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Business Process Engineering, Performance Optimization and Ethics: A Mathematical Model for Decisions

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Abstract

In the public administration, in corporate or corporate groups and in all complex companies, it is increasingly necessary to develop rigorous analytical criteria supported by effective mathematical tools for process engineering and to make the best decisions. In order to achieve successful results and optimize ethical and transparency profiles, the authors propose a systematic approach to the analysis of decision-making variables with "multi-objective" criteria to help with decisions, comparing the scenarios of the effects (positive and negative) of the different alternatives that respect the constraints, from an LCCA perspective. These optimization models help to maximize the overall utility that economic, financial and project management choices produce, monitoring the objectives achieved with teamwork with appropriate programming techniques to maximize performance, while avoiding extra costs and delays and enhancing the company's "reputation".

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1. Management, *ethical leadership* and mathematical variables of the *organization's* system

In recent years, human resources management has attracted increasing attention for institutions and companies in all the country's production sectors, as it represents an average of 35% of operating costs and sometimes even exceeds 50%.
Due to the overall impact exerted not only on the financial statements but also on the reliability and value of the "*brand*", this entails a periodic "*dynamic remodeling*" of the system of organization of the various production sectors, operating the constant enhancement of quality and skills. These values, in fact, can represent a real lever for development, optimizing both the competitive advantage and the services provided to the community.
We can define the management of "*human capital*" as the set of all the policies, practices and systems put in place within a company to direct the behavior and performance of personnel towards certain *strategic objectives* of industrial policy. Managing resources effectively and efficiently means positively influencing the *performance* of the entire organization, both in terms of *stability*, productivity and expected results.
The main *key activities* that make up the complex framework of personnel management are:

- ***Planning***. It is the activity at the heart of a personnel management strategy. Through the planning process, *HR Managers* (*Human Resources Managers*) identify, on the basis of the company's objectives, which are the "resources", i.e. the people that the company already has and which, on the other hand, those it must acquire externally;
- ***Recruiting and selection***. It is the activity of finding new resources on the labor market. The selection process involves several steps: the definition of the advertisement on the basis of the profile sought, the choice of the channel (paper newspapers, websites, specialized agencies, social networks), the analysis of the CVs received, the interviews and the choice of the ideal candidate;
- ***Training and development***. Training is one of the main *drivers* available to the company to remain competitive on the market and to achieve the best benefits also in terms of industrial objectives and collective interest. Sharing the company's "challenges" with employees and providing them, if necessary, with the appropriate skills to achieve them, is of crucial importance to guide the organization towards the expected results, with synergistic *teamwork*;
- ***Staff evaluation***. It concerns the monitoring of employee performance and is preparatory to the definition of staff incentive systems and the identification of any weaknesses. At the end of the evaluation process, the improvement plan is drawn up, a document in which the actions to be implemented to improve the performance of the individual worker are indicated, where necessary;

- ***Salaries and incentives***. Once upon a time, this was an almost exclusively accounting activity. Today, on the other hand, activities related to compensation management are defined with the expression *total reward*. *Total reward* refers to the set of remuneration systems adopted by the company, with the aim of attracting and retaining people by motivating them and directing their behaviour towards the company's objectives, also through an appropriate and stimulating "*incentive system*";
- ***"Industrial" relations***. It is the context in which two often opposing realities confront each other, the *employer* and the *employees' representatives* (trade unions) who must comply with the rules in force in the "*labor law*" system. The *trade union relations* officer supervises all activities related to compliance with collective agreements, remuneration, holidays, etc., and plays a fundamental role in the event of disputes or company crises, making a fair comparison between the parties, respecting their roles.

The HR Manager has an active role in making workers participate in the *company culture* and "*ethical values*". Corporate *culture* is now a central element thanks to which a company or *group* attracts qualified people and limits *turnover*, while increasing the level of *employee retention*, i.e. the ability to retain its employees over time, enhancing their potential.

The tasks of the Human Resources Manager therefore include the development of an HR policy that reflects the *company's vision*, *mission* and *values*, employer *branding and the* implementation of strategies to increase the *sense of belonging* and the *degree of professional satisfaction* and workers' personnel (e.g., *team building* activities), etc.

Finally, an HR manager has the responsibility of disseminating good practices in the management of the company's people and supporting *change paths* in the company organization (*change management*), in line with the growth and development strategies of the *business* and with the trends of the world of work and process efficiency, also thanks to new digital and *hi-tech systems*, with an appropriate use of "*Big Data*".

The Head of Human Resources Management is therefore a reference figure both for employees and for the administration and top management of the company, in order to pursue the strategic objectives of industrial policy: he must always be ready to deal with workers of any company sector and function, listening to their needs, any complaints and, above all, their ideas for improvement, in a collaborative perspective of "*teamwork*", to achieve the planned objectives.

Informed of the critical issues and problems of an organizational, remuneration, etc. nature that may arise, the HR Manager takes charge of addressing and resolving them, finding a solution in common agreement with the interested parties and with the trade unions that represent them. It is therefore clear that the fundamental characteristic to carry out this job in the best possible way is relational *and communication skills,* ethics and knowledge of suitable *project management tools* (Fig. 1).

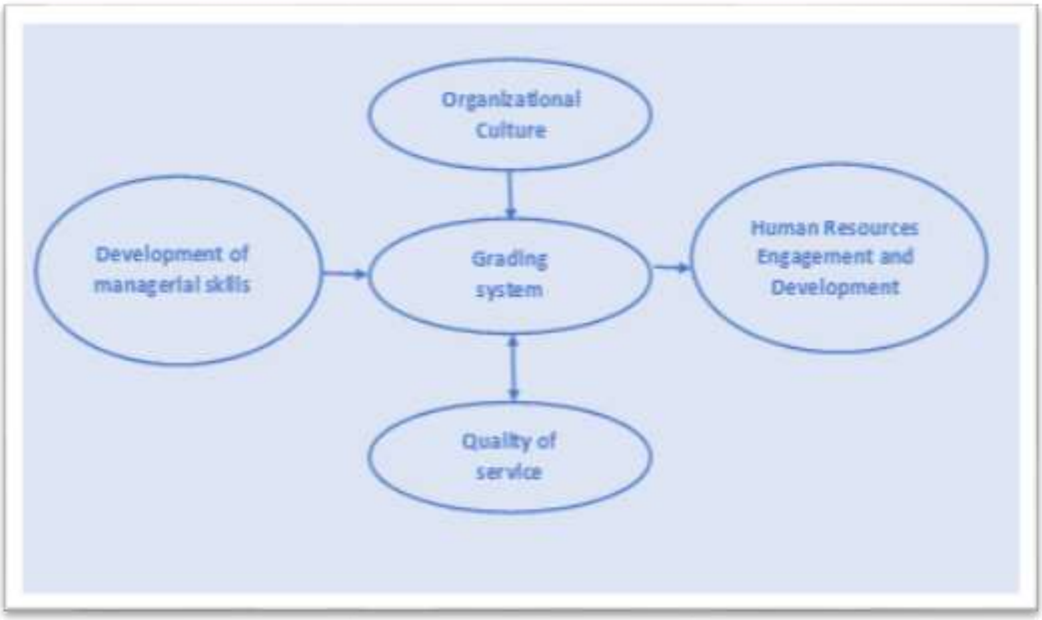

Fig. 1. Process of enhancement of organizational culture for the *quality of service*

In conclusion, the "*human factor*" always plays a primary role, giving maximum importance to the aforementioned "*change management*" in the modulation of the qualitative and quantitative resources of the personnel involved in the business processes and which will condition the *overall performance* of the services offered and subjectively *perceived*, facts that are also daily at the attention of the "*mass media*"", also due to the inevitable "malfunctions" that are recorded by users: these sometimes penalize the efforts of the structure, the company and its workers, encouraging the adoption of certain "correctives" with respect to the planned actions, so as not to frustrate the *expected results*.

The task of the top management is to identify and implement the functional processes *of the global quality management system* (including the pursuit of the corporate interest and the "*common good*") and to ensure their optimal application throughout the company organization. To this end, it is important to plan the *sequence and interactions* between these processes, as well as the stringent criteria and methods necessary to be used to ensure their effective operation and control.

Finally, once the necessary availability of the resources, the people constituting the various *Teams* and the information necessary for the operation and monitoring of these processes have been ensured, it will then be necessary to implement, with coordinated *teamwork*, the actions necessary to achieve both the planned results and the dynamic improvement of these *planned processes*, seeking the *optimum* of the *mathematical function* with which it is possible to analytically schematize these "*processes*".

From a technical-operational point of view, the overall picture of the *functional leadership activities* of management can be schematized in Fig. 2, where the interactions between corporate and strategic management with the internal and external environment are highlighted, with the repercussions on the planned objectives.

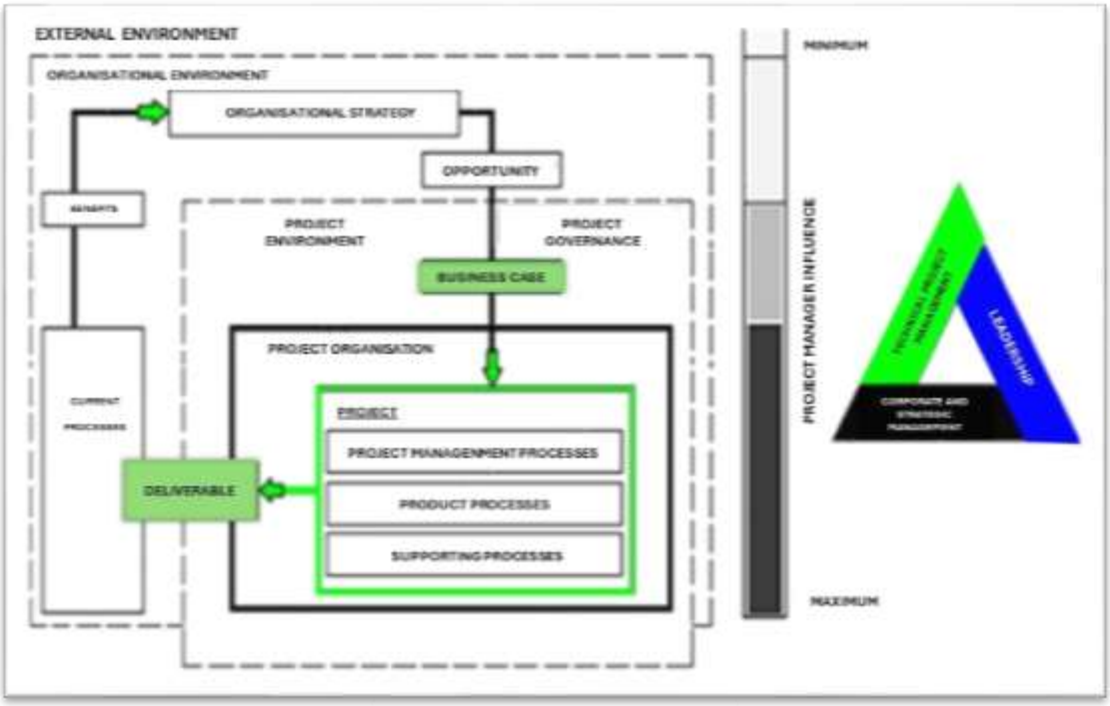

Fig. 2. Organizational structure and role of Project Management

The achievement of a company's *global objectives* are in fact related to the continuous improvement of the effectiveness and efficiency of the set of actions to optimize the *overall quality* of the *offer of services* or more generally of the "*product*", also in terms of the centrality of the *company/customer* relationship and the minimization of *risk* both in terms of *security* and *safety*, but above all "*reputation*", an essential aspect that enhances and consolidates credibility and *leadership*.

In fact, for successful results, both in companies and in the public administration, it is necessary to consider the fundamental and necessary ethics for the development and processes of managerial optimization, combining knowledge, values and behaviors in actions and in individual and *team work*: *ethics* It means directing behaviour in the desire to operate according to justice and equity, following universally accepted rules and norms of conduct that make decisions harmonious in order to achieve the *common good* made to "*converge*" towards the managerial objectives set.

Rediscovering the ethical dimension in public administration, in large corporate groups and, more generally, in companies translates into building responsible organizations and actions, reconciling the moral integrity of the individual and the efficiency of services of collective interest, assuming ethical values in the organizational culture oriented towards collective well-being and affirming respect for people and environmental protection.

The quality of people contributes to ensuring the effectiveness of administrations: enhancing the *ethical dimension* means encouraging employees – in every area of responsibility and role – to believe in their potential and to take effective initiatives as a manager and participant in team processes, being aware of acting successfully for clear and shareable objectives.

It is therefore necessary for the Manager to also take on the role of *ethical leadership* by encouraging people to bring out issues and problems of ethical relevance, to discuss them without fear of sanction or censure and to welcome any suggestions that can enhance the planned objectives: the exercise of *ethical leadership* supports commitment in the organisation and also contributes to the reduction of absenteeism from work.

A real "*change*" towards increasingly relevant and successful challenges proceeds through the willingness and motivation of people willing to adopt new behaviors and mental patterns for the development and affirmation of their company and of the public administration itself, with a different relationship with customers and citizens. It is necessary that management, as a manager of critical human and financial resources, must assume a specific leadership profile in overseeing behaviors and actions universally accepted as legitimate, contributing to the rediscovery of the *ethical dimension* of administration as a responsible organization, an example of *best practices* and that promotes **ethics-oriented *behaviors.***

Ethical *leadership* plays a fundamental role in the *sustainability of processes*, optimising both the corporate and behavioural organisational dimensions, nurturing people's motivation to provide the best results, especially if they are in the public interest; this, enhancing their commitment and conviction to carry out effective actions as managers of the team's actions. In particular, the effects of *ethical leadership* action are positive in terms of the employee's attitudes and behaviors towards work and commitment to the organization.

The Manager who is also an "*ethical leader*" is able to influence the attitudes and behaviors of employees by promoting *behaviors oriented towards values* and ethical principles that maximize the results of "*reputation*" (Fig. 3).

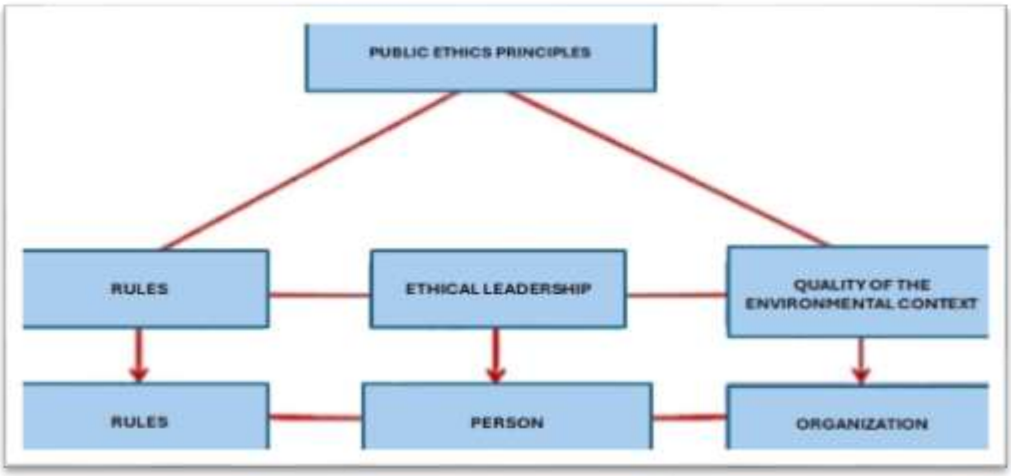

Fig. 3. *Ethical leadership* and enhancement of team people

In this way, it is possible to provide a complete managerial guide, perceived in the company (or in the Group) as a "*reliable reference*" and able to systematically define:

- *ethical standards* in compliance with the Code of Ethics and the anti-corruption plans pursuant to Law 190/2012 adopted and the Company Organizational Models pursuant to Law 231/2001 in force;

- criteria designed to preserve an *organizational climate* favorable to employees, who are led to discuss labor problems with an *inseparable* "unicum" of *technical-economic-financial-organizational* aspects and *ethical relevance* that also satisfy the general interest;

- effective "*control measures*" for compliance with rules and *best practices*.

This helps each *team* to grow in the interpretation of their role and in the assumption of the *task*, and encourages people to bring up ethically relevant problems and issues to discuss them with the *leader* for optimal solutions that maximize business and public benefits.

In this framework, therefore, *ethical leadership* enhances the relationship of *social exchange* based on mutual collaboration, esteem, trust and *fairness*, positively influencing *work performance* and the objectives of development plans, while inhibiting ethically unacceptable conduct and supporting *organizational commitment*: this "new" managerial approach reduces the number of cases and frequency of absenteeism and contributes to the training and psychological growth of the people in the *teams*, with significant *global benefits* for the company or *Group* and for the community.

In the above context, an original methodological approach to the problem of the optimal management of the "*people*" that make up the *Teams* is then developed through the formalization of a specific mathematical model that is based on the *systematic analysis* of the multiple *synthetic indicators* (numerical variables) that come into play in the choices of company *management* (Fig. 4); This is in relation to the programmatic objectives and *management guidelines* (depending on each practical case to which the model is applied) and the various technical-operational, economic-financial and business constraints to be respected.

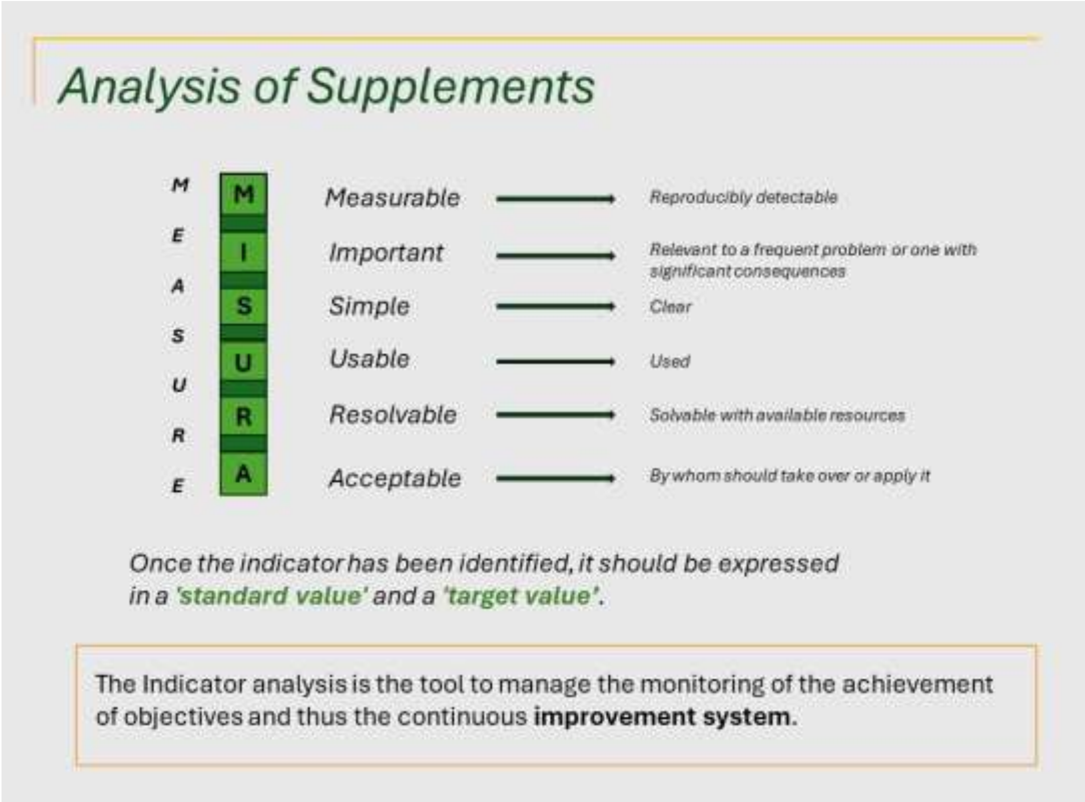

Fig. 4. Analysis of the "indicators" and monitoring of the objectives

In fact, any *strategic plan* functional to the improvement of the *overall quality* of the set of *coordinated actions* aimed at achieving a "*system of objectives*" planned (with a defined "*scale of priorities*") of a complex company or a corporate group (or *entities*), can be vectorially represented in *hyperspace* $\mathcal{R}^m$ through particular variables

$$\overrightarrow{x_1}, \overrightarrow{x_2}, \dots, \overrightarrow{x_n}$$

(some of which are also *random)*, representative of the various *factors* (endogenous and exogenous to the Company) that contribute to the achievement of the *key objectives* defined by these plans.
The latter can then be described by "*n*" appropriate *column vectors* (of order), "m"which give rise to a special "***objective function***" in the aforementioned *vector space* of variables:

$$F\,(\overrightarrow{x_1}, \overrightarrow{x_2}, \dots, \overrightarrow{x_n}),$$

Finally, taking into account the **constraints** g_j of the problem (regulatory, budgetary, etc.), which can be expressed through inequality

$$\boldsymbol{g_j(\overrightarrow{x_1}, \overrightarrow{x_2}, \dots, \overrightarrow{x_n}) \leq b_j},$$

with$j = 1, \dots, m;\ b_j \in \mathbb{R}$

It is possible to search for the *maximum* of the aforementioned function, provided by the resolution of a special system[3], where $\overrightarrow{x_1}, \overrightarrow{x_2}, \dots, \overrightarrow{x_n}$"weighted" vectors, suitably constructed with reference to the relative "*degree of relevance*" of the variables, are "weighted" vectors, using the mathematical formula

$$\boldsymbol{x_i = {x'}_i^{-w_i}\ con \sum w_i = 1}.$$

Therefore, the solution to the problem posed is provided by the system:

$$\begin{cases} \boldsymbol{Max\ \{F\ (\overrightarrow{x_1}, \overrightarrow{x_2}, \dots, \overrightarrow{x_n})\}} \\ \boldsymbol{g_1(\overrightarrow{x_1}, \overrightarrow{x_2}, \dots, \overrightarrow{x_n}) \leq b_1} \\ \boldsymbol{g_2(\overrightarrow{x_1}, \overrightarrow{x_2}, \dots, \overrightarrow{x_n}) \leq b_2} \\ \dots\dots\dots. \\ \boldsymbol{g_m(\overrightarrow{x_1}, \overrightarrow{x_2}, \dots, \overrightarrow{x_n}) \leq b_m} \end{cases}, \qquad (1)$$

whose analytical solution leads to the sought-after solution that provides the *decision-maker* with a framework of useful elements to optimize the *planned global objectives* .

In order to achieve successful results, mathematical models of "*decision aid*" play an important and central role in carrying out a rigorous analysis of the problem under study, but an essential role is played by the manager's experience, teamwork, *digital engineering processes*, *ethics* and other factors to describe, on a case-by-case basis, the constraints and reference scenarios of each problem.

2. The planning of *project management activities* and the search for the *optimal solution*

The task of the management of a company or group is to ensure the satisfaction of demand through the dynamic optimization of an *offer* suitable for consolidating and increasingly strengthening the user's perception of the "product" and therefore of the quality of services and safety levels, also making the *performance system* appropriately usable in the territory and at the same time maximizing the "value" of the *brand*tag.

Therefore, the interventions planned in the short to medium term must take into account the entire *useful life cycle* of each investment in terms of LCCA – *Life Cycle Cost Analysis*, according to the scheme in Fig. 5.

[3] The functional constraints to solve the problem can be expressed in the form of an $\boldsymbol{g_i}$*inequality* as indicated in the maximal search formula above , or, depending on the case study, also with the symbol , or in the form of a $[\boldsymbol{g_j \leq b_j}](\geq)$ *mathematical* equation$(=)$.

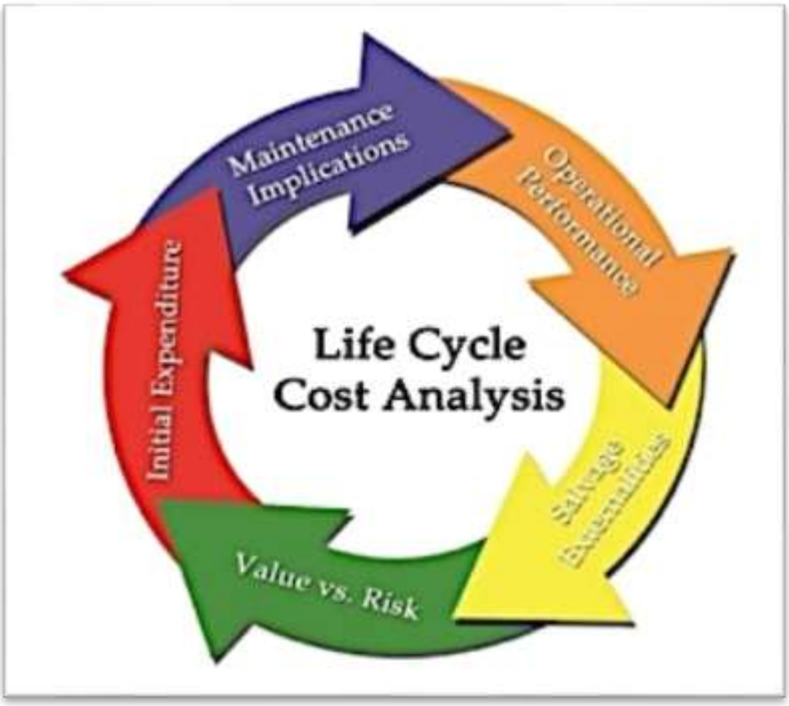

Fig. 5. LCCA – *Life Cycle Cost Analysis*

In this general framework, every "*optimization project*" (interventions on the organization, on the *corporate function chart*, creation of new areas of responsibility, etc.) is, in fact, by definition *a planned activity* that sees a limited time horizon for the realization of a service or a "product", on the basis of precise strategic and economic-financial choices upstream made by the decision-maker competent.

Therefore, it must be assessed for the direct, indirect and correlated effects (possibly also in the "*intra-group*" context) that manifest themselves in a monetary or non-monetary, tangible or intangible way and for the entire *useful life cycle of* the intervention examined.

The management of a *project* or complex of *planned activities* is usually delegated to a *Project Manager* or to an entire *company management*, which sometimes participates directly in the activities that compose it, but mainly focuses on the coordination and control of the various components and the different actors (*stakeholders*) involved with the aim of minimizing the *probability of failure*.

The first important step in planning is the analytical identification of the objectives of the project and the definition of the basic activities necessary to achieve them.

A frequently adopted approach for breaking down a complex project into elementary tasks is the *Work Breakdown Structure* (WBS): a *tree diagram* that allows you to describe and visualize all the parts of a project at different levels of detail, according to a *hierarchical order* (Fig. 6).

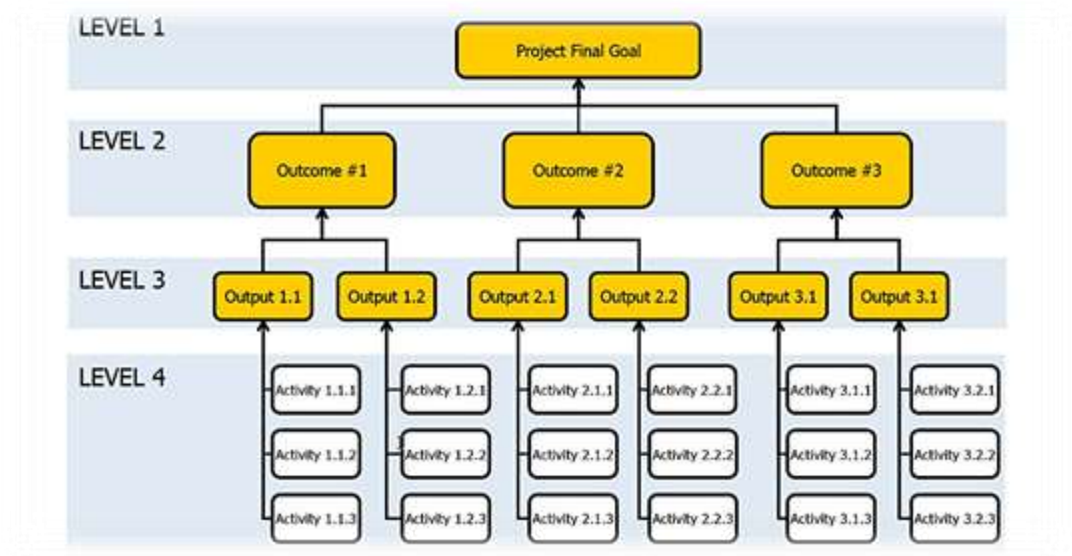

Fig. 6. Organization of activities into "*processes*" in *an engineered way*

At the highest level there is the *overall project*, while at the lowest level, as a result of a subsequent decomposition according to an increasing *degree of detail*, there are the *elementary activities*.
In this way, each "*level*" represents the result of the activities at the *lower level*.
The manager's task is to ensure compliance with objectives, costs and times, the *expected quality* and also the achievement of the satisfaction of the user of the "product" or services ("customer" or community in general).
Therefore, regardless of the field of implementation of the *project*, the management must be able to interpret the real objectives of the "*project*" (material or intangible), from its beginning to the end, ensuring an overall "vision" for the achievement of all the different activities and *performances* envisaged by the intervention, to achieve successful results in *the Team*.
According to this methodological approach, the logical phases of implementation can be summarized in **five *key points*** characterizing the typical dynamics of ***Process Groups*** (Fig. 7):

1. **Start of project activities and start-up phase** (*Initiating*);
2. **Planning and Design**;
3. *Executing*;
4. Monitoring and Controlling*;*
5. **Completion and completion of activities or *business process*** (*Closing*).

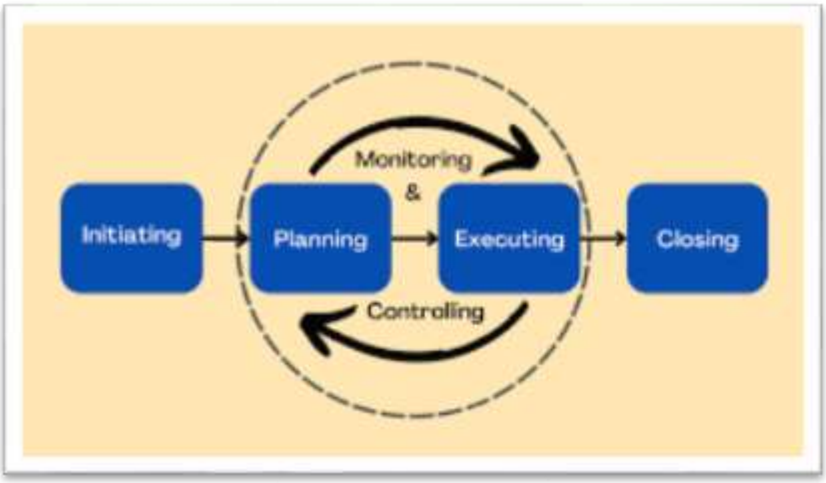

Fig. 7. Typical dynamics of *Process Groups*

In order to optimize the overall results related to the investment, the process requires an appropriate *cycle of checks* related to the monitoring and control of the activities, in order to avoid variations in costs and times and to ensure the full achievement of the multiple objectives (Fig. 8).

Fig. 8. Cycle of checks for the monitoring of the objectives

In addition, the task of the Manager and all the other company figures responsible for achieving the planned business objectives in the Team is to analyze all the technical-regulatory and logistical, economic-financial and temporal constraints, appropriately deepening each element of the *activity cycle*.

To this end, the ***Triangle of design constraints*** (*triple constraint*) is particularly useful in order to analytically represent the *characteristic events*, as schematized below:

- Scope;
- **Tempo** (*Schedule*);
- Cost/Resources,

and the variation of one of them impacts the remaining two elements of the triangle (Fig. 9).

Fig. 9 - Triangle of design constraints.

The planning, implementation and control activities can then be operationally carried out, with the use of reticular programming techniques, through a clear and defined *logical process*, schematized below (Fig. 10).

In order to better place the various activities to be carried out in order to complete the intervention under study within the prescribed timeframe, it is then necessary to proceed with the relative ordering (*scheduling*) by means of the distribution of *resources* over time, and taking into account, on the one hand, the maximum availability of resources (*allocation*) and, on the other, the economic advantage deriving from the elimination of discontinuities in the use of those resources over time. *leveling*).
Finally, by analyzing and representing the "*cost/time" link,* it is possible to search for the *minimum total cost* of execution of the project and its duration, called *optimal duration*.
The identification of the *minimum total cost* is based on the observation that costs are the sum of two rates: *direct costs* and *indirect costs*.

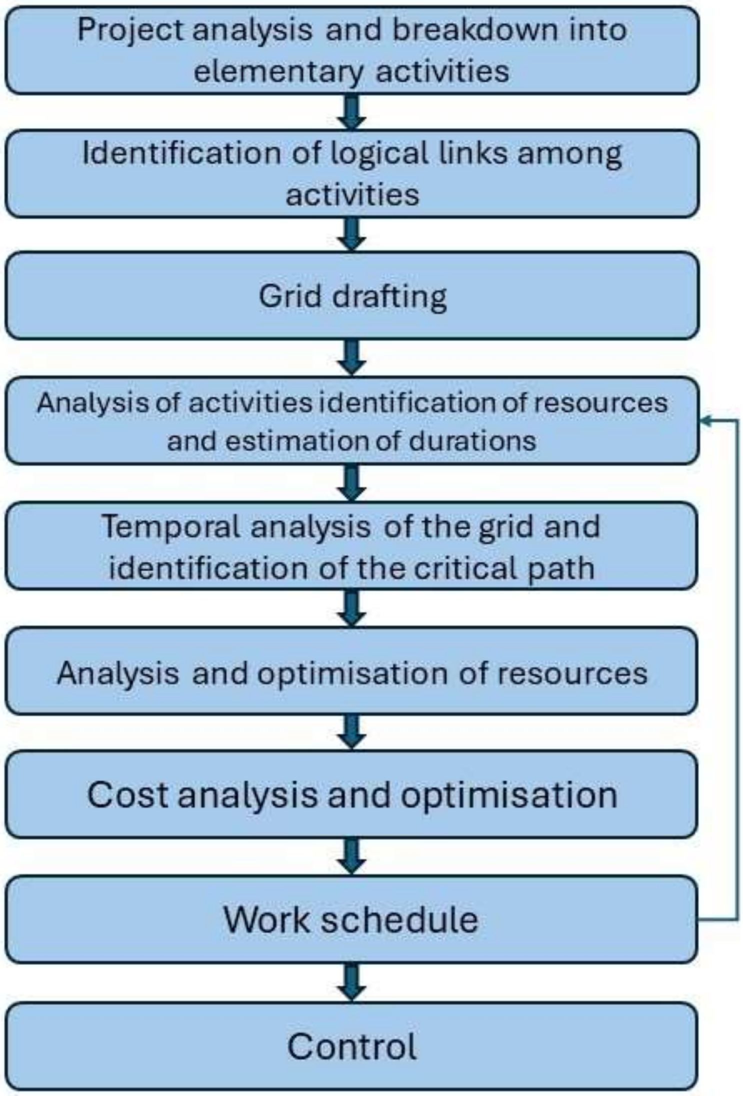

Fig. 10. The contribution of "*reticular techniques*" to process optimization

The former are inversely proportional to the execution time of the scheduled activities, in the sense that as time decreases, costs increase, while the latter are directly proportional to time. There is, therefore, an execution time, *an optimal time*, which corresponds to the *lowest total cost*.

This planning methodology provides a valid control tool, as any *deviations* between what was planned by the Manager and the actual progress of the work allow a review to be carried out "*in progress*", in order to undertake in time all the possible corrective actions necessary to achieve the pre-established objectives (Fig. 11).

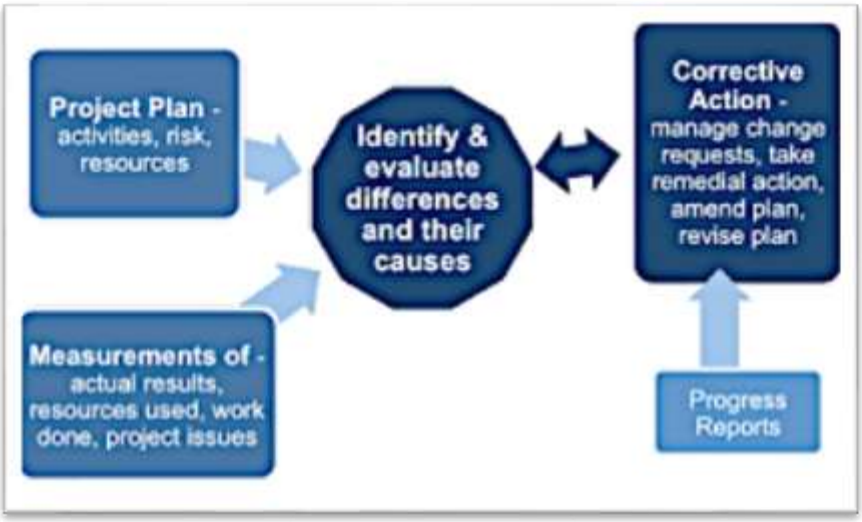

Fig. 11. Analysis and monitoring of the *project's scheduled activities*

3. The mathematical characterization of the organization optimization problem

Every *organized human activity* gives rise to two fundamental needs: the division of labor according to the various tasks to be performed and the coordination of the same.

Organization can be defined as the *set of ways* in which the division of labor into distinct tasks of a more or less complex structure is carried out, achieving an appropriate coordination between these tasks, functional to business processes.

In addition, it is understood as a complex set of people *associated* to achieve a *unitary purpose* among which the activities to be carried out must be divided, according to certain pre-established rules, establishing roles connected to each other in a hierarchical way and in relation to the "internal" and "external" environment.

In order to fully clarify these fundamental elements of an organizational process, the terms used in the definition summarized above are clarified below:

- *complex set*: because it requires *both* reductive *and* explanatory *models* capable of highlighting the *main variables*;
- *of people*: because it involves choices on *the degree of autonomy* of behaviour with respect to the *degree of compliance* with prescriptive rules;
- *associated for a unitary purpose*: in the search for coherence between *the individual objectives* of the organization and *the objectives of the groups*;
- *among which the activities to be carried out are divided*: choice of the *level of specialization* taking into account the needs of coordination and completeness of professionalism;
- *according to certain rules*: choice of the *level of formalization* of activities in written procedures, how much to leave to practice and how much to delegate to decision-making autonomy;

- *establishing roles*: choosing assignments of authority and responsibilities;
- *hierarchically*: centralization and/or decentralization of decision-making, also in relation to the size of the organization and objectives;
- *in relation to the external environment*: depending on the degree of openness or closure to the outside.

Organizing also means choosing the level of *functional correlation* on the various component points.

The variables or *elements of the organization* must be chosen in such a way as to achieve adequate "harmony" and appropriate internal coherence with the organization of the company. Therefore, it is necessary that both the parameters of the *organizational design* and the *situational factors* must be strategically combined by the *Project Manager* to create *optimal configurations*, in order to maximize *business performance* and *overall results* (perception of reliability in the market, optimization of the "company/customer" relationship, balance sheet performance, etc.)tag.

At the base of every effective organization, there is a careful work of *design, programming* and *planning*, through which the ability to modify and "direct" a system of business activities towards successful objectives is manifested.

In the case of organization, *design* implies *maneuvering* those levers that influence the division of labor and the coordination mechanisms, improving the way they function, also intervening on the functional relationships of the compositional elements.

In this sense, it is necessary to identify appropriate solutions that meet the requirements of efficiency, effectiveness and equity, in order to create an organization that achieves the following fundamental results:

- try to achieve the objectives for which it was created;
- optimising the use of resources according to those objectives;
- be perceived as *fair* by organizational *actors*.

A given organizational solution is concretely implemented through specific decisions relating to a variable or a set of organizational variables, through four broad groupings by type of design:

- design of *individual positions;*
- design of the *macrostructure;*
- design of *side connections* (planning and control systems, etc.)*;*
- design of the *decision-making system.*

The above considerations demonstrate, therefore, that in order to arrive at a mathematical evaluation of the problem it is possible to consider an appropriately *defined set* of *complex variables* which, in an *m-dimensional* $\mathfrak{R}^m$ reference space, can be represented by the construction of particular *vectors* $\vec{x_j}$, characterizing the *program of interventions* for the organizational structure (or "production") in the studio and formed, therefore, by the characteristic data of the problem.

The *vector* $\vec{X}$, having *components* $\vec{x_j}$, can be represented in *matrix form* by the set of *observed variables*

$$X \equiv \begin{Vmatrix} x_{11} & \cdots & x_{1m} \\ . & \cdots & . \\ x_{n1} & \cdots & x_{nm} \end{Vmatrix}; \quad (2)$$

In addition, in order to overcome the diversity of the respective units of measurement (some variables are generally also of *a qualitative* nature), it will be necessary to provide for the *transformation* of the original *indicators* into ***standardized variables***x_{ij}^*.

To this end, once the *arithmetic mean* $\overline{x_j}$ and the *standard deviation* σ_j of the *m* components of the aforementioned *vector have been calculated*, the algorithm can be used on a[4] statistical basis

$$x_{ij}^* = \frac{x_{ij} - \overline{x_j}}{\sigma_j \cdot \sqrt{n}},$$

To define the searched *matrix of dimensionless variables* that originates in the variable space the new vector :$\Re^m \overrightarrow{X^*}$

$$X^* \equiv \begin{Vmatrix} x_{11}^* & \cdots & x_{1m}^* \\ . & \cdots & . \\ x_{n1}^* & \cdots & x_{nm}^* \end{Vmatrix}. \quad (3)$$

Finally, it will then be possible to associate to this vector specific mathematical functions that express the $\overrightarrow{X^*}$*discounted utility/disutility flows* generated for the entire time scenario of the event considered, evaluating the actual global effects generated.

According to this methodological approach, starting from the previous examination of variables (1) and (2), now constructing in the *m-dimensional* space of reference a new vector useful to represent the sought-after $\overrightarrow{U_g}$ *global utility* of the analyzed project in terms of "repercussions" on the company:

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[4] This algorithm is based on *the central limit theorem*, according to which, the means of samples randomly drawn from a distributed population, provided that the samples are sufficiently large (n ≥ 10) and the *distribution* has finite mean and variance, are normally distributed$\overline{x_j}$ σ_j^2, with variance, where is the $\sigma_j^2/_n$ n *sample size*.

$$\vec{U}_g = \{\vec{u}_{gj}\}_{j=1}^{m}, \quad (4)$$

such that, from an algebraic point of view, the modulus of the vector can be expressed through the sum of the $\overrightarrow{U_g}$ m actualized *relative global utilities*, associated with each of its vector components according to the following expression:$\mathfrak{R}^m$,

$$U_g = \sum_{1}^{m} u_{g,i} = \sum_{1}^{m} \left[\frac{\Delta B_{ij} - \Delta C_{ij}}{\sum_1^k (1+r)^t}\right] \quad (5)$$

$$\begin{cases} \dfrac{\Delta B_{ij} - \Delta C_{ij}}{\sum_1^k (1+r)^t} = utility\ increases\ \left(\Delta B_{ij} - \Delta C_{ij}\right)\ updated \\ \quad for\ the\ generic\ j-th\ objective\ considered; \\ r = discount\ rate; \\ k = \text{"}useful\ life\text{"}\ cycle\ characteristic\ of\ the\ event; \\ t = time\ to\ observe\ the\ problem. \end{cases}$$

In particular, in (4) and (5), the overall cost can be considered by estimating its constituent elements, according to the formula C_G

$$(6) C_G = \left[c_i + \left(c_m + c_g\right) \cdot \left(\frac{q^k-1}{r \cdot q^k}\right) \cdot \left(\frac{1}{q^k}\right)\right] \cdot \alpha \cdot \beta$$

with the following meaning of the symbols:

$$\begin{cases} C_G = overall\ cost\ of\ the\ investment \\ c_i = overall\ initial\ cost \\ c_m = monitoring\ costs \\ c_g = management\ cost \\ \\ {}^{1}\!/_{1 + r^k} = anticipation\ factor \\ r = discount\ rate \\ k = characteristic\ \text{"}useful\ life\text{"}\ cycle \\ q = (1+r) = combination\ of\ interest \\ \alpha = investment\ risk\ factor \\ \beta = provision\ factor = 1 \\ if\ it\ is\ annual \end{cases}$$

The factor of expression (5) above can be derived from *αthe risk analysis*, which is fundamental in the evaluation of the *event* to analyze what are the most probable prospects and the possible damages that can be incurred, especially in the case of significant business investments.

4. Risk analysis in the assessments of the business decision-maker

From a methodological point of view, the analysis of the risk to be carried out in the decision-making process, which is the responsibility of the decision-maker, can be carried out by representing the problem in the *Cartesian plane* by means of a *coordinated system of axes* (x, y) consisting respectively of the *expected potential damage* **D** on the abscissa and the *degree of hazard* **H** on the ordinate (cf. Fig. 12), assuming that the *acceptable risk* depends linearly on the *estimated potential damage* for that public intervention examined, whether it is an infrastructural work, or any other public finance "action" involving a given *territorial* and socio-economic system considered in the problem under study.

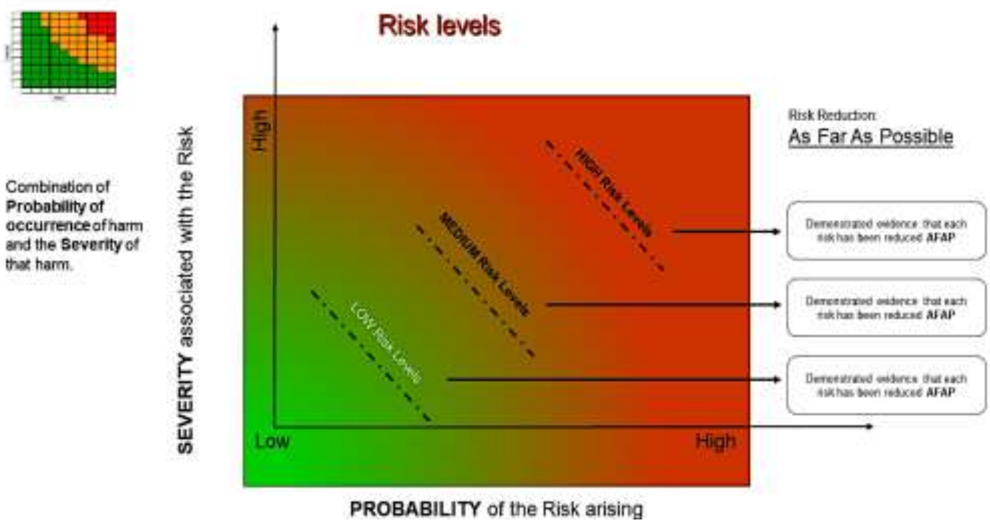


Fig. 12. The analysis of the *level of risk* and its *degree of acceptability*

The particular expression of the function **H =** ***f*** **(D)** then depends on the particular "*boundary conditions*" of the problem: in fact, the same *total risk* value, associated with a generic *j-th* variable examined in the process of choosing the "*optimal*" solution that is the responsibility of the public decision-maker, cannot always be considered scientifically acceptable.

This function is also related to the particular ***scenario of the*** relative context and, for example, for new infrastructures (think of a road or a railway), by the peculiarities of the territory in which the engineering work is inserted, such as the socio-economic situation of the area, the *vulnerability* of the places, etc.

In this regard, the two ***risk curves*** geometrically represented in Fig. 1 show that points **A** and **B,** although belonging to the same ***isorisk curve*** and therefore resulting in the same *level of total risk*, are not both characterized by an acceptable *level of sustainability*: the level of risk is in fact the result of two different combinations of the values of the variables "*degree of hazard*" and "*potential damage*".

In point **A** there is a low expectation of damage but a high probability that the harmful event will occur, while in point **B**, although the expectation of damage is high, the possibility of the harmful event occurring is very low; therefore, only the level of risk characterized by point **B** and not the level assumed in **A can be considered acceptable**.

Finally, it must be considered that the transition between the two zones of "*acceptable risk*" and "*not acceptable*" is not always clearly demarcated, but generally between the two zones, a particular "transition zone" is interposed (Figure 13).
In the event that the value of the *total risk* falls within it, it is considered acceptable; however, if possible, it is good to reduce its value.
When, on the other hand, the level of risk falls within the zone of non-acceptability, it is necessary to immediately prepare all possible interventions, in order to contain it appropriately, due to the particular territorial "*constraints*" characterizing the problem under study.
Therefore, by proceeding to analyze the set of variables considered, each alternative under consideration in the decision-making process relating to an intervention project with public funding can thus be associated with a specific global utility *indicator* $\boldsymbol{U_g}$ that synthetically expresses the characteristics of the *option* in question and is constructed on the basis of the study of the relative *discounted and "weighted*" by means of a specific indicator $\boldsymbol{\mu_j}$ che tenga conto del *level of relative importance* of the *j-th variable* with respect to the "*strategic objectives*" defined for that investment project.

The changes generated on the economic and social "system" concerned will all have to be related to the *neutral hypothesis*, i.e. to the "*non-intervention*".

It will therefore be necessary to evaluate the new scenarios that are being created for the quality of life, for the safety of citizens, for the better protection of the environment and natural and built resources, for employment, the competitiveness of businesses, etc., both in the site directly concerned and *in the vast area* (extended territorial area in which the effects of the public action in question are expressed).

In symbols, then, naming with

$\Delta\, \boldsymbol{B_{ij}}$ Utility *Boosts*

found in the generic *j-th component* of the system (among the m analysed) for the *i-th* unit constituting the set of elements (assumed to be equal to n) characterising the public finance problem considered,

with their respective $\Delta\, \boldsymbol{C_{ij}}$ *negative changes in utility*,

and finally

with the above-defined "$\boldsymbol{\mu_j}$ *correction factor*",

The sought-after global *utility indicator* takes the expression:

$$U_g = \sum\nolimits_{i,j} \mu_j \left(\Delta\, B_{ij} - \Delta\, C_{ij}\right).$$

In conclusion, formula (5) of the ***discounted global utility*** becomes:

$$\boldsymbol{U_g} = \sum_{1}^{m} \boldsymbol{u_{g,i}} = \sum_{1}^{m} \boldsymbol{\mu_j} \left[\frac{\Delta\, \boldsymbol{B_{ij}} - \Delta\, \boldsymbol{C_{ij}}}{\sum_1^k (\boldsymbol{1}+\boldsymbol{r})^{\boldsymbol{t}}}\right] \quad (5')$$

5. Decisions in "*conditions of uncertainty of the scenario*" with mathematical models

The Manager will not always find himself making choices for his company (or *corporate group*) in conditions of certainty, not having to manage only situations in which the consequences of an action are determinable *a priori*, but will often have to carry out complex evaluations in *conditions of uncertainty*.
This circumstance occurs when one or more *variables of the problem* are *random* and for which only the relative *probability values can be determined*.
A methodology for approaching the problem for such *decisions under conditions of uncertainty* can be schematized according to the methodological approach proposed below.

Consider *mrandom events that* describe the "scenario" of the problem to be solved

$$\boldsymbol{Ei}\ \ (\mathbf{i = 1, ..., })\boldsymbol{m}$$

and suppose that they are *independent* and complementary to each other; that is, such that if the event *E1* occurs, it excludes all other alternatives *Ei*, with i = 1, ..., $.m$

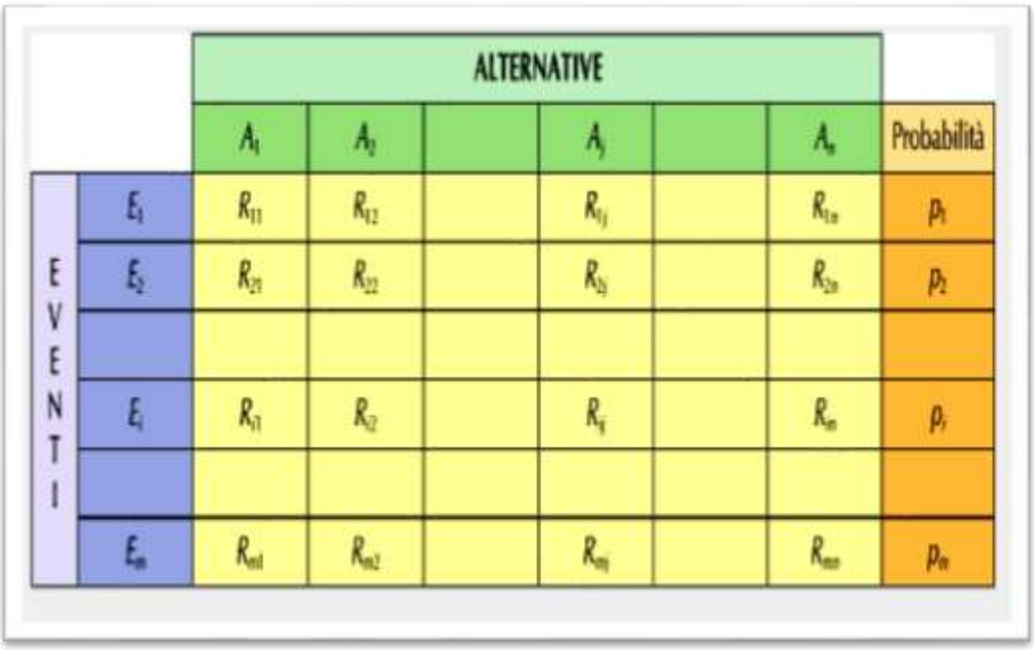
Now associate each of the possible events with the calculated relative probability p_i , with:

$$\sum_{1}^{m} p_i = 1.$$

If we indicate with the different A_j (i $= 1, \dots, n$) *alternative options* on which the Manager must make his *choice of intervention*, we configure a **set *I* composed of elements in number equal to $\boldsymbol{R_{ij}}$ $(\boldsymbol{n} \cdot \boldsymbol{m})$**, obtained from the relations

$$\boldsymbol{A_j} = \mathbf{f}\ ,(\boldsymbol{E_i})$$

which give rise to a table of data, such as the one in Fig. 14, where the *decision-making alternatives* A_j take on the mathematical connotation of *random variables*.



		ALTERNATIVE						
		A_1	A_2		A_j		A_n	Probabilità
EVENTI	E_1	R_{11}	R_{12}		R_{1j}		R_{1n}	p_1
	E_2	R_{21}	R_{22}		R_{2j}		R_{2n}	p_2
	E_i	R_{i1}	R_{i2}		R_{ij}		R_{in}	p_i
	E_m	R_{m1}	R_{m2}		R_{mj}		R_{mn}	p_m

Fig. 13. "*Alternatives-Events-Probability*" Matrix

Considering then that the *expected value* of a *discrete random variable* (i.e. one that assumes only a finite number or a *countable infinity* of values) is given by the sum of the possible values of that variable, each multiplied by the probability of being assumed (i.e. of occurrence of the event), i.e. it is the *weighted* average of the possible results (for a continuous random variable one has to resort to measure theory and the ***Lebesgue-Stieltjes integral***), one can now calculate the expected value of each variable $\boldsymbol{V_j}\left(\boldsymbol{A_j}\right)$ A_j .

This indicator is provided by the expression:

$$\boldsymbol{V_j}\left(\boldsymbol{A_j}\right) = \sum_1^n \boldsymbol{R_{ij}} \cdot \boldsymbol{p_i}.$$

Finally, on the basis of the previous reports, the Project Manager will be able to arrive at the "*optimal*" solution for the intervention

$$\boldsymbol{S_p}\ (A_k),$$

considering all the variables involved in the definition of the decision-making process, including those of A_k A_j *a random type*, using the following general formula for this purpose:

$$\boldsymbol{S_p}\ (A_k) = \boldsymbol{arg}\left\{\max_{\boldsymbol{k=1,\ldots,s}} [V_k\ (A_k)^{-w_k}]\right\},$$

where is the "w_k *weight*" given to each alternative , with A_k $\sum_1^s \boldsymbol{w_k} = \mathbf{1}$.

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