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"Defining new Risk Management Indicators aimed to sustain profitability and improve predictability of an EPC Projects Portfolio: the COMAU S.p.A. case"

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Abstract

The goal of this study is to define new indicators for Project and Portfolio's Risk Management processes in order to support the profitability of Project Portfolio's itself and improve its predictability as well. The definition of the above-mentioned indicators is aimed at processes of firms operating as EPC contractors, which usually manage Projects' Portfolios with a high degree of both complexity and risk exposure. The work was developed based on real data belonging to a Regional Projects' Portfolio of Comau S.p.A, multinational Company operating as EPC contractor in the robotics and industrial automation industries. The definition of these indicators implied the following procedure: first an extensive literature review was performed to find academic models and both analytical and statistical tools which could address a proper development of the indicators. For this stage two main sources have been considered: main standards concerning Project Management and Project Risk Management and academic papers focusing on risk management indicators. Once the theorical approach have been defined, it has been applied in the professional context making use of the experts' judgment through personal interviews and dedicated focus groups. The indicators have been computed on time period of six quarters and a relevant correlation with Portfolio's profitability was found. To reach evidences that the correlations between new defined indicators and the Portfolio's profitability were significative the following methodology was applied: first a dataset have been defined, which included Portfolio's figures related to profitability, risk exposure, turnover, Risk Management performance and the new defined indicators as well. Secondly, some analysis on the dataset were carried on investigating its reliability, including a normality test. Then a correlation test was performed to determine if relevant relations between Portfolio's data and the new defined indicators exist. Finally, any

relevant correlations found were submitted to a significance test, through a hypothesis test. The indicators thus defined were calculated based on real data of the Company and from the consequent analysis of the results conclusions were drawn in order to undertake eventual improvement actions for the entire Project Risk Management process, from the commercial phase to closure.

1 - Introduction

Projects awarded to EPC (Engineering Procurement Construction) Contractors can be exponentially complex and the degree of risks to which the Contractors are exposed is extremely high. This is due to the fact that the whole Scope of Work is assigned to the Contractor; accordingly, this implies that all responsibilities for the potential consequences of risks arising from Project activities belongs to the Contractor itself. For this reason, successfully Project and Portfolio Risk Management processes are crucial factors to pursue Project's fixed goals in terms of time, cost, quality and consequently sustain Portfolio's profitability. Therefore, effective Risk Management Processes allow to predict uncertainty determined by risks, preserving value through a combined management of both Threats and Opportunities along the entire Project lifecycle, starting from the tendering phase to the closure.

Considering the above-mentioned aspects, it is clear the importance of develop, enhance and update Project and Portfolio's Risk Management processes for EPC Contractors. According to this statement, this study has been developed. The goal was providing new indicators aimed at supporting the profitability of a Projects' Portfolio and improve its predictability as well. The definition of the above-mentioned indicators was strongly based on both academic models and experience coming from the professional's context. Indeed, the work's development was based on real Corporate data made available by Comau S.p.A, multinational EPC Contractor operating in robotics and industrial automation industries.

The pursued goals in defining those indicators were mainly two: first, provide tools which allow an effective monitoring of the expected Portfolio's profitability due to the existent correlation between Portfolio’s risk exposure and marginality. Secondly, give evidence through the indicators of how the effective management of risks (both those with positive and negative effects) along the entire Project lifecycle, starting with the bid phase until the end of warranty phase, can lead to increase to Portfolio’s profitability and consequently enhancing Costumers and Stakeholders satisfaction.

In addition to the main international standards for Project Management, Risk Management and scientific literature focusing on Risk Management for EPC Contractors, experts’ judgment has been extensively used. This allowed to combine contribute coming from the academic field to the one coming from the professional’s context.

The operative calculation of the indicators and their application on a Project Portfolio followed a structured methodology based on few sequential steps which combined analytical tools, statistical tools and decision-making problems.

Results have been analyzed making use of widely diffuse statistical approach and observations were drawn.

2 - Literature Review

In this chapter are described the main pillars taken from the analysis of the scientific literature to pursue the goal of this study, which is develop new Risk Management indicators (and consequently test their significance) in order to integrate them into a corporate Risk Management process both at Project and Portfolio level. The review focused first on literature elements referred to the field of Project and Portfolio Management for EPC Contractors in general, secondly to the specific context of Comau, benefiting of academic imprinting of its internal processes. The conceptual basis for the development of new indicators were drawn from specific models suggested by the literature. The “operative” development has been done translating experts’ judgment in a quantitative output through a combination of techniques coming from the hierarchization of alternatives and decision-making tools suggested by the Project Management standards.

2.1 - Project Risk Management Fundamentals

Project and Portfolio Risk Management (PRM) processes, are crucial factors to manage successfully a Projects’ Portfolio characterized by a high degree of complexity. A structured PRM process is fundamental to predict uncertainty determined by risks and implement the best response strategy. According to Project Management (PM) and PRM standards it is possible to list three key goals that an effective and well-integrated PRM should ensure:

- Guarantee expected Project’s performance through the effective management of risks along the entire Project’s lifecycle, starting from the bid phase until the end of warranty phase.

- Clearly states and give evidences of the response strategy to each risk, to lead resource allocation accordingly and a risk-based plan of work (PoW) as well.
- Lead the continuous improvement of key aspects such as Company's profitability, Customers and stakeholders' satisfaction, quality, commercial reputation and forecast reliability, along the Project's lifetime.

To achieve these goals, a proactive PRM strongly integrated in Company's Organization is needed. Anyhow the responsibility of the Risk Management is designed within an Organization (for example it could have a dedicated function or be fully integrated within another one), it is very important that the PRM is coordinated and cooperative with Project Management (or more in general the Organization's function which lead the Project execution) to enhance its efficiency. In line with Risk Management International Standards (ISO 31000) and content of the PMBOK®, the PRM should forecast and address risks in order to mitigate or eliminate the uncertainties. It is possible to define two main phases in which the PRM is divided, both characterized by two sub-phases:

- Risk Assessment: it consists in the identification and both qualitative and quantitative assessment of risks which can occur depending on the Project's Scope of Work (SoW).
    1. *Risk Identification:*

Since that risks' root causes and their potential consequences need to be identified early stage in the Project, the first step is dedicated to the analysis of Project's context, to determine which are the potential issues in each Project's phase. Based on experience and historical data different methods aimed at detecting risks have been developed. Approach used to identify risks could be both cause-and-effect and effect-and-cause. Multiple tools are available including fault tree analysis, FMEA (failure mode and effect analysis), checklists, questionnaires and event tree analysis. According to Ammar, Kayis and Sataporn (2007) the following description of risks family, which can occur anytime along the Project lifecycle, can be given:

I. External: depending on any interested part outside the Organization (for examples variations in Customer requirements and specifications).
II. Communication: determined by language and cultural differences which can create misalignments with Customers and Suppliers due to the lack of an effective communication channel.
III. Financial: related to all the financial aspects which could be source of risks (such as the cashflows).
IV. Location: risks determined by elements such as geographic location and physical distance between interested parties.
V. Organizational : related to Company's organizational situation (structure, Firm's culture, leadership), including management of human resources.
VI. Resource: related to supplies' available capabilities, including exchange rates, inflation, budget estimation and costs.
VII. Technical: includes issues related to design, production, quality and all the other aspects based on applied science (for examples issues during the detailed engineering phase or during manufacturing).

2. Risk Quantification

Once a risk is identified, its assessment both qualitative and quantitative is performed. The goal is to size the extent of the assumed consequences. A common approach considers two parameters to measure risk's magnitude: probability of occurrence and severity (impact of the output generated by the risk). The product between these two parameters determine the risk's exposure.

$$Risk\ Exposure = P * I$$

Qualitative approach usually implies the application of a scale based on qualitative levels for both probability and impact. For example, a scale with five levels on probability can be defined as follow: *very low, low, medium, high, very high*. As regard as the impact a five levels scale can be: *negligible, minor, medium, serious, critical*. Based on these scales or on a similar one a heat map can be developed. A heat map is a matrix which has as many rows and columns as the numbers of levels of probability and impact and it is used to prioritize risks and identify most relevant ones.

Impact / Prob.	*negligible*	*minor*	*medium*	*serious*	*critical*
very low					
low					
medium					
high					
very high					

Table 1: Example of Heat Map

Colors within the heat map depends on the combination of the two factors above-mentioned and usually higher color's intensity means higher priority. Risks with higher priority represent those which must be addressed as firsts in terms of response development.

Quantitative approach is based on historical data analysis through statistical tools. Moreover, simulation technique can be used as support (for example Montecarlo simulation and other models for costs estimation such as CPM,PERT,PDM,GERT). However, in many industrial contexts difficulties in collecting data do not allow to adopt a quantitative approach due to the small domain of historical series available. On opposite, a strong contribute to the quantification phase is given by experts' judgement, best practices (even coming through benchmarking with competitors) and lesson learnt from previous Projects.

- *Risk Response:* the goal of this phase is to implement and control the output of mitigation actions taken to manage identified risks, according to the priority given in the previous phase through the risks' assessment.

1. Response Development

An effective way to manage responses to risks is trying to maximize benefit coming from the Opportunities ("positive" risks) and minimize negative impact coming from Threats ("negative" risks). Due to budget and resources constrains, it is not feasible to develop mitigation actions for all risks. Moreover, consider a mitigation action for all the identified risks would be in contrast with the probabilistic approach adopted to evaluate them. The main output of this phase is the Project Risk Mitigation Plan. Mitigation actions can follow both a reactive approach (take corrective actions when a risk event triggers) and a proactive approach (mitigation action taken in advance, based on the probability that a risk occurs). A mixed approach is often adopted and in general two main categories of responses can be listed:

I. Strategic Responses: which include transfer the risk (potential effects coming from the uncertainty are transferred to a third part, such as an Insurance Company or to a Subcontractor) and avoid the risk (considering different technical solution, change goals).

II. Tactic Responses: which include risk acceptance (can be both active or passive and implies a control plan or plan to limit the impact when the risk occurs) and risk mitigation (the goal is to reduce cause or effect, even both, of the risk through actions such as modification of procedures and processes, improve inspections and controls, redesign of the critical path and/or the resources planning). Once mitigation actions have been evaluated and applied, that part of uncertainty which still remains is defined as residual risk. To manage it, a contingency plan can be developed in case residual risks occurs. The contingency plan must be commensurate (in terms of resources) to the impact of original risks. Monetary, time and other kind of resources planned for the contingency budget can be estimate combing risk exposure assessed during previous phase and other weights evaluation.

2. Response Control: the goals of this phase are to monitor how risks which have been identified, assessed and mitigated mute along the Project lifecycle and to verify if the managing of those risks is successful. Consequently, eventual corrective actions can be taken, if needed, to improve time, costs and quality performance.

Projects risks are monitored, and evidence are given (as for the other part of the Project). Usually a monthly report (depending on the context the frequency can be higher, for example bi-weekly) is developed to check which risks are still open (the event could still occur), closed (the event cannot occur anymore or it has already occurred and consequently managed) or on going (the event is occurring). The goal is to determine deviations from Project's baseline caused by risks occurrence and evaluate corrective actions, included the eventual use of the contingency planned or on opposite its release. In this phase a continuous update of the Risk Plan is carried on.

The monitoring of performance in managing Threats and Opportunities is part of the Response Control phase, both at Project and Portfolio level. Different approach can be used, in this study indicators already part of Comau's internal Project Risk Management process have been considered. The above-mentioned indicators and the entire process is fully descripted in Chapter 3.

2.2 - Project and Portfolio Risk Management Indicators

Extensive literature regarding Project and Portfolio Risk Management and how to integrate indicators in a PRM corporate process was reviewed to sustain this study. The review aimed at finding a way to implement with a proper methodology the development of those indicators, through the combination of academic models and both analytical and statistical tools. Due to the professional work environment were the study have been developed it was necessary to analyze with attention corporate processes as well, including a benchmarking with between Companies belonging to similar industries. Analyzed processes refers both to the Projects' tendering phase and execution phase. Indeed, PRM usually starts already in the first one when a preliminary risk assessment is carried out. This assessment can strongly influence the managing of risks during the second one. Since that the scope of this study cover Risk Management processes in general, including the portion which is performed before the handover between Commercial and Project Management functions, the primary goal was to develop an indicator which could be an expression of Projects risk exposure in terms of those risks which the Company accept under its responsibility even before starting the execution, possibly related to Portfolio’s marginality. According to Thaheem, Babar and Ayub (2016) for complex construction Projects (managed by EPC Contractors) is possible to identify constituent variables (CV) related to risks, belonging to different risks’ families, which can occur during the Project’s lifecycle. This CVs modeled together with a weighting system (which consider the weight of each variable within its family and the family’s weight with respect to the others) determine a Risk Performance Indicator which, integrated with others tools such as the CPI or the SPI allow to final forecast Project’s performance with respect to the fixed goals.

In line with the above-mentioned study a shortlisted group of variables have been selected, named Risk Variable in this study, and the formula of the proposed indicator have been adapted to the Company’s context to determine a new indicator. The variables selection was made on evidence provided by historical data and experts’ judgment. According to the PMI *“Such expertise is provided by any group or individual with specialized knowledge or training, and is available from many sources, including other units within the* Organization*, Consultants, Stakeholders including* Customers *or sponsor, professional and technical associations, Industry groups”.* For this work, the group of professionals involved in the interviews (all working within the Company) includes certified Projects Managers, Risk Manager and other professionals who have matured strong experience in the Project Management field.

Once the method of Risk Variables selection has been defined, the computation formula has been considered to develop a new indicator:

$$\mathrm{RPI} = \omega_1 \left[\sum_{i=1}^{n} \alpha_i \kappa_i \right] + \omega_2 \left[\sum_{\substack{i=1 \\ j=n+1}}^{m} \beta_i \kappa_j \right] + \omega_3 \left[\sum_{\substack{i=1 \\ k=m+1}}^{p} \gamma_i \kappa_k \right] + \omega_4 \left[\sum_{\substack{i=1 \\ l=p+1}}^{q} \rho_i \kappa_l \right] + \cdots \infty \quad (0 \leq \mathrm{RPI} \leq 1)$$

the element k (perspective values of the CV) have been substituted with a Boolean value (1,0) which indicates the presence or not, in the Project, of a certain Risk Variable. Other factors of the computation formula, group weightings (ω_i) and internal weightings ($\alpha, \beta, \gamma, \rho$) for the Risk Variables, have been computed through an analytical process. This process, based on the experts' judgment, translated opinions which emerged during personal interviews and dedicated focus group, in quantitative values with the auxilium of specific software. The entire procedure is described in Chapter 4.

2.3 - AHP as support for prioritizing risks

As stated in the previous section, to determine a proper weighting system to be integrated with the Risk Variables' values, personal interviews and focus groups were carried on in order to let experts' judgment emerge. To support this task, in order to elaborate the final evaluations of the group of experts an analytical tool, Analytic Hierarchy Process (AHP) have been applied. Vargas (1990) confirms that AHP is a widely diffused tool to face decision-making problems (in different fields including economics, management, finance, marketing, forecasting, resource allocation) due to its simplicity and robustness. He attributes this success to its simplicity and robustness. According to the creator of the process, Saaty, the Analytic Hierarchy Process (2003) is a tool which allow to manage both tangible and not tangible criteria during a decision-making process. Indeed, it represent a multicriteria decision-making technique based on pairwise comparisons between alternatives with respect to a criterion (for example between a pair of alternatives which one is preferable and how intense is the preference with respect to the other) or to a goal (for example which is the most relevant with respect to a certain goal). In this study, this process has been used to determine weights of the Risk Variables previously selected, with respect to a goal. The goal, to perform the comparisons between RV, was set on the base of the potential damage on the Project's result determined by a certain RV with respect to another ("between Risk Variable A and Risk Variable B which is the most dangerous with respect to Project's fixed goals? And how much is it more dangerous compared to the other?"). The desired output was a rank of the Risk Variables to give them a weight both internal (within their risk family) and global (considering the whole set of RVs selected). The original model, developed by Saaty in 1970', define a hierarchy model on levels: Goal, Criteria, Sub-Criteria and Alternatives. It is based on pairwise comparison between elements belonging to Criteria clusters and elements within Sub-Criteria clusters. Once elements are compared at Sub-Criteria level, a local weight is provided (the weight of the element within the Sub-Criteria cluster), then comparisons of elements at Criteria level are performed. Weights at Criteria level adjust local weights providing a global weight which express the relative importance with respect to the Goal. Comparisons are based on square matrix properties and allow the decision-makers to follow an analytical process in order to assign weights , avoiding the inconsistency of reasoning (as far as possible). In this study, the lowest level (Alternative) is not needed because no choice between alternatives need to be done, while the weights of Criteria and Sub-Criteria coming from the comparisons can be easily adapted to determine Risk families' and Risk Variables' weights with respect to the potential damage on Project's goal.

According to Vargas (1990), the model is based on four axioms:

I. Reciprocal Condition satisfaction: the pairwise comparisons done by the decision-makers must evidence the preferences and determine the intensity of the preferences. Reciprocal condition has to be satisfied: if a choice “a” is n times preferable than choice “b” consequently choice “b” is $\frac{1}{n}$ times for preferred than choice “a”. For example, if Risk Variable “A” is three times more dangerous with respect to the Project’s goals than Risk Variable “B”, then Risk Variable “B” is $\frac{1}{3}$ times preferred than Risk Variable “A”.

II. Homogeneity: a bounded scale is used to represent the preferences.

III. Independency: the properties of the alternatives and Criteria are independent when preference is expressed

IV. Expectations: the hierarchic structure is assumed to be complete to perform a decision (this axiom is irrelevant for this study because no decision on alternatives had to be taken).

According to Zahedi (1986) the analytical process can be divided in four sequential steps:

I. Decision hierarchy must be established

II. Pairwise data collection

III. Determine eigenvalue of the square matrix to calculate relative weights

IV. Aggregate the relative weights on the decision elements

Due to its properties a square matrix is used to perform the pairwise comparisons. Number of rows and columns are equal to the number of elements to compare (for example if within a Risk family there are eight Risk Variables to be compared, an 8x8 square matrix perform the pairwise comparisons). Values in cells represent the ranking of the two items being compared. The bounded scale used to perform comparisons usually has nine levels with level 1=equal (the elements of the comparison are considered equal with respect to the goal) and level 9=absolutely more important (one of the two elements is considered extremely more important than the other with respect to the goal). Due to the first Axiom, values below the diagonal are reciprocal to those above (each value on the diagonal is clearly equal to 1). So, the matrix results as follow:

$$\begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{pmatrix} = \begin{pmatrix} 1 & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & 1 \end{pmatrix}$$

a_{ij} represents the relative weight of criterion *i* over criterion *j*. The matrix has rank one and this allow to refer to some properties: first, there is a single non-zero eigenvalue which is equal to the number of rows. Normalized eigenvector related to maximum eigenvalue determine the relative weights of the different criteria. Literature is divided on this use of the normalized eigenvalue to determine relative weights which is considered by many controversial. The consistency of the obtained results is given by the “distance” between the above-mentioned eigenvalue and “exact” eigenvalue. A rank one matrix is characterized by perfect consistency, the rank is increased by inconsistency and so the measure which the computed eigenvalue differs from the “exact” eigenvalue. When the matrix is consistent, a_{ij} express the importance of criterion i over criterion j and a_{jk} represents the importance of criterion j over criterion k and $a_{ij} \times a_{jk}$ must equalize the importance of criterion i over criterion k. Although, weights' values are estimation, consequently the ratios are estimates too. According to this statement Saaty underline the need of a measure which represent the level of consistency and proposes a Consistency Ratio (C.R.). Usually acceptance threshold is set to 0.1. This ratio is based on a consistency index (C.I) which is divided by a Random Index (R.I). Last one is a factor which consider the inconsistency determined by the number of elements to be compared. Below are reported computation formula for above-mentioned indicators:

$$C.I = \frac{\lambda - 1}{n - 1}$$

$R.I =$

n	1	2	3	4	5	6	7	8	9	10
R.I.	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

$$C.R = \frac{C.I}{R.I}$$

The AHP have been used to prioritize the Risk Variables, defining that weighting system (local weights and global weights) which allowed to integrate them within the Risk Performance Index showed in previous section. In this way, was possible to integrate contributes coming from literature' models and experts' judgment of professionals coming from the development context of this study.

3 - Work context : Comau S.p.A

This chapter provides an overview on the industrial context where the thesis work has been developed. After a brief introduction of the Company and its internal Project Management Process, a focus on the current scenario of Project Risk Management Process has been carried out. The goal is to give a clear vison on the "starting point" in terms of processes and methodologies, which has represented the fundamentals for the development of new indicators together with the literature review.

3.1 - Brief overview on Comau Project Portfolio

Comau (*COnsorzio MAcchine Utensili*) is a leading multinational Company in robotics and in the industrial automation field. It is subsidiary brand of Stellantis N.V Group and the headquarter is in Grugliasco (TO, Italy). The Company is able to operate worldwide thanks to an international network of 36 operative centers in 15 different countries, with 14 manufacturing plants and 5 innovation centers. It counts around 9000 employees (more than 70% of Company's resources in BRIC countries).

Comau has fully integrated capabilities in design, production and delivery of high technological solutions. Its Portfolio includes technology and systems for a wide range of industries including electric, hybrid and traditional vehicle manufacturing, industrial robots, general industry applications, collaborative and wearable robotics, autonomous logistics, dedicated machining centers and interconnected digital services and products able to transmit, elaborate and analyze machine and process data.

Company’s core business is mainly Project-driven, and it is supported by a strong Project Management culture (PM*I-Based*) certified by the high number (constantly growing) of Project Managers awarded with the PM*P® Certification*. Projects are complex and their management requires strong Project Management hard and soft skills, first because is necessary to deliver multicountry *turnkey* Project*s* (complex automated integrated systems), secondly because working on a global market it is necessary to integrate global contributions and global needs (both internally in the Company’s Organization and externally in Customers Organization). The Company operates as EPC Contractor delivering complete solutions and facilities to the Customer who will only *“turn a key”* to start operating and producing. Those facilities are delivered for a guaranteed price, by a guaranteed date, and according to specified quality and performance levels.

Figure 1: Example of products

Comau is generally awarded of the whole scope of work which includes design, engineering, procurement, construction, installation, commissioning, start up and training of the entire industrial solution. This kind of complexity needs a structured approach, which follows the standards and rules suggested by the PM*I* both at Project level and at Portfolio level. According to the PM*I* the Portfolio management is defined as: “*The centralized management of one or more* Portfolios*, which includes identifying, prioritizing, authorizing, managing, and controlling* Projects*, programs, and other related work, to achieve specific strategic business objectives”.*

The culture of Portfolio Management according to structured methodologies is consolidated in the Company which is aware of the importance and undisputed benefits coming from the above-mentioned approach. In the first place it helps to understand how the associated business is progressing, if the Projects are maturing the expected strategic and economic objectives, and it also helps to make the correct and consistent decisions, with respect to the business model, to be achieved.

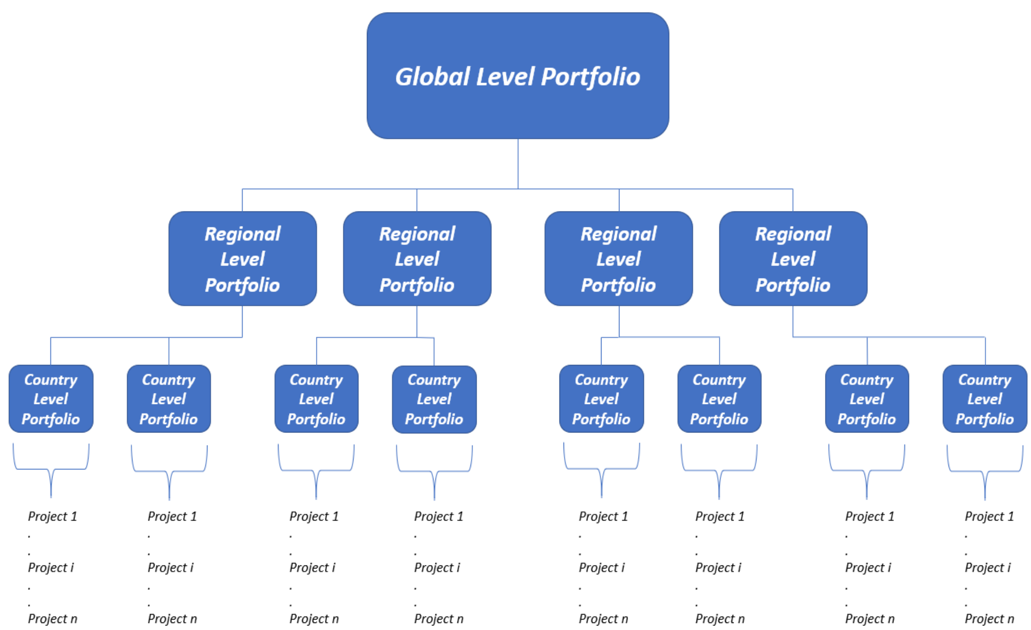

Figure 2: Projects Portfolio Structure

This Portfolio Management culture is integrated in Comau’s Organization in the following way: the Company is organized in Business Units (BUs) and geographical areas which are the typical four areas characterizing former FCA Organization: EMEA (Europe, Middle East, Africa); NAFTA (North America and Mexico); LATAM (South America) and APAC (Asia Pacific area).

Project Portfolios are defined and organized as follow:

- By Country, lowest hierarchical level, includes all BUs of a single country
- By Region, the intermediate level, includes all BUs of several countries according to a logic of geographical proximity
- By BUs, intermediate level, includes all Countries of a single BUs
- Global, is the highest level, it includes all geographical areas and BUs

Each Project can fall under the responsibility of a single Portfolio Manager or, sometimes, in case of multicounty Projects, it can cross over into wider management areas, involving different management figures who will require the intervention of higher-level Portfolio coordination if necessary. A Portfolio Manager manages resources, pursues strategic objectives and the breadth of his domain of competence is proportional to the hierarchy of levels of the Portfolio's Organizational structure. For example, a Country-level Portfolio Manager has his own domain of competence, within which Projects, resources and strategies fall.

Some of these are located on the edge, and this means that their control is not completely delegated to the Portfolio Manager in question but are shared. Furthermore, we note that there may be resources, strategies and Projects that intersect each other, this indicates an interdependence for the management of which cooperation between managers of adjacent domains will be crucial through the action of the Portfolio Manager of a higher level (in figure indicated as the Regional Portfolio Manager).

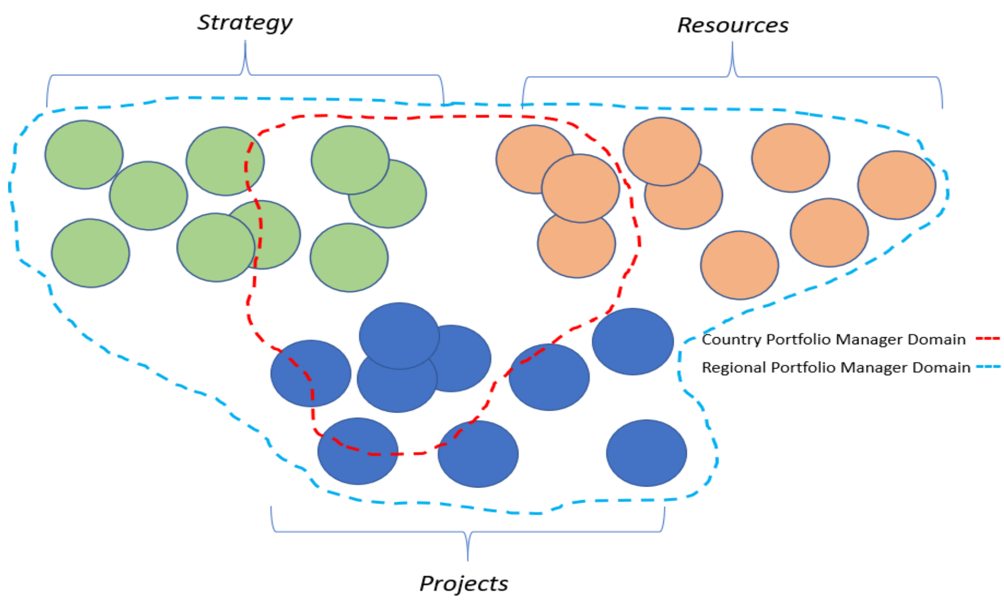

Figure 3: Example of Portfolio's Domain

3.2 - PMO, RMO and PM Academy

3.2.1 - Project Management Office

A significant pillar of the Project management culture is represented by the Project Management Office Corporate function (PMO), which works on processes, tools and methodologies that strengthen the level of cooperation all around the

Company create a link between leading roles and Project management ensuring coherence between execution and Company strategy. The main guidelines for the Organization's mission included the implementation of global Organizational policies related to Project management and since 2007, this function grew in responsibility within the Comau's Organization reaching the current configuration based on the coordinated sharing of activities between PMO, Risk Management Office and PM Academy.

3.2.2 - Risk Management Office

Risk forms an integral part of the daily challenge in the Governance of Company's Business. While mismanaged or, even worse, un-identified threats can destroy value, an effective Risk Management creates opportunities and competitive advantages for a Company, and significantly contributes to building the trust of Customers and Business Partners. In order to face the complexity (both Organizational and related to the multicultural and global nature of Comau Projects Portfolio) a structured and refined approach for managing Risks is necessary. For the above-mentioned reasons Comau created in 2011 a Risk Management Office as part of the PMO; the purpose of the RMO is to give a strong support to face the challenging Project size and complexity, providing support and governance on Risk Management to all ongoing Projects, Programs and Portfolios. In 2015, in order to create a more homogeneous and stronger Risk Management approach through the global Organization and to improve the effectiveness and quality of Risk Management and reporting at Portfolio level the Company decided to introduce an internal initiative to reinforce Risk Management culture and enhance its effective application. This was followed by another fundamental milestone: the creation of an online platform, named Risk Register Portal, where

Project Managers and Project team members can manage Project’s risks. This leaded to an improved accessibility for the Project Managers (higher quality of the analysis) and a strong time-saving centralization of data to the RMO, who has a global picture of the Risk Management effectiveness.

The main pillar of Comau RMO is that an effective risk management is proactive, and it is fundamental to identify, analyze and response risks that can potentially impact a Project and mitigate their potential impacts and or the probability of occurrence instead of reacting as issues emerge.

Currently, the role of the Risk Management Office includes the definition of corporate Risk Management process, methodologies and tools, improve the approach throughout the Project life cycle from a Risk Management point of view, provide support to the BUs for Risk Management during the bidding and negotiation phase and finally provide support to BUs for the Portfolio Risk Management. Portfolio Risk Management plays an important role within general management of the Project Portfolio. As for the management of a Project, also for a Project Portfolio the identification of the risk, the analysis and the corrective actions are vital moments of management for its success and necessarily follow logics which, although similar to those existing for a Project , however, are peculiar and deserve to be treated in their own right.

3.2.3 - Project Management Academy

Project Management Academy has been established in 2007 in order to facilitate the continuous development of extensive knowledge and skills in the Project Management field within the Company. This means the study of standards, the development of training, educational materials, special initiatives and support for Project Management professional family.

In the last years PM Academy trained thousands of managers, both inside and outside the Company thanks to the high recognition of Comau experience in the Project management field.

An internal Academy inside the Company bring a huge benefit due to continuous exchange of value between itself and the business. This allows both the side to improve and grow in terms of knowledge and business volumes.

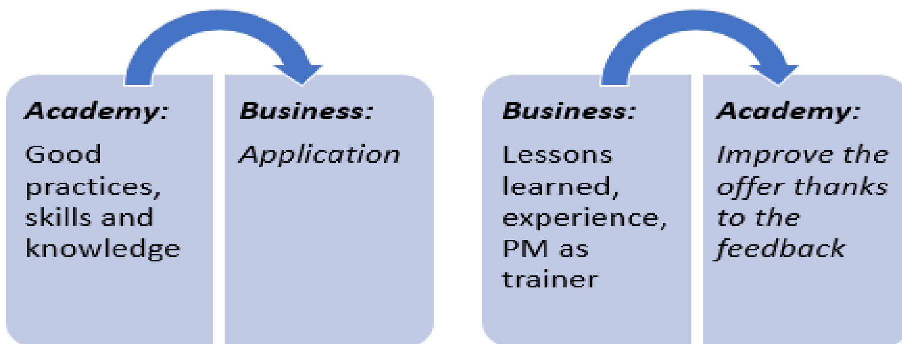

Figure 4: The relation between the PM Academy and the Business environment

3.3 - Current Internal Processes

In this section are described the internal processes of Comau as regard as the Project Management and Project Risk Management. These processes are strongly based on widely diffused approach coming from the adoption of Project Management and Risk Management international standards.

3.3.1 - Project Management Process

Comau Project Management internal processes follow the guidelines contained in the Project Management Body of Knowledge (PMBOK®, published by the PMI) and refers to others normative related to Quality Management System (ISO9001:2015), Project Management (ISO 21500) and to Enterprise Risk Management (ISO 3100) as well. Processes are described below: a different one is applied depending on the complexity of the Project. The general Project Management process is called P10.

P10 is intended to provide a framework for Project execution processes; this framework contains three alternative Project Management Processes for Project execution, which are activated based on Project complexity and Contract revenues:

• P10a - Main Projects

• P10s - Small Projects

• P10m - Micro Projects

The purpose of the P10 Process is to establish guidelines for the Project execution process, from Project start-up to Project closure. This process is intended to provide at global level a common behavior for executing Projects, in order to be consistent with the guidelines of the reference model adopted by the Company.

According to these standards Projects should be managed on the base of the following process groups:

1. Initiating
2. Planning
3. Executing
4. Monitoring & Controlling
5. Closing

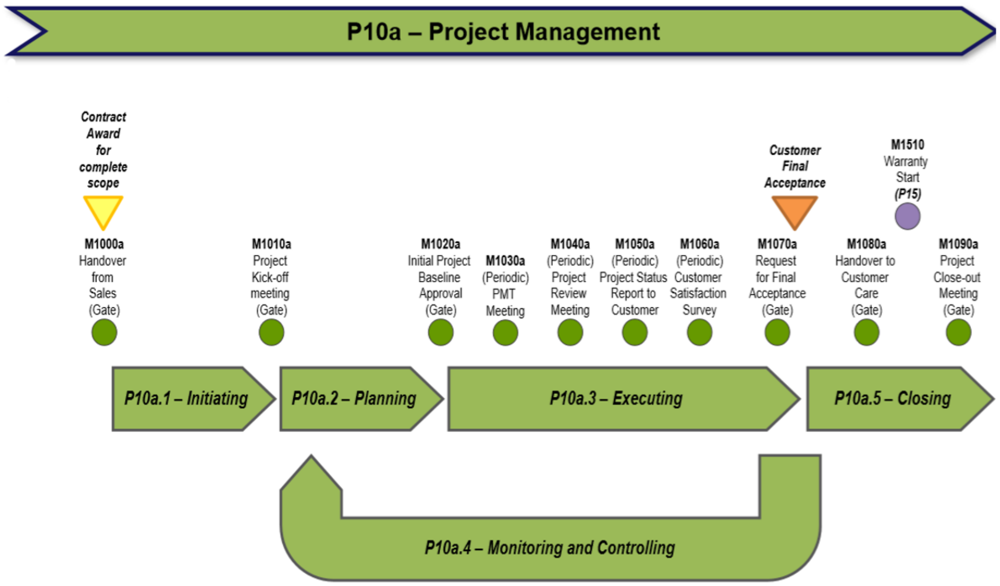

Figure 5 Main Project Management Process P10a in Comau

Initiation process group begin after that the Sales Department forward a Purchase Order (handover from sales). A detailed reassessment of the Project's SoW is conducted by the Project execution team in order to refine the work done by the proposal team during the bidding phase. The Project Charter is developed and simultaneously the PM team is formed based on available resources and workload. The main Project's stakeholders are also identified.

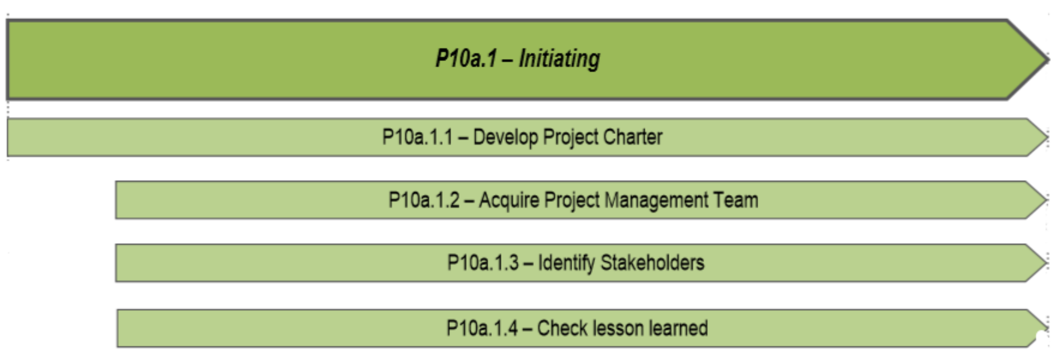

Figure 6: Initiating Process Group

Once the Project is approved and the kick-off meeting is carried out, the *planning process group* starts; a detailed plan is needed to lead the team, as well as to support the reaching of time, cost and quality goals of the Project. The Project plan provides guidance to obtain and manage resources, financing and procure the required materials. Moreover, it gives the PM team direction for deliver quality outputs, manage risks and the relation with the stakeholders involved. This process group requires the definition of the following output regarding the Project, showed in figure 7:

- Work Breakdown Structure (WBS)
- Schedule
- Risk Analysis (which will continue during Project's lifecycle)
- Project Baseline

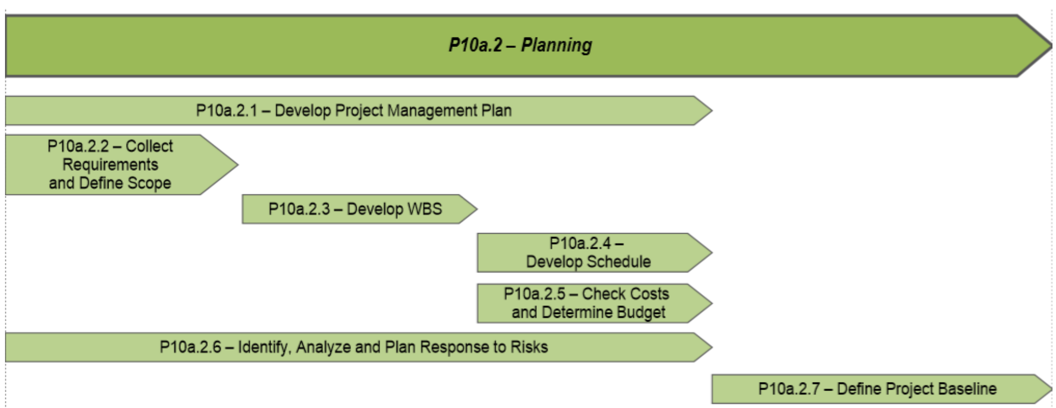

Figure 7:Planning Process Group

The following step is the *executing process group* where deliverables in order to satisfy the Customer are produced. This requires managing all the activities deemed necessary in order to reach Project goals such as manage the Project team, perform quality assurance, communicate with the stakeholder. Execution is done according to the planning, so work and contributes of the team during the execution phase are in line with the plan defined in the previous process group. This is a crucial phase for an effective and early risks identification, analysis and response. In fact, a correct and prompt approach to Project Risks in this process group can allow to avoid economic losses.

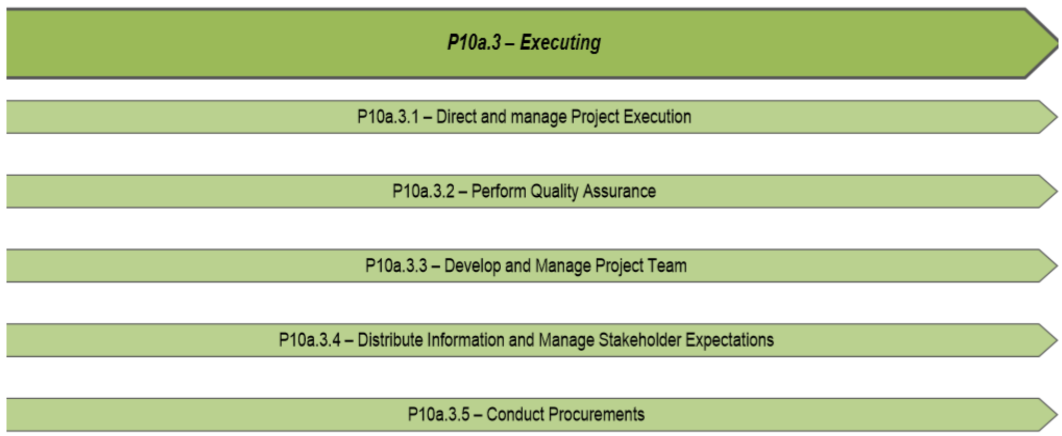

Figure 8: Executing Process Group

The *monitoring and controlling process group* proceed constantly in parallel with the entire Project’s progress. This allow to deliver correctly the scope of the Project as signed in the Project contract through the monitoring of specific key performance indicators and variations from the Baseline. This approach by the Project team drives the Project to a continuous smooth progress.

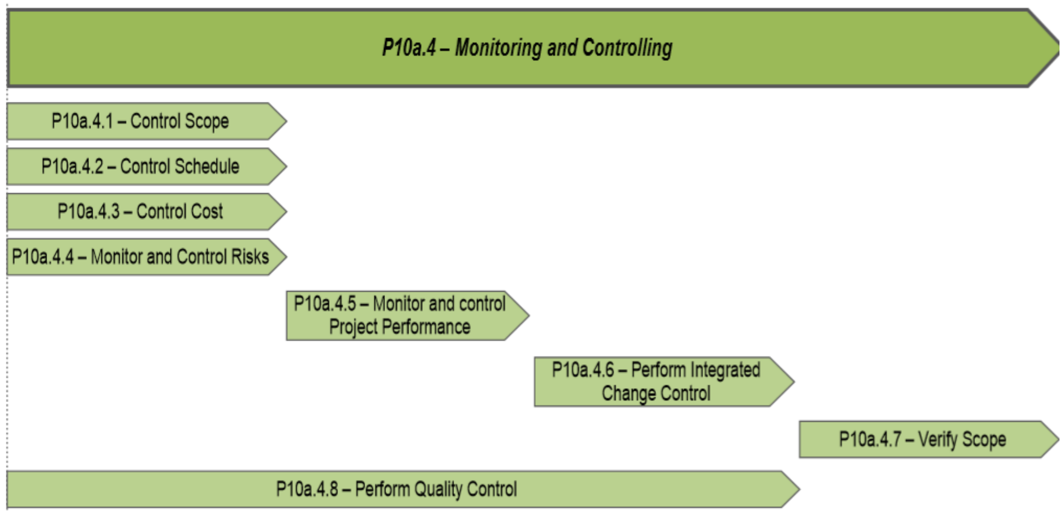

Figure 9: Monitor and Controlling process group

The last step of the Project management process is the *closing process group.* A Project is formally closed when all the deliverables are formally accepted by the Customer and this is communicated to all stakeholders. An important task performed during this last process group is the analysis of the Lessons Learnt. This is a crucial step because allows the team to move on next Projects, with an increased knowledge due to previous Project experience, characterized both by mistake and success factors. This could eventually lead to define improved processes, improve people competencies and more in general increase the risk sustainability . Moreover, usually is guaranteed after the Closing a support to the Customer Care.

Figure 10: Closing Process Group

In order to better face the needs expressed by the complex and variable business environment characterized by a strong volatility it is very important to adapt general procedure and processes to every kind of Projects.

So, for this reason the Project Management Process P10a have been made leaner to be adaptable to those kinds of Projects which need a simpler and more dynamic approach. P10s (small) and P10m (micro) are two reduced versions of the main process, which suit better to smaller Projects.

P10s was designed for Projects which need more flexibility, with a reduced number of mandatory milestones during Project lifecycle. To use this simplified Project Management approach, the Project cannot be multicounty or classified with a high level of risk.

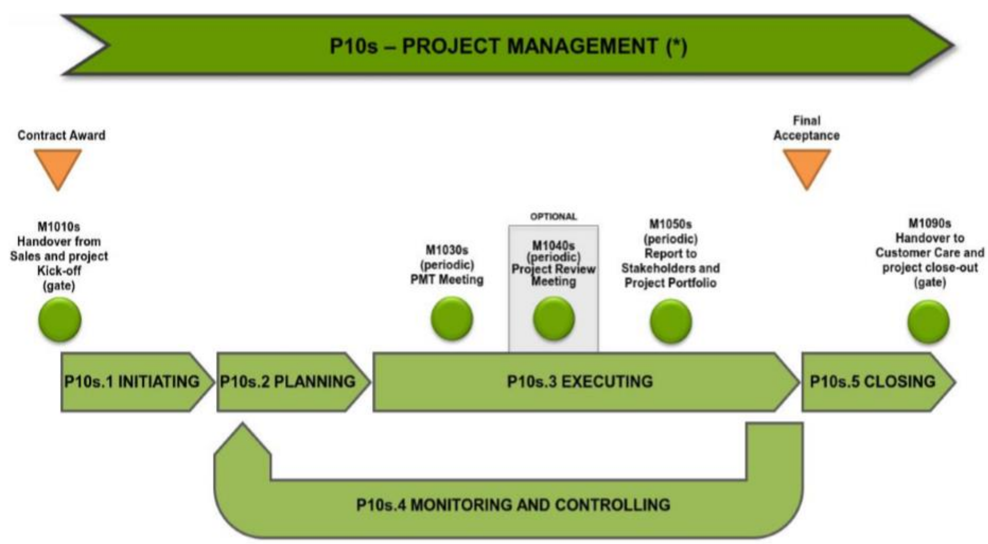

Figure 11:P10s Process

In P10m number of milestones is further reduced, a smaller Project team is required, all Projects meeting can be carried out virtually, communication and authorizations can be done via email from the Management. In this way a lot of time is saved when there is no actual need for a formal meeting. It is addressed to Project single country and not classified with a high level of risk.

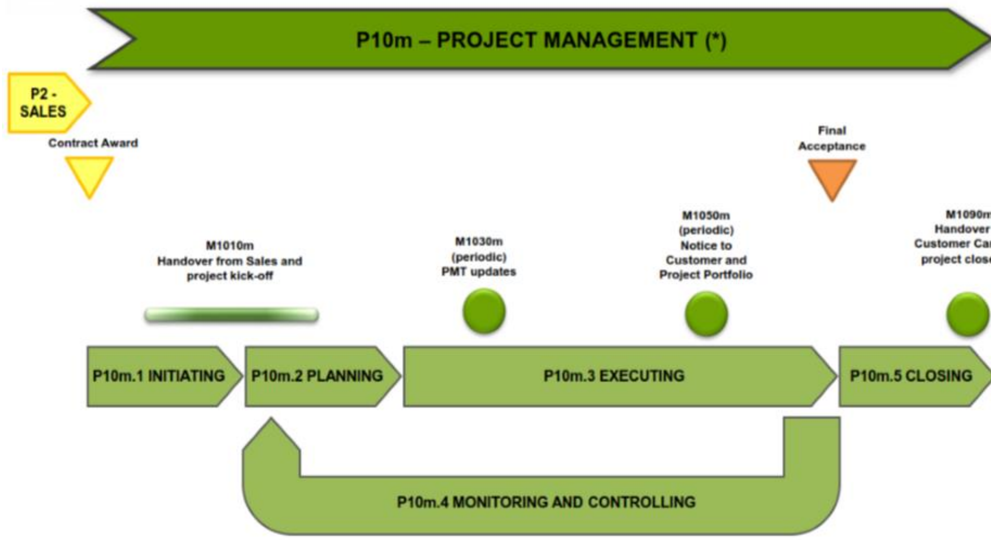

Figure 12: P10m Process

3.3.2 - Project Risk Management Process

According to the PMI a risk is defined as follow: *"an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more Project objectives such as scope, schedule, cost, or quality".* The Project Risk Management domain of action is the "*known unknown"* characterized by a partial uncertainty (risks are not issues which are characterized by a total certainty of occurrence). It is important to notice that risk is a general definition which includes both Threats and Opportunities, which represent the same thing but with an opposite sign of the impact respectively negative and positive.

The Risk Management Process has the main goal of create and preserve value in Comau Business Model through an effective management of both Threats and Opportunities and covers the entire Project life, starting from the Business case or Contract acquisition to the monitoring and control of the Risk Management

Performance on the Global Project Portfolio. It is a valuable integration agent within Comau Business Model context.

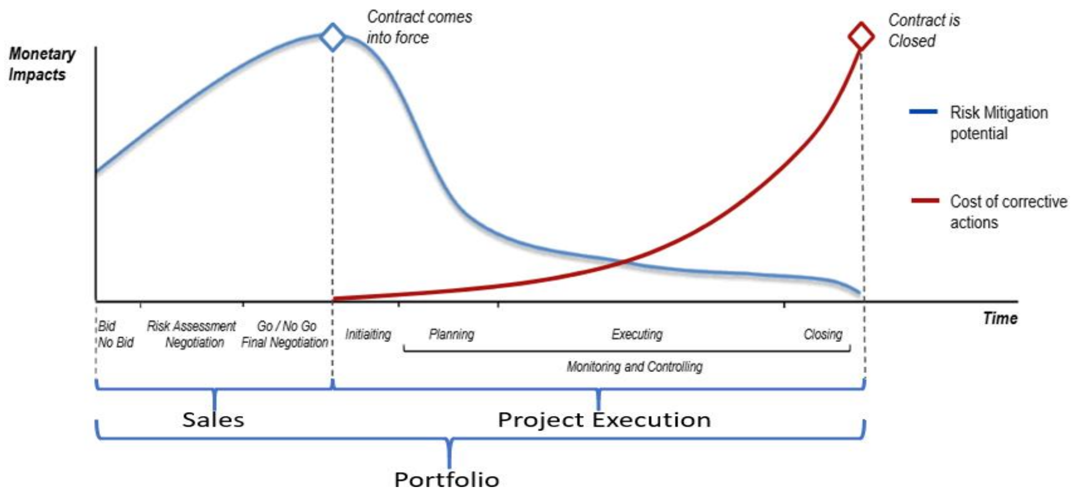

Figure 13: Risk Management Domain of Action

Operating as an EPC Contractor, the Company is usually appointed of "Fixed Price Turn-key" Contracts and plays a role of single point of responsibility towards the Customer. In this situation almost all risks are therefore transferred from the Customers to Comau that should add a substantial and well-estimated "Risk Premium" to the Bid Price.

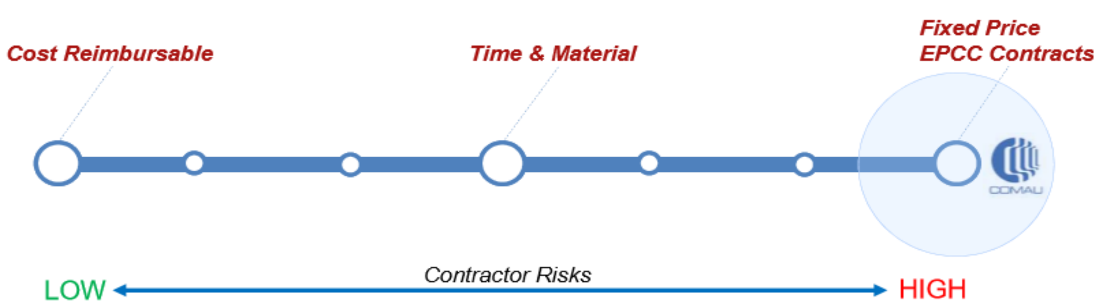

Figure 14: Comau positioning with respect to Risks' responsibilities

The *Sales Risk Management* is performed during the Sales Process when a new Contract is acquired; in coincidence with the Proposal Review and Approval, the Comau Sales Managers, supported by the Risk Management Office, respond to a Contract Risk Assessment (RAQ) questionnaire which includes a check on contractual and technological risks as well as on the list of proposal assumptions and deviations. The identified risks must be communicated and accepted by proper responsible before any formal engagement with Customers. Furthermore, the need of Technical Contingency financial protection adequate for the Contract risk exposure is to be considered in the price formation and while starting the internal Bid approval workflow.

The Risk Assessment Questionnaire is the key element of this phase, it defines the level of risks of the Project, from a contractual point of view, through a score based on the answers given related to a set of specific questions. Questions are divided on the base of four different Risks Families:

- Operation: these questions are related to risks which could have a more direct impact on the Project execution, such as particular limits on the Project delivery time, obligation on eventual retooling, new technology needed and all those aspects related to the reliance on information needed from both the Customer and the Suppliers during the execution.
- Finance: contains questions about risks mainly related to Contractual Payment terms, Project Cashflow, payment collection, bonds or guarantees, currency risk exposure. Finance team must be involved for support in the risk analysis.
- Legal: questions linked to all those contractual risks having a root cause in the Legal field, for example the specification of responsibility in case of indirect and consequential damages, or related to Incoterms rules which

are a series of pre-defined commercial terms relating to international commercial law accepted by governments and legal authorities worldwide and published by the International Chamber of Commerce (ICC). Another relevant aspect of Legal risks is associated to the Intellectual property rights.

- Tax and Country: questions are about topics such as the need of a permanent establishment in the country where the Project will be executed, the possible subjection to a withholding tax or to other kind of local taxes.

In each family the questions are divided in two level on the base of importance of the risks to which they refer: the first level is referred to those risks which need the Advisory Board to be informed and involved in the Bid\No bid approval milestone (which means an escalation of the approval level), the second one contain those questions linked to risks which doesn't cause eventually an escalation but contribute to the general view of the Project risk exposure and to the calculation of the Contract Risk Score.

As previously said, the given answer to each question produce an overall score, called Risk Score, which is a mandatory input to Portfolio Management and Decision Making to tune Portfolio basing on Company *Risk Appetite.*

All the risks identified through the questionnaire, together with a list of assumptions and scope deviations not accepted by Customer are the output of the sales risk management step and it represent the input for the risk management process during Project execution (performed during the *planning process group* and the updated for all the Project lifecycle). This risk identification input is integrated with the identification of new emerging risks found at the Project start (i.e. from a further contract and condition elements review by the PM team) and during the entire Project execution life.

The Risk Management Process is one of the most critical aspect of the wider Project management process. The process is driven basically by five key questions which determine as many process steps (sequential and recurring).

Figure 15: The Risk Management Process during Project Execution

Figure 16: The Risk Management Process during Project Execution

1. *Plan risk management*: "what are we trying to achieve and how?"

In this step the goal is to assure that objectives are well defined and the context where risks have to be managed is well understood (and collected into a Risk Management Plan) in order to set goals and methods to achieve an effective management of Project threats and opportunities, in line with the Company rules and expectations.

2. *Identify Risk: "what might affect us achieving the objectives?"*

The identification is carried out starting from the Project kick off and it continues during the Project planning and at each Project reviews, covering the entire Project lifecycle. In order to well define risks a standard taxonomy in their description must be followed: "Due to (…) *there is the risk that* (…) *which could cause* (…)". In this way root causes, Threats or Opportunities and negative or positive impact are clearly detected. Moreover, risks shall be classified according to *risk areas* (Project's phase where the risk may firstly impact if it realizes) and *risk categories* (define the category of the root-cause for the risk identified).

3. *Risk Analysis: "which risks are most important?"*

This step can be divided in two parts, a qualitative analysis and a quantitative one. The identified risks are reviewed with the aim to effectively estimate their *Probability of Occurrence (P)* and their *Potential Impact (I)* on Project's goals. Probability and impact are classified according to a standard metric, then Risks are prioritized through the computation of their *Risk Exposure (PxI).*

	Risk Probability (P)				
	Very Low	Low	Medium	High	Very High
DESCRIPTION	Extremely Unlikely to occur	Unluckily to occur	Possible to occur	Likely to occur	Extremely likely to occur
REFERENCE VALUES	< 20%	20%-40%	40%-60%	60%-80%	>80%

Table 2: Risk Probability Standard Metric

	Risk Impact (I)				
	Negligible	Minor	Moderate	Serious	Critical
DESCRIPTION	No significant effects in term of additional Project’s cost/savings	Small effects in term of additional Project’s cost/savings	Moderate effects in term of additional Project’s cost/savings	Serious effects in term of additional Project’s cost/savings	Critical effects in term of additional Project’s cost/savings
FINANCIALS IMPACT RANGE	< 1% of baseline margin	1%-5% of baseline margin	5%-10% of baseline margin	10%-20% of baseline margin	>20% of baseline margin

Table 3: Risk Impacts Standard Metric

The standard metrics allow to define a common *Risk Ranking Matrix* through the combination of their values. The analyzed risks are classified with a Rating Index which is a qualitative measure of its Risk Exposure. The metrics combination can provide three level of exposure: low (L), medium (M) and high (H) as showed in the table below.

This Matrix is valid for both Threats and Opportunities; for High and Medium Risks a response plan is needed and eventually the allocation of a Technical Contingency could be request. Consequently, to the qualitative analysis a quantitative one is also performed. It consists in a numerical estimation of the monetary impact, made by experts in the work area of the Risk.

Impact / Probability	Negligible	Minor	Moderate	Serious	Critical
Very Low	L	L	L	L	M
Low	L	L	L	M	M
Medium	L	L	M	M	H
High	M	M	M	H	H
Very High	M	M	H	H	H

Table 4: Risk Exposure

4. Plan and implement responses:

Risks can be avoided (exploited in case of opportunities), mitigated (enhanced), transferred (shared) or accepted (actively or passively for both threats and Opportunities) according to the type and significance of the Risk. The most appropriate response strategy must be selected by the Project Manager. As regard as the *avoidance strategy* it consists in the complete elimination of the root-cause of the threats, in order to ideally reduce the probability of occurrence to 0%. This action could determine strong modifications on Project's plan. On opposite the *exploitation strategy* for Opportunities is aimed to raise the probability of occurrence to ideally 100%.

The *transfer strategy* means allocate risk's ownership to a third Party passing to this the responsibility and the managing of the threats (the third part could be for example an insurance Company or a sub-Contractor). By contrast, the *sharing strategy* for Opportunities is aimed to involve a third part who is in a better position to exploit the opportunity and increase the potential overall benefit or value.

The application of a *mitigation strategy* means performing actions to reduce the impact of the threat and/or its probability of occurrence. Similarly, the *enhancement strategy* for Opportunities is aimed to increase the impact or the probability of occurrence.

Finally, Risks in general can be *accepted* in an *active way* (prepare a response in a form of contingency plan but to be implemented only when the risk occurs) or in a *passive way* (be conscious of the existence of the risk but do nothing unless it occurs).

Strategies	
Threats	**Opportunities**
Avoidance	Exploitation
Transference	Sharing
Mitigation	Enhancement
Acceptance active/passive	

Table 5: Response Strategies

5. Control Risk:

This is ideally a daily effort by the Project Manager and its team to be periodically reported (usually monthly in correspondence to the Project Review) having a dual goal: firstly it is necessary to evaluate the real effectiveness of the response strategy adopted on the Risks identified and analyzed in the previous step and, secondly it should lead to new risks identification, update of the existing ones, redefinition of response strategy and eventually to risks *closure.* The closure action could have two possible outcomes: the risk is *realized* so it is not anymore in the uncertain field and it transforms in an issue (the associated Technical Contingency is then used to manage the issue) or in a materialized opportunity, on opposite when the risk in *not realized* it means that the response strategy was successful (in case of threats, so the allocated Technical Contingency is released) or wrong (in case of opportunity not achieved).

As previously described in Chapter 2, through the cooperation between the Company and academic experts, since 2017 the Risk Management Process have been enhanced with the development of Risk Management Key Performance Indicators. Therefore, to assess the effectiveness in risk responses planning and implementation on every Comau's Project a numerical analysis based on closed risks is conducted and three different indicators (one for Threats and Opportunity respectively and one combining the previous two) are monitored:

$$\mathrm{RE_t} = \frac{\mathrm{MI_{TCnr}}}{\mathrm{MI_{TCnr}}+\mathrm{MI_{TCr}}};$$

$$\mathrm{RE_o} = \frac{\mathrm{MI_{OCr}}}{\mathrm{MI_{OCnr}}+\mathrm{MI_{OCr}}};$$

$$\mathrm{RE_c} = \frac{\mathrm{MI_{TCnr}} + \mathrm{MI_{OCr}}}{\mathrm{MI_{TCnr}} + \mathrm{MI_{TCnr}} + \mathrm{MI_{OCnr}} + \mathrm{MI_{OCr}}}$$

With t= Threats; o= Opportunities; MI = Monetary Impact (quantitative measure of PxI); C_{nr}= Closed Not Realized; C_r = Closed Realized

Considering the actions implemented against (to pursue) the identified Project Threats (Opportunities), these indicators measure the current effectiveness achieved by every Comau Project at any point in time. Consolidating the KPI results of group of Projects it is also possible to determine the Risk Management Performance as well as the weaknesses or exposed areas at Portfolio Level.

The whole Risk Management process is managed through an online tool, the Project Risk Management Portal (PRRP). This tool is integrated with other Comau's Data Management Systems and produces standardized outputs easy to merge according to the appropriate level of management.

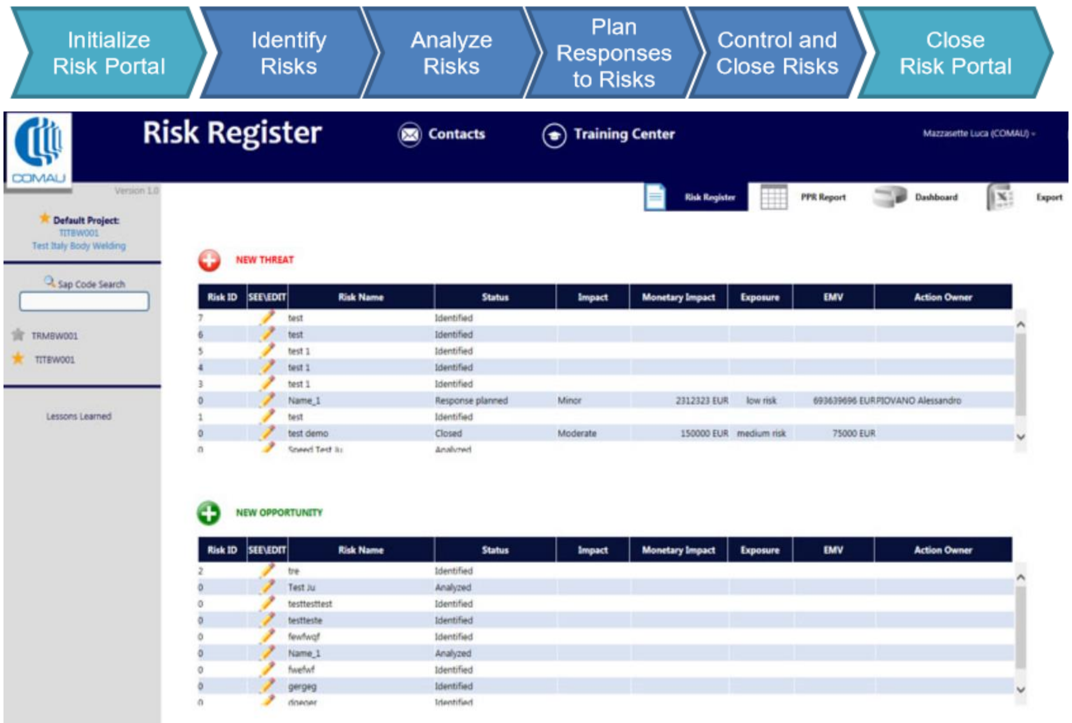

Figure 17: A view of the PRRP

Figure 18: A view of the PRRP

4 - New indicators development based on the current Risk Management Scenario

In this chapter is investigated how new indicators have been built and how they could be integrated on the current Risk Management Process in order to enhance Portfolio predictivity and profitability. The goal is to explain clearly how ideas coming from literature review have been applied in the industrial context through specific analytical tools managed from experts in the field of Project Management and Risk Management.

4.1 - Development of a new Portfolio Risk Score Index

The new Portfolio *Risk Score Index (RSI_{PF}),* which is the result of an extensive literature review together with dedicated focus groups carried on in cooperation with industrial experts, is essentially built up by two elements: the *Project Risk Score Index (RSI_j)* and the associated *Project's weight (W_{prj})* on the Portfolio, as showed in the following formula:

$$RSI_{PF} = \sum_{j=1}^{n} RSI_j * W_j, \text{ with } j = \{1,\ldots,n\} \text{ Project's number}$$

These two elements have required a set of sequential actions in order to be built in the Company's context: once the Risk Score Index have been defined at Project level then a weighing system has been defined, in order to apply the indicator at Portfolio level. The set of sequential steps which has been followed is listed below:

1. *Selection of the appropriate Risk's root causes for EPC Contracts (named as Risk Variable):* this first step has been done to review the current Risk Score for single Projects (which has been defined in the previous Chapter in the

field of Sales Risk Management, section 3.3.2). The goal was to make the output coming from the analysis of contractual risks more based on Risk Variables that may have a significant impact in the Project execution phase in order to give greater predictive value to the measure it provides. The selected Risk Variables have been grouped in macro Risk's Categories (same as Risk Families defined in Chapter 2).

2. *Determine the weight of each Risk Variable through analytical method:* the relative weight of each Risk Variable has been calculated using the Analytical Hierarchy Process (AHP) performed with a specific software tool through personal interviews of PMO, RMO and PM Academy members to benefit of the *experts' judgment.*
3. The approach used in the previous step have been iterated to define the weights of the three Risk Categories. In this case model was applied using the same specific software but instead of conduct personal interviews a focus group have been organized with the same members of the previous step. Since the goal was to produce a common output through a group discussion, to manage situations of uncertainty a set of rules has been defined, inspired by the Planning Poker methodology which is typical of Agile Project Management.
4. Once defined the relative weights of both the Risk Variables and Risk Categories the RSI_j can be calculated through a Risk Assessment Questionnaire based on Comau model, constituted by questions associated to each Risk Variables selected. Only Boolean answers (Yes/No) are allowed according to the presence or not of the risk linked to the root cause mentioned in the question. If Yes, the Risk Variable contribute to the RSI_j with its relative weight adjusted by the weight of the Risk Category to which it belongs.

5. To move from the Risk Score Index defined at Project level to the one at Portfolio level it has been necessary to sum the contribute of each RSI_j of active Projects in the Portfolio. Of course the sum cannot consider the simple average of RSI_j values because each Project has a different relevance within the Portfolio, so each RSI_j must be weighted to have a weighted sum according to the impact of the different Projects within the Portfolio.
6. Finally, having computed Risk Variables' local weights, Risk categories' weights and Projects' weights on the Portfolio, simply combining these factors was possible to determine the Risk Score Index at Portfolio level.

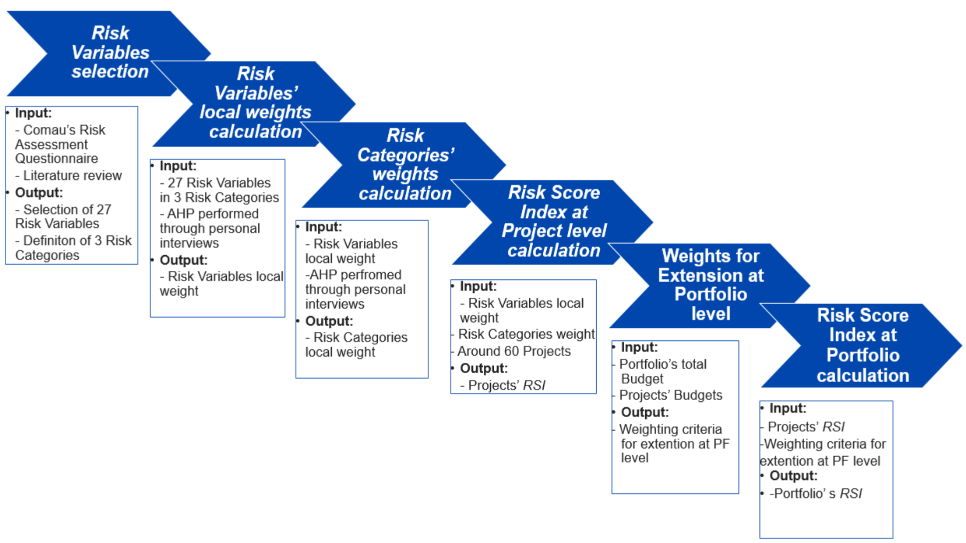

Figure 19: Sequential steps to determine the Risk Score Index at PF level

4.1.1 - Risk Variables selection

Figure 20: Sequential steps to determine the Risk Score Index at PF level

The Risk Variables selection was made starting from the original Comau Risk Assessment Questionnaire identifying those risks which could have an impact in the Project execution. This allowed to define an indicator representative of a Portfolio which contains Projects at different stages. Therefore, since that the considered Regional Portfolio stays at an average percentage of completion between 50% and 60% (according to monthly report), the goal was to build an indicator based mainly on Risk Variables referred to risks which can occur during the Project execution. According to this, its monitoring can have a predictive value which, as explained in the following Chapter (see section 5.4), it is also possible to associate with variances in the Portfolio's profitability.

A selection of twenty-seven Risk Variables was performed, these have been divided in three Risk Categories according to Comau taxonomy of the risks (two of original four have been grouped due to numeric reasons). It is important to note that this selection could be valid for others EPC Contractors operating in the same industry or in similar one but, at the same time each Company could enlarge this selection according to its specific Business Context. The three Risk Category are

1. *Finance and Tax*
2. *Legal*
3. *Operations*

Below, three tables list the Risk Variables belonging to each Category with a brief description:

Finance and Tax		
1	Permanent Establishment	Company liability to be taxed in the Customer Country (i.e. have to register for a "Permanent Establishment")
2	Witholding Tax	Company' risks subjected to witholding tax (WHT) or similar on Payments from the Customer
3	Employees Social Security	Company' Employees need to stay in the Customer Country (different from their Country) more that 182 days in each year and need a working VISA permission and social security obligation
4	Cashflow	Proposed cumulated Cashflow during the Project execution show a negative amount higher than 1 M€ for more than 2 consecutive months
5	Collections	Contract foresees Collections of total or part of the Contractual Value which depend on achievement of milestones out of Company control
6	Bonds or Guarantees	Customer/Contract expressly require Company to secure its contractual obligation by providing one or more specific support (Corporate guarantee, Bank guarantee or Insurance policy)
7	Currency Exposre	Currency Exposure during Project Execution
8	Insurance	Company's existing Insurances policies (risk covered, Limits and Deductibles) not sufficient with the Contractual obligations

Table 6: Tax and Finance Risk Variables

Table 7: Tax and Finance Risk Variables

Operations		
9	Project Delivery Time	Delivery time of the Project requested by Contract to be considered TIGHT if compared with Company estimation and/or previous similar Project
10	Retooling Content	Company's Contractual Obligation include entire or partial retooling on existing systems originally provided by others
11	Technology and Standards	Contract's requirements impose the application of a new Technology (defined as Technology which has not been utilized with success in at least two profitable prior Projects) or significant deviations from Company standard products and solutions
12	Offer Assumptions	Following the Contract Customer requirement analysis, there is at least one "unclear or undefined item" on which Company is making major assumptions to base the Proposal (scope and costs)
13	Customer requirements Deviations	At least on deviation from documented Customer requirements (technical, commercial, contractual etc.) accounted in our offer
14	Feasibility Assessment (Resources)	Resources availability in terms of workload, job sharing structure, specific skill eventually not available in Company, enginnering/manufacturing capacity etc. could be mot suffcient and not adequate for the feasibility of the Project
15	Reliance on Customer's deliverables	Risks on timely delivery of input documentation, material, availaibility of costruction areas etc. expected from Costumer
16	Project Acceptance Criterias	Scope of work Acceptance Criterias (in terms of Performance Levels to be achieved and Performance test conditions) not clearly defined by Contract and/or not reviewed and understood at all by Company
17	Imposed Suppliers / Subcontractors	Do the Customer Requirements impose to Company the employement of SOLE SOURCE SUPPLIERS (unique provider of a specific product\service in the market) or IMPOSED SUPPLIERS, which are deemed to be not appropriate or critical (i.e. due to past negative experiences,
18	Local Regulations	Shall the Project during construction and commissioning at the Customer Site, comlpy with specific local regulations, environmental requirements or Site Health&Safety requirements poorly known or never experienced by Company?
19	Certifications	Does the execution of the Project require Company to obtain specific product\equipment\systems\design Certifications (such as CE, UL, EAE etc.) NOT standard for Company to be in compliance with Customer Contract requirements and\or with normes
20	Change Orders	Does the Contract include clear clauses and a well defined and agreed procedure (communication protocol, change orders forms, defined submission and approval workflow etc.) to manage change orders?

Table 8: Operations Risk Variable

Table 9: Operations Risk Variable

Legal		
21	Indirect and Consequential Damages	Are Indirect / Consequential Damages expressly excluded from the Contract?
22	Penalty and Liquidated Damages	Are penalties included in the Contract? If yes, are they limited in the overall to a maximum of 5% of the Total Contract Value?
23	End Users	Is the Customer the END USER of the products/systems under the Contract?
24	Country Risk	Is the Country, where the Contract is to be executed, included among the Countries subject to commercial restrictions or prohibitions (i.e. embargo, mandatory public licence, etc.)?
25	Mandatory Business Requirements	Are the products/services/data involved in the Contract subject to the US/EU export control laws and regulations (i.e. dual-use) or other specific export or re-export or mandatory requirements? (if YES, provide evidences on status in the notes)
26	Termination	Is Customer's right to Terminate the Contract for Convenience (i.e. "At will") expressly stated in the Contract?
27	Dispute Resolution	Is any Dispute Resolution Clause (e.g. Tribunal or Arbitration) provided under the Contract?

Table 10: Legal Risk Variables

Table 11: Legal Risk Variables

4.1.2 - Risk Variables' local weights calculation

Once the Risk Variables have been selected a further step was performed to calculate their relative weights within Risk Categories. To determine a consistent weighting system, AHP multicriteria decision model as stated in Chapter 2. The goal in applying this method was to support experts' judgments with an analytical tool to develop a well-defined weighting system characterized by a high logical consistency. Those weights are then applied to the RSI_j formula, which is based on the one taken from the literature (see paragraph 2.2). The AHP has been selected as decision model to define the weighting system due to its perfect suit to the specific features of the RSI_{PF} formula. Exploiting the formula above-mentioned referred to the j^{th} Project results:

$$RSI_j = \{W_{FIN\&TAX} * (\sum_{i=1}^{n} w_{FIN\&TAX_i} * RiskVariable_{FIN\&TAX_i})\} +$$

$$\{W_{LEGAL} * (\sum_{i=1}^{n} w_{LEGAL_i} * RiskVariable_{LEGAL_i})\} +$$

$$\{W_{OPERATION} * (\sum_{i=1}^{n} w_{OPERATION_i} * RiskVariable_{OPERATION_i})\}$$

Said that the members *Risk Variable* can only assume Boolean values (1/0), this formula requires the definition of two different kind of weights: the first one is a *local weight (* $w_{FIN\&TAX_i}$*;* w_{LEGAL_i} *;* $w_{OPERATION_i}$*,* note that $\sum_{i=1}^{n} w_{FIN\&TAX_i} = \sum_{i=1}^{n} w_{LEGAL_i} = \sum_{i=1}^{n} w_{OPERATIONS_i} = 1$*)* *,* related to each Risk Variable within its Category, the second one is the *Risk Category weight (*$W_{FIN\&TAX}$*;* W_{LEGAL}*;* $W_{OPERATION}$ *note that* $W_{FIN\&TAX}$+ W_{LEGAL}+$W_{OPERATION}$ =1 *)* to determine the relative importance of each Risk Category with respect to the others.

The *local weight* adjusted by the *category weight* (both values included between 0 and 1) provide the *global weight* of the single Risk Variable which, combined with the Boolean value of the associated *Risk Variable* (1/0) determine the contribute of that Risk Variable to the final Risk Score Index at Project level. Based on the above-mentioned structure the AHP was developed accordingly; as described in the Chapter 2, the original methodology defines a hierarchy model constituted by a goal, criteria, sub criteria and alternatives (not needed for the aim of this study). It is based on *pairwise comparison* between elements within Criteria clusters and elements within sub criteria clusters to determine relative importance respect to the goal. Adapting this approach to this specific context the hierarchy model was defined as showed in the figure below:

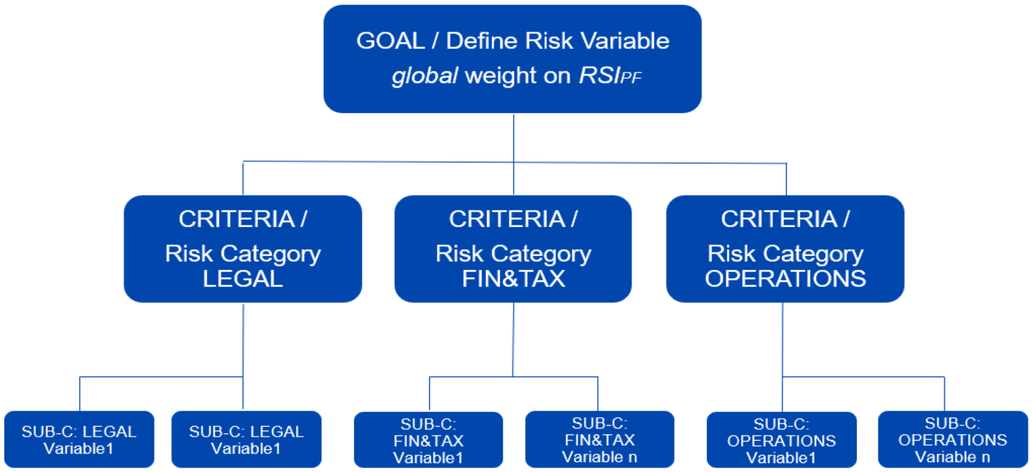

Figure 21: AHP Model

Figure 22: AHP Model

The pairwise comparisons have been effectively performed through the dedicated software *SuperDecisions*© (2020 Creative Decisions Foundation, responsible of development and maintenance, all rights reserved) which is an educational tool that implements AHP developed by the team of the creator of the method (Thomas Saaty), using the following scale of values to compare the importance of the each variables with respect to the others (as explained previously the importance is intended as severity of the possible impact on the Project's execution caused by an eventual occurrence of the risk related to that Risk Variable):

Intensity of importance	Definition
1	Equal importance
3	Somewhat more important
5	Much more important
7	Very much more important
9	Absolutely more important
2, 4, 6, 8	Intermediate values

Table 12: Ratio scale for pairwise comparison

The comparison's technique is based on square matrix properties and allow the decision-makers to avoid the inconsistency of reasoning (as far as possible); this aspect is monitored through the *consistency ratio* which is the rapport between the *consistency index* and a *random consistency factor* (proportional to matrix size):

$$\textit{Consistency Ratio= C.R} = \frac{CI}{RI}$$

where, $CI = Consistency\ Index = \frac{\lambda_{max}-n}{n-1}$ and *RI* tends asymptotically to 1,49 for matrix size bigger than 10x10. Considering all the interviews, the maximum inconsistency value measured was 5.98%, well below the acceptance limit proposed by the literature (10%). Once each member of the PMO, RMO and PM Academy has completed his personal interview, where each Risk Variable within

TAX&FINANCE

1	Permanent establishment	20,58%
2	Collections	16,35%
3	Cashflow	15,77%
4	Currency exposure	13,45%
5	Employees social security	12,37%
6	Witholding tax	10,74%
7	Bonds or garantees	6,00%
[illegible]	[illegible]	[illegible]%

Table 13: Tax&Finance Risk Variable local weights

the different Risk Categories was compared to the others, the values of *local weight* ($w_{FIN\&TAX_i}$; w_{LEGAL_i}; $w_{OPERATION_i}$) have been assigned:

OPERATIONS

9	technology and standards	19,33%
10	project acceptance criterias	10,24%
11	offer assumptions	9,00%
12	Project delivery time	8,97%
13	feasibility assessment (resources)	8,62%
14	retooling content	8,49%
15	certifications	7,21%
16	imposed suppliers/subcontractors	6,31%
17	customer requirements	6,26%
18	local regulations	6,20%
19	change orders	4,93%
20	reliance on customer's deliverables	4,46%

Table 15: Operations Risk Variables local weights

Table 16: Operations Risk Variables local weights

23	Termination	17,91%
24	Dispute resolution	6,59%
25	Country Risk	6,47%
26	Export Control and dual use	6,09%
27	End Users	4,84%

Table 12: Legal Risk Variables local weights

Table 12: Legal Risk Variables local weights

4.1.3 - Risk Categories' weights calculation

To define the Risk Categories' weights, the AHP methodology was iterated. Within each Risk Category, the Risk Variables determining the top 50% of the total weight were selected. Then, pairwise comparisons have been made between this subset of variables (without distinction of category). The Risk Variables' weights so determined have been aggregated according to the Risk Category to which they belong, and their sum determined the Category weight.

To perform the pairwise comparison was decided to organize a *focus group,* to facilitate the group decision-making. Moreover, to face uncertain situation where it was complicated reach a common decision, a set of rules were fixed (a simple algorithm showed in the figure below) which is inspired by the *planning poker* methodology.

Rules were decided according both to the possible scenarios which could occur after a group comparison and to the number of attendants at the focus group. Three scenarios after a comparison were possible:

1. There is a majority who retains one of the two Risk Variables more relevant
2. There is no majority who retains one of the two Risk Variables more relevant
3. The rare case in which everyone agrees on the equal value

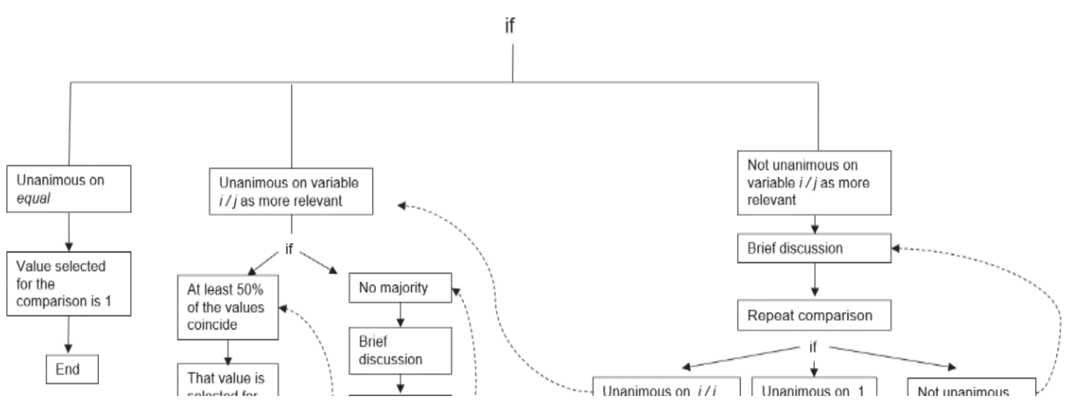

Figure 23: Rules for pairwise comparisons during the focus group

Figure 24: Rules for pairwise comparisons during the focus group

The inconsistency level at this step was even lower than the previous one (around 4,4%); Risk Categories' weights, provided as common result of the above-mentioned focus group are listed below:

Risk Category	**Weight**
TAX&FINANCE	13,16%
OPERATIONS	46,62%
LEGAL	40,22%

Table 13: Risk Categories weights

Each Risk Category "adjusts" the local weights of the Risk Variables within its perimeter through these weights. In this way, the *global weights* of the Risk Variables are provided which represent the single contribute of each Risk Variable to the total Project Risk Score Index (which is necessarily a value between 0 and 1).

The global weights are listed in the table below:

1	Indirect and consequential damages	13,85%
2	Penalty and Liquidated Damages	9,52%
3	Technology and standards	9,01%
4	Termination	7,20%
5	Project acceptance criteria	4,77%
6	Offer assumptions	4,19%
7	Project delivery time	4,18%
8	Feasibility assessment (resources)	4,02%
9	Retooling content	3,96%
10	Certifications	3,36%
11	Imposed suppliers/subcontractors	2,94%
12	Customer requirements	2,92%

13	Local regulations	2,89%
14	Permanent establishment	2,71%
15	Dispute resolution	2,65%
16	Country Risk	2,60%
17	Export Control and dual use	2,45%
18	Change orders	2,30%
19	Collections	2,15%
20	Reliance on Customer's deliverables	2,08%
21	Cashflow	2,08%
22	End Users	1,95%
23	Currency exposure	1,77%
24	Employees social security	1,63%
25	Withholding tax	1,41%
26	Bonds or guarantees	0,79%
27	Insurance	0,62%

Table 14: Risk Variables Global weights

4.1.4 - Risk Score Index at Project level calculation

Comau Risk Assessment Questionnaire model have been applied due to its simplicity and effectiveness. It is an intuitive method to determine the contribute of each Risk Variable to the *RSI* at Project level and consequently determine its final value for each Project within the Portfolio.

The main benefit of this type of questionnaire is the simplicity of response, which being Boolean exclusively determines the presence or absence of a Risk Variable before than then Project's Execution starts (so if the Company is going to keep under its responsibility the uncertainty related to certain Risk Variable). RV contribute to the final value of the Index just with their *global weight*.

As defined in the previous chapter, this questionnaire associates to presence of a certain Risk Variables to the Boolean value 1 (“yes”), by contrast the Boolean value is 0 associated to its absence (“no”). To facilitate filling in the questionnaire, the "not answered" option is also allowed. In this case, following a prudential logic, the *worst-case scenario* is considered, which is the one in which the Risk Variable is present.

According to the structure above-mentioned, to determine the RSI_j is sufficient sum the Risk Variables’ contribute, calculated through the product between their global weight *(local weight adjusted with the category weight*) and the associated Boolean value. Below is showed, as example, a possible Project Risk Score Index calculation (for simplicity reasons, only the name of the Risk Variable has been reported, in the extended Risk Assessment Questionnaire to each variable a question is associated according to the description provided previously):

Risk Variable			Answers			Contribute
1	Indirect and consequential damages	13,85%	YES	NO	NOT ANSWERED	0,00%
2	Penalty and Liquidated Damages	9,52%	YES	NO	NOT ANSWERED	9,52%
3	Technology and standards	9,01%	YES	NO	NOT ANSWERED	0,00%
4	Termination	7,20%	YES	NO	NOT ANSWERED	0,00%
5	Project acceptance criterias	4,77%	YES	NO	NOT ANSWERED	4,77%
6	Offer assumptions	4,19%	YES	NO	NOT ANSWERED	0,00%
7	Project delivery time	4,18%	YES	NO	NOT ANSWERED	0,00%
8	Feasibility assessment (resources)	4,02%	YES	NO	NOT ANSWERED	4,02%
9	Retooling content	3,96%	YES	NO	NOT ANSWERED	3,96%
10	Certifications	3,36%	YES	NO	NOT ANSWERED	3,36%
11	Imposed suppliers/subcontractors	2,94%	YES	NO	NOT ANSWERED	2,94%
12	Customer requirements	2,92%	YES	NO	NOT ANSWERED	0,00%
13	Local regulations	2,89%	YES	NO	NOT ANSWERED	0,00%
14	Permanent establishment	2,71%	YES	NO	NOT ANSWERED	2,71%
15	Dispute resolution	2,65%	YES	NO	NOT ANSWERED	0,00%
16	Country Risk	2,60%	YES	NO	NOT ANSWERED	0,00%
17	Export Control and dual use	2,45%	YES	NO	NOT ANSWERED	2,45%
18	Change orders	2,30%	YES	NO	NOT ANSWERED	2,30%
19	Collections	2,15%	YES	NO	NOT ANSWERED	2,15%
20	Reliance on customer's deliverables	2,08%	YES	NO	NOT ANSWERED	2,08%
21	Cashflow	2,08%	YES	NO	NOT ANSWERED	0,00%
22	End Users	1,95%	YES	NO	NOT ANSWERED	0,00%
23	Currency exposure	1,77%	YES	NO	NOT ANSWERED	1,77%
24	Employees social security	1,63%	YES	NO	NOT ANSWERED	1,63%
25	Witholding tax	1,41%	YES	NO	NOT ANSWERED	0,00%
26	Bonds or garantees	0,79%	YES	NO	NOT ANSWERED	0,79%
27	Insurance	0,62%	YES	NO	NOT ANSWERED	0,62%
					RSI j	45,07%

Table 15: Example of Project Risk Score Index calculation

The RSI_j have been detected for each Project active in the Portfolio in the six-quarter taken as reference time period (85 Projects in total). Final values have been rounded to the lower or upper entire value Final according to whether the second decimal place was less than or higher than 5. Some specifications are needed: first, the actual number of Projects within the Portfolio does not exactly match the number of RSI_j calculated. In fact, for some Projects it was not possible to determine the RSI_j value as they still responded to an older different Risk

Management process. Other Projects may not have been included in the Portfolio as part of this study because, due to their small Contract Value, their Risk Management Process don't follow the exact procedure mentioned above. Secondly, the RSI_j calculated result from the contribute of the twenty-seven Risk Variables selected integrated with few others which are specific of the Company's business context and so hidden due to privacy reason (hardly applicable in others business situations and so not listed in the selection):

Project Risk Score Index														
Project	1	23%	Project	21	47%	Project	41	23%	Project	61	42%	Project	81	35%
Project	2	37%	Project	22	47%	Project	42	29%	Project	62	35%	Project	82	45%
Project	3	40%	Project	23	33%	Project	43	42%	Project	63	45%	Project	83	37%
Project	4	39%	Project	24	34%	Project	44	35%	Project	64	44%	Project	84	49%
Project	5	47%	Project	25	29%	Project	45	45%	Project	65	39%	Project	85	43%
Project	6	38%	Project	26	23%	Project	46	44%	Project	66	49%			
Project	7	42%	Project	27	29%	Project	47	39%	Project	67	37%			
Project	8	35%	Project	28	37%	Project	48	49%	Project	68	43%			
Project	9	45%	Project	29	43%	Project	49	37%	Project	69	21%			
Project	10	44%	Project	30	21%	Project	50	43%	Project	70	18%			
Project	11	39%	Project	31	18%	Project	51	21%	Project	71	35%			
Project	12	49%	Project	32	35%	Project	52	18%	Project	72	42%			
Project	13	37%	Project	33	58%	Project	53	35%	Project	73	35%			
Project	14	43%	Project	34	56%	Project	54	58%	Project	74	42%			
Project	15	21%	Project	35	54%	Project	55	56%	Project	75	33%			
Project	16	18%	Project	36	47%	Project	56	33%	Project	76	37%			
Project	17	35%	Project	37	47%	Project	57	34%	Project	77	44%			
Project	18	58%	Project	38	33%	Project	58	29%	Project	78	39%			
Project	19	56%	Project	39	34%	Project	59	23%	Project	79	49%			
Project	20	54%	Project	40	29%	Project	60	29%	Project	80	39%			

Table 16: Projects Risk Score Index

4.1.5 - Weighting Criteria for indicator extension at Portfolio level

In the previous section it was shown how the first member of the Portfolio Risk Score Index formula, have been developed and calculated. To extend the indicator from Project level to the Portfolio level, it is still necessary to define the second member of the formula, which is the weighing mechanism associated with the Project Risk Score Index.

The RSI_j have been detected for each Project in order to develop the Risk Score Index at Portfolio level but the contribute of each Project Risk Score Index to the Portfolio's one cannot be considered as the simple average value. Each Project has a different relevance within the Portfolio, so Project Risk Score Index need to be weighted with respect to some criteria.

Several elements contribute to determine the relevance of a Project within a Portfolio, but the most intuitive and simple to determine is certainly the economic one. Below the weight based on Project's Budget on the total Portfolio's Budget is showed:

$$W_j = \frac{Project_j\ Budget}{Total\ PF\ Budget}$$

However, it is necessary to underline that other factors could be important when considering the relevance of a Project within a Portfolio; for example, market strategies (expansion in new countries, retain new Customers) or the correlation to Projects belonging to another Portfolio's Domain (resources sharing, sequential activities). This can lead to determine other types of weights (for example a strategic one) to be integrated with the economic one.

$$W_j = \frac{Project_j\ Budget}{Total\ PF\ Budget}$$

4.1.6 - Risk Score Index at Project level calculation

The last step necessary to determine the Risk Score index at Portfolio Level was combining the two members of the formula defined in the previous steps.

For this study, the Index level have been calculated monthly according to the periodic report on the Regional Portfolio. Below is showed how the RSI_{PF} have been operatively computed: to give higher evidence to the most relevant Projects belonging to the Portfolio, data referred to Contract Value, weight on the Portfolio and Project Risk Score Index have been explicitly indicated for top ten Projects (by Revenues), while as regards the remaining Projects in the Portfolio (having a weight on the total generally around 1%) the average values have been reported for reasons of data visualization simplicity.

All data referred to the Projects (including Project's Name, Contract Value, Risk Score Index have been adjusted with a random factor to preserve the confidentiality of Company's Data). In total, eighteen RSI_{PF} have been computed, one for each time period observed.

The next Chapter will investigate how the behavior of this Indicator can be related to the one of Portfolio's Profitability and how this correlation ca be used to enhance the predictivity of the Risk Management Process.

	Quarter 1- month 1				
	TOTAL PF (K€)	1.373.856,00	**Weight on total**	**Project Risk Score Index**	**Weighted Risk Score**
	Project's Contract (K€)		***W_j***	***RSI_j***	**Index**
TOP 10	Project 1	254.584,00	18,53%	43,00%	7,97%
	Project 2	121.440,00	8,84%	20,50%	1,81%
	Project 3	109.003,40	7,93%	35,00%	2,78%
	Project 4	60.390,00	4,40%	18,00%	0,79%
	Project 5	42.752,60	3,11%	45,00%	1,40%
	Project 6	34.073,60	2,48%	46,50%	1,15%
	Project 7	32.340,00	2,35%	42,00%	0,99%
	Project 8	27.612,20	2,01%	37,00%	0,74%
	Project 9	27.559,40	2,01%	44,00%	0,88%
	Project 10	22.400,40	1,63%	39,00%	0,64%
OTHERS	Projects exceeding top 10	641.700,40	46,71%	37,00%	17,28%
					***RSI_{PF}*:** **36,43%**

Table 17: RSI calculation at Portfolio level

4.2 - PRM KPIs from Project to Portfolio

As explained in the Chapter 2, in a previous Thesis Work, now part of the academic Literature, three KPIs aimed to measure the Risk Management Performance at Portfolio level have been defined. Following the same logical reasoning it is possible to simply extent these indicators from a Project level to a Portfolio's one. The Company already use the KPIs at Portfolio level in its monthly report activity but the aim in this work is to formally define them and through the analysis of their trends in the observed time period understand the potential predictive capacity with respect to the fluctuation of Portfolio's profitability.

These indicators are based on the Closed Threats and Opportunities of ongoing Projects and provide information about the effectiveness of the risk responses implemented. While at Project level the Monetary Impact is aggregated on single Projects, at Portfolio level each member of the formula refers to the total value at Portfolio level resulting from the Monetary Impact summing on the *n*-Projects active in the Portfolio. It is important to note that when a Project is definitively closed from a financial point of view (which is different than the Risk Management one, since that a Project could have all Threats and Opportunities managed, and so closed, but still being on going) and it is not anymore counted in the Portfolio (Technical Completed), it do not contribute anymore to the calculation of the KPIs.

Extending formally the three KPIs at Project level they result as follow:

$$RE_T = \frac{\sum_{i=1}^{n} MI_{TCnr}}{\sum_{i=1}^{n} MI_{TCnr} + \sum_{i=1}^{n} MI_{TCr}} \quad ; \qquad RE_O = \frac{\sum_{i=1}^{n} MI_{OCr}}{\sum_{i=1}^{n} MI_{OCnr} + \sum_{i=1}^{n} MI_{OCr}}$$

$$RE_C = \frac{\sum_{i=1}^{n} MI_{TCnr} + \sum_{i=1}^{n} MI_{OCr}}{\sum_{i=1}^{n} MI_{TCnr} + \sum_{i=1}^{n} MI_{TCr} + \sum_{i=1}^{n} MI_{OCnr} + \sum_{i=1}^{n} MI_{OCr}}$$

$$RE_T = \frac{\sum_{i=1}^{n} MI_{TCnr}}{\sum_{i=1}^{n} MI_{TCnr} + \sum_{i=1}^{n} MI_{TCr}} \quad ; \qquad RE_O = \frac{\sum_{i=1}^{n} MI_{OCr}}{\sum_{i=1}^{n} MI_{OCnr} + \sum_{i=1}^{n} MI_{OCr}}$$

4.3 - Auxiliaries Indicators on Portfolio

This section wants to introduce three simple indicators defined to assist the analysis carried out on the Portfolio. Indeed, these indicators, express not only the changes in Portfolio composition from a numerical point of view, but the goal is to use them as a tool to better explain the behavior of all the data related to the Project Risk Management Process and the Financial one during the considered period.

- Project absolute variance: (provide the absolute variance in the Portfolio composition between two consecutive time period)

$$PAT\ (t \rightarrow t+1) = \frac{N_c(t) + N_n(t+1)}{N(t)}$$

- Portfolio renovation: (provide the Portfolio's renovation at time t with respect to t-1):

$$PRN\ (t) = \frac{N_n(t)}{N(t)}$$

- Portfolio Technical Completion: (provide the completion of the Portfolio at time t with respect to t-1):

$$PTC\ (t) = \frac{N_c(t)}{N(t)}$$

$$PTC\ (t) = \frac{N_c(t)}{N(t)}$$

5 - Calculation of the indicators on a Projects Portfolio and analysis of the obtained results

The indicators have been computed on actual data belonging to an Industrial Regional Project Portfolio (counting between 45 and 55 Projects monthly) with a time horizon of six quarters (18 months). The process of computing the indicators have been carried out in a few consecutive steps: first, it was necessary to perform a quality check on collected data, then descriptive statistics on a reliable data set were calculated and a normality check was performed. Finally, correlations between the data collected, with attention to relevant correlations involving new defined indicators, were analyzed and consequently a significance test was performed to validate the observations done. Data values and relevant information regarding the Company have be correct through a random vale, due to privacy reasons.

5.1 - Data set construction

Data set consists in nineteen different types of data (including the indicators defined in previous Chapters) relevant to a Regional Project Portfolio, grouped in four categories: Financials, Risk Exposure, Risk Management Performance, Portfolio Composition & Turnover.

- *Financials*: these data give a synthetic and clear overview on the Portfolio financial status at each observed period. Below, are listed the four data belonging to this group:

I. Total Contract Value (*TCV*): TCV represents the total value of Portfolios' contracts. This value includes costs estimated during the sales phase and expected profit and is therefore the "as sold" price resulting from negotiation and agreements with Customers. Trend's fluctuations depend mainly on turnover of Portfolio's composition (new Projects/closing Projects), change orders on ongoing Projects (scope of work extension or reduction)

$$TCV = \sum_{i=1}^{n} ContractValue_i$$

II. Portfolio Margin (PM*F*): Portfolio Margin is the monetary premium on top of costs which the Firm expect to earn from the delivery of the Project results to the client. The summation of Projects' revenues within a Region/Country/BU determine the aggregate Portfolio's revenues (TCV), which compared with total Portfolios' costs provide the Portfolios' Profit (expressed in k€). Consequently, Portfolio Profit Margin is expressed as the percentage of Profit on the TCV.

$$PFM = \frac{\sum_{i=1}^{n} Profit_i}{TCV}$$

III. Portfolio Margin Reviewed (PMFr): Portfolio Margin Reviewed provides basically the same information of the previous PM*F*; although PMFr don't consider TC in the total amount of Costs (because TC actually are just monetary allowance in order to response Project's Risk, but the goal of an effective PM Process is trying not to use them).

$$PFMr = \frac{\sum_{i=1}^{n} Profit_i - \sum_{i=1}^{n} TC_i}{TCV}$$

IV. Technical Contingencies (*TC*): Technical Contingency is defined as a monetary allowance allocated in the Project cost budget to cover the cumulative Monetary Impact of Threats identified in the Risk Register. If considered within a Portfolio they are the reserves dedicated to the entire Region/Country/BU, constituted by the consolidated of each single Project TC and is therefore the budgeted cost needed to manage risks in case they happen. As a global Comau's rule, the total amount put aside as TC shall reflect proportionally the aggregate value of the Monetary Impacts of all Threats classified as High or Medium exposure. PM in collaboration with the Project Controller has the obligation and authority to manage the Project TC during the lifecycle of a Project.

$$TC = \sum_{i=1}^{n} TC_i \propto MI_i(m/h\ exposure)$$

- *Risk Exposure:* these data provide information about open negative risks (Threats) and open positive risks (Opportunities) within the Portfolio at each observed period. The main data which has been monitored is the Monetary Impact for Threats and Opportunities which represent the total impact considered as if the risks happen. Consequently, the Expected Monetary Value represents the weighted impact considering the probability of occurrence. Moreover, new defined Risk Score Index at Portfolio level have been assigned to this group of data.

I. Threats/Opportunities Monetary Impact (*MI*):

$$MI_t = \sum_{i=1}^{n} MI_{t\ i} \qquad MI_o = \sum_{i=1}^{n} MI_{o\ i}$$

II. Threats/Opportunities Expected Monetary Value (*EMV*):

$$EMVt = \sum_{i=1}^{n} EMVt_i \qquad EMVo = \sum_{i=1}^{n} EMVo_i$$

III. Risk Score Index:

$$RSI_{PF} = \sum_{prj=1}^{n} RSI_{prj} * W_{prj}$$

- Risk Management Performance: Data refers to the indicators defined at Portfolio level. Those indicators are based on the closed Threats and Opportunities of ongoing Projects and provide information about the effectiveness of the risk responses implemented. The KPIs can be applied both for Threats and Opportunities allowing also to create a combined KPI.

$$RE_T = \frac{\sum_{i=1}^{n} MI_{TCnr}}{\sum_{i=1}^{n} MI_{TCnr} + \sum_{i=1}^{n} MI_{TCr}}$$

$$RE_O = \frac{\sum_{i=1}^{n} MI_{OCr}}{\sum_{i=1}^{n} MI_{OCnr} + \sum_{i=1}^{n} MI_{OCr}}$$

$$RE_C = \frac{\sum_{i=1}^{n} MI_{TCnr} + \sum_{i=1}^{n} MI_{OCr}}{\sum_{i=1}^{n} MI_{TCnr} + \sum_{i=1}^{n} MI_{TCr} + \sum_{i=1}^{n} MI_{OCnr} + \sum_{i=1}^{n} MI_{OCr}}$$

- *Portfolio Composition & Turnover:* these indicators express not only the progress of the Project Portfolio and changes in its composition, but they allow to better explain the behavior of the others collected data during the considered time periods. In particular, considering those data belonging to the Risk Exposure group, each new Project activated in the Portfolio means a contribute to global MI (consequently to the EMV) on opposite a closed Project has an impact on RM Performance KPIs because a new Project always brings an higher content in open risks while a closed Project normally has only closed risks which mostly contribute to the Risk Management performance KPIs. As regard as the Portfolio composition, the following data have been extracted from historical data: completion of the Portfolio (in percentage) and referring to a certain time period t: number of Projects in the Portfolio and related new or closing Projects. Working on the above-mentioned data then three derived indicators have been computed to assess Portfolio's turnover between two consecutive time period.

I. Completion (*%Completion*): provides the average Portfolio's completion percentage. Fluctuations in value are due to the progresses of each Project (raise) and to the presence of new Projects (drop) which, of course, start at 0% of completion. This indicator has a cyclical trend, accordingly to the typical duration of Portfolios' Projects and accountant policy of Projects closure.
II. Number of Projects belonging to the Portfolio at a certain time period t ($N(t)$)
III. Number of Projects entering the Portfolio when a new time period t occurs ($N_n(t)$)
IV. Number of Projects (which already belong to the Portfolio) exiting the Portfolio when a new time period t occurs ($N_c(t)$).
V. Portfolio absolute turnover ($PAT(t \rightarrow t+1)$): this indicator determines the total turnover which effects the Portfolio considering two consecutive time period due the contribute of

both Projects closing at time t and Projects joining the Portfolio at time t+1.

$$\text{PAT (t} \rightarrow \text{t+1)} = \frac{N_c(t) + N_n(t+1)}{N(t)}$$

I. Portfolio Renovation (*PRN(t)*): provides the renovation of the Portfolio determined by the new Projects (with *%Completion* equal or near to 0%)

$$\text{PRN (t)} = \frac{N_n(t)}{N(t)}$$

II. Portfolio Completion (*PTC(t)*): provides the degree of technical completion of the Portfolio determined by the Projects in an advanced stage which close at the end of time period t (*%Completion* reaches 100%).

$$\text{PTC (t)} = \frac{N_c(t)}{N(t)}$$

The nineteen different type of data described above represent the whole dataset where further analysis has been developed. On those data, collected for eighteen time periods, a preliminary work to ensure data reliability have been carried out. First, data have been checked punctually and through statistical analysis outliers have been detected. Those outliers have been excluded from the data set. Moreover, a minor set of data were missing due to difficulties in extract them from Company's historical data. In these cases, data were added coherently to preserve the reliability of the entire dataset.

5.2 - Data analysis

In this paragraph it is shown how the dataset was investigated. For each type of collected data some general descriptive statistics were calculated (trend, average value, standard deviation, maximum and minimum value, range). Below, are reported the relevant graphs and observation on the behavior along the observed period just for those data which will be relevant for the conclusions done after having analyzed the correlation (see paragraph 5.4). According to the goal of this study, relevant data to monitor were related to Portfolio's profitability (it has been decided to consider the reviewed PMFr instead of the PM*F* in order to not consider the eventual contribute to the profitability given by release of TC), to the Portfolio's risk exposure (in terms of Monetary Impact and Risk Score Index) and to Risk Management performance (response effectiveness KPIs).

- The expected Portfolio Margin (and so the reviewed one) might fluctuate mainly for: turnover of Portfolio's composition, impact of Threats/Opportunities realization and others effects due to Issues (unforeseen risk which occurred) and updating of EAC -*estimate at completion*- value.
- Monetary Impacts of both Threats and Opportunities depends on the risks which are open within the Portfolio. The trend is determined by new risks identified and risks which have been closed. Moreover, fluctuations can depend on the response strategy as well (some risks could still be open within the Portfolio, but their potential impact is reviewed according to the response strategy applied).
- The trend of Response effectiveness KPIs depends on the goodness of the response actions taken and their implementations. Indeed, decreasing trends identify worst performances in managing both Threats and

Opportunities while an increase in value means a better performance. When KPIs are combined, if the performances follow opposite trends, the combined trend's behavior is balanced between the two contributes and leaded by the one with a higher value.

- RSI_{PF} is a dynamic indicator, it varies according to Project Portfolio's composition. Indeed, its computation is based on the number of active Projects in the Portfolio. Every time a Project is activated on the Portfolio its Risk Score Index value contributes to the global value of the RSI_{PF} while when a Project is closed (at least from a Risk Management point of view, which means all its Threats and Opportunities are definitely Closed) does not contribute anymore to the index at Portfolio level.

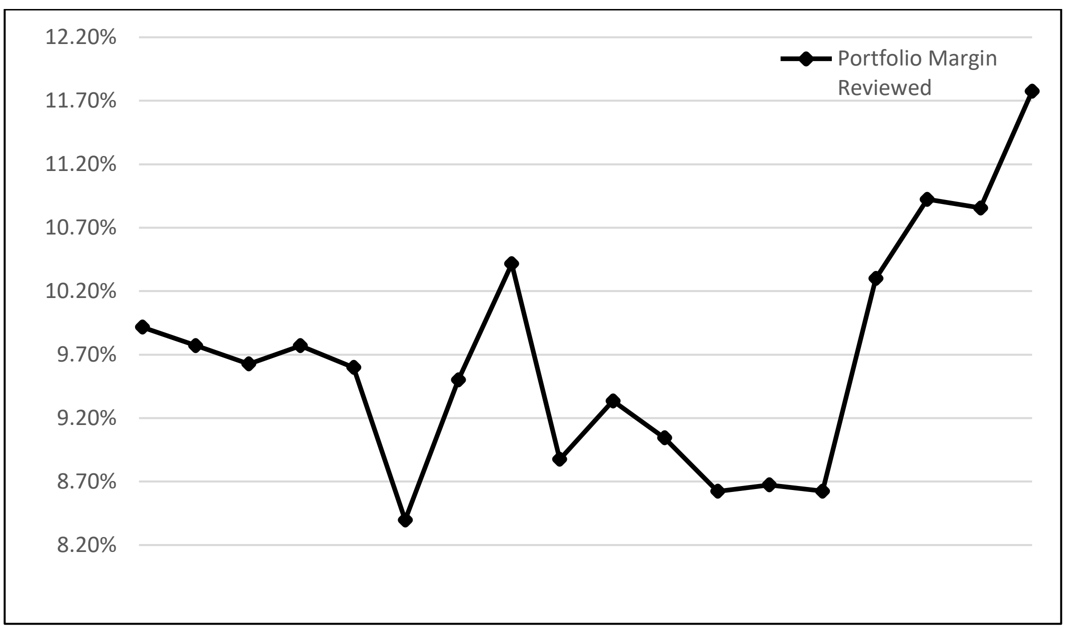

Chart 1: PFMr Trend

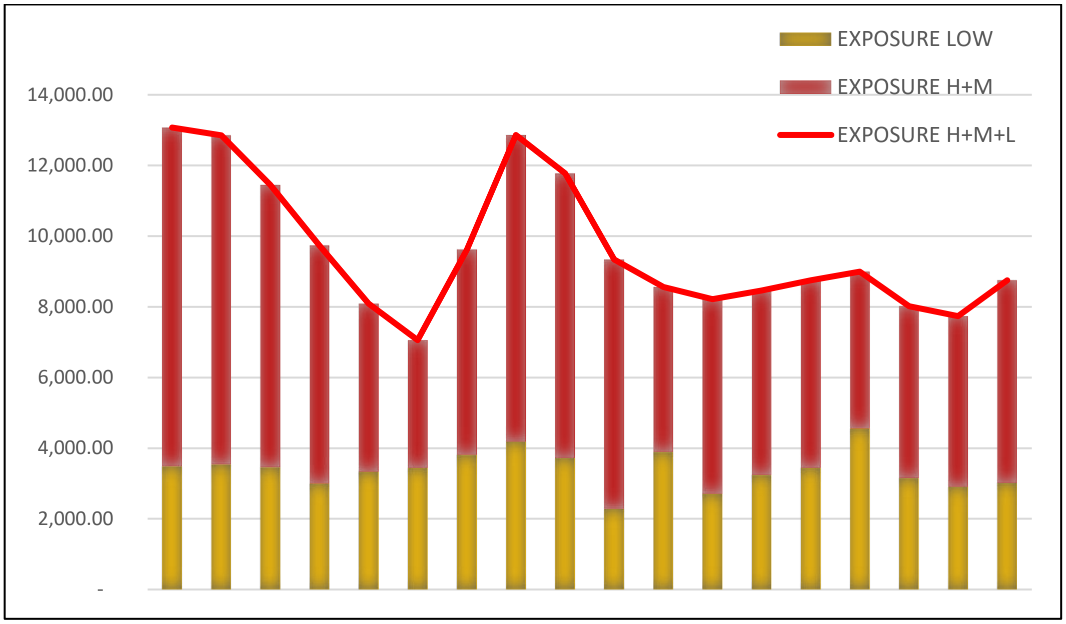

Chart 2: Threats MI Trend

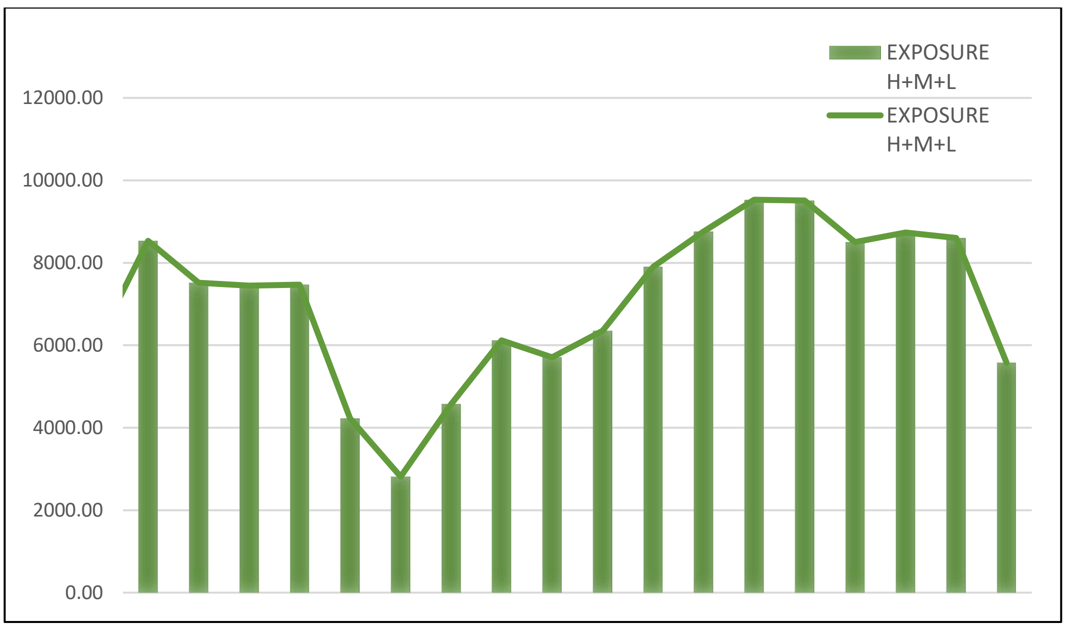

Chart 3: Opportunities MI Trend

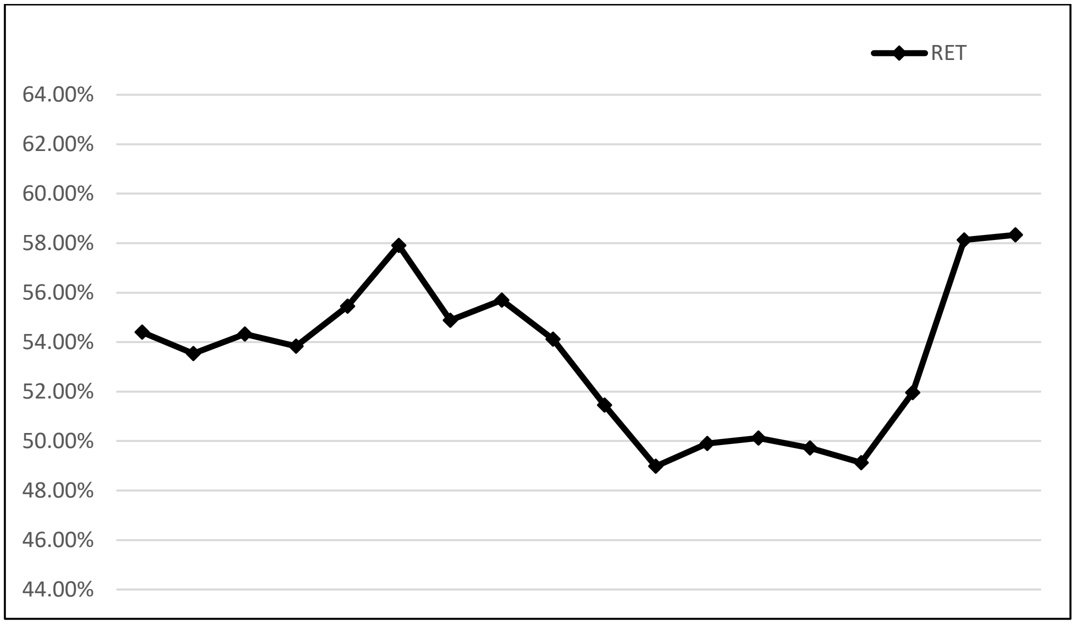

Chart 4: RE_t Trend

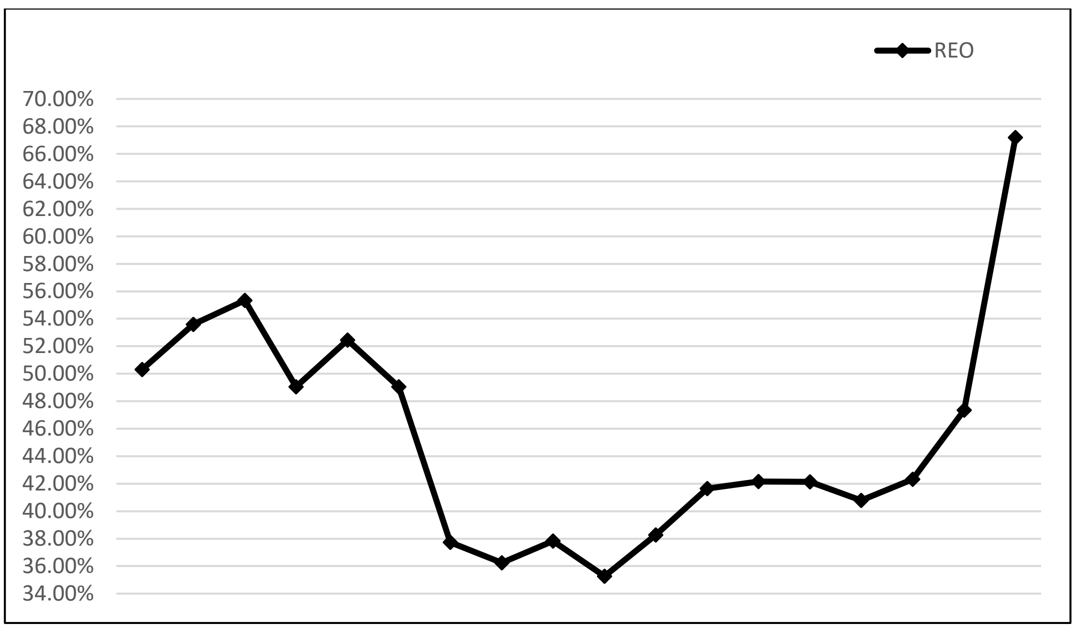

Chart 5: RE_o Trend

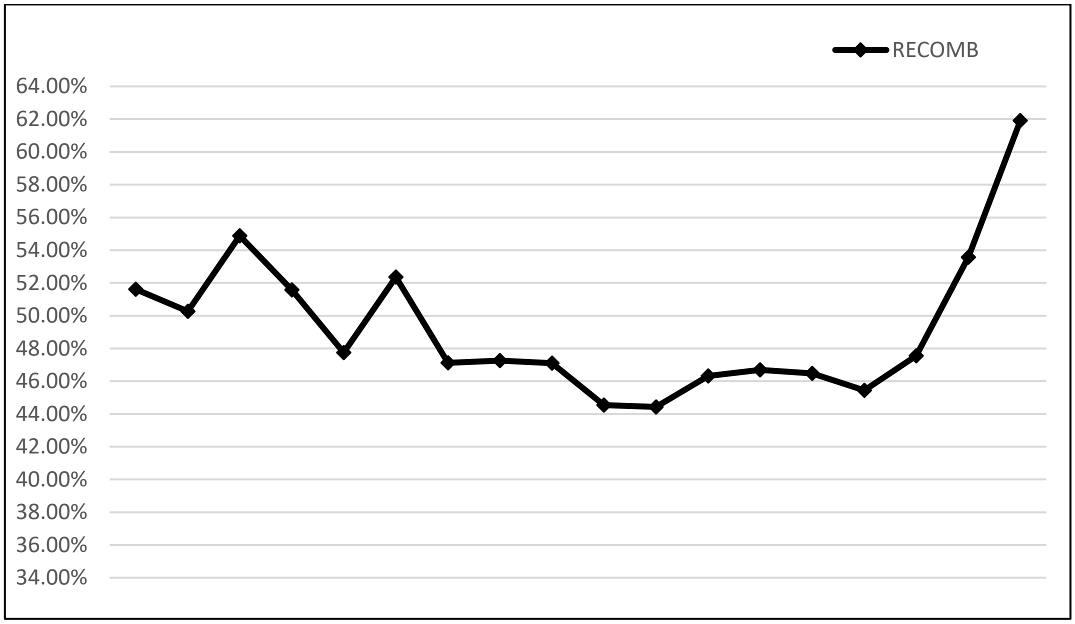

Chart 5: RE_c Trend

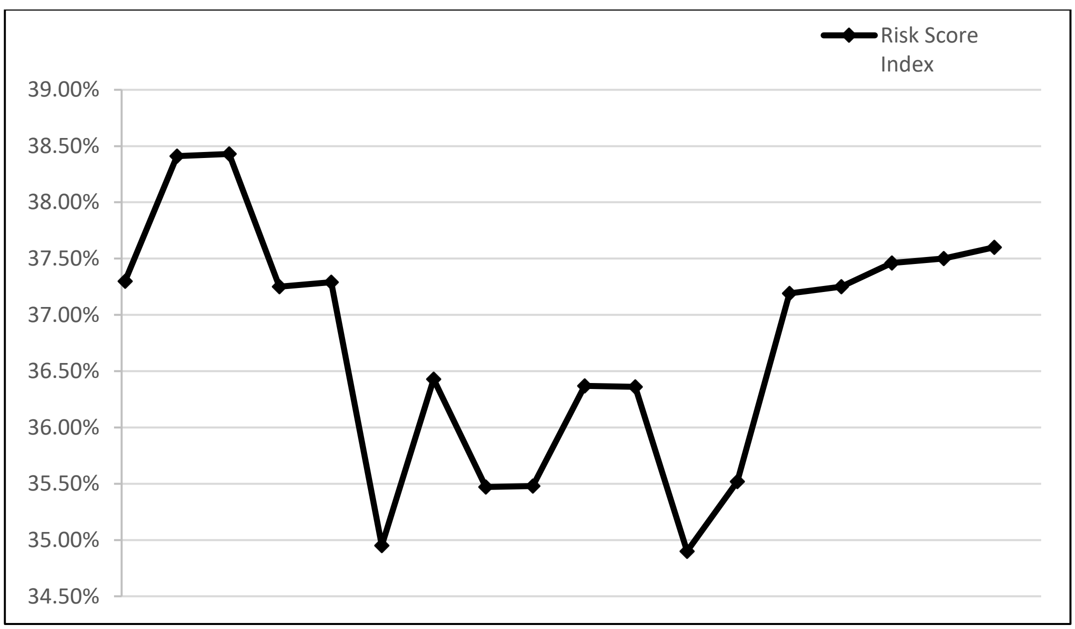

Chart 5: RSI_{PF} Trend

5.3 - Data normality test

Before performs a correlation test, a normality test as preliminary step has been carried out to determine if the data set could be considered well-described by a normal distribution. The test was performed on each one of the nineteen type of data, but the focus was on those data relevant for further correlation tests, as for the previous data analysis step. Normality was tested through the Anderson-Darling test. The AD statistic needed to be adjusted due to the small sample size (AD*) and according to the formulas showed below the p-values have been calculated:

- If AD*=>0.6, then p = exp(1.2937 - 5.709(AD*)+ 0.0186(AD*)2
- If 0.34 < AD* < 0.6, then p = exp(0.9177 - 4.279(AD*) - 1.38(AD*)2
- If 0.2 < AD* < 0.34, then p = 1 - exp(-8.318 + 42.796(AD*)- 59.938(AD*)2)
- If AD* <= 0.2, then p = 1 - exp(-13.436 + 101.14(AD*)- 223.73(AD*)2)

The acceptance threshold to consider the data normally distributed were set to p-values higher than 0.05. According to this procedure it resulted that those data of interest for correlation analysis (Portfolio Margin reviewed, Threats and Opportunities Monetary Impact, Risk Score Index and response effectiveness KPIs) were normally distributed. Below are reported AD test values and normality plot for the above-mentioned data.

	Portfolio Margin Reviewed	*Threats MI (m/h exp)*	*Threats MI (low exp)*	*Opps MI*	*RSI*	*REt*	*REo*	*%Compl*
Average	0.09	5662.56	3091.89	7104.27	0.37	0.53	0.45	0.67
Sigma	0.01	1640.77	486.16	1929.53	0.01	0.03	0.08	0.03
n	18	18	18	18	18	18	18	18
S	-329.43	-336.18	-327.30	-332.94	-333.19	-331.19	-333.26	-333.03
AD	0.30	0.68	0.18	0.50	0.51	0.40	0.51	0.50
*AD**	0.32	0.71	0.19	0.52	0.54	0.42	0.54	0.53
p Value	0.54	0.06	0.90	0.19	0.17	0.33	0.17	0.18

Table 18: Anderson-Darling statistics and p-values

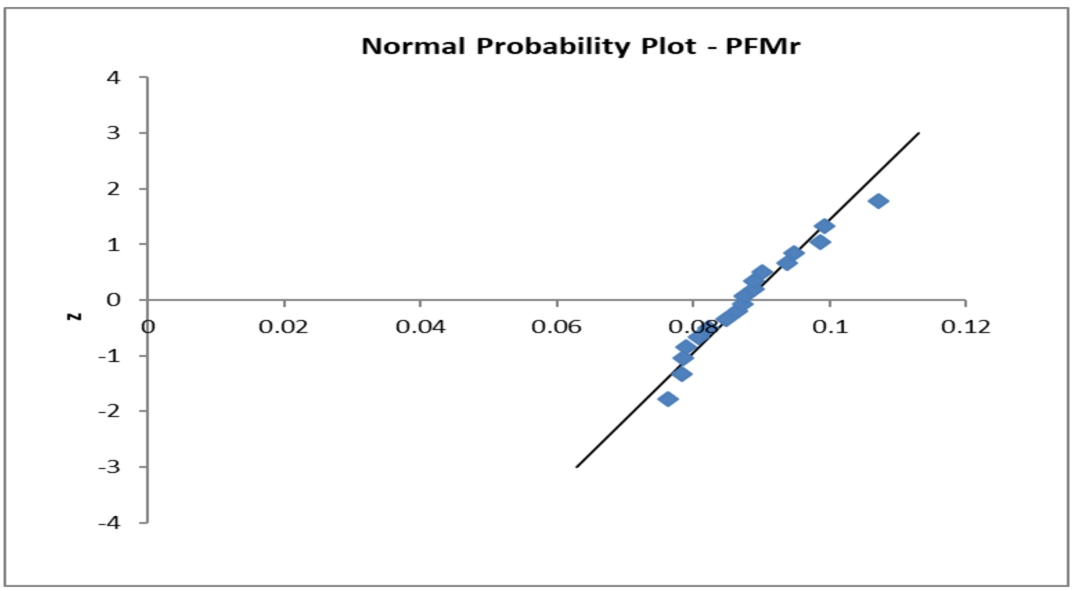

Chart 6: Normal probability plot for PFMr

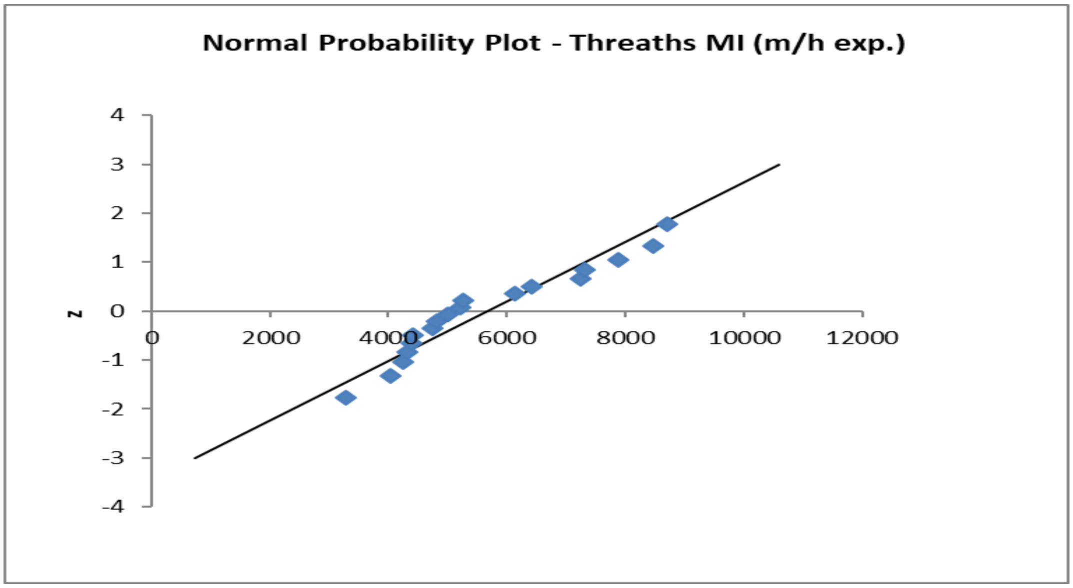

Chart 6: Normal probability plot for Threats MI (h-m exp.)

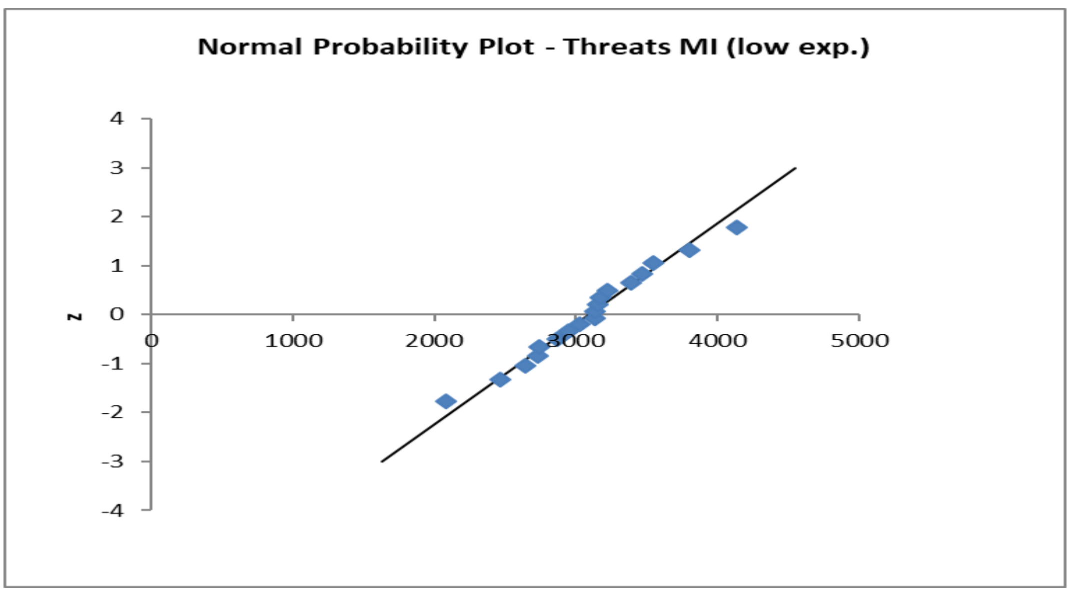

Chart 7: Normal probability plot for Threats MI (low exp.)

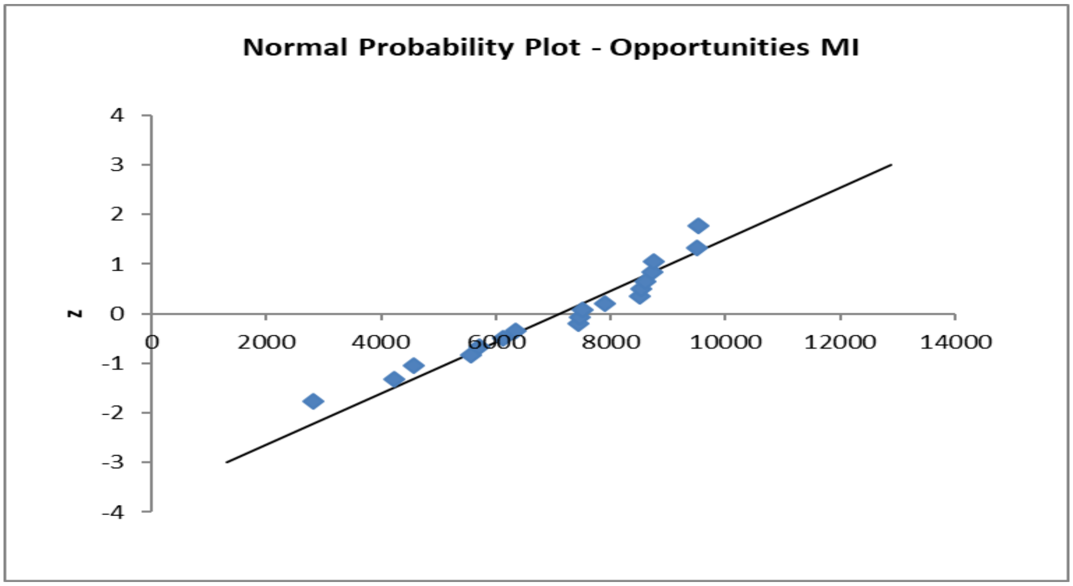

Chart 8: Normal probability plot for Opportunities MI

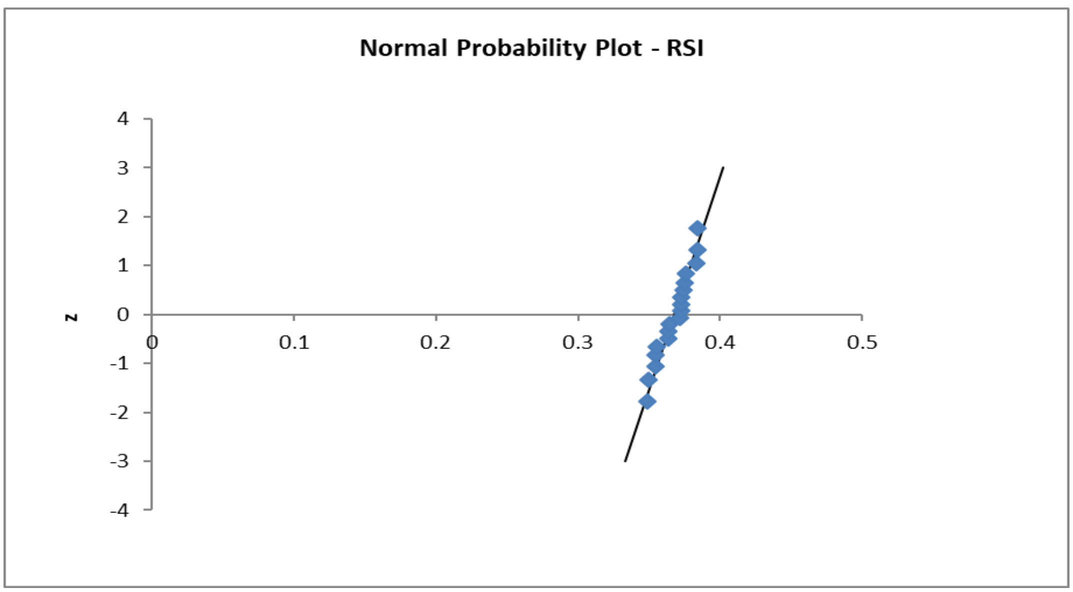

Chart 9: Normal probability plot for RSI_{PF}

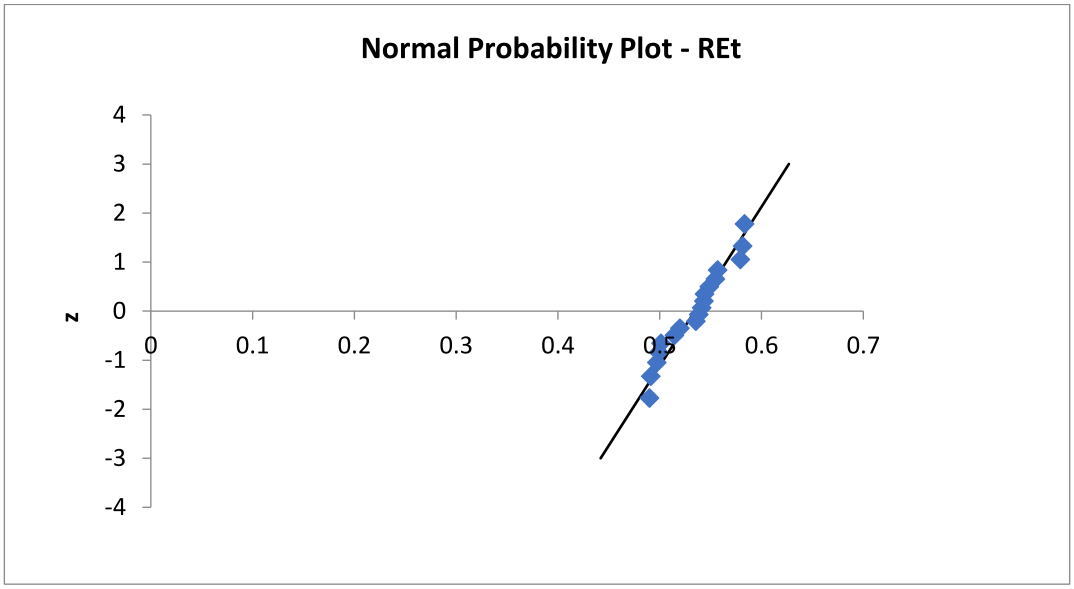

Chart 9: Normal probability plot for RE_t

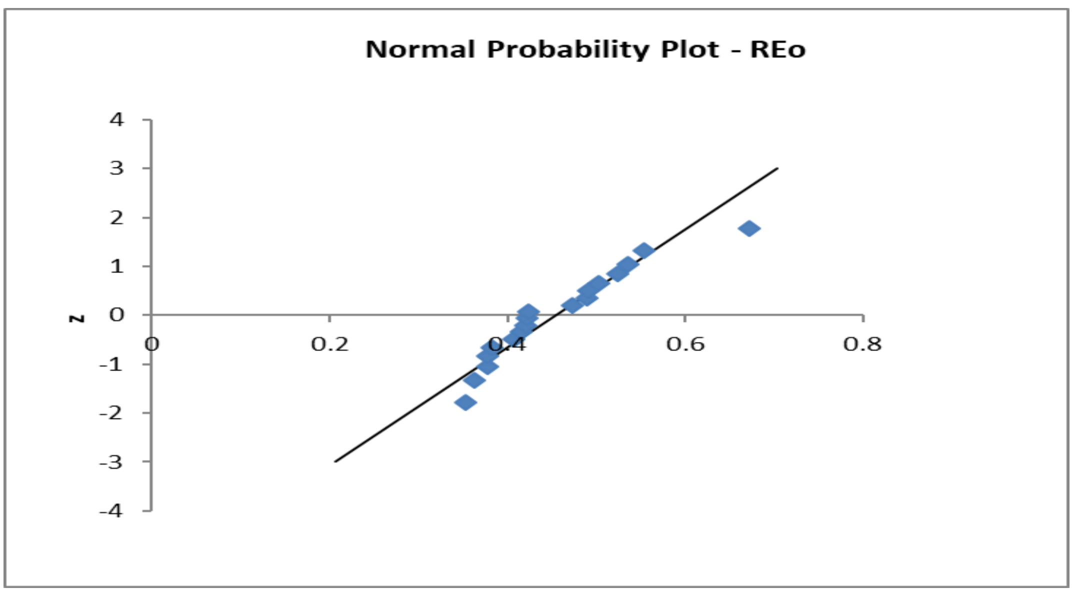

Chart 9: Normal probability plot for RE_o

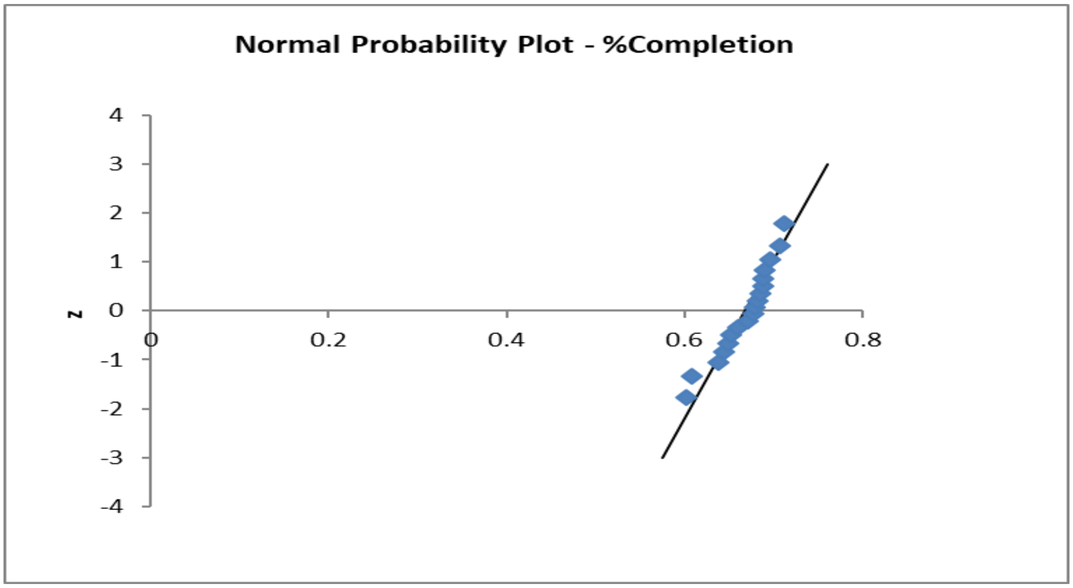

Chart 10: Normal probability plot for RE_c

5.4 - Correlation test and significance test

Having verified the normal distribution of elements belonging to the dataset, further analysis to determine if relevant correlations exist were performed. Person Correlation coefficient was calculated between each couple of data type, through the formula referred to a sample, which is an estimator of the correlation coefficient applied to a population (ρ):

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

considering each possible pair of data, more than two hundred correlation coefficients have been calculated through a correlation matrix. Calculated coefficients range between values -1 (total negative linear correlation) and +1 (total positive linear correlation), according to the Cauchy-Schwarz inequality.

Although, many of them were not relevant for the analysis, for examples all the trivial coefficients (those on the matrix's diagonal, which are equal to +1). Moreover, some of the collected data share calculation factors (e.g. Monetary Impact and Expected Monetary Value) so even if a significant correlation exists, it is due to the collinearity between the pair of data. In addition, relevant correlations involving the Portfolio Margin have been discarded due to the choice of consider the reviewed margin, which is built based on the Portfolio Margin itself.

Anyway, the new defined Risk Score Index and the Response Effectiveness KPIs has shown a relevant correlation with the profitability. According to the focus of this study, this result allowed to proceed with further adjustment of these values, due to the sample size, and later tests to determine the significance of correlations found.

	Total Contract Value	*Portfolio Margin*	*Portfolio Margin Reviewed*	*Technical Contingency*	*EXPOSURE H+M+L thr*	*EXPOSURE H+M*	*EXPOSURE LOW*	*EXPOSURE H+M+L OPP*	*EMV Threats*	*EMV Opps*	*Risk Score Index*	*Num. Projects (t)*	*New Projects (t)*	*Closing Projects (t)*	*PAV*	*PRN*	*PTC*	*%Completion*	*REt*	*REo*	*REc*
Total Contract Value	1																				
Portfolio Margin		1																			
Portfolio Margin Reviewed			1																		
Technical Contingency				1																	
EXPOSURE H+M+L					1																
EXPOSURE H+M						1															
EXPOSURE LOW							1														
EXPOSURE H+M+L opps					-0,5973	-0,6169		1													
EMV Threats								-0,6359	1												
EMV Opps									-0,6091	1											
Risk Score Index		0,6662	0,6580								1										
Num. Projects												1									
New Projects (t->t+1)							0,6542						1								
Closing Projects (t->t+1)														1							
PAV															1						
PRN							0,6560									1					
PTC																	1				
%Completion						-0,5754		0,7146	-0,6949	0,6857			-0,5725			-0,6007		1			
RET		0,6836	0,6737																1		
REO		0,6236	0,6306																	1	
RECOMB		0,7220	0,7244																		1

Table 19: Relevant correlation coefficients

Due to the small size of the sample for each data type, it was necessary to adjust calculated correlation coefficients through the following formula:

$$r_{\mathrm{adj}} = \sqrt{1 - \frac{(1-r^2)(n-1)}{(n-2)}}$$

Following adjusted correlation coefficients r_{adj}, relevant to new defined indicators, have been determined:

	PMFr
RSI	0.6305
REt	0.6478
REo	0.6000
REc	0.7036

Other relevant correlations, for which the r_{adj} have been computed as well, were found between the following pair of data: Threats MI and Opportunities MI (0.5626); Threats MI (m/h exposure) and %Completion (-0.5378); Opportunities MI and %Completion (0.6928).

Once the adjusted correlation coefficients have been computed for the eight above-mentioned pair of data, to determine if they were significant the widely diffused approach of test-t was selected. To test whether a linear relationship exists the following hypothesis were used

$$H_0: \rho_{xy} = 0$$

$$H_1: \rho_{xy} \neq 0$$

The statistic t for each value of r-coefficient was determined using the formula below:

$$t_c = r_{xy}\sqrt{\frac{(n-2)}{(1-r_{xy}^2)}}$$

The t values calculated have been compared with t values for α=0.05 and v=n-2 degree of freedom (equal to 2.12). Since that the absolute value of t calculated was higher than the critical one for each r_{adj} value, it was possible to reject the null hypothesis and so that ρ coefficient between the two type of data is equal to zero (independency).

According to statistical evidence showed above, the following observations were drawn:

- The general level of riskiness of the Portfolio, expressed through the RSI_{PF}, and its profitability are positively correlated. This relation suggests that a Portfolio composed by Projects characterized by a higher level of risk (in terms of accepted risks under Company's responsibility already in tender phase) can lead to a higher margin: for companies operating in complex business this is usually true due to the risk's premium. Moreover, from a predictive point of view, this relation allows to state that positive variations in Portfolio's profitability are expected when RSI_{PF} increases as well but this relation exists until the Project Risk Management performance has a positive trend. On opposite, if the Portfolio's Risk Exposure increases but the PRM performance is on a negative trend, it is reasonable expect a drop of the profitability.
- Response Effectiveness Indicators are positively correlated with the Portfolio Margin Reviewed. This relation suggests that better performance in avoiding threats and achieving opportunities and impact positively on the Portfolio Margin. This relation is true since that non-realized threats are

counted as "savings" and opportunities are counted as extra-profits. The relation is stronger if considered with respect to Threats management. This suggested that while the managing of Threats and the monitoring of related performance is already quite mature, improvements can be done in managing the Opportunities. Considering the relation between profitability and the combined indicator it seems to be stronger than considering them separately. This suggest that an effective combined management of Threats and opportunities during the execution phase can determine strong positive variation of Portfolio’s financial result.

- A negative correlation between total MI of Threats and the total MI of Opportunities is suggested. One possible interpretation is that when Projects have many relevant threats (and so MI increases) , Projects' team are less confident on achieving Opportunities (often Projects with many Threats can bring to a conflictual situation with the Customer).
- Another suggested negative correlation refers to MI of Threats having High and Medium exposure which decreases as the %Completion of the Portfolio is increasing. This can be true because for these Threats during Projects lifecycle response strategy is implemented and if successful, they reduce the MI along the Projects timeline. This relation is even stronger if computed on the Threats EMV instead on the Threats MI (based just on those with medium-high exposure). This suggests that a risk covering scenario based on EMV could lead more effective, first because it implies the covering of all Threats (including those with low exposure) which considering good performance on Risk Management could improve Project’s profitability.
- The positive correlation between %Completion and Opportunities MI suggests that when the Portfolio increases its percentage of completion the

Monetary Impact of the Opportunities raise accordingly. This is due to fact that in the closing phase of Projects, usually work deriving from variation orders is recognized by the Customers. Moreover, a contribute to this correlation can be detected in the extensive induction on Project's team, led by Company’s PMO in past years, to improve the identification of Opportunities and the consequent management. Although, it can suggest as well a poor capacity in detecting Opportunities in Projects’ early stage while a good reactive approach once Opportunities are directly shown by the Customers.

6 - Conclusions

According to the objective of this study new indicators for Project and Portfolio's Risk Management processes have been defined. The pursed goals were defining them to sustain the Portfolio's profitability and improve its predictability.

The indicators showed their potential to be integrated into processes for EPC Contractors. Indeed, due to the development methodology followed, these indicators combined academic contributes and the expertise coming from the Company and this allow to define them suitable for professional contexts. Indeed, statistical analysis performed showed how the observations drawn thank to correlation tests can be considered relevant.

Focusing on the results provided through the analysis of the new indicators together with furthers Portfolio's data, it is possible to state that the Risk Score Index at Portfolio level shows a good positive correlation with the marginality of the Portfolio itself. This relation allows to state that positive variations in Portfolio's profitability are expected when RSI_{PF} increases. Moreover, the marginality of the Portfolio seems to be is positively related to the effectiveness of Risk Management process. This result confirms the importance of an effective and proactive approach in managing Project's risks and allow to state that if variations occur to the indicators which monitor the Risk Management performance, variations can be expected on the Portfolio's profitability as well.

From a predictive point of view, these indicators can be considered relevant if considered as possible estimators of the Portfolio's profitability. Indeed, due to their correlations with the marginality they are suitable to be used within sophisticated predictive model (for example, machine learning predictive models, non-linear regression models).

Finally, the indicators can be considered suitable to be integrated in processes of Firms operating in general as EPC Contractors while observations drawn based on Company’s real data can be deeply investigated in order to undertake eventual improvement actions for the entire Project Risk Management process, from the commercial phase to closure.

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List of abbreviations

AD	Anderson Darling	**PoW**	Plan of Work
AHP	Analytic Hierarchy Process	**PRM**	Project Risk Management
BU	Business Unit	**PRN**	Portfolio Renovation
C.I	Consistency Index	**PRRP**	Project Risk Management Portal
C.R	Consistency Ratio	**PTC**	Portfolio Technical Completion
C_{nr}	Closed Not Realized	**R.I**	Random Index
CPI	Cost Performance Index	**RE_t**	Response effectiveness Threats
C_r	Closed Realized	**RE_o**	Response effectiveness Opportunitiess
CV	Constituent Variables	**REc**	Response effectiveness Combined
EPC	Engineering Procurement Construction	**RM**	Risk Management
MI	Monetary Impact	**RPI**	Risk Performance Index
N(t)	Number of Projects	**RSI_{PF}**	Portfolio Risk Score Index
$N_c(t)$	Number of closing Projects	**RSI_J**	Project Risk Score Index
$N_n(t)$	Number of new Projects	**RV**	Risk Variables
PAT	Portfolio Absolute Turnover	**SoW**	Scope of Work
PF	Portfolio	**SPI**	Schedule Performance Index
PFM	Portfolio Margin	**TC**	Technical Contingency
PFMr	Portfolio Margin Reviewed	**TCV**	Total Contract Value
PM	Project Manager/Project Management	**W_j**	Project's Weight

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