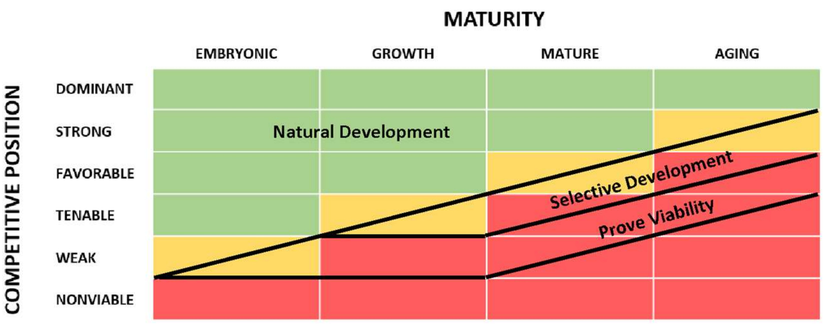

Figure 3-14: Natural Strategic Thrust

	DEVELOPMENT STAGE			
	Embryonic	**Growth**	**Mature**	**Aging**
Growth Rate	Accelerating; meaningful rate cannot be calculated because the base is too small	Faster than GMP, but constant/decelerating	Equal to or slower than GNP; cyclical	Industry volume cycles but declines over long term
Industry Potential	Usually difficult to determine	Substantially exceeds the industry volume but is subject to unforeseen develop.	Well-known; primary markets approach saturation industry volume	Saturation is reached; no potential remains
Product Lines	Basic product line established	Rapid proliferation as product lines are extended	Product turnover, but little or no change in breadth	Shrinking
Number of Participants	Increasing rapidly	Increasing to peak; followed by shakeout and consolidation	Stable	Declines; but business may break up into many small regional suppliers
Share Distribution	Volatile	A few firms have major shares, unlikely to change	Firms with major shares are entrenched	Concentration increases as marginal firms drop out, or shares are dispersed among small local firms
Customer Loyalty	Little or none	Some; buyers are aggressive	Suppliers are well-known; buying patterns are established	Strong; number of alternatives decreases
Entry	Usually easy, but opportunity may not be apparent	Usually easy; the presence of competitors is offset by vigorous growth	Difficult; competitors are entrenched, and growth is slowing	Difficult; little incentive
Technology	Concept development and product engineering	Product line refinement and extension	Process of materials refinement; new product line development to renew growth	Role is minimal

Table 3-3: The Industry Maturity Guide

3.3. A MENTION TO THE AGILE APPROACH

In this section will be provided a brief mention to the **Agile** practices and their correlation with project portfolio management (PPM), giving an overview of the practices and some examples of how to align them to PPM's objectives and company's strategy. Agile is the ability to create and respond to change; it is a way to deal with un uncertain and turbulent environment, and ultimately succeed. The term Agile was first coined in 2001, and it was born as an innovative approach to software development, focusing on the people doing the work and how they work together; solutions emerge through the collaboration of self-organizing cross-functional teams (they do not have any more specific roles involved but instead are composed of a balanced skill set) using practices appropriate to their context. Ultimately, Agile is a mindset informed by the values and principles of the Agile Manifesto. These values and principles provide guidance on how to create and respond to change and how to deal with uncertainty, and the methodologies applied are just the "conventions" that the team chooses to follow.

AGILE MANIFESTO: *"We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:*

Individuals and interactions over processes and tools

Working software over comprehensive documentation

Customer collaboration over contract negotiation

Responding to change over following a plan

That is, while there is value in the items on the right, we value the items on the left more."[60]

Business and technology leaders face increased market pressures to innovate and rapidly deliver new technology solutions. The confluence of these factors is leading many organizations to adopt agile methods as the primary means of delivering solutions to internal or external customers. Agile blurs the lines between business and technology teams, shifts decision making closer to the team doing the work, and fosters continuous prioritization and delivery of a product that works. The goal of PPM

[60] Beck, K., et al. (2001) The Agile Manifesto. Agile Alliance. http://agilemanifesto.org/

is to provide leaders with clear insight into the direction, status, and resources to move their organization forward and make strategic adjustments as needed. The key processes of PPM are demand, portfolio, project/program management. Together, they form the basis for decision making and process monitoring.

Demand management focuses on receiving, evaluating, and deciding on requests for work. This is done with prescribed entry points for new requests and qualifiers to prioritize them. Agile introduces two key concepts that improve demand management and support portfolio management. These new concepts are Value Streams and Epics. Value Streams are the ecosystem of teams working on Epics. Epics are large cross-functional initiatives that deliver solutions to the end user. As more teams across the enterprise adopt agile, defining Value Streams and Epics is critical to ensure coordinated planning and delivery. Incorporating these practices into demand management is essential for agile teams to plan effectively.

Portfolio management is responsible for continuously evaluating the performance of active programs and projects against defined criteria. The focus is on managing the portfolio to optimize resources to meet the highest priorities of the business. One way to accomplish this is to fund projects that have a specific investment amount, a defined scope, and a targeted delivery date. At the macro level, traditional and agile companies perform portfolio management in the same way. Even when a company starts implementing Agile, there is no real difference in the way the portfolio is managed. However, organizations that adopt Agile at scale can fund value streams, enable decentralized financial decisions within the portfolio, and continuously prioritize their backlog of activities within each Agile project to adapt to changing business needs. Consequently, the link between portfolio-level decisions and team-level implementation can be broken if the change in methodology is not anticipated. Therefore, PPM incorporates value stream management and funding to enable effective portfolio-level trade-offs.

Project/program management implements controls to manage scope, finance, progress, and quality of delivery. Project status (Red-Yellow-Green) is the primary method of determining whether or not a waterfall project is under control. Since the project scope, budget, and schedule are established at the beginning of the project, status is determined based on actual results compared to this baseline. In contrast, agile project status is determined by an analogous set of portfolio-level metrics. For PPM, this means being clear about status definitions and what red-yellow-green means in an Agile context. Companies adopting Agile are adapting to this change and integrating these new metrics into their PPM playbook and reporting.

Companies adopting Agile will experience an inflection point where adapting Agile concepts to PPM is essential to fully realize the benefits of Agile. The impact on people, processes, and tools is consistent, and those who anticipate the changes can leverage their PPM role as Agile catalysts. From an employee perspective, Agile relies on a decentralized model of decision rights for projects within a given portfolio. This can help hold individual leaders more accountable than a central decision-making body. Leaders who proactively review their PPM governance models and incorporate Agile practices can conduct focused and meaningful portfolio reviews.

4. Case Study – PUNCH Torino P.P.M.

This chapter focuses on a specific case study carried out in Punch Torino. The discussion takes into consideration the Company's process leading to the definition of a project (also called *Study Request*, *SR*) to be included in the Company's portfolio, and aims at providing an application, comparing the different selection approaches discussed in Chapter 3, to a real-case portfolio.

4.1. THE "STUDY REQUEST" PROCESS

The SR process is a standardised tool used to make economic estimates for new projects within Punch Torino; it is an estimation method for all new projects, including R&D, production, investment, product cost, etc. and involves all company functions (such as Engineering, Finance, Sales, etc.) in the appraisal phase. The SRs differ in the precision with which the estimation is carried out, and thus the speed of response as a function of the input requested. Going back to the categorisation of Wheelwright and Clark discussed above, in which a distinction is made between pure research projects, radical development projects, platform projects, and spin-off projects, most of the estimates are made on the latter category of projects (e.g., extension of the application range of an engine to new vehicles, adaptation of an aftertreatment system to the standards in force in the relevant market, etc.), with the exception of some key R&D projects on radically new technologies to be introduced on the market. Projects must be carefully estimated ex-ante, focusing in particular on R&D costs such as personnel costs, prototype costs (engines, vehicles), and material costs. A very small percentage of the total number of proposed new projects can be categorised as platforms. In a platform project, the company decides on the common technological characteristics of all the projects that will be implemented from it over a sufficiently long period of time. The main platform projects concern the development of a new engine or a new generation of engines.

4.1.1. RESOURCES ALLOCATION

Each project has a specific degree of complexity, which derives from the amount of work to be carried out on each ***work-package***; work-packages are categorised within macro-categories named:

- *Core Engine*: direct modifications to the engine.
- *Application*: integration/application of engine, transmission, and vehicle.
- *Core Controller*: direct modifications to the ECU

Each macro-category comprises a limited number of sub-categories, known as work-packages (e.g., under category *Core Engine* there are the following work-packages: cylinder head, combustion chambers, turbocharger system, valve timing system, cooling system, etc.; under category *Application*: catalytic converter, intake component block, particulate filter, etc.). A project has a different impact on each work-package in terms of changes to be made to the existing platform. The degree of modification to be made is translated by an ordinal scale with six levels (ratings), illustrated in the Table 4.1.

Bill of Materials Reuse	**A1**	Same part (all the future engineering changes must consider this application). Uses exactly the same component tools. Exactly the same assembly plant process and tools.
	A2	Variant of the current Bill of Material element. Requires minimal changes to the component tools. Reuses all datums and interfaces. Does not affect form dies or assembly tools/equipment. Must cancel and replace the previous Bill of Materials equipment.
	A3	Variant of the current Bill of Material element. Reuses most of the component tools, specifically salvaging the significant investment component. Reuses all datums and interfaces. Does not affect assembly tooling. Can be run in assembly equipment.
	A4	Variant of a current Bill of Material element. May require significant change to the component tool set. Reuses most assembly datums and interfaces specifically salvaging the significant investment elements. Can be run in the assembly tooling and equipment.
	A5	Variant of a current Bill of Material element with a known engineering solution. All new component tooling, all new assembly tooling. Assembly equipment and process remains the same.
	A6	Not currently in Bill of Material. This engineering solution has not been executed anywhere within the company. All new component tooling, all new assembly tooling. May require new assembly equipment/process Bill of Process.

Table 4-1: Ratings definition, defining the level of modifications generated on each work-package

During the next step, materials entering the estimation process such as components/hardware and prototypes are quantified. Prototyping is a very expensive product development process. Prototypes are used within a product development project for four purposes: learning, communication, integration, and achievement[61]. Depending on the complexity of the project, a different prototyping process is identified; within a project, it is possible to distinguish between different applications, each with a certain degree of complexity. For example, the vehicle with the earliest production date has the main tests carried out (*vehicle lead*, requiring more work). All other vehicles are considered as secondary applications, which do not need to be calibrated in the same way as the vehicle (called *followers*). Generally, a very low classification (A1) constitutes a **carry-over**. The phenomenon of carry-over occurs when certain components and design solutions are reused in derivative products, in derivative products of common periods or in subsequent generations. A high classification instead is characterized by a sophisticated prototyping system that includes both engines and vehicles. Prototypes are differentiated into *experimental* (more expensive and complex to produce), *alpha*, and *beta* (prototypes that are closer to the final production product). For the less complex classifications, there are no experimental prototypes and development times are obviously shorter. The more complex the application, the higher the prototyping costs, the longer the development time and thus the **time-to-market**. Specific tests are carried out on each application or vehicle to assess, for example, its drivability on the road, the perfect functioning of the transmission, specific tests on the engine (such as noise, exhaust gas after-treatment system) and on the control unit. Each test requires a predetermined number of engines and vehicles to be tested at each stage of the process to monitor engine and vehicle performance step-by-step.

The final stage of the process coincides with the costing of FTE[62]s, i.e. the cost of personnel, test benches used, materials needed, prototypes and vehicles purchased for testing. The final output is an estimate of how much an engineering

---

[61] Ulrich & Eppinger, 2000

[62] A Full Time Equivalent (FTE) is a unit of measurement that helps employers to forecast the workforce needs. A FTE is equal to the number of hours a full-time employee works in a year (the standard number of working days in a year is equal to 220 days: considering 8 hours per day, the total number of hours in one year is 1’760 hours)

project might cost. This step in the process requires the expertise of several business functions. The justification for starting or continuing a project is provided by a document called a business case. A business case is a business plan for the project; both serve to justify a new initiative. However, the former is a business plan that has the individual project as its unit of analysis; in a business case, interference between the project and the company is overlooked. The construction of a good business case facilitates the decision-making process: downstream of the portfolio management process described in Chapter 3, the business cases of all the selected projects are analyzed and a filter is made to approve the best processes. The business case contains technical, strategic, economic recommendations and estimates of the project's feasibility timeframe.

4.1.2. PORTFOLIO DEFINITION PROCESS

The process of defining the project portfolio, also known as **Study Request**, consists of three main phases, each led by its specific "owner" and attributable to a specific business function such as Engineering, Sales, and Finance, and ends with the definition of a document called Business Case. Each Company's initiative can be categorised into three main categories, which represent the progress of the project. During the definition of the business case a project will be categorised as "Under Study"; in the definition of the prioritisation of projects in the portfolio this category assumes a secondary level because the level of risk is not yet well defined, being still subject to variations both from a technical and financial point of view. Two instead are the categories for the completed and approved projects: "*Backlog*" and "*Self-Funded*". The first category includes all the projects approved, generally generating revenues with a positive EBIT; the second one includes all those projects that, despite their profitability, are considered strategic from the company's point of view and therefore worth of investing in.

The SR process starts with the "**kick-off meeting**" in which the people who will interact with the project are informed about the project. During this phase, led by the Product Owner, is provided a preliminary analysis of the project timing (developed in accordance with the main development phases), the activities and the effort required to achieve the requested target. This is followed by an in-depth technical feasibility analysis, in which the phases and resources needed to complete the project are outlined in detail, the level of risk involved is assessed (as far as the technical aspect is concerned), and the costs associated with the project under analysis begin to be outlined. Normally, the kick-off meeting, and the subsequent loops associated with it, are attended by the main functions of the engineering area, such as the Balance Architecture (BA), Design and Analysis, Calibration (whether engine or vehicle) and Validation, Cost Engineering and Benchmarking areas, managed by the management figures in charge of the project (a function known as Program Execution, which for each project foresees a dualism of Chief Engineer and Program Manager). The main deliverables requested at the end of this technical feasibility phase are:

- The work perimeter, with the technical assumptions and feasibility; in this phase it is also investigated the possibility to apply for patents or licensing
- Material cost, proto material, and tooling
- Vendor tooling and manufacturing capex (capital expenditure)
- FTEH and engineering costs estimation
- Time-to-market

Almost in parallel begins the activity led by the Sales department of investigating market potential, which consists of researching market opportunities in terms of accessible and achievable customers and volumes, as well as competitive benchmarking of the other players present. The Sales department is also responsible for the definition of the pricing: the profit of a project is given by a mix of revenues, such as:

- **Engineering services**, in which the company sells its resources (whether human resources or test benches) at a fee pre-established during the negotiation, for research and development and/or integration of previous technologies on the requested product.
- **Products,** where the profit is given by the mark-up applied on the cost of the product itself.

- **Services**, as in the case of a software (e.g., access fee, maintenance fee, etc.)

The Finance department finally collects the inputs coming from the two abovementioned functions and builds the Business Case. Firstly, for the construction of a business case, the Finance team is required to validate the resource costs calculated by the various teams in the Engineering area. The costs are composed of:

- **People Cost**, where both the resources actually responsible for the work and all those "indirect" figures are taken into account, i.e. the resources that are not directly attributable to a single project but are involved in all the company's initiatives (such as the Finance departments themselves and Sales) and which go by the name of SG&A[63], and all the management resources (e.g. managers of individual departments).
- **Test Benches**, which include both the cost of the actual cell (including consumables such as fuel) and the people who directly work on the cell.
- **M&T** (Material and Tooling), prototypes
- **Software Licences,** directly attributable to the project
- Costs directly linked to sales volumes, known as **COGS** (Cost of Goods Sold), such as materials, logistics and transport costs, product warranty costs, etc.
- And a whole series of external expenses that the company is required to incur over the life of the project.

The second task required by the Finance department consists of the compilation of the project's income statement, or Profit and Losses (P&L). The input data requested are the one collected from the other functions, such as volumes and revenues from Sales, R&D costs, COGS, and all the other costs above listed. The P&L output is represented by the EBIT[64] (acronym for Earnings Before

[63] Selling, General, and Administrative expenditure. In a company's income statement, the SG&A category covers all general and administrative expenses (G&A) as well as direct and indirect selling charges. In truth, this line item contains practically all company expenditures that are not directly related to the production of a product or the provision of a service. SG&A encompasses the costs of running the business as well as the costs of supplying its products or services (known as Operative Expenditure).

[64] "Earnings before interest and taxes measures the profit a company generates from its operations making it synonymous with operating profit. By ignoring taxes and interest expense, EBIT focuses

Interest and Taxes) that gives a good measure of the profitability of the project and is given as the sum of the revenues and costs per each year considered and account also for the D&A (Depreciation and Amortization of the CAPEX[65] investments necessary). Consequently, the cash flow can be evaluated: starting from the *Operating Cash Flow*, that is a measure of cash flow generated by a company's normal business processes[66], the CAPEX and other investments, and the financing (either private or public) are considered so that to calculate the yearly cash position. A positive cash position means that the business is profitable, whether a negative one that the company needs to self-fund the project or seek external funding. To calculate the **NPV** (Net Present Value), that with the **Payback** is the final deliverable requested to the Finance team, is necessary to discount the cash position, meaning to apply a discount rate (usually set by the top management) to each year's cash position to obtain its present value. This analysis aims to determine the current value of an investment based on future forecasts of how much money it will earn. This pertains to decisions made by investors in firms or securities, such as acquiring a company or purchasing a stock, as well as decisions made by business owners and managers about capital budgeting or operational expenses. The goal of the analysis is to estimate how much money an investor would get from a certain investment after adjusting for the time value of money[67]. In this context, the discount rate refers to the interest rate used to determine the present value. However, the evaluation of a precise discount rate is not a simple task; in general companies use as interest rate the WACC (*Weighted Average Cost of Capital*); in most cases it has little value for assessing individual projects, some of which will be less risky than the averages (and the WACC would lead to excessive discouragement of their activation), and conversely others will

solely on a company's ability to generate earnings from operations, ignoring variables such as the tax burden and capital structure. EBIT is an especially useful metric because it helps to identify a company's ability to generate enough earnings to be profitable, pay down debt, and fund ongoing operations". Source: https://www.investopedia.com

[65] Capital Expenditures (CAPEX) represent cash outflows for the realisation of investments in fixed assets of an operational nature. These are investments in fixed assets.

[66] Operating cash flow indicates whether a company can generate sufficient positive cash flow to sustain and grow its business. If this is not the case, external funding may be required to expand capital.

[67] The time value of money assumes that a dollar now is worth more than a dollar tomorrow because it can be invested.

be riskier. To avoid this, corporate finance experts should therefore prepare a catalogue of typical discount rates for each project category and communicate them to the project portfolio management office.

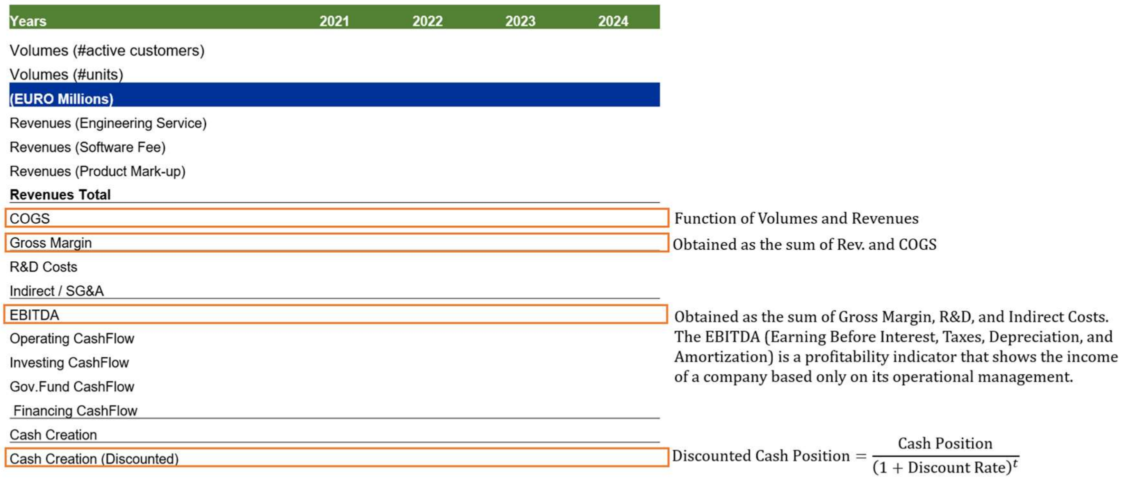

Figure 4-1: Example of Income Statement and Cash Flow Analysis

In conclusion, the process leading to the project's definition touches almost all the departments of the company and has as its ultimate goal the definition of those parameters necessary for future prioritisation in the field of portfolio management, which can help management to make a choice on the basis of profitability but also strategic relevance among the projects analysed.

4.2. PORTOFOLIO SELECTION APPROACHES

This section is devoted to a real application of the selection techniques discussed in Chapter 3. In particular, the prioritization approaches known as Benefit Measurement Techniques will first be discussed, highlighting the differences between the different approaches in categorizing and prioritizing projects within a portfolio. Then at the end of this first section the approach used in Punch Torino will be discussed, which summarizes the techniques mentioned above and provides a prioritization of projects according to the classical scoring method. The second part is aimed at reviewing the most well-known matrices in the literature, applied to the portfolio under analysis. It should be noted that the values given below have all been normalized for reasons of confidentiality, as well as the name of the projects.

The portfolio under analysis is reported in Figure 4-2. In the first column are displayed the three business units (BU) that make the portfolio, reported as **A**, **B**, **C**, and **D**; the second column instead shows the projects enclosed in each BU, named as roman numbers: each project is associated to a *level*, which identifies the complexity of the project itself, whereby level 1 stands for a complex project, which might also contain several level 2, representing single applications or integration for specific customers: i.e., in BU **B**, the level 1 project (B-I) contains the two sublevels B-II and B-III.

The other columns in the portfolio are referred to the economic performances of each project; are in fact reported the lifecycle *revenues, R&D costs*, *Cost of Goods Sold* (*COGS*), and the capital expenditure needed (*CAPEX*). Finally, two important parameters are showed, useful in the following discussion for the prioritization of the projects, that are the *lifecycle* (meaning the time duration of the project, to which are reported the financial values abovementioned) and the EBIT, expressed as a percentage: Earnings Before Interest and Taxes is a measure of a company's profitability. EBIT is computed as revenue minus costs excluding taxes and interest. EBIT is also known as operational earnings, operating profit, and profit before interest and taxes.

BU	Project	Level	Stage	Revenues	R&D Cost	COGS	Capex	Life Cycle [years]	EBIT [%]
A	VIII	1	Backlog	0.27	(0.09)	(0.13)	(0.00)	7	20%
C	IV	1	Self Fund	0.07	(0.04)	(0.01)	(0.01)	6	21%
A	V	1	Self Fund	0.03	(0.05)	(0.00)	(0.00)	4	-71%
A	IV	1	Self Fund	0.21	(0.03)	(0.12)	(0.01)	7	22%
A	III	1	Self Fund	0.15	(0.03)	(0.10)	(0.00)	3	14%
A	VI	2	Backlog	0.15	(0.03)	(0.10)	-	3	17%
A	VII	2	Self Fund	-	(0.00)	-	(0.00)	3	
A	II	1	Backlog	1.00	(0.12)	(0.63)	(0.01)	5	23%
B	I	1	Self Fund	0.44	(0.13)	(0.17)	(0.01)	5	1%
B	II	2	Self Fund	-	(0.02)	-	(0.01)	1	
B	III	2	Backlog	0.44	(0.11)	(0.17)	(0.00)	5	8%
C	I	2	Self Fund	0.07	(0.01)	(0.01)	-	6	64%
C	II	2	Self Fund	-	(0.00)	-	(0.00)	1	
C	III	2	Backlog	-	(0.03)	-	(0.01)	6	
D	I	1	Backlog	0.02	(0.01)	-	-	5	34%
A	I	1	Self Fund	0.41	(0.06)	(0.25)	(0.01)	4	25%

Figure 4-2: Example of Portfolio in Punch Torino

The abovementioned Portfolio is the starting point of the analysis, to which the following prioritization approaches are going to be applied (in Table 4-2 is reported the overall view of the techniques under study):

Method	Approach	Technique
Benefit Measurement Technique	Benefit Contribution Model	Cost Benefit Analysis
		Economic Return
		Risk Analysis
	Scoring Method	Punch
Project Selection	Portfolio Matrices	ADL
		BCG
		McKinsey

Table 4-2: Project Selection and Prioritization Techniques Analyzed

Starting from the *Benefit Measurement Techniques*, the main indexes to express the economic return have been calculated and compared, highlighting the differences in the ranking due to the choice of one indicator rather than another. Since the **Cost-Benefit Analysis** consist in ranking the projects based on the calculation of a benefit-to-cost ratio expressed in present-value units, which is nothing more than the **NPV**

(Net Present Value), it will not be discussed further, but the result of this analysis will be approximated to the prioritization provided by comparing the NPVs of different projects. In the following discussion focus will be given only to *level 1* projects:

BU	Project	Level	Stage	NPV	IRR	ROI	Paybac k	EV
A	I	1	Self Fund	0.60	0.60	5.1	3.0	(0.03)
A	II	1	Backlog	1.00	0.52	6.4	3.1	(0.55)
A	III	1	Self Fund	0.09	0.73	4.0	3.3	(0.10)
A	IV	1	Self Fund	0.22	0.29	3.9	2.6	(0.13)
A	V	1	Self Fund	(0.24)	(0.1)	(0.4)	8.0	(0.08)
A	VIII	1	Backlog	0.30	0.18	2.0	3.0	(0.13)
B	I	1	Self Fund	(0.33)	0.27	2.2	6.0	(0.27)
C	IV	1	Self Fund	(0.02)	0.07	0.5	5.0	(0.04)
D	I	1	Backlog	0.02	0.08	0.5	4.0	0.00

Table 4-3: The Economic Indicators of Each Level 1 Project

Net Present Value (**NPV**) – defined as the difference between the present value of cash inflows and the present value of cash outflows over a period of time. The NPV is the result of computations used to determine the present value of future stream of payments; if the NPV of a project or investment is positive, it signifies that the discounted present value of all future cash flows associated to that project or investment will be positive, and hence appealing.

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

Where R_t is the net cash inflow-outflows during a single period t, i is the discount rate or return that could be earned in alternative investments, and t is the number of timer periods.

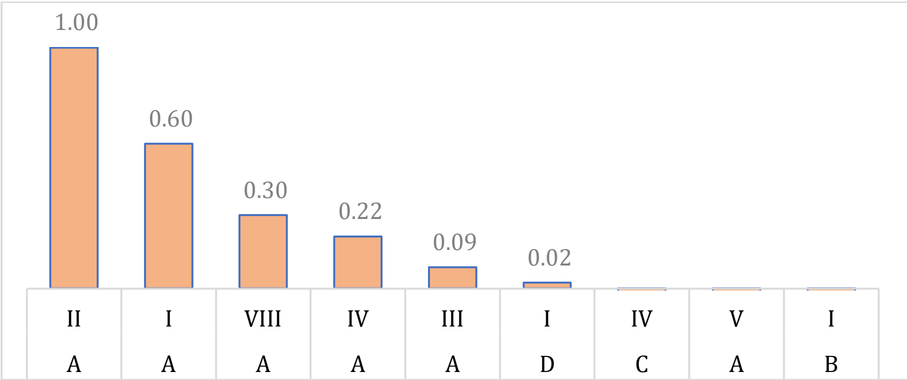

Figure 4-3: Prioritization Based on Net Present Value

Internal Rate of Return (IRR) – in a discounted cash flow analysis, IRR is the discount rate that makes the NPV of all cash flows equal to zero. In other words, the IRR is the projected yearly rate of growth from an investment; in general, the higher the rate of return, the more favourable an investment is to make.

$$0 = NPV = \sum_{t=1}^{T} \frac{C_t}{(1 + IRR)^t} - C_0$$

Where C_t is the net cash inflow during the period t, C_0 is the total initial investment costs.

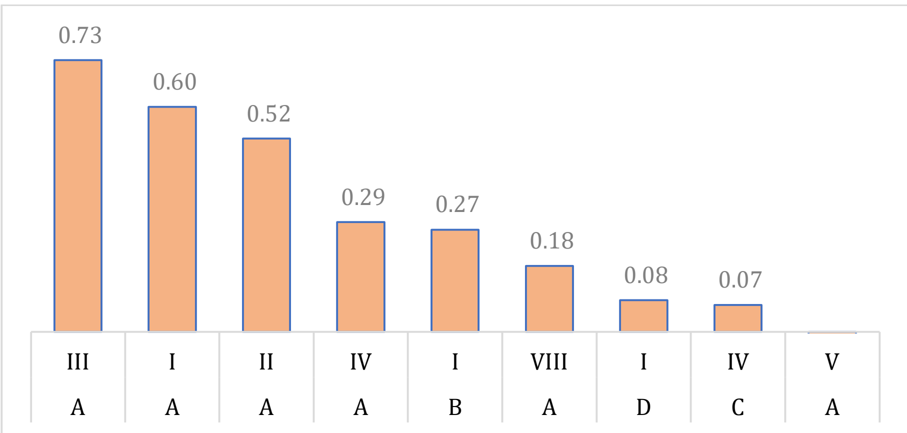

Figure 4-4: Prioritization Based on Internal Rate of Return

Return on Investment (ROI) – it is a performance metric used to assess the efficiency or profitability of an investment (or compare several investments); it attempts to directly measure the amount of return on a certain investment in relation to the cost of the investment.

$$ROI = \frac{Current\ Value\ of\ Investement - Cost\ of\ Investement}{Cost\ of\ Investment}$$

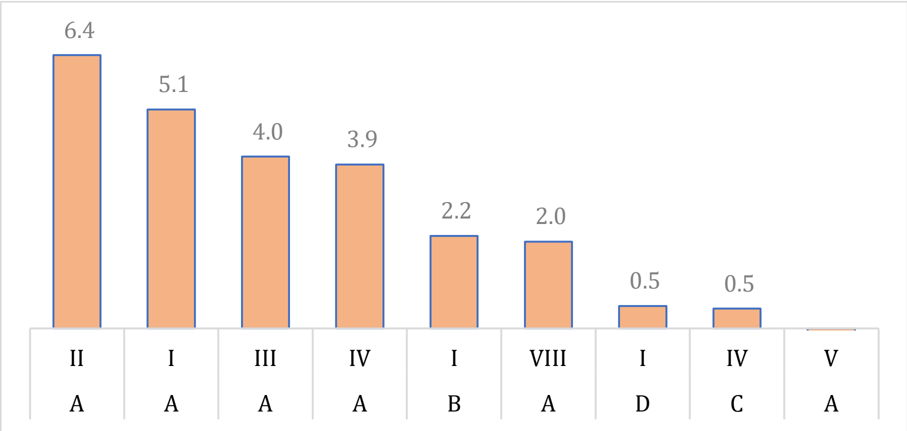

Figure 4-5: Prioritization Based on Return on Investment

Discounted Payback Period – it is a capital budgeting process used to determine a project's profitability. A discounted payback period expresses the number of years required to break even from undertaking the initial expenditure by discounting future cash flows and accounting for the time value of money.

Figure 4-6: Prioritization Based on Payback Period

Expected Value (EV) – it is the predicted value of an investment at some point in the future. In statistic and probability analysis, the EV is calculated by multiplying each conceivable outcome by the likelihood that each outcome will occur and then summing all those values. In particular, in the following analysis is presented the so called *Expected Commercial Value* (*ECV*):

$$ECV = (NPV * P_c - C) * P_t - D$$

that correspond to the decision tree of Figure 3-4, where *NPV* is the *Net Present Value* already discussed, P_C is the probability of commercial success, P_t the probability of technical success, *C* the value of the investments necessary for production, and *D* the value of the R&D costs that the project will occur in the future.

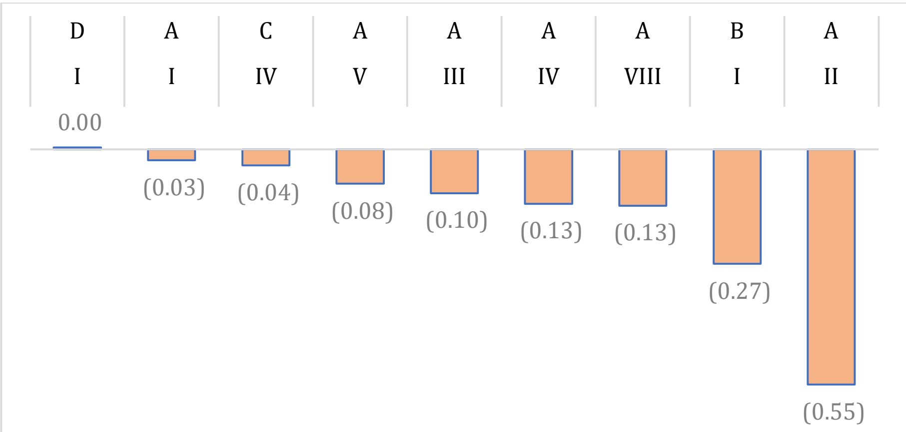

Figure 4-7: Prioritization Based on Expected Commercial Value

This analysis shows that there is no single correct method for prioritizing projects, but that each indicator produces a particular order. In analysing the different indices, however, an attempt has been made to maintain the same profile, and only R&D costs have been taken into account (which in any case include the share of depreciation) while COGS have been excluded (except for the calculation of NPV where they are considered). That said, there is some consistency in the results, in particular the Table 4.4 shows the frequency with which projects are ranked, combining the results of all the indices assessed.

	Position								
Project	1	2	3	4	5	6	7	8	9
A-I		100%							
A-II	40%		20%	20%					20%
A-IV	20%			60%		20%			
A-VIII			40%			40%	20%		
A-III	20%		20%		60%				
D-I	20%					40%	40%		
C-IV			20%				40%	40%	
B-I					40%			40%	20%
A-V				20%				20%	60%

Table 4-4: There is some consistency in the results of the prioritization according to the different indexes, especially looking to the top three positions (the same can be said to the bottom ones).

However, it is important to mention that certain projects, which according to some indices would be the most profitable and worth entering in the portfolio, according to others are at the bottom of the prioritization scale (or vice versa), such as the A-II project, which in most cases is at the top of the list, but when analysed according to EV is the last one.

All the above indices in any case have a common flaw, they do not consider the risk associated with each project (with the exception of EV). Moreover, the company might want to account more than one index at a time, and as was shown the results are not much consistent. For this reason, it is suggested to develop a *Scoring Method*[68], which takes into account both financial indicators, and in particular NPV and Payback, as well as a set of weights associated to three categories: **Technical Risk**, **Commercial Risk**, and **Business Assessment**, taking into account both the risk associated to the individual project and the strategic nature of the same (plus a fourth category taking into account potential fundings, that anyway does not influence the analysis since most of the projects are eligible to external fundings). The strategical importance of a project is a key element in the portfolio selection, and must be taken into account, as some projects may also not be very profitable but may have a key role from a strategic

[68] These approaches assume that a small set of criteria, such as cost, resources availability, technical success likelihood, etc., can be defined and used to determine the attractiveness of each potential project.

point of view, e.g. to enter a particular market or win a key customer for the evolution of technology. The scores are then combined to produce an over benefit estimate of each project, as shown in Table 4-5:

Financial Index norm	Potential Fundir		Comm Ass		Business As		Tech Ass		Tot Scor
3.1	Y	5	Prior 2	4	Mandatory	5	Low Risk	5	22
0.1	Y	5	Strategic	5	Strategic	3	Low Risk	5	18
- 0.0	Y	5	Strategic	5	Mandatory	5	High Risk	1	16
4.6	Y if	3	Mid Risk	2	Strategic	3	Mid Risk	3	16
0.2	Y	5	Mid Risk	2	Strategic	3	Low Risk	5	15
1.1	Y	5	High Risk	1	Mandatory	5	Mid Risk	3	15
	Y	5	Low Risk	3	Strategic	3	Mid Risk	3	14
- 0.0	Y if	3	Mid Risk	2	Mandatory	5	Mid Risk	3	13
1.3	Y	5	Mid Risk	2	Prior 2	1	High Risk	1	10

Table 4-5: Scoring Card for the Projects' Prioritization

According to this method, the prioritization will be as follow:

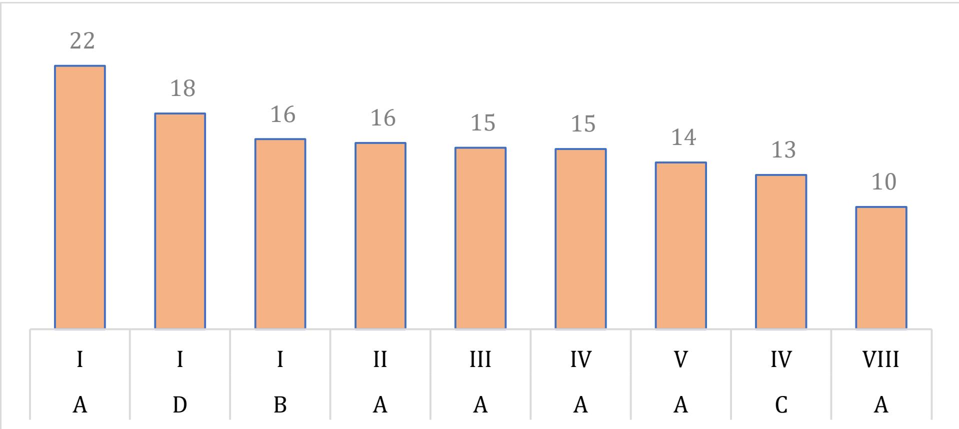

Figure 4-8: Scoring Method Final Ranking

Comparing it with the results obtained before, we clearly see how much the introduction of the risk assessment into the prioritization process changes the ranking. The most frequent output was, in descending order:

– Best overall: A-II, with an incidence of 40%, now fourth. The overall best project, according to this approach is A-I.

- Second: A-I, with an incidence of 100%, now first. Second place has been taken by the project D-I (which moved up from the sixth place).
- Third: A-VIII, with an incidence of 40%, last according to the Scoring Method. On the last step of the podium there is now the project B-I, showing an evident lack of consistency between the two methods.

	Benefit Measurement Technique		**Scoring Method**
Position	**Project**	**Frequency**	**Project**
1	A-II	40%	A-I
2	A-I	100%	D-I
3	A-VIII	40%	B-I
4	A-IV	60%	A-II
5	A-III	60%	A-III
6	D-I	40%	A-IV
7	C-IV	40%	A-V
8	B-I	40%	C-IV
9	A-V	60%	A-VIII

Table 4-6: Comparison between Benefit Measurement Technique and Scoring Method, Highlighting the differences in the Prioritization of the Projects

Once the prioritization has been defined, *Project Selection/Resource Allocation* approaches can be used to represent a second stage in portfolio selection, using inputs that can be the outputs of first stage benefit measurement methods. In particular, the following discussion will focus on the use of Portfolio matrix approaches, useful to prioritize and allocate resources among competing projects. Several well-known consulting companies have developed matrices, among which we will analyse The Boston Consulting Group (BCG), McKinsey & Company, and Strategies Decision Group (SDG). Portfolio matrices are two-dimensional visual representations of all the projects being considered. In a portfolio matrix, one dimension usually reflects the chance of success and the other the economic value of the project, or more broadly, one represents the external elements impacting the business and the other the internal aspects defining the firm's strengths and weaknesses. The location of a project inside a matrix recommends the pursuit of a certain strategy in all such matrix techniques. The goal is for decision makers to be able to pick an appropriate mix of projects on the dimensions indicated by these approaches.

We will start with the well-known **BCG Matrix**, whose dimensions are *Relative Market Share* (or the ability to generate cash) on the horizontal axis and *Growth* (or the need for cash) on the vertical one. According to this method, most of the BUs in the analysed portfolio fall into the category known as *Question Mark*, which includes those projects that have high growth prospects but a comparatively low market share (Figure 4-8). In the following exercise each BU/Project is depicted as a circle; the size of the circle represents the dimension of the revenues generated by it.

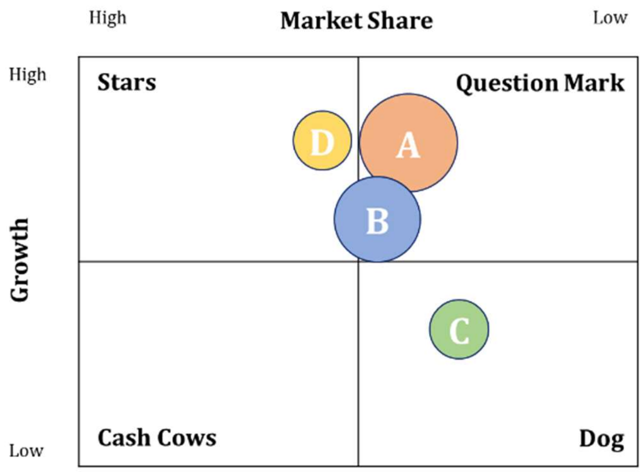

Figure 4-10: BCG Matrix Approach applied to BU level

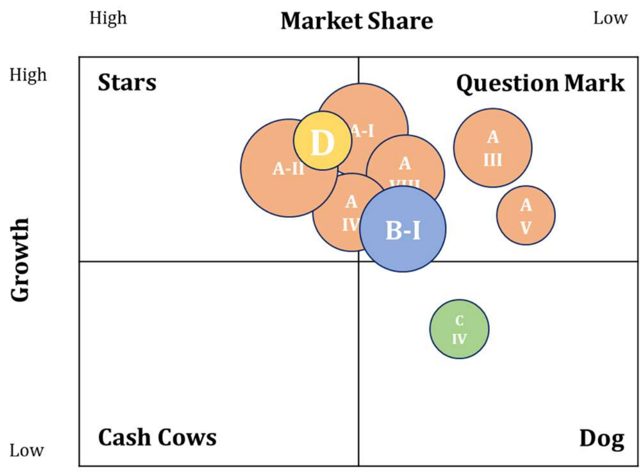

Figure 4-11: BCG Matrix Approach applied to Level 1 Projects

In both cases, the economic implications arising from this representation can be summarized as in Table 4-5, and in particular the BU A and B will require a high investment to gain market share and become *Stars*, while for BU C the BCG approach would propose to disinvest as it falls into the *Dog* category. However, if the Company realizes that BU B is not worth the investment and will eventually become a *Dog*, they can decide to disinvest. The growth share matrix has been criticised for encouraging businesses to worry too much over market share, and this can cause people to lose sight of the greater picture: in this particular case the BU C represent a strategic opportunity for the company, as it is indispensable for the implementation of other initiatives, giving them an important competitive advantage.

Business Category	**Business Profitability**	**Investment Required**	**Net Cash Flow**
Stars	High	High	Around zero
Cash Cows	High	Low	Highly positive
Question Marks	None or negative	Very High	Highly negative
	Low or negative	Disinvest	Positive
Dogs	Low or negative	Disinvest	Positive

Table 4-5: Strategic Positioning implication for the BCG Matrix

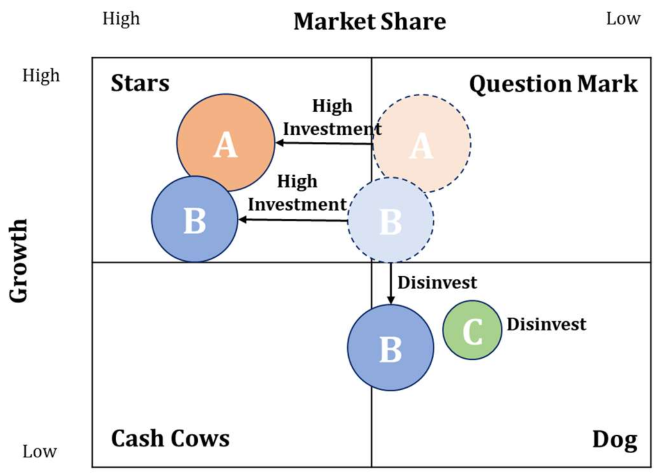

Figure 4-12: BCG Matrix Approach Investments Implications

A second approach to the portfolio selection is represented by the nine-box **McKinsey Matrix**, which depicts the BUs on its 9 cells, indicating whether the corporation should invest in a product, harvest/divest it, or conduct additional research on the product and invest in it if there are still some resources available. The BUs are evaluated on two axes: *industry attractiveness* and *competitive strength of a unit*. The process that leads to the definition of the matrix is briefly depicted below:

Step 1**.** Determine industry attractiveness of each business unit.

Step 2**.** Determine the competitive strength of each business unit.

BU	Industry Maturity	Market Attractiveness	Business Strength
A	Embryonic	Medium	High
B	Growth	High	Low
C		High	Medium
D	Growth	High	Medium

Table 4-6: Industry Attractiveness and Business Strength of the different BUs

Step 3**.** Plot the business units on a matrix. With all the evaluations and scores in place, we can plot the business units on the matrix. Each business unit is represented as a circle. The size of the circle should correspond to the proportion of the business revenue generated by that business unit.

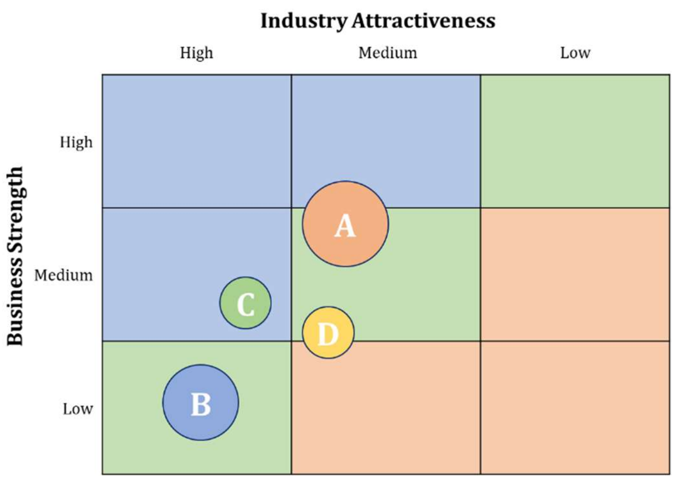

Figure 4-12: McKinsey Matrix Approach applied to BUs

Step 4. Analyse the investment Implications:

- **Invest/Grow box.** Companies should invest in the business units that fit into these categories because they guarantee the best future returns. These business units will want a large amount of capital since they will be engaged in rapidly increasing sectors and will need to maintain or increase their market share. It is critical to supply as many resources as possible to BUs in order for them to expand freely. To accommodate future demand, expenditures should be made in R&D, advertising, acquisitions, and increasing manufacturing capacity.
- **Selectivity/Earnings box**. You should invest in these BUs only if you have money left over from your investments in the invest/grow business units' category and feel that the BUs will create cash in the future. These business divisions are frequently regarded as the last to be examined since they are fraught with uncertainty. The basic guideline should be to invest in business units that operate in vast marketplaces where there are few dominating players, allowing the investments to easily obtain a higher market share.
- **Harvest/Divest box.** Harvest/divest business units are those that operate in unappealing sectors, lack durable competitive advantages or are incapable of gaining them, and perform relatively badly.

Step 5. Identify the future direction of each business unit. The assessment of the future trends of the BUs is carried out through the evaluation of three main parameters:

- *CAGR* (*Compound Annual Growth Rate*):it is the Rate of Return (RoR) necessary for an investment to increase from its starting balance to its ending balance if profits were reinvested at the conclusion of each period of the investment's life cycle, and it is calculated as:

$$CAGR = \left(\frac{Ending\ Value}{Beginning\ Value}\right)^{\frac{1}{n}} - 1 \times 100$$

  Where *n* is the number of years considered.
- *Technology Degree of Innovation*: according to the categorisation of Wheelwright and Clark

– *Commercial Assessment*: it represents the present market analysis of the project, carried out in the selection process. Accounts for the strategic value of the project.

BU	Project	CAGR	Technology deg innov	Market Attractiveness	Business Strength	Comm Ass
A	I	41%	Radically New	Medium	High	Mandatory
A	II	44%	Radically New	High	High	Strategic
A	III	71%	Radically New	Low	High	Strategic
A	IV	11%	Radically New	Medium	Medium	Mandatory
A	VIII	4%	Radically New	Medium	Low	Prior 2
B	I	98%	Next Generation	High	Low	Mandatory
C	IV	14%		Low	Medium	Mandatory
D	I	25%	Next Generation	High	Medium	Strategic

Figure 4-13: Market Assessment of the Level 1 Projects of the Bus Making Up the Portfolio Under Analysis

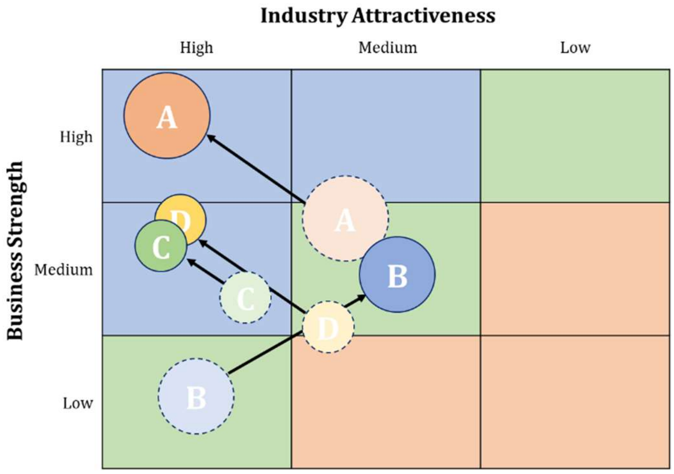

Figure 4-14: McKinsey Matrix BUs' Future Direction

From this analysis, the portfolio management should primarily invest in the BU A: it shows the best future trend, gaining higher strength in an attractive market, and moreover because it has the largest turnover. BUs C and D also represent a good prospect for the future, while BU B remains in the selectivity range and, according to this approach, should receive only left-over investments from the company.

The last approach to be evaluated is a slight variation of the **SDG Matrix**, in which the first dimension indicates *Net Present Value* or *NPV* (instead of the Expected Value), and on the other dimension the *Probability of Technical Success* of the project. The two factors are calculated for each line of the portfolio and then plotted in a bubble diagram for all of the candidate projects. The size of the bubbles or circles represents the amount of financial resources dedicated to each project, therefore functioning as a third dimension, project size. The four categories depicted in the SDG Matrix are:

- *Pearl* – Highly attractive initiatives with a high commercial value as well as a high likelihood of technical success
- *Bread* and *Butter* – Projects having a high technical success rate but a low commercial value.
- *Oyster* – Projects with a low chance of success but a high commercial value. To safeguard the firm's future, oysters must be bred to produce pearls.
- *White Elephant* – These projects have neither a high technical success rate nor a high commercial value. This category includes oysters that have been discovered to be commercially inflated, as well as bread and butter initiatives with overstated chances of success.

From this categorization, the BUs in the analysed portfolio would fall as shown in Figure 4-15:

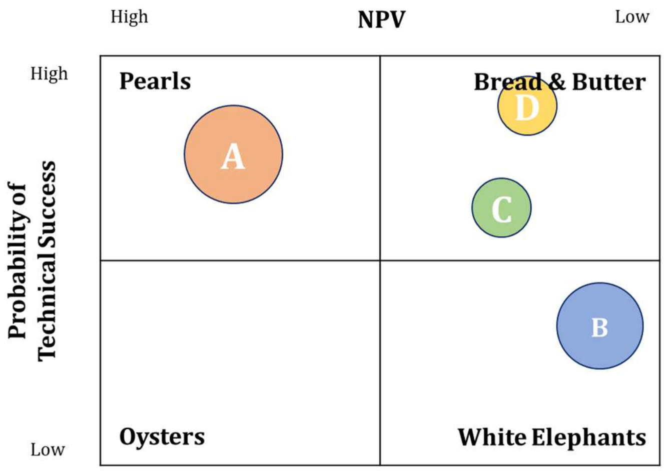

Figure 4-15: SDG Matrix Approach applied to BUs

This approach shows again a marked preference for BU A, and in particular for projects A-II and A-I (both categorized as Pearls). The majority of the projects anyway fall into the Bread & Butter category, due to their reduced profitability.

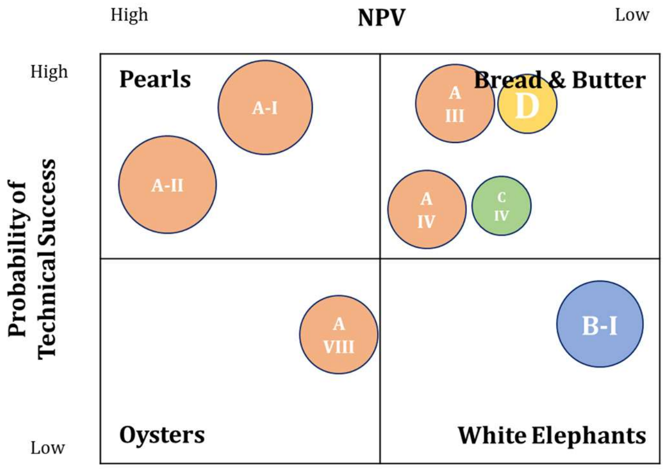

Figure 4-16: SDG Matrix Approach applied to Level 1 Projects

In conclusion, the above analysis would lead a company to invest the majority of its resources on the BU A and in particular on the projects A-I and A-II. The remaining capital should be devoted to BU C and D, both showing good profitability, low technical success risks and more importantly a good growth trend. This result is also consistent with the prioritization carried out in the first step of this analysis, at least as far as BU D is concerned.

The consistency with the results of the prioritization, either the scoring method developed in Punch Torino or the other economic indexes, and the Portfolio selection techniques leads to assume that a merging of the two stages (as it was presented in this discussion, with the latter approach developed in a second moment following the analytical ranking of the projects) would provide a comprehensive analysis of the portfolio, helping the decision makers in the projects selection. Moreover, the use of graphic and highly visual tools, such as matrices (regardless of the choice in the approach), is of great help in the selection process especially in providing a clear view of the merits of one project rather than another and facilitating both presentations and discussions during meetings.

REFERENCES

Archer, N.P., **Ghasemzadeh, F.** (1996). Project Portfolio Selection Techniques: a review and a suggested integrated approach. Innovation Research Working Group, Working Paper no.46.

Archibald, Russell D. (1992). Managing High-Technology Programs and Projects (Second Edition), New York, NY: Wiley.

Armstrong, I.Scott, Brodie, Roderick J. (1994). Effects of portfolio planning methods on decision making: Experimental results, International Journal of Research in Marketing, 1 1, 73-84.

Baker, N. R., Freeland, J. (1975). Recent advances in R&D benefit measurement and project selection methods. Management Science, 21, 1 164-1175.

Beck, K., et al. (2001) The Agile Manifesto. Agile Alliance

Canada, John R., White, John A. (1980). Capital Investment Decision Analysis for Management and Engineering, Englewood Cliffs, N.J.: Prentice-Hall.

Cantamessa, M., Rafaele, C., Cobos, E. (2007). Il Project Management. Un approccio sistematico alla gestione dei progetti. s.l.: Isedi, 2007.

Churchman, C.W., Ackoff, R.L. (1954), An approximate measure of value, Operations Research, 2

Clark, K.B., Wheelwright, S.C. (1992). Managing the New Product and Process Development. New York: The Free Press, 1992.

Cooper, R.G., Kleinschmidt, E.J. (1987). New Products: What Separates Winners from Losers. Journal of Product Innovation Management. 3, 1987, Vol. 4, p. 169-184.

Cooper, Robert G. (1993). Winning At New Products (Second Ed.), Reading, MA: Addison-Wesley.

Gibson, J.E. (1981). Managing Research and Development. New York: Wiley, pp. 24-33, 1981

Harker, Patrick T. (1989). The art and science of decision making: The Analytic Hierarchy Process. In Analytic Hierarchy Process: Applications And Studies (Golden,Bruce L., Wasil, dward A., & Harker Patrick T.,

Hax, Arnoldo C., Majluf, Nicolas S. (1984). Strategic Management: An Integrative Perspective, Englewood Cliffs, N.J.: Prentice-Hall.

Hax, Arnoldo C., Majluf, Nicolas S. (1996). The Strategy Concept and Process: A Pragmatic Approach (Second Ed.), Upper Saddle River, N.J.: Prentice-Hall.

Helfat, C.E., Raubitschek, R.S. (2000). Product Sequencing: Co-evolution of Knowledge, Capabilities and Products. “Strategic Management Journal”, Vol.21 No.10, pp.961-79.

Hess, Sidney W. (1993). Swinging on the branch of a tree: Project selection applications, Interfaces 23 (6), 5 - 12.

Kamenetzky, E., Ricardo, D. (1982). The relationship between the Analytic Hierarchy Process and the additive value function, Decision Sciences, 13, 702-71 2.

Martino, Joseph P. (1995). R&D Project Selection, New York, NY: Wiley.

Matthieu, R.G., Gibson, J.E. (1993). A methodology for large-scale R&D planning based on cluster analysis, IEEE Transactions on Engineering Management, 40(3), 283 -292.

Meredith, Jack R., Mantel, Samuel J., Jr. (1995). Project Management: A Managerial Approach (Third Ed.), New York, NY: Wiley.

McFarlan, F.W. (1981). Portfolio approach to information system. HBR 1981 (Sept-Oct): 142-151.

Murphy, Catherine Kuenz (1993). Limits on the analytic hierarchy process from its consistency index, European Journal of Operational Research, 65, 138-139.

Pessemier, E.A., Baker, N.R. (1971). Project and program decisions in research and development, R & D Management, 2(1).

Porter, M. (1980). Competitive strategy: Techniques for analyzing industries and competitors. New York: The Free Press, 1980.

Project Management Institute (2011). A guide to the Project Management Body of Knowledge (PMBOK guide). Project Management Institute.

Project Management Institute (2011). The Standard for Portfolio Management. Project Management Institute.

Remer, Donald S., Stokdyk, Scott B., & Van Oriel, Mike (1993). Survey of project evaluation techniques currently used in industry. International Journal of Production Economics 32, 103-1 15.

Riggs, Jeffrey L., Brown, Sheila B., & Trueblood, Robert P. (1994). Integration of technical, cost, and schedule risks in project management, Computers & Operations Research,21 (5), 521 -533.

Saaty, Thomas L., Rogers, Paul C., Pell, Ricardo. (1980). Portfolio selection through hierarchies, The Journal of Portfolio Management, 6(3), 1 6-21.

Schniederjans, Mark J., Santhanam, Radhika (1993). A multi-objective constrained resource information system project selection method. European Journal of Operational Research.

Schwartz, S.L., Vertinsky, I. (1977). Multi-attribute investment decisions: A study of R&D project selection, Management Science, 24, 285-301.

Souder, William E. (1984). Project Selection and Economic Appraisal, New York, NY: Van Nostrand Reinhold

Wheelwright, S.C., Clark, K.B. (1992). Creating project plans to focus on product development. HBR 1992; 70(2): 67-83.

Zahedi, Fatemeh (1986). The Analytic Hierarchy Process - A survey of the method and its applications, Interfaces, 16(4), 96-108.