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RISK-BASED DECISION MAKING AND RISK MANAGEMENT OF EUROPEAN UNION REGIONAL PROGRAMS

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Abstract: This paper presents a generalized method for management decision making incorporating risk assessment techniques. The risk based decision making methodology is applied to European Union expenditure programs used to implement its regional policy, such as the community support framework, community initiatives, special initiatives and other European policies. An example is presented for the development of an audit (inspection) program in the region of West Macedonia, Greece, during the implementation of the 3rd Community Structural Support Framework Operational Program. The generic nature of the method permits its use in the management of similar European regional programs in Greece and other European countries. It is also applicable to many other industries interested in applying risk–based management decisions to physical or process based systems.

Keywords: Risk management, risk assessment, risk-based inspection, risk-based decisions, European operational programs, Community Support Framework.

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1. INTRODUCTION

Risk assessment techniques and risk based methods have been used in some form in various industries for many years. However, methods which use formalized techniques to make decisions based on qualitative or quantitative risk calculations are fairly new. In 1988 the American Society of Mechanical Engineers (ASME) in cooperation with private industry and government agencies formed a multi-discipline Research Task Force on Risk-Based Inspection. Its scope was to develop inspection programs of mechanical systems for industrial applications based on risk assessment techniques. The main objective of this effort was to develop and test new technologies to replace traditional inspection program development methods used by code and standards organizations. This effort resulted in the development of a generalized risk-based inspection program development methodology [[4]]. A number of subsequent publications applied this methodology to the development of inspection programs in the fossil fuel, nuclear, petroleum, chemical and other industries [[5], [6], [7]]. This technology has been adopted by ASME and other standard bodies in the development of risk based inspection standards, such as the Nuclear Code Cases N-577 and N-578 of the ASME Section XI Nuclear Inspection Code which contain risk based inspection requirement of piping systems [[8], [9]], the API 579 Recommended Practice for Fitness for Service [[1]] , the API RP 580 Recommended Practice of Risk Based Inspection [[2]] and the API RP 581 Base Resource Document [[3]]. Since 1995, ASME has formed a Post Construction Committee and numerous subcommittees and groups with the task to develop risk based standards of mechanical systems in all industries.

In 2002 the European Union requested the Management Authorities of European countries to incorporate risk methods in the management of European funded regional operational programs [[12], [13]]. The objective of this paper is to address this recent European request by adopting and expanding the ASME risk-based inspection development methodology to a comprehensive decision methodology applicable to the management of European regional programs.

2. DEFINITION OF RISK ASSOCIATED TERMS

2.1. Public and common uses of the term risk

The term risk in the public has many different uses that are sometimes confusing and often lead to misconceptions when communicating risk in technical terms to decision makers. Risk as commonly used refers to undesirable events or outcomes which can cause harm (safety, injury or death) to the public, environment or financial losses. It is interchangeably used and related to terms like hazard, frequency (likelihood or probability), consequence (severity or magnitude of loss). Often uncertainty or lack of knowledge of a desirable or undesirable event is referred to as a risk. In financial industries, such as stock or bond markets, risk is used to describe the uncertainty of the expected return on investment, which sometimes can lead to losses in the original investment. In the insurance industry risk refers to the customer or the insurance policy. In the area of health and safety causes or other risk-related factors are often referred to as a risk. Examples are smoking, pollution, driving, traffic road conditions, car breaks, sport accidents, work safety conditions etc. Often risk factors are associated only with frequency or consequence and do not incorporate both effects.

Risk originates from the Latin term "resicum", which means the challenge presented by a barrier reef to a sailor [[11]]. The Oxford Dictionary defines risk as a chance of hazard, bad consequence, loss, etc., or risk can be defined as the chance of a negative outcome. It can be seen that in the Oxford Dictionary definition risk is associated only with the chance (probability) and is not associated with the magnitude of the consequence, which is the second part of risk.

In summary, all of the previous risk terms are used interchangeably in the public without any exact definition of their meaning. Confusion exists on the use of terms like risk, hazard, event, causes and other factors, which need to be differentiated in a technical risk-based decision making process. Therefore, there is a need for clear technical definitions of risk and other risk related terms, such as hazard, risk factors, risk analysis, risk system, etc.

2.2. Hazard

In the definition of risk the term hazard is almost always incorporated. Therefore, it is helpful to examine this term is details. Common dictionaries define hazard as: 1) risk, peril, jeopardy, 2) a source of danger, 3) a. chance, b. a chance event, accident, 4) mistake, 5) something risked.

Roland and Moriarty [[19]] state that a safety person sees hazard as an implied threat or danger, or possible harm. It is a potential condition waiting to become a loss. A stimulus is required to make the hazard transfer from the potential state to the loss. The stimulus could be a component failure, a condition of the system such as pressure, temperature, switching condition that is out of tolerance, a maintenance failure, an operator failure, or a combination of multiple events and conditions.

The technical definition of hazard given by Roland and Moriarty [[19]] is a potential condition, or set of conditions, either internal and/or external to a system, product, facility, or operation, which, when activated transforms the hazard into a series of events that culminate in a loss (an accident). A simpler and more fundamental definition of hazard is a condition that can cause injury or death, damage to loss of equipment or property, or environmental harm.

ASME [[4]] defines hazard as a physical condition or a release of a hazardous material that could result from component failure and result in human injury or death, loss or damage, or environmental degradation. Hazard is the source of harm. Components used to transport, store, or process a hazardous material can be a source of a hazard. Human error and external events may also create a hazard.

Ayyub [[11]] defines hazard as an act or phenomenon posing potential harm to some person or thing (i.e., is a source of harm) and its potential consequences. In order that hazard causes harm, it must interact with persons or things in a harmful manner. The magnitude of the hazard is the amount of harm that might result, including the seriousness and exposure levels of people and the environment. Potential hazards must be identified and considered during lifecycle analyses of projects in regard to the threats they pose that could lead to project failures. The interaction between a person (or a system) and a hazard can be voluntary or involuntary.

2.3. Risk analysis

Modarres [[17]] and Modarres et al. [[18]] provide an excellent presentation of what a risk analysis, risk perception and risk acceptability are. The following is liberal summary of that presentation.

Risk analysis is a technique for identifying, characterizing, and evaluating hazards. It consists of two distinct phases: a qualitative step of identifying, characterizing and ranking hazards; and a quantitative step of risk evaluation, which includes estimating the likelihood (e.g. frequencies) and consequence hazard occurrence. After risk has been quantified, appropriate risk-management options can be derived and considered; risk-benefit and cost-benefit analysis may be performed; and risk-management policies may be formulated and implemented. The main goals of risk management are: to minimize the occurrence of accidents by reducing the likelihood of their occurrence (e.g., minimize hazard occurrence), to reduce the impacts of uncontrollable accidents (e.g., prepare and adopt emergency responses), and to transfer risk (e.g., via insurance coverage). The estimation of likelihood or frequency of hazard occurrence depends greatly on the reliability of the system components, the system as a whole, and human-system interactions.

2.4. Technical aspects of risk

The American Society of Mechanical Engineers (ASME) Research Task Force on Risk-Based Inspection defined risk as a measure of the potential for harm or loss (i.e. hazard) that reflects the likelihood (frequency) and severity of an adverse effect to health, property, or environment [[4]].

Ayyub [[11]] formally defines risk as the potential of losses and rewards, resulting from an exposure to a hazard or as a result of a risk event. Unfortunately this definition of the term incorporates the word risk itself (i.e. risk event). Ayyub farther states that risk results from an event or sequence of events referred to as a *scenario*. The event or scenario can be viewed as a cause which results in consequences with various severities. Risk can be viewed to be a multidimensional quantity that includes event occurrence probability, event occurrence consequence, consequence significance, and the population at risk; however, it is commonly measured as the probability of occurrence of an event plus the outcomes or consequences associated with occurrence of the event.

2.5. Risk in the present study

In this study *risk* is defined as a measure or quantification (qualitative or quantitative) of the potential for harm, loss or negative change of a condition (state) in a physical or procedural system that combines the likelihood (e.g. frequency, probability) and severity (consequence) of an event or scenario with an adverse effect to the health, environment or property (finances) due to a hazard or procedural failure. It is the expected loss or harm due to inherent hazards.

Hazard is a potential condition, or set of conditions, either internal and/or external to a system of products, equipment, facilities, people and procedures which, when activated transforms the hazard into a series of events that culminate into a financial loss or harm (such as injury or death), damage, loss of equipment or property, or environmental harm. A stimulus is required to cause the hazard to transform from the potential state in the system to a loss or harm.

The above definition differentiates the terms risk and hazard. It characterizes risk as the *combination* and *quantification* of both *frequency* and *consequence* of undesirable events. It covers both physical and procedural systems.

The differences and the relationship of the key risk associated terms are illustrated in Figure 1. In this figure there is a clear distinction between the terms hazard and risk. Risk involves quantification of frequencies and consequences of anticipated events due to an inherent hazard or condition in a system. Hazard is a physical condition or a cause that can be transformed by a stimulus into an undesirable event. Hazard and hazard analysis typically involve systems and events which have consequences that affect the safety of people or damage to the environment. For other types of consequences (i.e. financial or other measures) hazard is not used but the words "inherent condition" are more appropriate than the term hazard. Typical hazard analysis or hazard mitigation or safety analysis do not necessarily involve full quantification or assessment of risk.

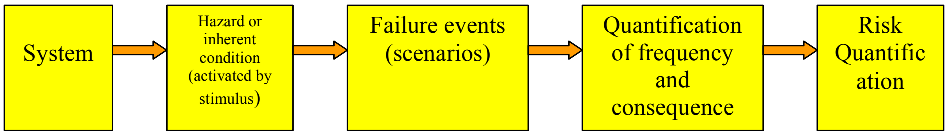

Figure 1: Relationship of system, hazard, failure events and risk

3. MATHEMATICAL BACKGROUND OF RISK

3.1. Notation

The following notation is used in subsequent sections of this paper.

C = consequence
F = frequency
R = risk
i = individual subsystem identification number (index)
j = single failure event identification number (index)
k = combined system or subsystem identification number (index)
l = combined failure event identification number (index)
I = cost (investment)
m = decision identification number (index)

3.2. Definition of risk

Mathematically, in the case when risk is described in *qualitative terms* using solely verbal descriptions, risk can be expressed as a combination of likelihood and severity

$$R = f\,(likelihood, severity) \qquad (1)$$

In the case where *quantification* is made

Risk = Frequency x Consequence

$$R \equiv F \cdot C \tag{2}$$

It is noted that variables F and C are functions of other factors such as hazards, conditions, system properties etc. Thus, risk is a function of these factors, too. The terms likelihood, frequency and probability are used interchangeably and their use depends on the level of accuracy of quantification. The term likelihood is normally used when verbal descriptions (e.g. unlikely, likely, low, medium and high) are used to describe the rate of the occurrence of an event. Frequency is typically used when the point estimates (average quantities) based on available data can be made. Probability is used when mathematical probabilistic distributions can be fitted from available data. Similarly, the terms consequence and severity are used interchangeably, but here there is no implication regarding the accuracy of quantification.

The above mathematical formulation can be applied to either qualitative and quantitative risk analysis or a mixture of both. The level of quantification effort depends on the nature of the decisions to be made and the availability of the required input data.

4. DEFINITION OF A SYSTEM FOR RISK ANALYSIS

The first step in the risk based decision making process involves the definition of the system and success criteria. Therefore it is appropriate to define the term "system" and other related terms.

Formal definition of the word system is provided by Roland and Mortiarty [[19]]. System is a group of interacting, interrelated, or interdependent elements forming or regarded or as to be forming a collective unity. A more direct definition of a system is a composite of people, procedures, and equipment that are integrated to perform a specific operational task or a function within a specific environment. A subsystem represents a part of the system that may constitute a system in itself.

The above definition is judged to be appropriate for this study since it encompasses people and procedures which play a significant role in the risk management of the implementation of the European operational programs in Greece. The development of the mathematical model of the system is based on the philosophy of the ISO 9001:2000 Quality Management Systems [[16]] which is organized around the concept of a process. A process is an activity or set of activities, that use resources to transform inputs to outputs.

On *physical systems* the hierarchy is typically defined with a tree like structure *of subsystems, assemblies, subassemblies, components, elements, items* etc. Different words are used to describe system subdivisions with increasing level of detail and subdivision of the physical space. The number of these subdivisions in the hierarchy structure varies with the type of the system and its complexity.

On *process-based systems* the hierarchy is similar to the physical systems, except that level and sublevel numbers or other descriptive terms of the system subdivisions are employed. A summary of the physical and process system subdivision terms is presented in Table 1.

Table 1: Hierarchy of system subdivisions

System subdivision or sublevel number	Physical and procedural system	Physical systems	Procedural systems (European operational programs)	Number of subdivision in example case
0	Total system, Level 0	Total system	Total of European programs	1
1	System level 1	Subsystem	Fund	24
2	System level 2	Assemblies	Priority	7
3	System level 3	Subassemblies	Sub-priority	36
4	System level 4	Components	Category of action	108
5	System level 5	Elements	Action (project)	289
6	System level 6	Items	Sub-action (Sub-project)	696
……	………	Other descriptive system terms	Work management process	6721
n	System level *n*	Failure modes, risk parameters, etc	Failure modes, risk parameters, etc	> 100,000

A system requires input in the operational state to create output. This is illustrated in Figure 2. The components, elements or items of the system are connected in such a manner that they perform a specific function when input is provided from a source, such as another component or a human operator. Thus, an action on a component will create output. This series of interconnected events cause a sequential, logical action in the system as it is designed. For a system to create an undesirable output a *stimulus* (external or internal to the system) is required to transform a hazard or a condition *from a potential state* to a risk loss which is called a consequence associated with harm or loss.

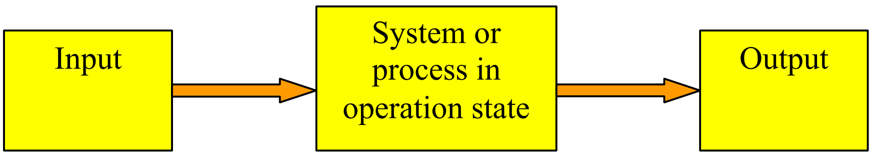

Figure 2: System state

Typically, to assess the impact of the decision on the system or the failure event, the level of the detail of the system or the procedure has to be refined to at least one more detail level from the hierarchy level where the decision strategy is applied.

5. RISK CALCULATION FOR A SYSTEM

The mathematical formulation for the calculation of the risk in a system starts from the mathematical definition of risk, i.e.

$$R \equiv F \cdot C \tag{3}$$

The above expression can be used for both qualitative and quantitative analysis.

For a *subsystem* the total risk and the risk of individual system components is represented as follows:

$$R_i \equiv \sum_j F_j \cdot C_j \tag{4}$$

where, i = subsystem index and j = failure event index.

The total risk of the system is given by:

$$R \equiv \sum_{i,j} F_{i,j} \cdot C_{i,j} \tag{5}$$

It is noted that frequencies and consequences are always a pair and are associated with a specific failure event. The calculation of frequencies (F) and consequences (C) is made using well known methods from statistics and probability theory.

For systems and failure events that are not independent in probability or consequence terms, such as for the systems with redundancies or in the situations combined failure events, which often have very severe or catastrophic consequences, techniques such as *fault tree, event tree* etc are used. These techniques are capable of providing values of probabilities and consequences of combined events. In such cases it is convenient to separate independent and combined failure events, and express risk as

$$R \equiv \sum_{i,j} F_{i,j} \cdot C_{i,j} + \sum_{k,l} F_{k,l} \cdot C_{k,l} \tag{6}$$

where,

i = individual subsystem identification index,
j = individual single event index,
k = combined subsystem identification index, and
l = combined failure event identification index

The subscripts i and k are identification indices associated with individual systems and combined systems, respectively. They are assigned by the model developers during the model development and failure mode assessment stages. In relation to the hierarchy process based system of the European operation program model depicted in Table 1, index i is associated with individual action (projects) or sub-actions (sub-projects). Each of these actions can have one or more separate failure modes. Single failure modes are associated with separate management processes. In contrast indices k and l are associated with combined system and combined failure events, respectively. A failure event can involve a multitude of management processes and a number of separate distinct systems. They are typically low frequency events but often have significant consequences. As a typical example, if a problem is discovered during the bid procedure of a construction project after the contract has been awarded, and construction has been initiated or even completed, this can affect additional projects apart from the one where the problem was discovered. If the failure is characterized as systemic (or systematic), a combined consequence could be the removal of all similar projects from the operational program because of penalties imposed by the Greek government and European Union procedures. The differentiation of single failure mode and combined failure modes is used in the present paper to track and assess such combined low frequency - high consequence extreme events separately.

It is noted that combined events are sometimes very important since they are associated with very low frequencies or probabilities of occurrence but can have very high or catastrophic consequences. Obviously, they can impact the calculated risk and the decisions to be made for risk mitigation or risk reduction. In this situation also, the concept of risk perception or the acceptance criteria for risk become very important. Examples are business interruption and upper limits on insurance policies. Similar examples involve large numbers of injuries, deaths or large financial losses due events of nature (earthquakes, hurricanes, tornadoes, tidal waves and other extreme events), nuclear or chemical plant accidents, oil spills with catastrophic impact on the population and the environment, penalties on operational programs by the Greek government and European Union, etc.

The determination of the frequency and consequence quantities employed in the above mathematical risk computations can cover the spectrum of qualitative, semi-quantitative to fully-quantitative techniques. In qualitative type analyses, expert opinion and relative rankings are typically employed due to lack of available data. Approaches such as relative ranking, the weight-factor approach, the Analytical Hierarchy Process and other format expert solicitation approaches are typically used [[10],[11],[20]]. In semi-quantitative analyses point estimates of frequencies and consequences are normally used based on available actual data. When the data are not sufficient, these are supplemented with expert solicitation data. In fully quantitative analysis probabilistic mathematical representations of frequencies and consequences are employed. Quantitative analyses require both sufficient and good quality data. Often complete mathematical closed form solutions are difficult to develop for large and complex systems. In this case techniques such as Monte Carlo simulations are used in fully quantitative approaches.

The rigorousness of the mathematical computations increases progressively from qualitative to semi-quantitative or fully-quantitative techniques. However, this does not necessarily imply improvements in the accuracy of the risk analysis results, since the quality of the results depends on the quality of the input data. Often, due to lack of appropriate and good quality input data, input data developed by expert solicitation methods produce more accurate risk output results than those obtained from more rigorous quantitative risk analyses employing less accurate input data.

6. COST OF A DECISION AND RISK CHANGE IN A SYSTEM

For decision making, it is useful to visualize the system in an existent state of operation. The system can be an existing system or a new system to be created in the future but the analysis is being made from a postulated state or condition. This applies to both physical systems and procedural systems (e.g. management systems).

For the case with an existent or postulated state of the system the change of the risk due to a mathematical decision action, it is expressed as

$$\Delta R_m \equiv \Delta F_m \cdot C + F \cdot \Delta C_m + \Delta F_m \cdot \Delta C_m \tag{7}$$

where,

Δ = differential symbol representing change
m = decision identification number

Decisions related to risk reduction and risk mitigation could involve significant changes to either frequency or consequence or both.

The new total risk after the decision is implemented is

$$R_m \equiv R + \Delta R_m = (F + \Delta F_m) \cdot (C + \Delta C_m) \tag{8}$$

Decision options require investment (cost) for the implementation of the decision. Thus optimized decisions that incorporate cost or investment quantities can be made using rankings based on the following risk to investment ratios:

$$\frac{R_m}{I_m}, \qquad \frac{\Delta R_m}{I_m} \tag{9}$$

where I_m = investment or cost of implementing the decision *m*.

The risk measures and risk to cost ratio information can be communicated to decision makers using standard tabular and graphical representation methods.

7. GENERALIZED RISK-BASED DECISION MAKING METHODOLOGY

Risk based decision making involves the computation of risk, risk ranking of systems, subsystems, failure events, and the impact of possible desirable decisions on the risk (risk reduction or risk mitigation). Also, a very important facet is the appropriate method of communication and explanation of the computed risk information to decision makers, policy makers, regulators and the public. Decisions to be made are always associated with costs in addition to other criteria associated with business objectives, safety concerns, environmental issues, regulatory policies, public concerns etc. Thus, optimization techniques can involve multi-dimensional criteria.

A generalized risk-based decision making methodology has been developed in this study utilizing the above risk concepts. This is illustrated in detail in Figure 3 .

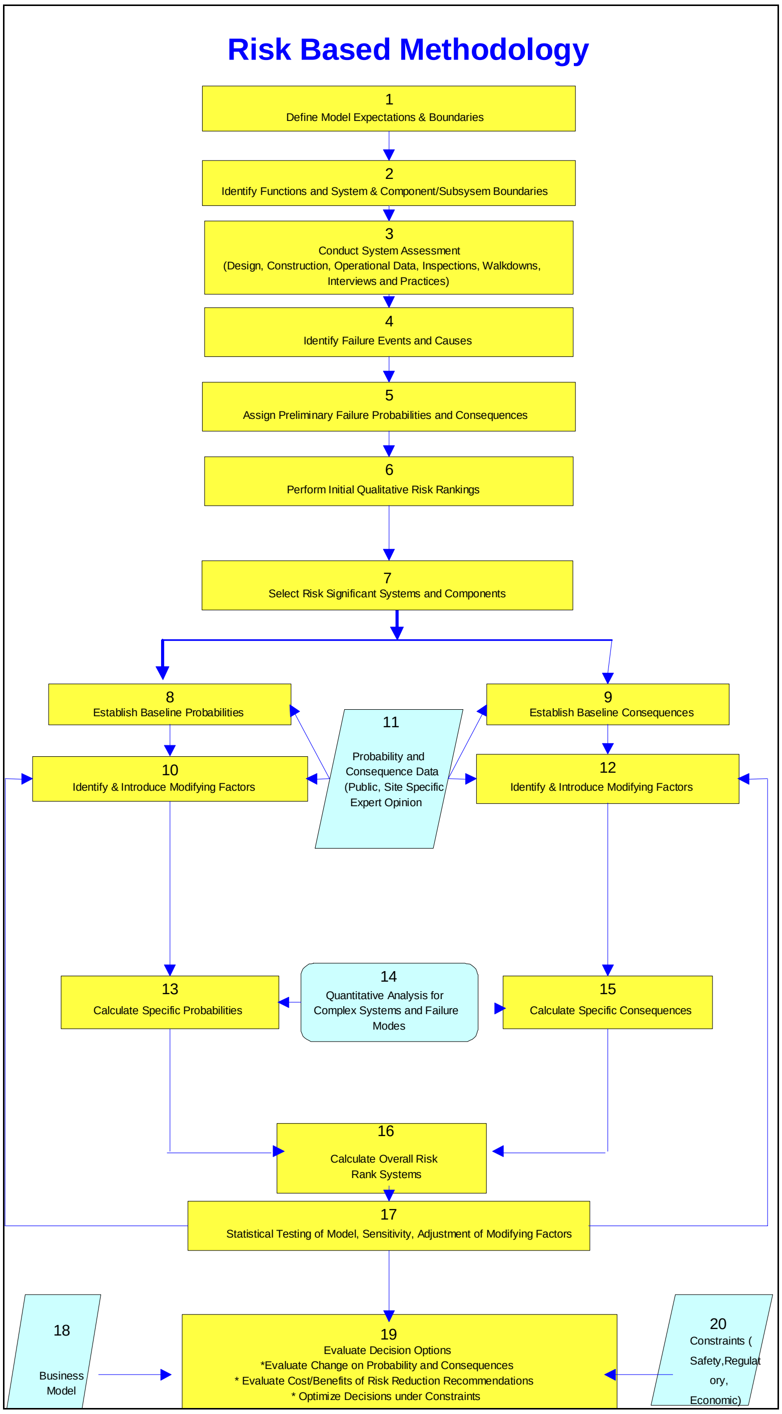

Figure 3: Risk-based decision making methodology

The risk-based methodology involves the following major steps where the corresponding steps in the flow chart are also indicated for convenience:

i. Definition of the system, boundaries, and success criteria (block 1)
ii. Identify functional characteristics of systems and sub-systems (block 2)
iii. Condition assessment of existing system (existing system or new system in hypothetical state) (block 3)
iv. Identification of hazards, conditions, failure events and failure causes (block 4)
v. Initial qualitative assessment of event failure frequencies and consequences (block 5)
vi. Qualitative risk calculation, risk ranking and prioritizing of systems and failure events (block 6)
vii. Selection of significant systems and failure events based on risk significance including assessment in uncertainties in the risk calculation (block 7)
viii. Quantitative risk analysis and risk ranking of selected systems and failure events (blocks 8-17)
ix. Development of decision strategies and individual decision plans (Part of block 19))
x. Assessment of decision strategies on the changes to risk and associated frequency and consequence (blocks 18 and 19)
xi. Selection of decision strategies based on impact on risk changes using any constraints or business criteria. (blocks 19 and 20)

In summary, basic elements of the decision making process involve the development of the model that represents the system, the identification of the failure events, the determination of frequency and consequence for each failure event, the risk computations, risk ranking, the development of decision strategies that might be implemented, the ranking and prioritization of the decision strategies based on their impact on the risk changes. The above basic elements apply to all types of analytical approaches, e.g. qualitative, semi-quantitative and fully-quantitative.

8. RISK MANAGEMENT IN EUROPEAN UNION REGIONAL PROGRAMS

The risk based decision making methodology has been applied to the management of European regional operational programs in the Region of West Macedonia, Greece. The mathematical model and associated application which was developed in this study is general in nature and can be applied to all other European operational programs in Greece and in other countries.

8.1. Hierarchy of system definition

The hierarchy of the system definition follows the general structure of the operational programs in Greece and is organized around the hierarchical process level concept. The breakdowns and the level descriptions are specified by the user and depend on the structure of the specific operational program. The hierarchical structure of the operational program in West Macedonia Greece is presented in Table 1.

The Operational Program in Greece for the 2000-2006 period is organized around eleven (11) Greek sector operational programs (managed by national government ministries) and thirteen (13) regional operational programs (managed by the national government regional administrations).

The basic funding of each operational program is summarized in Table 2 and illustrated in Figure 4. It is observed that major budget allocations of the sectoral operational programs are associated with transportation infrastructure projects (roads, ports, railroads and airports), followed by business competitiveness, information technology, education and employment. It is also pointed out that these areas have even larger budgets since the regional operational programs also contain budget allocations in these areas.

Table 2: Budget allocations in operational programs in Greece

Greek 2000-2006 Budget Allocation		
Operational Program	Budget (€)	Percent
Roads & Ports	9.317.357.641,00	22,20%
Bussiness competition	6.392.333.213,00	15,23%
Agriculture	3.010.155.273,00	7,17%
Railroads & Airports	2.937.600.380,00	7,00%
Information Society	2.839.078.394,00	6,76%
Education	2.484.599.225,00	5,92%
Employment	1.998.895.185,00	4,76%
RG Attiki	1.542.869.230,00	3,68%
RG Central Macedonia	1.458.922.675,00	3,48%
RG W. Macedonia & Thrace	1.115.648.907,00	2,66%
RG Thessalia	928.839.893,00	2,21%
RG Central Greece	873.110.228,00	2,08%
RG Western Greece	781.436.566,00	1,86%
RG Crete	730.310.263,00	1,74%
RG Pelopponisos	698.690.896,00	1,66%
RG Ipirus	680.013.237,00	1,62%
RG South Aegean	609.510.460,00	1,45%
Culture	604.900.000,00	1,44%
RG West Macedonia	580.514.032,00	1,38%
RG North Aegean	547.904.763,00	1,31%
Health	513.306.663,00	1,22%
Fisheries	499.292.920,00	1,19%
Environment	449.200.000,00	1,07%
RG Ionian Islands	375.146.562,00	0,89%
TOTAL	41.969.636.606,00	100,00%

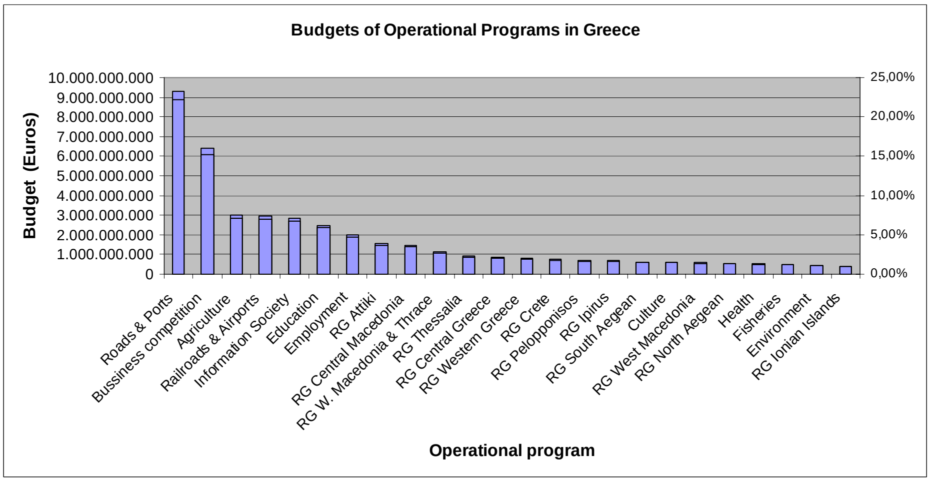

Figure 4: Funding of operational programs in Greece

The budget breakdown of the Greek West Macedonian program is summarized in Table 3 and illustrated in Figure 5. The major budget priorities are associated with transportation, agriculture and rural development. These are the areas where the region of West Macedonia in Greece needs the most improvement due to its infrastructure, economic and geographic characteristics.

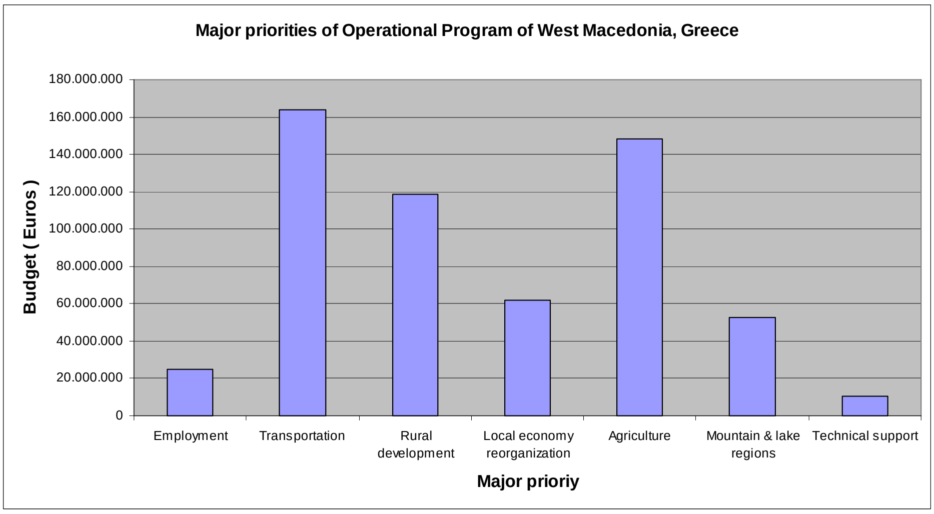

Figure 5: Budget of Operational Program of the Region of West Macedonia, Greece

Table 3: Budgets of major priorities in operational program in West Macedonia, Greece

Budget Allocation in Operational Program of West Macedonia, Greece			
Major Priority number	Major Priority Description	Budget (€)	Percent (%)
1	Employment	24.705.396	4,26%
2	Transportation	163.903.155	28,23%
3	Rural development	118.822.405	20,47%
4	Local economy reorganization	61.922.230	10,67%
5	Agriculture	148.064.736	25,51%
6	Mountain & lake regions	52.824.650	9,10%
7	Technical support	10.271.460	1,77%
	Total	580.514.032	100,00%

The system hierarchical breakdown of the West Macedonian operational program follows the subdivisions presented in Table 1. It is subdivided into priorities (major), sub-priorities, actions (projects), sub-projects, processes, failure modes and other risk parameters. The major priorities with their associated budget allocation are presented in Table 3. The processes have been defined following the principles of the ISO 9001:2000 quality management philosophy. The failure modes are associated with individual processes in the project and sub-project level. Risk parameters are utilized to characterize and relatively rank failure event frequencies and consequences.

8.2. Risk calculation

Risk calculations of the management processes of various levels of the system have been performed utilizing equations 1 to 9. The model development and structure has been described in Section 8.1 Failure events were identified for each management procedure and process. The events were ranked relative to each other using expert solicitation techniques such as those by Saaty [[20]] and Ayyub [[10]]. Relative weight factors were developed separately for frequency and consequence event quantities. Risk computations were performed using these relative weight-factors. The risk results were ranked and grouped in accordance with the hierarchical model structure presented in Table 1 (e.g. such major priorities, sub-priorities, actions, sub-actions, etc).

The risk contribution of the major priorities and sub-priorities in the operational programs is presented in Figure 6 and Figure 7. It is seen that certain priorities and sub-priorities have higher risk contribution than others. This risk contribution is not solely related to the priority budget but depends on the status of the implementation of the programs and all the risk parameters. For example, from Figure 6 and accompanying Table 3, it is observed that agriculture projects are the most risk significant, followed by rural development projects. Transportation projects, which have the largest budget allocation in the operation program and have progressed more in the implementation stage, are relatively low risk projects. The reason is that significant management experience and technological developments have been gained in Greece during previous operational programs. Operational programs such as the 2nd Programmatic Period 1994-1999 had an emphasis on infrastructure projects such as transportation.

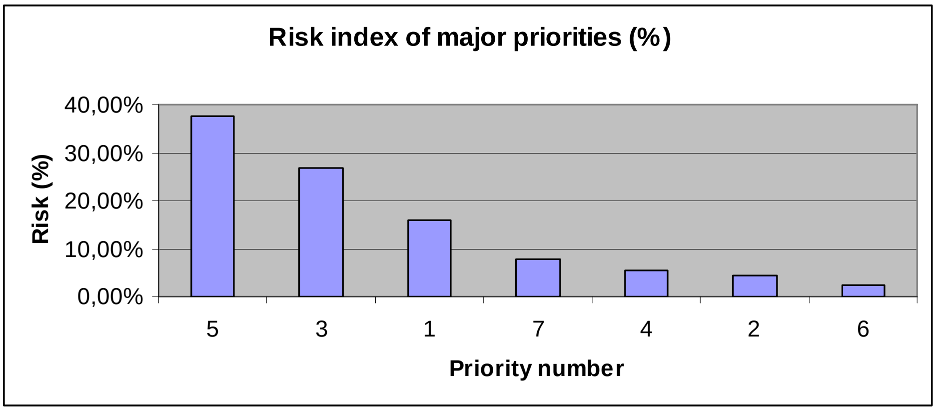

Figure 6: Risk of major priorities of operational program

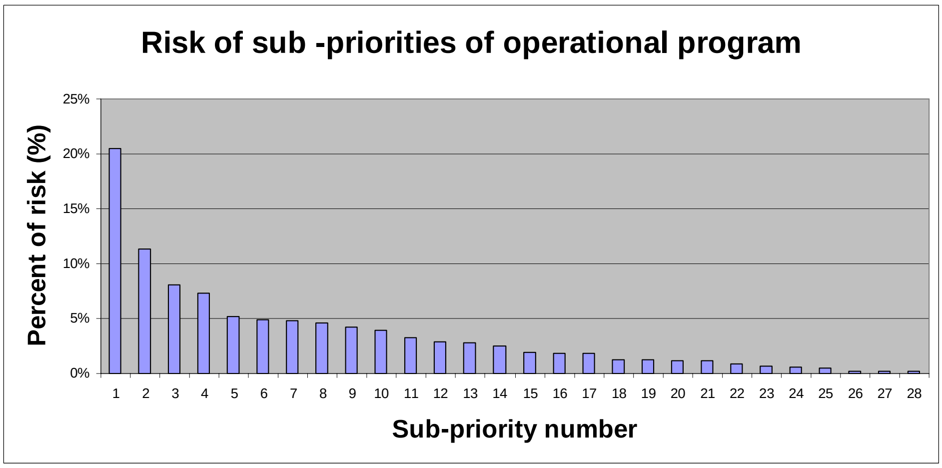

Figure 7: Risk of sub- priorities of operational program

A similar plot of the cumulative risk of the individual projects or action in the operational program is presented in

Figure **8**. It is observed that approximately 30% of the projects are associated with 70% of the total system risk. This information can be used to select the most risk significant projects for applying management decision options to reduce the operational program risk. It is also observed that the nature of the behavior is similar to the common 80-20 approximate rule found in many applications (Pareto effect).

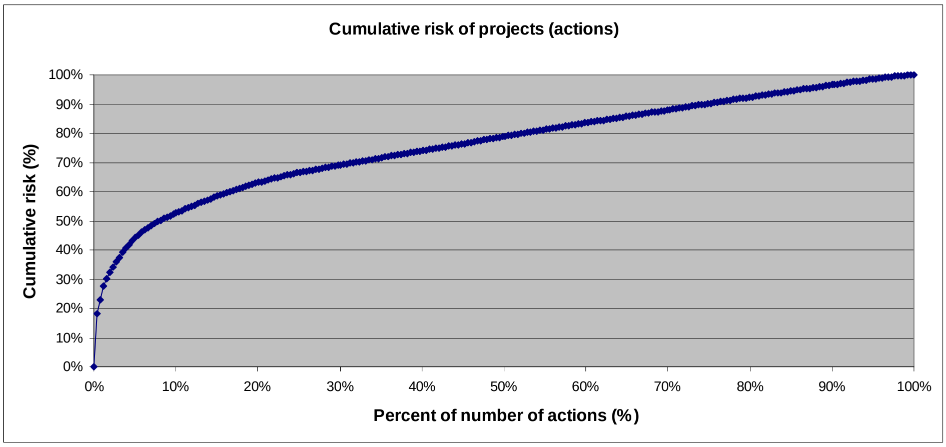

Figure 8: Cumulative risk of projects (actions)

The benefit of the risk analysis results in the management decision making process is that resources can be prioritized and directed toward the most risk significant projects. For example, because of budget constraints management actions can not be applied to all projects equally. By selecting 30% of the most risk-significant projects the management can address 70% of the risk. This also has an additional benefit of improving the effectiveness and quality of the management actions while simultaneously reducing the implementation costs.

8.3. Audit (inspection) program development

Based on the previous risk calculation and relative risk ranking an annual field audit (inspection) program of projects in implementation stage was developed. In the risk computation only management processes that are associated with field implementation have been used in the risk computations.

The cumulative risk of the annual audit plan on the sub-project level is illustrated in Figure 9. The significance of this method is that manpower and resources are optimally applied to selected risk significant management process instead of the thousands of processes in the systems, which is often unattainable based on time, available budgets or other resource constraints. The audit program is typically developed for planning purposes on a yearly basis because European and Greek program procedures dictate minimum yearly frequency and budget audit targets. However, the risk evaluation and audit program is a continuous process since the program implementation and the relative project risk contribution change continuously. Thus, the projects and sub-projects selected at the yearly planning level can change during the year within the constraints discussed above.

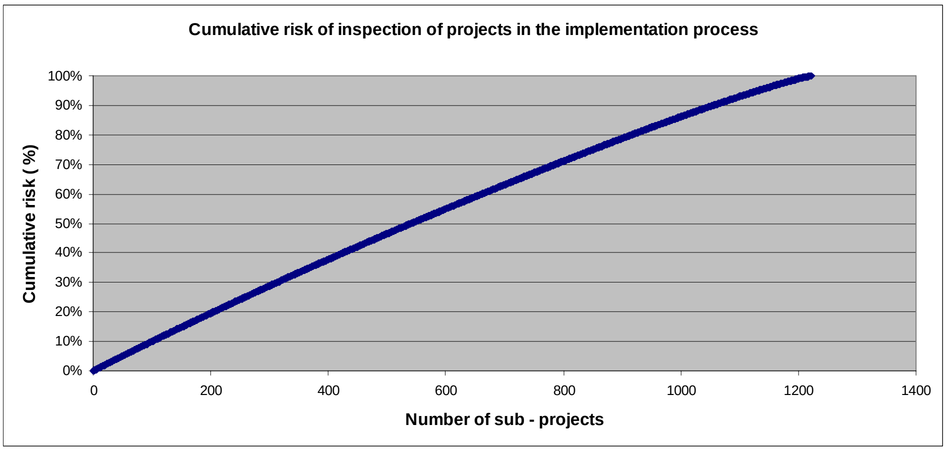

Figure 9: Cumulative risk of subprojects selected for inspection (audit) plan

The impact of the risk results on the decision making processes on the sub-project level is similar to those observed on the project-level. Resources can be directed towards the most risk-significant sub-projects and associated audit (inspection) processes. Improvements in quality and effectiveness of the audit program are achieved while implementation costs of the program are reduced.

9. CONCLUDING REMARKS

A generalized method for management decision making incorporating risk assessment techniques is presented. The risk based decision making methodology is applied to European Union expenditure programs used to implement its regional policy, such as the community support framework, community initiatives, special initiatives and other European programs. An example is presented for the development of an audit (inspection) program in the region of West Macedonia, Greece, during the implementation of the 3rd Community Structural Support Framework Operational Program. The generic nature of the method permits its use in the management of similar European regional programs in Greece and other European countries. Its is also applicable to many other industries interested in applying risk–based management decisions to physical or process based systems.

The limitations of the results presented in this paper are associated with the definition and detail of processes in the hierarchical model developed to represent an operational program, the postulation of the failure events, the dynamic nature and the implementation status of the operational program, the accuracy and sensitivity of the qualitative data obtained from the expert solicitation process and the selection and definition of the risk parameters used to calculate the frequency and consequences of the system failure models.

Future improvements can be made to utilize quantitative instead of qualitative frequency and consequence data, to develop risk index relationships to unify qualitative, semi-quantitative and fully quantitative risk analysis methods, and to include benefit quantities in the decision making process in addition to the risk and cost factors considered in this study.

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