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THE LICENSING PROCESSES INFLUENCE ON NUCLEAR MARKET

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ABSTRACT

The paper deals with the licensing nuclear power plants; it focuses primarily on the licensing process implications into the international nuclear market. Nowadays there are twenty-six countries that are planning to build new nuclear facilities, and thirty-seven where nuclear reactors are proposed; on the other hand, there are mainly ten international reactor vendors. At international level, there are few vendors that have sufficient resources, capabilities and experience to carry out the design and delivering of a nuclear power plant in the international market; On the other hand, the licensing processes are strictly dependent on national law frameworks, and on the nuclear policies. The paper proposes a comparison of six licensing processes (the ones established in Finland, France, Italy, South Korea, USA and UK), and analyzes its main features and implications; the IAEA licensing process is taken as reference point. The objective of the paper is to propose a systemic approach for considering the licensing procedures. The framework proposed enables facilitating the licensing management and inferring the main features of licensing contexts. The paper concludes with a forecast of the nuclear licensing context, especially with respect to the fourth generation of nuclear reactors.

1. INTRODUCTION

1.1. Preliminary definitions

To avoid confusions, this paper adopts theses definitions.

-Operator: is the energy utility who operate the nuclear power plant NPP. Usually other synonymous are: utility, reactor importer, applicant (in the licensing process).

-Rector vendor: is the firm who develops and sell the reactor design, synonymous are: vendor, nuclear vendor, reactor exporter;

-Owners' groups: is the cooperation network between the operator, the reactor vendor and the contractors.

-Country, possible synonymous are, state (with the exception of the federal states) and nation.

-Importing country: is the country where the operator intends to develop the NPP importing the reactor design from abroad.

-Exporting country**:** is the country where the foreign reactor vendor comes from.

1.2. The actual scenario

There are three main categories of nuclear importing countries: the emergent, the occidental (which have their indigenous nuclear industry but have experience only in operating activities and not in constructing or updating new reactors) and the oil exporter that prefer to sell their oil products rather that use it for electricity generation purposes. Moreover some countries, that now are importing nuclear technology, are already planning to became nuclear reactor vendor in the future e.g. China (World nuclear news, 2010). There are twenty-six countries that are planning to construct new nuclear power plants and thirty-seven where such facilities are proposed (World nuclear association, 2011); furthermore most these plants can be considered "large reactors" because have nominal power higher the 700 MW (IAEA, 2004).

On the other hand the nuclear vendors that could embark an international selling campaign of large NPP are really few: ten firms or conglomerates usually structured as joint ventures. The authors think that the critical success factors for the reactor vendors are: 1-Strong governmental support; 2-Huge operating experience (in nuclear electricity generating), and high capabilities in research and development of NPP; 3-Vast project management experience. The lack of one of these key aspects could dramatically increases the probability of failure during the contract awarding route, or generates problems during the construction phase. Furthermore the nuclear business is characterized by a strong governmental involvement due to the need of an opportune infrastructure (IAEA, 2007a) for both the acquisition or selling of nuclear facilities. This paper will focus on the licensing process, as a part of the intangible infrastructure (IAEA, 2006a), and its relationship with the bidding phase of the nuclear project. Indeed most of the principles governing the licensing processes are internationally recognized (IAEA, 2002c), the application of these is deeply influenced by the national legal traditions and by nuclear program strategies underpinned at country level. This differentiation is one of the most influencing factors that affect both the environment complexity and the risk from the reactor vendors and investors point of view. The lack of an international harmonization of "rules" is one of the greatest obstacles to the development of the nuclear industry worldwide (CORDEL group, 2007). The risk derived from the licensing delays or no acceptance (that most of time implies the modification of the NPP) is especially emphasized for the financial nature of the NPPs that are capital intensive (AREVA, 2006).

1.3. Research questions

(R1: How the nuclear program and the licensing process are linked?); (R2: How the reactor vendor could take into account different licensing frameworks?); (R3: How the governments could take into account the reactor vendor's perspective in designing the licensing framework?); (R4: Which are the main differences between the licensing practices worldwide?).

1.4. Paper roadmap

Fig. 1 shows the structure of the paper and the connection between the different paragraphs, figures and tables.

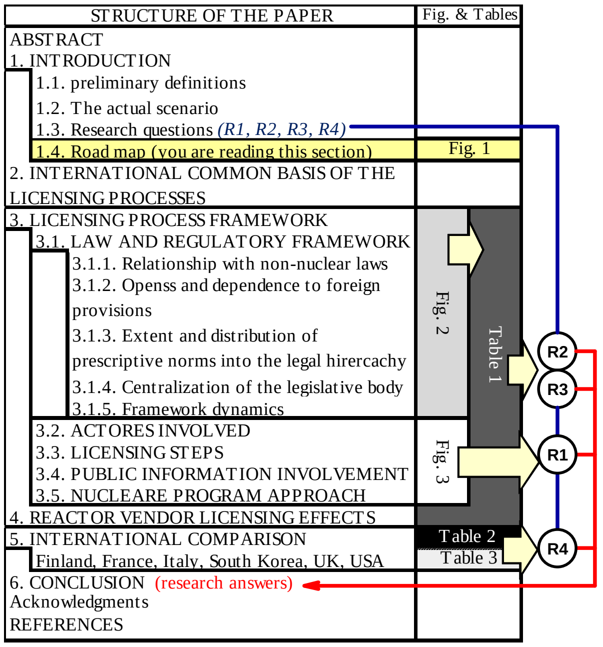


Fig. 1: Roadmap

2. INTERNATIONAL COMMON BASIS OF THE LICENSING PROCESSES

In the 40-80's the safety framework was mostly developed at country level, as a result few nuclear practices were in common between countries. After Chernobyl accident a fundamental change of thinking was made, by governments and citizens, because the detrimental trans-boundary nature of the nuclear incidents was recognized (IAEA, 2002c); so an international safety framework was considered. Only after some years, the first Convention on Nuclear Safety CNS I (IAEA, 1994) was developed and implemented and now it's adopted by almost all nuclear countries (IAEA, 2010a); the implementation of the CNS I was a fundamental milestone because for the first time the licensing functions where internationally recognized (article 7.2) and a general safety framework was settled down; the technical provisions of the CNS I are: legislation and regulation (Art: 7-9), general safety consideration (Art: 10-16) and safety of the installation (Art: 17-19). The most influencing elements, with respect the licensing process are: the need of an effective and independent regulatory body RB (Art 8), provided with sufficient financial resources, for carrying out the: regulatory, licensing, inspection and enforcing actions (Art 7) and the prime safety responsibility of the operator (Art 9). Nowadays the licensing processes shall ensure the respect of some international prescriptions developed in conventions and treaties, the most important are (further then the CNS I): (IAEA, 1987) (IAEA, 1992) (IAEA, 1997) (IAEA, 2002). These international instruments refer to the following matters: safety principles (IAEA, 2006b) , non-proliferation of nuclear materials, nuclear liability in the case of incident, emergency preparedness measures and transport of radioactive materials.

3. LICENSING PROCESS FRAMEWORK

The IAEA licensing framework (IAEA, 2010c) is taken as reference point because: it incorporates all international provisions and represents "the synthesis" of the licensing approach adopted worldwide. Two main perspectives are incorporated into the framework: 1-The licensing process as the necessary procedure that permits to obtain the authorization to construct and operate the NPP; 2-The licensing process as part of the intangible infrastructure settled-down in the early phases of the nuclear program, (the Fig.3 will shows the relationship between the licensing process and the nuclear program). Both perspectives are important in the eyes of the owner's group. The key elements of the licensing framework are divided into two sets: the licensing parameters (endogenous to the legislator and government action) and the licensing effects (adopting the reactor vendor's perspective). The first set includes the following elements: law framework, actors involved, licensing steps, public information & involvement, nuclear program approach. The second set includes the following elements: country's barrier, public acceptance, clearness and simplicity, degrees of freedom left to the reactor vendor, licensing lead time and risk. These two sets of licensing elements are the basic drivers that permit to understand the main differences between countries and will be crossed in the

Table.1[i] after a detailed presentation in the following paragraphs.

[i] Table 1 presents the linkages between the “licensing parameters” and the “licensing effects” on reactor vendor. These linkages are: directs (presented in the bale) and indirect (showed at the bottom by a triangular Rel-chart). This later typology of linkages shall be understood one-trough; hence the table shall be read from the left columns to the right ones.

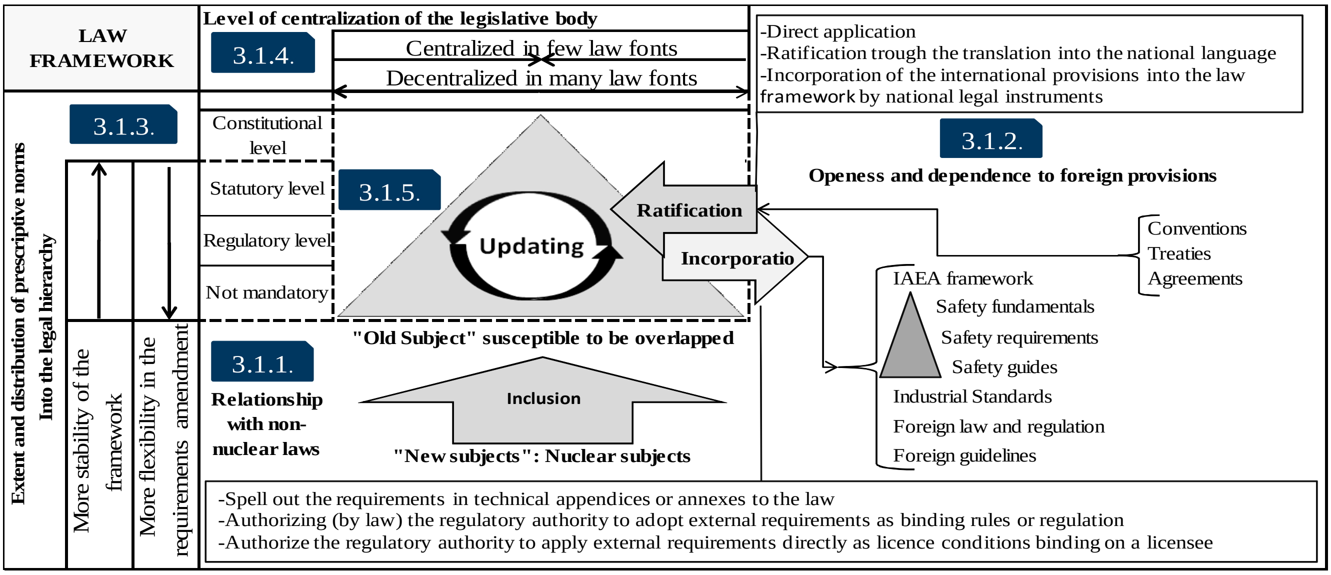


Fig. 2: Law framework

3.1. LAW FRAMEWORK

The law framework is a really influencing factor affecting the licensing approach. Even if the legal traditions could change significantly between countries, is possible to cluster the main features into: relationship with non-nuclear laws, openness and dependence to foreign provisions, extent and distribution of prescriptive norms into the legal hierarchy, centralization of the legislative body, framework dynamics; all these are presented in the next paragraphs and in the Fig.2.

3.1.1. Relationship with non-nuclear laws

Usually the nuclear legislative body has many degree of connection with the non-nuclear one, because when the nuclear body is settled down[ii] many sensible subjects has been already regulated. This shared subjects usually are: “*local land use controls, environmental matters, the economic regulation of electric power utilities, the occupational health and safety of workers, general administrative procedures of governmental bodies, transport, the export and import of nuclear material; intellectual property rights, liability for non-nuclear damage, emergency management, taxation*” (Stoiber, et al., 2003). The lack of a clear connection between the shared bodies drastically reduces the clearness and simplicity of the law framework.

3.1.2. Openness and dependence to foreign provisions

A first kind of international dependences are the conventions and treaties (paragraph 2); the implementation of these, into the legal framework, usually require special measures (showed in the Fig.2) that may change depending of the legal traditions adopted in the country considered. A second kind of international/foreign linkages is the implementation of detailed provisions with the form of: standards, regulations or guidelines. The direct linkage between the country’s framework and the international standards/guidelines enable to maintain an updated framework (with respect the technological advances, safety procedures, etc.) without an unrequited efforts in amending law and regulations. Furthermore the country who chose to embark the nuclear program usually prefers to develop first a basic legal infrastructure and then revise it periodically (IAEA, 2007b); as result the first basic legal and regulatory infrastructure could have a reduced scope and some part can be “recycled” from foreign countries (IAEA, 2006c). Usually the importing country shares some technical provisions with the exporting one to facilitate the work to the reactor vendor[iii] (e.g. South Korea implements some USA’s regulations).

[ii] in the early phases of the nuclear program, see the Fig.2

[iii] that usually operates on turnkey basis in the firsts NPPs

3.1.3. Extent and distribution of prescriptive norms into the legal hierarchy

A typical trade off that legislators must solve is the level of detail of the framework: it must be detailed enough to maintain the required level of safety and flexible enough to take into account different circumstances and technological advances (IAEA, 2002b). There are two basic approaches: "performance based" and "prescriptive based" (IAEA, 2002b) . The first one enables a greater flexibility due to the lower level of detail of the norms[iv]. When this approach is adopted usually the RB has more discretional powers in assessing the conformance of the installation's safety with the existing law framework; to improve the clearness/predictability of the licensing process, detailed examples and safety approaches are furnished trough not mandatory guidelines. Another typical legal instrument used in this context is the license conditions: prescriptive rules crafted to the specific site and design and are emitted during the licensing process. In the second approach ("prescriptive based"), the level of detail is higher so the legal framework is less flexible but more predictable. In this case the detailed provisions can be settled down at different levels; when the detailed norms are included into the statutory level the resulted law framework is really static and require long and complex procedures to amend its. Usually the detailed norms are included into the regulatory and not-mandatory level because easily amendable and under the RB control.

3.1.4. Level of centralization of the legislative body

This element is directly linked to the first one (section 3.1.1). In the last years, many advanced states have undertaken reforms to merge fragmented subjects to centralized and comprehensive bodies: a centralized nuclear law framework shall be contained into approximately ten laws (Bredimas, et al., 2008).

3.1.5. Framework dynamics

This section is directly section 3.1.3. In general terms, the principles established at the top of the "legal pyramid" are rarely revised, on the other hand it's lower levels require frequent amendments to enable the required to update the framework with respect to different circumstances and technological advantages. The instruments used by the legislator (and RB) mostly depend of the country's legal and administrative traditions. In this paper the framework's dynamic is treated in a simplified manner because from reactor vendor perspective it is not so influencing[v]. The only element taken into account is the frequency by which the norms are updated.

3.2. ACTORS INVOLVED

The main actors involved into the licensing process are: Government, RB, operator, reactor vendor and a series of contractors[vi]. Even If the actors are similar between countries, their functions widely change between them. In this simplified licensing framework (IAEA, 2010c), the main actors are only two: the RB and the owner's group (see Fig.3). Indeed an independent RB (empowered to assess and grant a license) is presented as a best practice for safety (IAEA, 2003) few state delegated all the decision-making responsibilities to a single organization. In most countries the final decision, on grant or not a license, is underpinned by the government or a minister in concurrence with the technical decision made by the RB. Bredimas and Nuttall (Bredimas, et al., 2009) argue how the system of double checks enable a better public confidence because the democratic institutions have the politic responsibility; on the contrary the RB is usually perceived as an obscure and close organization by the public (Bredimas, et al., 2008).

3.3. LICENSING STEPS

[iv] The norms fix only general objectives and principles

[v] In the actual scenario most of the importing countries are starting now to develop its first nuclear program so, for these countries, no amendments are available yet.

[vi] and the public, that is presented in the sections 3.4

The basic steps of the IAEA's framework are the ones that necessitate an approval by the RB: siting, design, construction, a set of commissioning tests and operating (see Fig.3). Even if all these steps require a formal approval (in every country) usually the number of licenses is two (e.g. one for constructing and one for operating).

The choice of the licensing steps is critical in the eyes of the risk incurred by the Operator-Suppliers. A licensing best practice consists to anticipate all the critical decisions points as early as possible (Golay, et al., 1997) because the cost of modifications dramatically increases during the life cycle of the project (Project Management Institute, 2008).

3.4. PUBBLIC INFORMATION & INVOLVEMENT

One of the most critical elements of both nuclear program and licensing process is the public involvement and the information transparency. The IAEA's framework prescribes that at minimum two points of connections must be established between the institutions and the public: In the first leap of the nuclear program (IAEA, 2010b) and in the early steps of the licensing process, (any NPP), as showed in the Fig.3. The basic instruments used by the public hearings and inquiries are conferences and forums on-line (with instrument of notice and comment). In every nuclear program the public acceptance is seen a prerequisite because the financial risk, incurred by the owner's group during the construction of the NPP, is really sensible to the delays (due to the high capital cost of nuclear projects). Then the public opposition could influence the politic and administrative decisions, and the legal-regulatory activities; in the extreme cases the public could interfere with the works at the nuclear site.

3.5. NUCLEAR PROGRAM APPROACH

This paper distinguishes between three basic nuclear program approaches that differ due to the politic involvement: free market approach (low involvement of the government), government leadership and an intermediate leadership position. In the first approach the government is involved only for developing some elements of the nuclear infrastructure (as showed in the figure 2). In the second approach the government develop most of the nuclear infrastructure, control (directly or indirectly) the operator and it's partly involved in the licensing process decisions. The third category represents an intermediate position between the two previous approaches. A critical nuclear program's element is the reactor choice. A typical feature of the nuclear business is the strong involvement of the government. Usually, in other sectors the technology choice is mostly decided the bidding phase of the project (Titolo, 2005). In the nuclear field the NPP development requires a strong partnership and support between the reactor vendor/operator and the exporting country/importing one; as result the contract awarding route is longer due to the need of an opportune infrastructure: the technological agreements and the cooperation agreements (usually in the forms of bilateral agreements between countries and memorandum of understandings between firms). These instruments usually cover the following subjects: technology transfer, fuel supply, waste, training, research, forms of mutual support like: financial loan, guarantee, and export/import credit.

4. REACTOR VENDOR LICENSING EFFECTS

The elements considered are: country's barriers, public acceptance, clearness and simplicity, degree of freedom left to the reactor vendor, licensing lead time and risk.

The **country's barriers** is a measure of permeability of the nuclear market (of reactor design) considered. This element is usually connected with the maturity of the nuclear program: in the early phases few capabilities are available within the country then importing the nuclear technology is the only choice available; on the other hand when the nuclear program is mature the country's reactor market could become close and autarkic.

Hence nuclear program strategy and approach is the most influencing factor. **Public acceptance** is treated as prerequisite in the nuclear sector because it directly affects the licensing risk incurred by the owner's group.

The **clearness and simplicity** of the licensing framework is one of the most important element it is directly controllable by the legislator/regulator, and it is a really influencing risk factor and includes the epistemic risk.

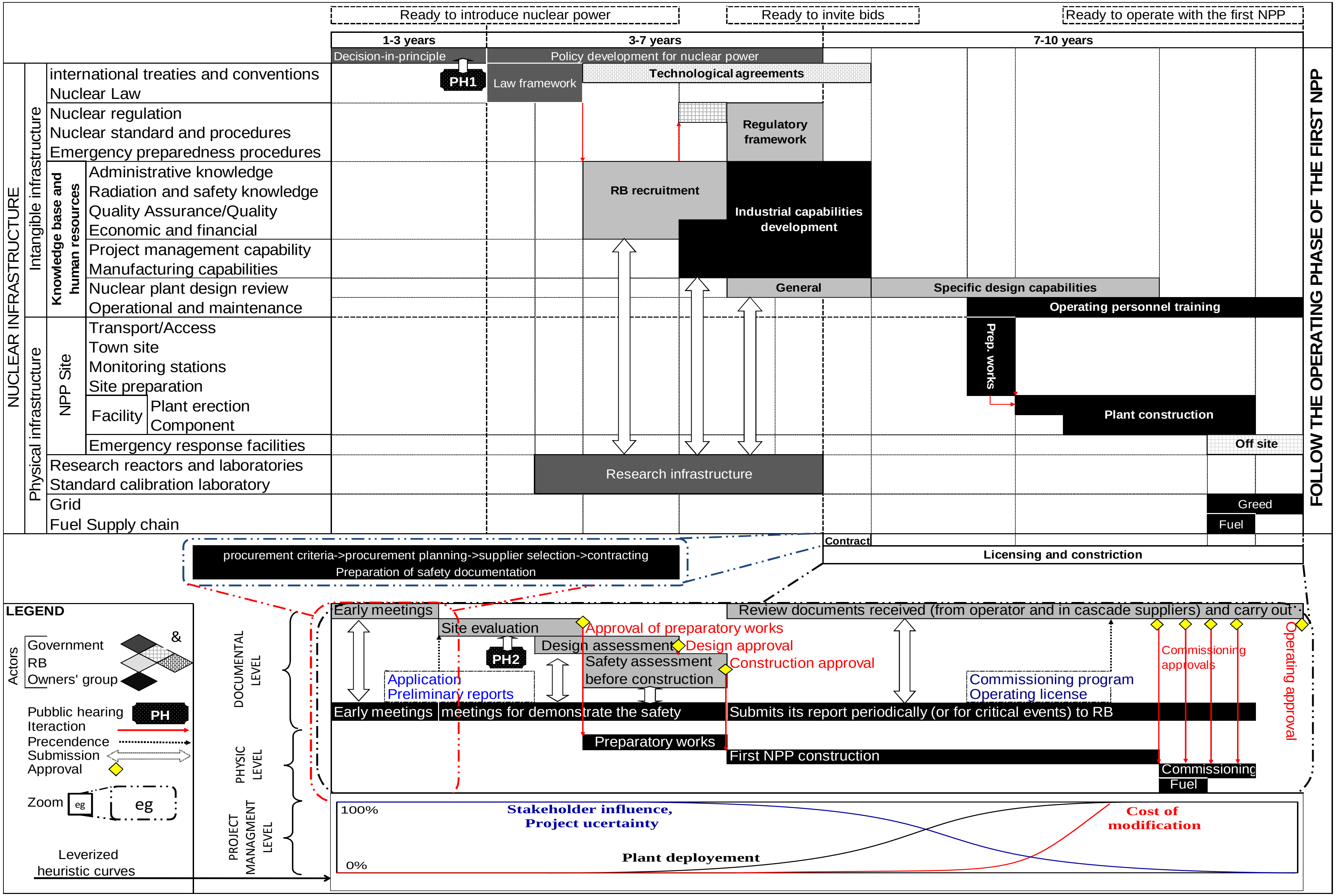
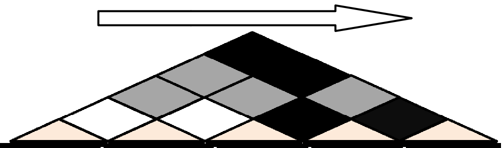

Ready to introduce nuclear power
Ready to invite bids
Ready to operate with the first NPP
1-3 years
3-7 years
7-10 years
Decision-in-principle
Policy development for nuclear power
PH1
Law framework
Technological agreements
Regulatory framework
RB recruitment
Industrial capabilities development
General
Specific design capabilities
Operating personnel training
Prep. works
Plant construction
Off site
Research infrastructure
Greed
Fuel
FOLLOW THE OPERATING PHASE OF THE FIRST NPP
NUCLEAR INFRASTRUCTURE
Intangible infrastructure
Physical infrastructure
Knowledge base and human resources
NPP Site
Facility
international treaties and conventions
Nuclear Law
Nuclear regulation
Nuclear standard and procedures
Emergency preparedness procedures
Administrative knowledge
Radiation and safety knowledge
Quality Assurance/Quality
Economic and financial
Project management capability
Manufacturing capabilities
Nuclear plant design review
Operational and maintenance
Transport/Access
Town site
Monitoring stations
Site preparation
Plant erection
Component
Emergency response facilities
Research reactors and laboratories
Standard calibration laboratory
Grid
Fuel Supply chain
Contract
Licensing and constriction
procurement criteria->procurement planning->supplier selection->contracting
Preparation of safety documentation
LEGEND
Actors
Government
RB
Owners' group
&
Pubblic hearing
PH
Iteraction
Precendence
Submission
Approval
Zoom
eg
eg
Leverized heuristic curves
DOCUMENTAL LEVEL
PHYSIC LEVEL
PROJECT MANAGMENT LEVEL
Early meetings
Site evaluation
PH2
Design assessment
Safety assessment before construction
Approval of preparatory works
Design approval
Construction approval
Review documents received (from operator and in cascade suppliers) and carry out
Application
Preliminary reports
Commissioning program
Operating license
Commissioning approvals
Operating approval
Early meetings
meetings for demonstrate the safety
Submits its report periodically (or for critical events) to RB
Preparatory works
First NPP construction
Commissioning
Fuel
100%
0%
Stakeholder influence, Project uncertainty
Plant deployement
Cost of modification

Fig. 3: The nuclear program, the nuclear infrastructure and the licensing process

LEGEND		
Very positive influence	+++	Correlation between the licensing effects
Quite positive influence	++	
Positive influence	+	
Depends: (e.g.)	+/-	Positive correlation
Negative influence	-	Negative correlation
Quite negative influence	- -	No correlation
Very negative influence	- - -	



LICENSING PARAMETERS (§3)				REACTOR VENDOR LICESNING EFFECTS (§4)					
				Min	Max	Max	Max	Min	Min
				[A] Country's barriers	[B] Public accentante	[C] Clereness & Simplicity	[D] Vendor's degree of freedom	[E] Licensing lead time	[F] Aleatoric Risk
[1] Law framework (§3.1)	relationship with non-nuclear laws	Many shared subjects				- - -			
		Few shared subjects				+++			
	openness/ dependence to external linkage	Ratification of treaties and conventions		-		+			
		International standards linkage		- -		++			
		foreign Law, regulation, standard (From vendor's country)		- - -		+++			
	extent and distribution of prescriptive norms into the legal hierarchy	Low detailment				-	+++		
		High detailment	Statutory level			++	- -		
			Regulatory level			++	- -		
			Not-mandatory level			++			
	legislative body centralization	Centralized framework				++			
		Decentralized framework				- -			
	Dynamic	Revised Sometimes				+/-			
		Revised periodically				+/- -	+		
[2] Main actors (§3.2)	One check: RB					++		- - -	
	One check: Gov., RB gives its option/opinion				+	++		- -	
	Double checks: RB and Gov.				+	+/-		- -	+
	Multiple checks: Gov., RB and other institutions				++	- - -		+++	+++
[3] Licensing steps (§3.3)	Early meetengs					+++	++	--	- -
	Site: (Xa="first site certification"; Xb="the site has already be certificated")						+	Xa:+ Xb:- -	-
	Design (Xc="first design certification"; Xd: "design has been already certificated")						+	Xc:+ Xd:- -	-
	Construction						+/-	+/-	+/-
	Commissioning tests						- - -	++	+++
	Operating						- - -	+	+++
[4] Public informationa & involvement (§3.4)	Transparency	High transparecy			++				
		Low transparecy			--				
	Pubblic involvement	Public opinion has blinding rule			+++	- -	-	+++	+++
		The main comments arisen must be taken into account			+	-		++	+
		The comments require only to be answered			- -			+/-	

[5] Nuclear program approach (§3.5)	Gov. leadership (Xe="the Gov. support the foreign vendor"; Xf=" the Gov. Doesn't support it")	Xe:- - - Xf:+++	Xf:+ + Xf:+/-		+/-	Xe:-	Xf: + +
	Free market oriented (operators)	- -			+ +		
	Exist the Nuclear industry in the country	+ + +	+		- -		

Table 1: Licensing framework. Effects of the licensing parameters on reactor vendor. This framework is applied to the six countries under study (see Table 2, Table 3)

The **degree of freedom left to the reactor vendor** is the flexibility with respect the technical solutions and project development schedules. This element permits to show relevant differences between the licensing approaches considered. Furthermore it incorporates the effect of one important licensing parameters (not treated explicitly in the paper for the limited space available) the "safety criteria" that represent the approach used by RB in assessing the installation safety (IAEA, 2005).

The **licensing lead time** considers the whole licensing process: it is the time incurring between when the application is submitted by until when the operating license is granted.

The **risk** is maybe the most important licensing process effect in the eyes of the owner's group (AREVA, 2006).

The risk is usually presented as the product of the probability that an uncertain event take place, with its potential impact (Williams, 1996). This paper is focused on those uncertain events that may have an impact into the NPP development and that are generated trough the licensing process; the most important are: delays, not acceptance of the proposed application, request of plant modifications, etc. As result, differently to the project management literature (Hillson, 2002), the paper considers only those licensing events that may have a negative impact into the NPP development. Total risk considers the influence of the Public, the degree of freedom left to vendor and the epistemic risk[vii] (Ross, 2006); this last mostly depends to the "clearness and simplicity" of the licensing framework;

5. THE INTERNATIONAL COMPARISON

The sample of countries chosen in this paper represents some best practices in the eyes of the licensing process and/or the nuclear program. These countries are: Finland, France, Italy, South Korea SK, UK and USA that will briefly presented at follow.

Finally Table 2 presents the main licensing features of the countries considered, adopting the framework previously introduced; Table 3 shows the main differences/similarities of the national licensing frameworks. These two tables use the taxonomy introduced in the Table 1 with few modifications for enhancing synthesis: first the licensing steps and the related lead times are presented together; second is presented the total risk aggregating the direct and indirect[viii] effects of licensing parameters.

Finland is the first country "back to nuclear" in Europe, with the construction of the EPR. The country is relatively small and the number of commercial NPP is 4 that produce, on average 27.8% of the total state energy produced in the state (World nuclear association, 2011). The country have a national nuclear industry only for the operating activities; the main utilities are primarily owned by the Finnish industry who beneficiate to the low cost of the electricity.

France is one of the most important nuclearized countries, with 58 reactors who produce 75% of the energy) (World nuclear association, 2011). It is one of the most active reactor vendor and fuel exporters; it detains one of the greatest fuel infrastructures in the world and is

[vii] Epistemic risk: is generated when the uncertainty of an event derived from lack of knowledge; in the licensing case it's derived from the scarce applicant's awareness of the licensing rules and safety acceptance prerequisites.

[viii] Trough the "licensing effects" correlation.

leader for the fuel reprocessing techniques. The country particularity is the centralized nuclear strategy leaded by the government, and the emphasis of the reactor standardization (Roche, 2004). Even if the defence pervasive activities had historically reduced the information transparency, the public acceptance is one of the highest of the world (Herbst, et al., 2007).

Italy is starting a second nuclear program and recently Enel (the main Italian utility) signed a memorandum of understandings with EDF to the construction of four EPRs (ENEL, 2009). Italy is that is the only country in the World that shouted down its existing nuclear plants after the Chernobyl accident (Ambrosetti, et al., 2010). Nevertheless the Italian nuclear industry is still active in and operates abroad. Now the Italian nuclear program is in the phase where the RB (Nuclear safety agency) is recruitment the needed personnel for carrying out its duties. The licensing process is defined only in general terms by a recent law framework (Baini, et al., 2010).

South Korea base most of its economy and development in the nuclear sector that in the lasts decades has growth significantly. Now the reactor under operation is 21 for a produced that represent 40% of the country's generation mix (World nuclear association, 2011). The Korean nuclear program is one of the most successful because of: the fast learning curve achieved for the construction of the nuclear facilities (in terms of both time and overnight cost), the final cost of the electricity produced and the high capacity factor of its reactors (Matzie, 2005). This program success has been achieved for a comprehensive strategy led by the Government the emphasis on reactor standardization and knowledge development (Choi, et al., 2009). Recently Korea has signed maybe the biggest nuclear contract (20 billion $) for the construction of four APR 1400 in Saudi Arabia (World nuclear news, 2009).

UK was a exporting country during the first development of the nuclear sector; nevertheless the British nuclear technology has become obsolete and expensive relatively soon and then was considered a commercial failure (Thomas, 2010). Now in UK are operating 19 reactors that represent 25% of the generation mix in the country (World nuclear association, 2011). Nowadays UK can be considered as nuclear importer because some foreign reactors (EPR and AP1000) are under licensing review. The licensing process is really particular for the high discretion left to the RB (Nuclear Installation Inspectorate NII a branch of the Health Safety Executive).

USA is the most nuclearized country in the World; its nuclear industry is one of the most active in the field of the reactor vendor. The actual operating nuclear plants are 104 for over the 20% of the energy mix production in the country (World nuclear association, 2011). The American nuclear program main features are: the market freedom approach (even if many administrations have established incentives for this sector), fragmentation of the utilities (even due to the large extension of the country), and the absence, in the past, of reactor standardization that had led to high cost of the electricity produced with this technology (Sasrty, et al., 2010).

6. CONCLUSION

The actual international nuclear market scenario highlights the need of a licensing harmonization. From one hand many countries, with different licensing frameworks, want to develop a nuclear program importing the first NPP units. On the other hand, few reactor vendors can embark an international selling campaign. As result few reactor vendors are spending great efforts in facing really different licensing frameworks. The aim of the paper is to answer to the questions presented in the paragraph 1.3.

R1: ***How the nuclear program and the licensing process are linked?*** Fig.3 shows the linkage between the licensing process and the nuclear program: first the licensing rules are considered part of the intangible infrastructure contained in the law framework; furthermore these have direct effect into the deployment of the physic-infrastructure piece: the NPPs. The leadership role in the nuclear program has direct effect into the division of responsibilities in the licensing framework. From on hand the countries where the government detains the leadership role (France, South Korea) the risk perceived by the state’s utilities is lower, and the licensing process is more predicable (even when the licensing framework is complex).

F I N L A N D	[**1)Law framework**: "prescriptive based": the law establish the general principles and the detailed provisions are establish in the standards and guidelines (YVL)];[**2)Main actors**: system of multiple checks: the main decisions on grant or not the licenses are left to: the government, the parliament and the RB (STUK) for the technical aspect related to the safety];[**3,E)Steps and related time:** two main steps: Construction License (it takes 2-3 years) and the operating one (issued in parallel with the construction)];[**4)Public**: the public hearing are anticipated before the decision-in-principle (only for the stakeholders in the vicinity of the site); the tools to disseminate information are: internet sites, television teletext, the telefax bulletin, television, newspaper];[**5)Nuclear program**: the nuclear program leadership is shared between the government, who operate as energy planner and the utilities];[**A)Country's barriers**: language, cost of workers, detailed and prescriptive rules][**B,C,D,F)Total Risk**: the rules are really prescriptive, and even the subcontractors are checked and inspected by STUK]
U K	[**1)Law framework**: "performance based"; most licensing are settle down by not- mandatory guidelines; important regulating tools are the license conditions that have force of the law];[**2)Main actors** the RB (HSE-NII) has many discretionary powers in granting the license, the government is involved just for the siting policies];[**3,E)Steps and related time:** generic design assessment (Gda, it takes 3 years) promote the design standardization and Site License (it takes 1 year)];[**4)Public**: during the GDA the applicant publishes the safety documents submitted to the RB and answer to the main questions arisen by its internet site. During the Site License, the Secretary of state[ix] is empowered to carrying to the public Inquiries.]; [**5)Nuclear program**: the nuclear program leadership is mostly left to the Utilities];[**A) Country's barriers**: the facilities design already approved take really less time for the next licensing process]; [**B,C,D,F)Total Risk**: high risk due to the discretionary powers left to the RB; the licensing system lack of clearness and predictability even due to the extensive use of the license conditions as part of the regulatory framework];
F R A N C E	[**1)Law framework**: "prescriptive based ", and fragmented in many fonts];[**2)Main actors**: admistrative framework fragmented; most of the licensing decision are issued by the system of "double check": the RB (NSA) gives its option (on the technical matters) and the government make the decision];[**3,E)Steps and related time:** construction permit an the operating one.(the law set up the licensing lead time of 3 years but there are some example where the period was longer like 4 years)];[**4)Public**: the public inquiry (within 5 Km) is coordinated by the prefect. The Information is controlled by a chain: the RB (NSA) communicates with the local information committees and the Prefect (who coordinate the information provided to the medias). The "High committee for transparency" monitors the level of inf. transparency nevertheless the defence related activities reduce it];[**5)Nuclear program**: the Nuclear program leadership is led by the government. A key feature of the program is the high standardization of reactor design to achieve the economies of scale and learning];[**A) Country's barriers**: the nuclear defence policy; long collaboration tradition of the main actors involved (all owned by the state), reactor standardization];[**B,C,D,F)Total Risk**: the main risks derive to the framework complexity, however it's is perceived low from the main French actors due to its long experience of the system and to their long term partnership strategy]
K O R E A	[**1)Law framework**: general law framework, the detailing is issued by regulation, but the institution has a high degree of power flexibility. The regulatory framework results "prescriptive based" due to the detailed technical standards. The fonts are really decentralized];[**2)Main actors:** really concentred administrative framework; the Minister of Science and technology has the power to grant the license and control the inspector department. Other monitoring activities are carried out by the RB (KINS),and expert body that usually assist the Minister in the licensing decisions];[**3,E)Steps and related time:** construction license and operating one; emphasis on the anticipation of civil and preparatory works that are undertaken in parallel with the licensing process];[**4)Public**: Few provisions are made about this matter];[**5)Nuclear program**: The Nuclear program is led by the government ;emphasis on design standardization];[**A) Country's barriers**: nuclear program emphasis on national participation for economic development purposes, standardization of reactor design, language , prescriptive standards];[**B,C,D,F)Total Risk**: Low, due to the fact that the nuclear policy really strong and is strictly under governmental control, and there is an intense collaboration between the main licensing actors]

[ix] Or the Scottish Minister for development, in Scotland

ITALY	[**1)Law framework**: "prescriptive based" approach, the administrative procedures are really detailed and fixed by law (no regulations are available yet). The law fonts are really concentrated];[**2)Main actors**: The main powers during licensing process are shared between three different ministers (Minister for economic development, Minister for the environment , Minister for infrastructure and transport). The RB (Agency for the nuclear safety) gives it's option on the technical matters related to the safety];[**3,E)Steps and related time:** the main steps are: Site certification (1 year) and design license (2,5 years); this time forecast is present in the legislation (maybe optimistic)];[**4)Public**: the information is disseminate by: media and internet sites ; the transparency is assured by the "Information and transparency committee", present in every nuclear region, must answer to the question arisen from the public]; [**5)Nuclear program**: the government has a main role in the nuclear program leadership: directly (constructing the nuclear infrastructure) and indirectly (it possess the main share of ENEL)];[**A) Country's barriers**: Low, firstly the international agreements established (the most important: ENEL-EDF)];[**B,C,D,F)Total Risk**: involvement of the regional and local authorities into the licensing process, public acceptance, need for rebuilt the nuclear capabilities (especially to set up the RB), political instability]
USA	[**1)Law framework**: vast and complex: a balanced synthesis of the prescriptive and performance based approaches. the prescriptive details are left to the regulations or the standards. the framework is really is revised on periodic basis];[**2)Main actors**: The RB (NRC) is the main institutional actor involved into the licensing decisions];[**3,E)Steps and related time:** Exist two licensing system: the traditional one (10 CFR 50) is divided into two licenses: one for constructing and one for operating ;in the newest (10 CFR 52) the steps are: Early site permit, Design certification and the combined license (for both the construction/operation).];[**4)Public**: Most of the documentation is made available by NRC by internet[x] and the public can assist to the safety meetings between the applicant and the NRC. the mandatory public-hearings are collocated in the early phases of the licensing process.];[**5)Nuclear program**: The leadership is left to the different utilities under the logic of the market freedom];[**A) Country's barriers**: strong nuclear industry , governmental incentives];[**B,C,D,F)Total Risk**: public incontinence, judicial reviews, Antitrust decision. the mitigation actions are: emphasis in the preliminary meetings , the rule: "what is approved in the early steps can't be modified in the latter ones]

Table 2: Licensing frameworks applied to the countries under study
(Adopting the taxonomy presented in Table 1)

[x] Removing the commercial and security sensitive information

	FRANCE	ITALY	KOREA	UK	USA
FINLAND	[**1**) prescriptive based];[**3,E**) construction/operation]	[**2**) strong government role]	[**1**) detailed regulation and guideline];[**3,E**) construction/operation]	[**4**) both high];[**5**) market openness];[**A**) low]**;[B,C,D,F**) high for both countries]	[**1**) detailed standards and guides];[**3,E**) for the traditional USA's licensing approach];[**4**) both high;[**5**) market openness, low standardization];[**B,C,D,F**) both high]
FRANCE	[**1**) law detailment];[**2**) level of centralization, RB role & Gov. Role];[**4**)]; [A)];[**B,C,D,F**)]	[**1**) prescriptive law];[**2**) system of double checks];[**4**) similar administrative framework]	[**2**) strong government involvement];[**3,E**) construction/operation];[**4**) low];[**5**) strong government role, standardization];[**A**) high];[**B,C,D,F**) low]	[**5**) fuel fabrication, waste reprocessing and military activities (indeed with different extent)]	[**3,E**) just for the old USA's system];[**5**) historical military development]
ITALY	[**1**) law detailment];[**2**) level of centralization, RB powers];[**3,E**) in Italy there is an unified license for both constructing and operating, in Finland this two aspects are covered by two different license)];[**4**) In Finland there is an higher public involvement;[**5**)];[**A**)];[**B,C,D,F**) different kind of]	[**1**) centralization of law];[**2**) centralization/fragmentation of responsibilities];[**3,E**) different approach];[**5**)strongeness of the government, defense related policy, emphasis on standardization];[**A**) the French system is closer];[**B,C,D,F**) really different with respect the experience and stability]	[**2**) level of centralization]	[**2**) centralization];[**3,E**) just for the site license];[**B,C,D,F**) high]	[**A**) low]
KOREA	[**1**) Koran law is decentralized];[**2**) stronger role of the Korean government];[**3,E**) lead time, anticipation and parallelization of preparatory works];[**4**) different emphasis];[**5**) different strategy and leadership];[**A**) really different];[**B,C,D,F**)]	[**1**) the Korean law is less detailed];[**2**) centralization/fragmentation of responsibilities]	[**1**)];[**3,E**) different kind of, lead time and level of parallelization];[**4**)];[**B,C,D,F**) really different]	[**1**) law detailment];[**2**) centralization]	[**3,E**) just for the old USA's system]

	FINLAND	FRANCE	ITALY	KOREA	UK
UK	[**1**) really different systems, level of detailment, legal tools used];[**2**) RB role, Gov. involvement];[**3,E**) different sequence construction/operation VS design/site];[**B,C,D,F**) different kind of: low predictability VS detailed provisions]	[**1**)];[**2**) UK centralized, France decentralized];[**3,E**) different sequence construction/operation VS design/site];[**4)**];[**5**) leadership role, extent of standardization];[**A**) really different];[**B,C,D,F**) different level and type]	[**1**)];[**2**) RB and Gov.role];[**3,E**)];[**4**)];[**5**) leadership role];[**B,C,D,F**) different kind of]	[**1**) regulation detailment];[**3,E**)];[**4**)];[**5**) really different];[**A**) really different];[**B,C,D,F**) really different]	[**1**) Anglo-Saxon-system];[**2**) strong RB role and independence];[**3,E**) license for site and design; the operator has more options in choosing the licensing steps];[**5**) market freedom leadership role];[**A**) low];[**B,C,D,F**) high]
USA	[**1**) really different legal traditions];[**2**) RB role, Gov. involvement];[**3,E**) different for the newest USA's licensing approach];[**B,C,D,F**) different kind of];[**A**) different kind of]	[**1**) law detailment];[**2**) RB and government role];[**3,E**)just for the newest USA's system];[**4**): really different];[**5**) leadership role, extent of standardization]; [**A**) really different];[**B,C,D,F**)]	[**1**)];[**2**) RB and Gov.role];[**3,E**)];[**4**)];[**5**) government involvement]	[**1**)];[**2**) RB and Gov. role];[**3,E**)];[**4**) really different];[**5**) extent of reactor standardization, leadership role];[**A**) really different];[**B,C,D,F**) really different]	[**1**) Uk's system is more "performance based" oriented];[**3,E**) for the old USA's system];[**4**) higher transparency in USA]

LEGEND					
	1)Law framework	**3,E)Licensing steps**	**5) Nuclear program**	**B,C,D,F) Total Risk**	**DIFFERENCES**
	2)Licensing actors	**4)Public information & involvement**	**A) County's barrier**		**SIMILARITIES**

Table 3: Comparison of six licensing frameworks (Adopting the Taxonomy introduced in Table 1)

In this cases the national barriers are really strong; depending of the nuclear program maturity, the degree of closeness with respect foreign firms will be significantly increased during the pass of time until when the technological independence is been achieved: this was the case of the South Korea and what China, India and other developing countries are planning to achieve. When this critical leap will be passed, is expected that these countries will become "nuclear exporters". On the other hand the countries who adopt the logic of market-freedom (Firstly USA and UK), emphasize the element of licensing flexibility and amendability, public transparency/involvement and the need of an independent regulatory body, in accordance with the best practices proposed by IAEA.

The third category of nuclear program approach can be viewed as in the middle of the previous ones.

R2: ***How the reactor vendor could take into account different licensing frameworks?*** The reactor vendors need a systemic framework that enables it to highlights the critical features of any licensing process. The paper proposes a model (showed in the Table 1) to translate the licensing parameters (paragraph 3) into effects in the project deployment (paragraph 4). Furthermore the International comparison in the Table 3 presents the main differences and similarities between the countries considered. Adopting this method, the reactor vendors could prioritize the depth study of the licensing practices: focus their attention on the licensing differences, and reducing the efforts in the study of the similarities.

R3: ***How the governments could take into account the reactor vendor's perspective in designing the licensing framework?*** The governments willing to implement a nuclear program shall first decide their approach (see R1) using a long term strategy. The nuclear vendor involvement is usually emphasized in the development of the first NPP units; in this case may be useful to create a flexible licensing framework that takes into account the initial transient of the nuclear programme. For the NPPs implementation success, Government need to takes into account the reactor vendor perspective (more generally, it shall evaluates a trade-off of whole set of nuclear programme stakeholders perspectives); Table 1 permits to consider the licensing framework effects (endogenous to the Government action) into the reactor vendor. Government, could drastically decrease the licensing efforts, required by reactor vendors, emphasizing the similarities between the importing country licensing framework (endogenous to the Government action) and the exporting one (reactor vendor's country); Table 3 gives an example of an international comparison of licensing practices.

R4: ***Which are the main differences between the licensing practices worldwide?*** The paper provides an example (Table 2, Table 3) of six licensing practices adopted in the following countries: Finland, France, Italy, South Korea, UK, and USA. The main differences between countries are: the nuclear program approaches, legal traditions and institutional ones.

France and South Korea emphasize the leading role of Government in their respective nuclear program; the resulted institutional framework is centralized.

On the other hand, the nuclear programs of UK and USA are inspired to the open market approach; the independence of the RB and the public information transparency is emphasized. In Italy, Government is the most important institutional actor affecting the licensing process decisions (RB gives it technical option); with respect the nuclear program, Government has a direct and indirect influence. It operates directly in: the licensing process, the nuclear program planning; developing and financing some elements of the nuclear infrastructure. It operates indirectly because of the State's share (about 30%) of the main utility (ENEL).

The Finnish system has the particularity of multiple institutional involvements in the licensing process: Parliament, Government and RB. The nuclear programme is characterize for the Government planning (Decision-in-principle) and the private implementation of NPPs (utilities are privates and the reactor are imported).

In short terms the international harmonization is perceived as a utopia
With respect the fourth generation of nuclear reactors, the authors think that a substantial rethink of licensing practices shall be made.
The IV generation of nuclear reactor emphasizes the modularity to enhance: fast NPP deployment, greater flexibility, grating approach in construction, lower risk, economies of learning, simplification of plant, and standardization of components. The actual licensing practices adopted worldwide could impede most of the positive features of the modularity. Historically the economy of scale is being emphasized as one of the most important features in the nuclear field; as result most of the licensing practices are being designed for the medium-large reactors.

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1. INTRODUCTION TO LARGE PROJEC

After a brief presentation of some of the most popular definitions of “project” (§1.1.) the chapter presents a framework that highlights the differences and similarities of: “large projects” (§1.2.1.), “mega project” (§1.2.2.), “major public project” (§1.2.3.), and “giant project” (§1.2.4.). These project sets can be considered mutually overlapped and the definition that better regroups this “project family” is: large project filed (§1.2.).

The chapter also presents a comparison between previous definitions (§1.3.) and a uniform large project framework considering six main attributes (economic dimension, long timing horizon, complexity, strategic importance/ politic sensitivity, physicality of the project outcome and risk) (§1.4.).

1.1. Definition of project

Since the beginning of the "Project Management" as a scientific subject, the definition of project has changed many times and many authors contribute to this development of concept.

Caron presents a comparison between two different definitions of project, provided by the Project Management Institute PMI in different periods (Caron, 2008); the project is:

"-combination of resources	*"-a temporary process*
-joined by a temporary organization	*-finalized to the production of one or more entities of one product or service*
-for meet a defined objective	
-with limited resource"	*-where their characteristics are progressively elaborated"*
(Project Management Institute, 87)	(Project Management Institute, 92)

Both definitions introduce the provisional and instrumental nature of projects.

From one hand (oldest definition) emphasizes the feature of "resource scarceness"; on the other one (newest definition) underlines the "progressively elaboration nature" of projects.

Caron argues how in the project field the outcome is knew "ex-post" its deployment; in contrast to the repetitive process where the product and the process are known "ex ante" (Caron, 2008).

The extensive definition of project, recently adopted by the PMI (Project Management Institute, 2008), highlights how some actions or procedures are repetitive within the organizations (who implement the projects), and some other are unique and crafted to the specific project or environment.

"A project is a temporary endeavor undertaken to create a unique product, service or result. The temporary nature of projects indicate a definite beginning an end. The end is reached when the projects objectives have been achieved or when the project is terminated because its objectives will not or cannot met. Temporary does not generally apply to the product, service, or result created by the project; most project are undertaken to create a lasting outcome. For example, a product to built a national monument will create a result expected to last centuries. Projects can also have social, economic, an environmental impacts that far outlast the project themselves.

[…]

An ongoing work effort is generally a repetitive process because it follows an organization's existing procedures. In contrast, because of the unique nature of projects, there may be uncertainties about products, services, or *results that the project creates. Project task can be new to a project team, which necessitates more dedicated planning than other routine work. In addition, projects are undertaken at all organizational levels. A project can involve a single person, a single organization unit, or multiple organizational units.*

A project can create:

- A product that can be either a component of another item or an end item itself

- A capability to perform a service (e.g., a business function that supports production or distribution)

- A result such as outcome or document (e.g., a research project that develops knowledge that can be used to determine whether a trend is present or a new process will benefit society).” (Project Management Institute, 2008)

Turner defines the project as:

“an endeavor in which human, material and financial resources are organized in a novel way, to undertake a unique scope of work of given specification, within constraints of cost and time, so as to achieve unitary, beneficial change, through the delivery of quantified and qualitative objectives” (Turner, 1992)

This definition introduces further elements: the change-inducing nature of project and the inherent uncertainty related to a central organization (Chapman, et al., 2003).

Another definition of project exploits the input-output process (Maylor, 2003), as showed in the **Error! Reference source not found.**.1. This last definition introduces other elements:

First the output, described here, generalizes the one presented in the previous definitions. Second it’s underlined the contingency approach derived to the constrained environment, where the project is undertaken; with respect to some constrains (Time T, Financial C[i], Quality Q) a further clarification is needed because in some texts this triad is presented as an objective to achieve rather than a constrain.

[i] The letter C represents the “Cost” of project that generalizes both economical perspective (using the principle of competence) and the financial one (the real cash flows). For verify this assumption is possible to see the Cost breakdown structure CBS presented in the common project management texts [e.g. (Caron, 2008), (Maylor, 2003), (Project Management Institute, 2008)] that take into account all data necessary for present both perspectives (e.g. overnight cost, capital cost).

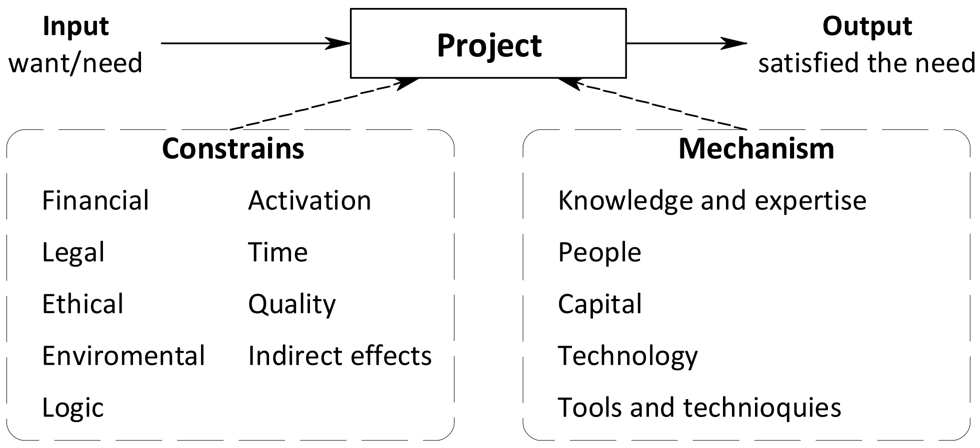

Fig. 1.1: Definition of project (Maylor, 2003) (revised Fig.)

Especially when the project outcome is instrumental[i] (e.g. industrial facilities, transportation infrastructures, etc.) the triad TCQ represent "the need"[ii] that the prime costumer, of the project, want to satisfy. In the Fig. 1.2 introduces a framework which exemplifies the generic identification of the two tiers of instrumental project objectives.

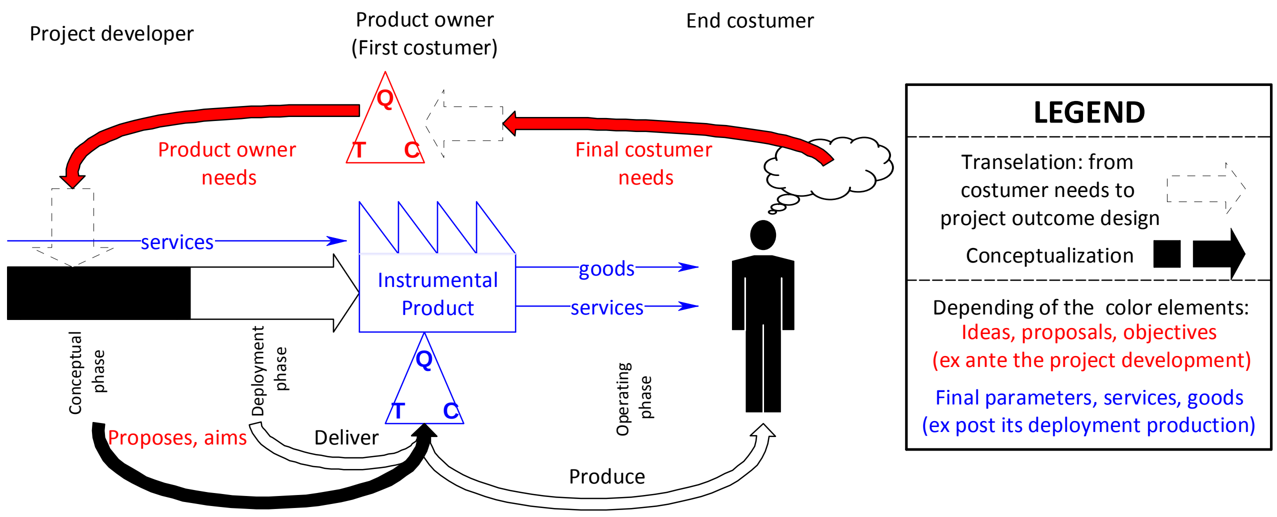

Fig. 1.2: Instrumental Projects' objectives

This focalization on the instrumental projects is being made because the subject treated in this thesis refers to the large nuclear power plants that are instrumental outcomes of the nuclear projects. Furthermore, in the field of large projects, usually the outcomes are instrumental goods as well.

1.2. The large project field

[i] Instrumental because it permits to produce goods or services to an end costumer.
[ii] This notion is emphasized for underline the Mayor's definition of project.

The large project literature is empirical and empirically based; similar definitions like: major, mega, complex and giant project can be considered as components of the family of large project (Ruuska, et al., 2009). Nevertheless a little difference between these definitions exists and will be argued at follow.

1.2.1. Large Project

The Large projects are characterized by the following features (Miller, et al., 2001), (Floricel, et al., 2001):

- substantial irreversible initials commitments
- long period of revenue generation (indicatively 10 years or more)
- high complexity
- high risk, high likelihood of failure and limited upside gain (especially from financial perspective)
- multiples actors involved in the project.

On the other hand (van Wee, 2007) emphasizes the economic dimension of the large project: "should be bigger than 500 million $" and affirms that the large project definition and the mega project one can be considered as synonymous.

1.2.2. Mega-project

A comprehensive definition of mega project is (Turner, 2009), (Koppenjan, 2005):

- *a multibillion dollar infrastructure*
- *usually commissioned by governments*
- *usually delivered by private enterprises*
- *characterized as uncertain, complex and politically sensitive*
- *involving large number of partners.*

This definition emphasizes the organizational complexity due to the presence of multiple private firms in connection to the politic actors, especially the government.

Another driver that permit to distinguish between Mega project and the others one is the economic dimension:

"A mega-project is an investment of $1B or more to build the physical infrastructures that enable people, resources, and information to move within buildings and between locations throughout the world" (Davies, et al., 2009).

In addition the scope of the project is underlined in this last definition: "a physic infrastructure".

With respect the economical dimension, Warrak argues how dimension of $1B is not a constrained element in the definition of mega project, because sometimes is possible to use a relative approach in defining this field: "*In some context a $100 million size could constitute a mega-project*" (Warrack, 1985). The same author presents ten main features of the mega projects (Warrack, 1993):

- Joint sponsors
- Public policy
- Uniqueness
- Indivisibility
- Time lags
- Remoteness
- Social environmental impact
- Market impact
- Risk
- Financing difficulty

Some of these features are in common with the previous definitions (especially high risk and the politic involvement).

With respect the project scope, this definition generalizes the concept of physic infrastructure trough its effects: the impact into the society, environment and market.

A typical feature of the mega project is the cost overruns and time overscheduled (Flyvbjerg, et al., 2003); this is consistent to the previous definition (risk, time lags, financing difficulties).

Another point of connection between (Warrack, 1993) and (Flyvbjerg, et al., 2003) is the assumption with respect the relative economic dimension (the second study has taken into account 258 infrastructure projects where the smallest one was 1,5 million $).

1.2.3. Major Public Project

In the major public projects the complex organizational environment is poned as central element; similarly to some definitions of mega projects the politic involvement is presented as a typical feature (Warrack, 1993), (Turner, 2009), (Koppenjan, 2005).

In this case the public involvement is stressed because, further then the politic influences, it include many others typologies of project stakeholders (e.g. the administrative actors). A formal definition of major public project is presented as follow:

“Major public projects are typically conceived as the result of politically expressed needs in dialogue between various stakeholders. This is followed by some lengthy process to develop the project and make necessary decisions. This typically involves government at various administrative levels, local government, political institutions, the public, media, and consultants and contractors in the private sector.” (Samset, et al., 2006)

1.2.4. Giant Project

The giant project definition emphasizes tree aspects (Grün, 2004):

- *Multi- organization, multi actors work environment.*
- *High Complexity*
- *Goals: they apt to met challenges like developing space technologies, improving public facilities (traffic, health service, and power supplies), hosting international events (like Olympic Games) or changing the social, economic, and ecological standards in developing and industrialized countries.*

The first two elements of this definition are in common with the previous definitions. The third element presented here represents a novel characteristic: the strategic importance related to the territory, economy, society, ecology.

1.3. Comparison between the previous definitions

The definitions previous introduced shall be understood as non-prescriptive, because draft general principles for distinguish between the general concept of project and the large project family (LP); this is consistent with the literature empirical and empirically based (Ruuska, et al., 2009).

The main features that characterize the large project family are: vast dimension, high risk (especially in negative terms), high complexity (especially in the organizational terms), long time commitments, with great impact into the society, economy and environment. Furthermore these projects are characterized to be public sensitive with the presence of many stakeholders. The features just mentioned are, most of time, connected to each others; then when authors presents just some of these characteristics the remained ones can be considered as implicit. (e.g. a project characterized for its high complexity and vast economic dimension indirectly can be considered as risky as well). The emphasis on a specific set of these large project characteristics can be considered the basic driver which permits to distinguish between the concepts of: large project, mega project, major public project and giant project.

Table **1.1: Comparison between the definitions within the large project family**

.1 permits a better comparison between the different definitions previous presented. On the left side of the table, a hierarchical list permits to highlight the level of detail used by the authors for introducing the large project features; this hierarchical representation partly derived from the literature and partly derived from reasoned structuring by the author of this work.

Moreover Table 1.1 distinguishes (showed in the right side of the table) between the feature in common between the previous definitions (not-differential), and the ones discrepant (differential).

In this manner is possible to underline the difference between the large project family definitions.

Dimension	Sub-dimension	Detail	(Miller, et al., 2001); (Floricel, et al., 2001)	(Van Wee, 2007)	(Turner, 2009), (Koppenjan, 2005)	(Davies, et al., 2009)	(Warrack, 1985), (Warrack, 1993)	(Flyvbjerg, et al., 2003)	(Samset, et al., 2006)	(Grün, 2004)	Differential features
Economic dimension				≥ 500.000 $	Multi billion $	≥ 1B $	Relative, even 100.000 $	Usually ≥ 1B $, indirectely adopted relative definition (the smallest project considered in its survey, dealing with large projects, as: 1.5 million $)			Diff.
Complexity			High		High			High		High	Not-Diff.
Complexity	Organizational		Multiples organizations involved		Large number of partners, usually commissionated by Gov.		Joint sponsors		Various stakeholders: governemts at various adminitrsative levels, local governemt, political institutiona, public, media, consultant and the contractors	Multi organizational, multi actors work enviroment	Diff.
Complexity	Technical										Not-Diff.
Complexity	Resource related										
Long time horizons			long lead time				Long time lags				
Startegic sensitiveness (Governmnt and society)					Political sensitive, affected by public policy		Impact on market, society and enviroment		Politically expressed needs	Goal as challanges	Diff.
Physicality of the project outcome (impact into the enviroment)					Infrastructure	Physical transportation infratsructure	Uniqueness, indivisibility, remoteness	Physical animal (Physic infratrsucture)			
Risk											Not-Diff.
Risk	Uncertainty & probability		High likehood of failure and limited upside gain		Uncertain		High risk	High risk (especially in negative terms)			
Risk	Project impact	Technical	Technical risk								
Risk	Project impact	Market related	Market risk; Initial irreversible committments and long revenues generation (after 10 years)				market impact, financing difficulties				
Risk	Project impact	Socio-political					Socio-enviromental impact				

Table 1.1: Comparison between the definitions within the large project family

Furthermore, to check the mutual overlaps of the definitions previous introduced, the "differential" features are logically ranked using the principle of generalization (e.g. 1st: the set of projects, 2nd:the set of the of projects where many firms are involved; 3rd: the set of projects where many firms and public stakeholders are involved, etc. The firsts sets generalize, then include, the following ones).

After such raking logic is applied to the four "differential" LP's features these are compared using a radar graph, as showed in the Fig. 1.3.

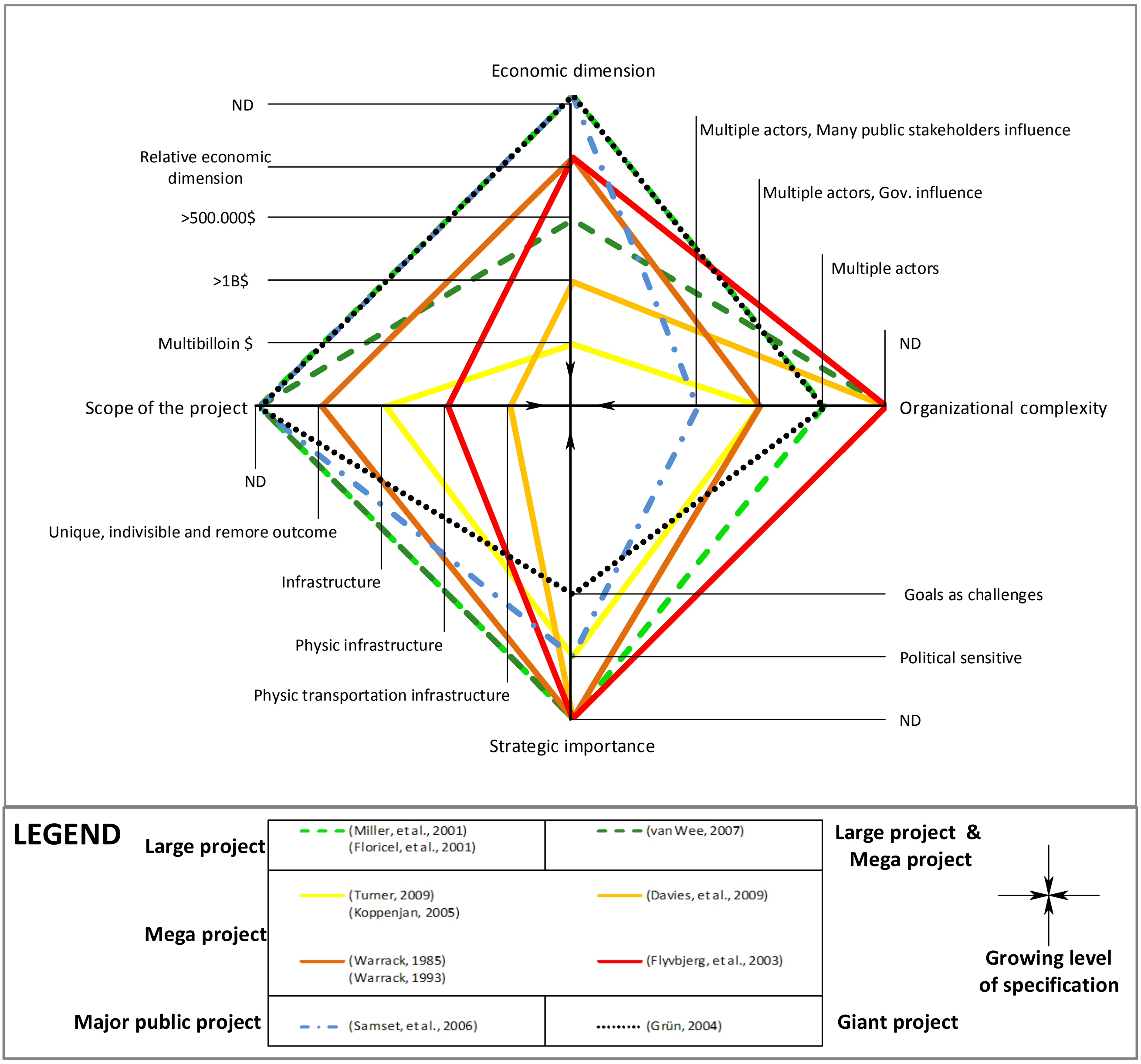

Fig. 1.3: Mutual inclusion between the definition sets within the large project family

When authors don't mention a specific feature, they implicitly generalize this feature (e.g. in the definition of project is not mentioned the dimension, this definition generalizes the concept of large project where the dimension is mentioned).

The definition provided by the authors are similar, mutually overlapped and its difficult to cluster specific features that permits to distinguish between these.

In general terms the "Large project" definition generalizes the other ones.

The definition of "Mega project" underlines the physicality of the output. The physicality of the output is the most opposing element with respect the large project literature[i].

The definition of "Major public project" underlines the public stakeholder's influence, especially from the governments (this last element is strictly connected to the country's strategic significance of the project).

Finally the "Giant project" definition highlights the strategic importance of the project.

1.4. Integrative framework of the large project family

Table 1.2 present the main large project features, considering the relationship between these and the paragraphs where are introduced (in general terms and specifically to the nuclear sector).

Large project features	Num.	Linkages between features		Introduction to large project features	large project features discussed in relation to nuclear projects
		affects other features	is affected by other features		
Economical dimension	1	4,6		§1.4.1.	§2.2.1.
Long timing horizon	2	4,5,6		§1.4.2.	§2.1.2.
Complexity	3	6		§1.4.3.	§2.1.3.
Strategic importance	4		1,2,5	§1.4.4.	§2.1.4.
Physicality of the outcome	5	4	2	§1.4.5.	§2.1.5.
large project risk	6		1,2,3	§1.4.6.	§2.1.6.

Table 1.2: Large project features

These features are briefly introduced, in particular with respect risk and complexity which are of primary importance within this thesis work.

1.4.1. Economical dimension of large projects

A project can be considered large (in economical sense) if its total cost is higher than one billion dollars (this reference value is not considered as prescriptive but gives an order of magnitude).

This feature affects directly the strategic importance of the project (§1.4.4.) and its risk (§1.4.6.) (E.g. delays, during project development, may cause higher escalation cost with respect a "small" project, as result the risk of delays is higher in the first case).

1.4.2. Long timing horizon of large projects

Large project is characterized for long time financial commitments and its scope affects the society, environment and economy for long time horizons.

This emphasizes the public perceptions on public opinion which assigns a character of irreversibility to large projects.

[ii] exists a literature for intangibles large projects; e.g. the development of a complex software (Charette, 1996)

Furthermore long horizons imply uncertainty (because of the long horizon that need to be forecasted for the success of project) (§1.4.6.), strategic importance (§1.4.4.), and physicality of the project outcome (§1.4.5.), which in general have longer lifecycle with respect the intangible ones.

1.4.3. Complexity of the large projects

There are three main perspectives in considering complexity; these may be understood as mutually overlapped:

- Structural complexity
- Uncertainty (epistemic)
- Inherent complexity

Structural complexity is explicated by two factors: the number of elements (that compose the dimension under review) and their interdependency (Baccarini, 1996), (Williams, 1999).

The term dimension refers to the complexity nature, such as: technical complexity, organizational complexity, resource complexity (Maylor, 2003).

Uncertainty is sometimes considered into the complexity definition e.g. (Williams, 1999), (Gidado, 1993); in contrast with others authors (Baccarini, 1996).

The uncertainty considered refers to the lack of knowledge and familiarity with respect: project goals, methodologies, environment and specifications.

This typology of uncertainty mostly refers to the epistemic uncertainty[i] which can be reduced, or totally avoided, trough the growing of knowledge and familiarity on project attributes by implementing organizations.

Inherent complexity refers to the intrinsic nature of organizations, activities, artifact, objectives, etc. (called complexity objects) to be complex.

There are three main dimension of inherent complexity: technical complexity, task difficulty and analyzability (Gidado, 1993).

The complexity objects are inherent complex if require special skills, knowledge and equipment to be carried out, assessed, developed or understood.

I believe that the most effective and correct definition is the inherent structural complexity.

Some authors present the term complexity as sub definition of difficulty[ii] (Campbel, 1988), others presents the two concepts in a reverse manner (Gidado, 1993).

I agree with (Campbel, 1988)when he considers the complexity as subset of difficulty; he demonstrated this assumption introducing an example:

---

[i] By contrast, environment uncertainty is characterized to be epistemic and aleatoric uncertainty (§1.4.6.).

[ii] Note that the term difficulty can be applied only to activities and task; by contrast complexity can be applied also to artifacts, organizations, etc.

may exist difficult and non complex tasks, such as to lift a heavy weight. On the other hand the complex tasks are inherently difficult; as result the concept of difficulty generalizes the complexity one.

Furthermore I think that uncertainty affects task' difficulty but not its inherent level of complexity.

As before I try to argue the last sentence trough exemplification:

Lets we assume that a person (for example Tristano) would like to assembly a table purchased at IKEA.

The table itself may be considered simple (adopting the structural complexity definition) because its pieces and the related interdependences are few and simples. Hence the table is inherently not complex (simple).

Let we assume that Tristano don't find the instruction within the package purchased; in this case may find some difficulties in assembling the table because of the lack of knowledge and familiarity with the task described: Tristano associates a level of uncertainty to the task.

In this scenario the table is simple; the task "assembling the table" is simple, uncertain and difficult.

As result the definition of complexity adopted within this thesis work is the: inherent structural complexity.

Complexity is understood in terms of: organizational, technical and resource related one.

Large project is characterized to be complex (considering all the three dimension of complexity), this imply further uncertainty associated it (§1.4.6.)

Note that the multi-organizational attribute of large project (emphasized by all large project definitions previous introduced, §1.2.) is generalized by the concept of organizational complexity.

1.4.4. Strategic importance of large projects

Large projects are considered of strategic importance in political, social and economical sense.

This because of: the vast economical dimension (§1.4.1.), the long time horizons associated to it (§1.4.2.), and its vast potential impact into society, environment and economy (§1.4.5; §1.4.6.).

1.4.5. Physicality of the large project scope

Usually the large project outcome is physic, such as transportation infrastructure, off-shore platforms, aerospace projects, civil infrastructure, electricity generating facilities, etc. This large project feature shall not be understood as prescriptive.

The physicality of large project outcome, in addition to its vast economical dimension (§1.4.1.), emphasizes the potential impact into the environment and society.

1.4.6. Large project risk

Large project are characterized for the high risk of failure, in technical, financial or socio-political sense.

Especially financial risks are emphasized.

Two definitions of risk (one qualitative and one quantitative) are introduced at follow.

- One of the most popular definitions of risk applied to project is: *"Un uncertain event or condition that, if it occurs, has a positive or negative effect on project objective"* (Project Management Institute, 2000)

The elements composing this definition are: uncertainty, event or condition, and effects on project objectives.

Uncertainty refers to the lack of certainty.

The uncertainty can be epistemic (also called ambiguity, or reducible uncertainty) or aleatoric (also called variability, or not-reducible uncertainty) and is usually associated to: estimates (of project and market scenarios), design and logistic, objectives and priorities, and about relationship between project partners (Chapman, et al., 2003).

Epistemic uncertainty is associated to the lack of knowledge in considering any of the previous aspects, Aleatoric one is characterized for its intrinsic variability.

The terms "events or conditions" refer to the "sources of risk"; generic typologies of risk' sources are: Technical (requirements, technology, complexity and interfaces, performance and reliability, quality), External (subcontractors and suppliers, regulatory, market, customer, whether), Organizational (project dependencies, resources, founding, prioritization), Project management (estimating, planning, controlling and communication) (Project Management Institute, 2008).

A key concern in considering risk is the influence that initiating events (or conditions) have on others risk sources (postulated events and conditions) (Chapman, et al., 2003).

Effects on project objectives consider the potential influence that the uncertain events and conditions may have on project objectives, when its take place.

The project objectives (§1.1) are multiples depending on the project phase and the organization considered; adopting the project management perspectives, the project objectives can be grouped into three main sets: Time, Cost and Quality. As result the potential effect of risky event (and circumstances) consist on project performances changes (positive or negative).

- Quantitative definition of risk is founded under the assumption that the risk pattern is described by a probability distribution (Chapman, et al., 2003)

This distribution associates a measure of impact[i], on the project performances, with the probability of occurrence of such scenario.

The resulted definition of risk, usually reported, is: the product of impact (on objectives or performances) with its probability of occurrence (Chapman, et al., 2003) .

$$Risk = Impact * Probability$$

The impact and probability terms may be understood as single values or vector (discrete or continue) depending on the probability distribution considered for describing risk.

[i] both in positive and negative terms (Hillson, 2002).

This quantitative definition of risk has the same meaning of the expected value of the probability curve describing it; such measure refers to the impact that risk have, on average, on the project objectives and performances.

The large projects are deeply characterized of the vast risk (emphasizing the negative effects on project objectives) in technical, financial or socio-political sense.

The most relevant risk sources belong to the following sets: technical, market related and socio-political risk.

Paragraph §2.1.6.2. and (ANNEX III) introduce a risk taxonomy for large engineering projects and nuclear one, considering the different typologies of risk sources, the level of uncertainty and probability and impact (on project objectives) associated to these. Furthermore the link between different risk sources is also presented. Finally the ranking or risks affecting nuclear projects, and large projects, is presented in the paragraph §2.1.6.3.

Outline of the chapter

- Large project field is empirical and empirically based and regroups the definition of (Large project, Mega-project, Major public project and Giant project)
- Large project are characterized by six main features (economical dimension, long timing horizon, complexity, strategic importance, physicality of the large project scope and risk)
- Large projects are inherently complex and risky

2. The Nuclear Project

This chapter deals with nuclear project as typology of large project.

First the large nuclear project is defined (§2.1), then an extensive framework (derived from the previous chapter) presents the nuclear project features in connection to the large project literature (§2.2); finally the conclusion (§2.3) synthesizes the point of connection between nuclear and large projects, underlines the peculiarity nuclear project and furnishes a linkage to the next chapter.

2.1. Nuclear project definition

Nuclear project can be understood in financial or project management terms.

Financial perspective considers the whole lifecycle of the NPP as considers it as nuclear investment.

Adopting the project management perspective, nuclear project consists to the: engineering, contracting, procurement, construction and start-up of a nuclear facility.

This thesis work mostly[i] deals with the second definition.

There are several kinds of nuclear facilities (fuel fabrication, storage and disposal facilities, etc.) (IAEA, 2004); in this work, the scope is reduced to nuclear power plants for commercial electricity generation. The definition of large nuclear reactors takes into account the nominal electrical power of the plants; the reactor sizes are (IAEA, 2004):

Small reactor	P < 300 MW
Medium reactor	300 MW < P < 700 MW
Large reactor	700 MW < P

2.2 The nuclear project as large project

In this section, the nuclear project is compared to the large project literature; the main large project features are (§1.4):

- Vast economical dimension (§2.2.1)
- Long lead time horizons (§2.2.2)
- High complexity (§2.2.3)
- Strategic importance/ politically sensitive (§2.2.4)
- Physicality of the output (that led to high impact into environment) (§2.2.5)
- High risk (especially in financial terms) (§2.2.6)

A large nuclear project accomplishes entirely all these characteristic as following discussed.

2.2.1. Economical dimension of large nuclear projects

The Nuclear project is considered capital intensive; the final cost of the NPP depends of many factors, the most important are: typology and size of technology design, maturity of the design, experience among workforce and leading organizations (especially in the field of project management, construction and manufacturing ,contracting, nuclear technology, and licensing) , geographical area where the NPP is deployed (for the cost of the workforce, licensing approach, etc.), nuclear infrastructure supporting the NPP implementation and cost of raw materials (MIT, 2003), (IAEA, 2007).

[i] By contrast when the term "nuclear project" refers to the financial perspective it's opportunely signaled.

Several studies have been developed for drafting the final cost of the nuclear projects; nevertheless this matter remains controversial due the complexity and uncertainty associated to the estimation of the final cost of nuclear facilities. After Three Mile Island and Chernobyl accidents practically all occidental countries stopped to propose new nuclear power plants (Herbst, et al., 2007) meanwhile the Asiatic countries continued to deploy its.

By contrast, modern scenario is characterized: from one hand by a new push on nuclear development (nuclear renaissance[i]); to the other one by the public aversion on nuclear technologies due to the Fukushima accident (this later pose high uncertainty on the future of the "nuclear renaissance").

The long NPP deployment suspension (30-40 years), in conjunction with: the introduction of a new class of NPPs (III+ generation), the public controversy over nuclear power, the introduction of new requirements, and higher safety standards, contribute to long delays and high overnight cost in recent nuclear projects in North America and Europe (MIT, 2009).

The estimation of future overnight cost remains controversial.

From one hand there are studies which advocates how new technologies have being designed to reduce the construction lead time and cost, of the new nuclear units, and improving, at the same time, the installation safety; this is made possible through insight derived from the long experience maturated in the operating plants, e.g. (AREVA, 2006). With this respect, the most important features emphasized in the III+ generation technology are (Fortunato, 2010):

- Passive systems (that reduce the complexity of the plant and enhance higher reliability of safety components),
- Redundancy of components (that from one hand enhance higher safety and to the other one permits to harmonizes the components)
- Modularization of assemblies (that permits to build assemblies with higher tolerance in manufacturing environment and to install these at the nuclear site; hence is possible to reach benefits in terms of: lower cost, lower lead time and lower uncertainty associated to the manufacturing and installation of the assemblies)

On the other hand there are studies which advocate that overnight cost will increase following the statistical trend of recent NPPs cost; because of the growth of NPP's complexity due to the higher safety requirements and more prescriptive regulation that will be required in the future (Cooper, 2009).

Fig. 2.1 compares cost overnight estimation with the consumptive values achieved[ii] by all NPPs already deployed in North America.

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[i] The NPP under construction are: 53, the ones planned are: 136 and the ones proposed are: 299 (World nuclear association, 2011)

[ii] (Koomey, et al., 2007), (Koomey, et al., 2007)

These forecasts are showed in Table 2.1, which presents also estimation of all-in and busbar costs[i] for the construction of a nuclear facility in North America (Cooper, 2009), (Locatelli, et al., 2010).

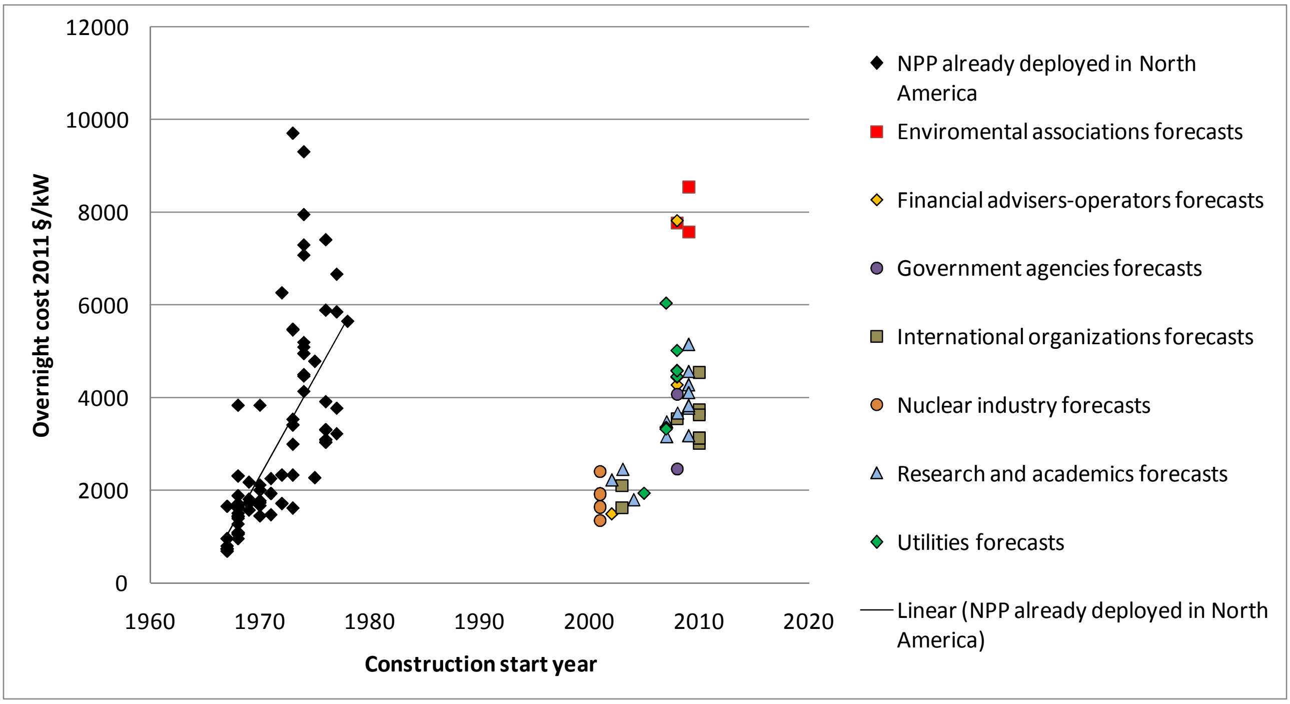

Fig. 1.4: Overnight cost of NPP (North America); a comparison between NPP already deployed and forecasted estimation for future units. (Cooper, 2009) revised figure

The aim of this paragraph is not to advocate the economic competiveness or un-competiveness of the nuclear option for electricity generating purposes (in contrast with most of the studies presented), but just mention a credible values of the cost of a NPPs.

[i]Overnight and All-in (total capital) cost component accounts are showed in the (§ANNEX I); underlined by letters "D" and "E". Busbar cost also considers the operating costs, such as operating and maintenance, fuel, etc.

	Overnight cost [$/kW]			All-in cost [$/kW]			Busbar costs [$/mWh]		
	Low	Mid	High	Low	Mid	High	Low	Mid	High
Bell Bend, 2009		9781							
Callaway 1, 2008		4434			6390				
Calvert 3, 2007		6028							
CBO, 2008		2460						77	
CEC, 2007		3152			4006			111	
CRS, 2008		4069						87	
DOE Loans, 2008					6811				
Du and Parsons, 2009 (ABWR,2007)		3173							
Du and Parsons, 2009 (ABWR,2007)		3769							
Du and Parsons, 2009 (AP1000,2007)		4555							
Du and Parsons, 2009 (AP1000,2007)		4101							
Du and Parsons, 2009 (AP1000,2007)		5139							
Du and Parsons, 2009 (ESBWR,2007)		3823							
Duke, 2008		5008							
EIA, 2003	224	2102	2313				75		81
EIA, 2003	1295	1631	1861				51		64
EIA, 2008		3547							
Harding, 2007		3473		4537		4857	100		130
Harding-High, 2009	6457	8538	10833				156	198	245
Harding-Medium, 2009	5763	7578	9616				143	180	221
IEA, 2008					4434				
Keystone, 2007	3149		3149	3811		4269	89		119
Lazard, 2008	3912		5477	5999		7877	104		131
Levy 1&2, 2008		4444							
MIT, 2003	1226	2452					68	82	
MIT, 2009		4269						90	
Moody's, 2008	6521	7825	158						
S&P, 2008		4278							
SAIC, 2001	2400	2400	2400				78	85	93
SAIC, 2001	1920	1920	1920				72	64	66
SAIC, 2001	1638	1638	1638				55	58	66
SAIC, 2001	1351	1351	1351				47	54	77
Sandia, 2002	2223	2223	2223				71		99
Schlissel and Biewald, 2008					4257				
Scully, 2002	1496	1496	1746				43	48	53
Severance, 2008	6503	7762		9242	11010		261	313	
Shaw (Schlissel and Biewald, 2008)					4751				
South Texas 3&4, 2007	3058	3353	3917						
Summer 2&3, 2008		4577							
Turkey Point 3&4, 2007	3317	3317	4845						
TVA, 2005		1933							
U of C, 2004	1440	1800	2160				64	74	86
Vaillancourt et al., 2008		3661							
Vogtle, 2008		4571			6726				
WNA, 2010 (ABWR)		3130							
WNA, 2010 (ABWR,2009)		3038							
WNA, 2010 (AP1000)		3130							
WNA, 2010 (AP1000, 2008)		4552							
WNA, 2010 (AP1000,2009)		3752							
WNA, 2010 (AP1000,2009)		3626							
WNA, 2010 (ESBWR, 2008)		3130							
World Nuclear News, 2009					3590				

Table 2.1: Estimates of Nuclear Reactor Overnight, All-in and Busbar ($/2010) (Cooper, 2009)

An intermediate perspective are the estimation provided by (IAEA, 2010), differentiated by macro geographical regions as showed in the Fig.2.2[i]; using this ranges, Table 2.2 shows the final overnight cost for the large projects (for the sizes of: 700, 1000 and 1600 MW).

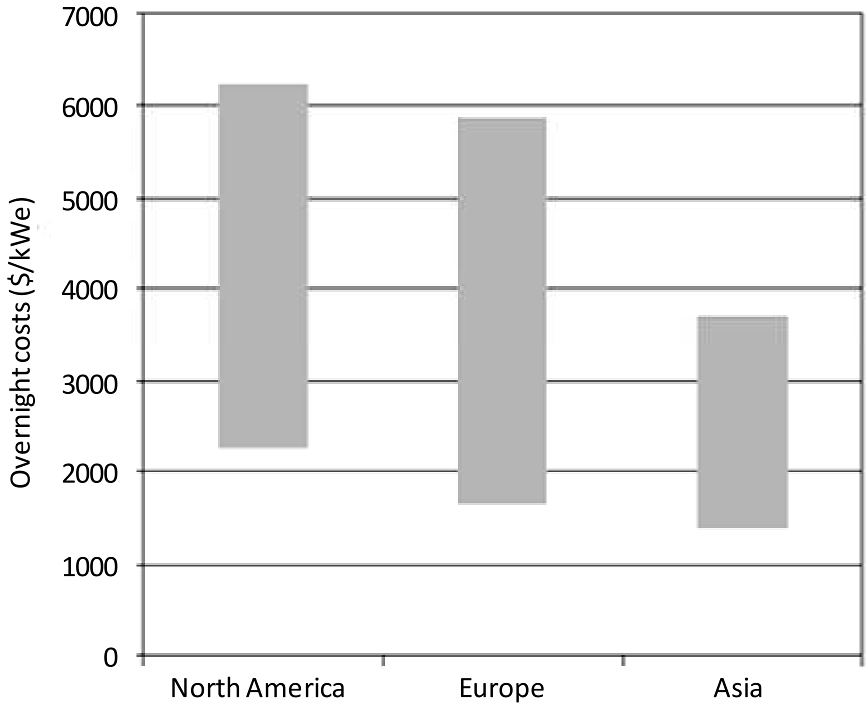

Fig. 1.5: Ranges for overnight cost estimates by region, 2007–2009 (IAEA, 2010), revised fig.

NOMINAL ELETTRIC POWER	GEOGRAPHIC REGION		
	North America	Europe	Asia
700 MW	1.540.000-4.340.000 $	1.260.000-4.130.000 $	910.000-2.660.000 $
1.000 MW	2.200.000-6.200.000 $	1.800.000-5.900.000 $	1.300.000-3.800.000 $
1.600 MW	3.520.000-9.920.000 $	2.880.000-9.440.000 $	2.080.000-6.080.000 $

Table 2.2: Overnight cost of large nuclear projects (IAEA, 2010)

At this point It's clear that the economical dimension of large projects accomplish all the definitions of large project (§1.3.). The table also reflects the high level of uncertainty associated to the overnight cost of a NPP.

2.1.2. Long timing horizon of nuclear projects

The nuclear project has great impact into the society, economy and environment for several decades. A generic NPP lifecycle is presented in the (IAEA, 2007).

The effort needed for the construction of a NPP may vary significantly depending of the maturity of the nuclear program considered; this paragraph considers the most difficult case, when the construction of the

i The different currencies are referred to the dollar by the average monetary values of the 2008

NPP requires the development of an opportune infrastructure (§3.2.). This case is typical for those countries that are starting now their first nuclear program or has not deployed any NPP since long time[i].

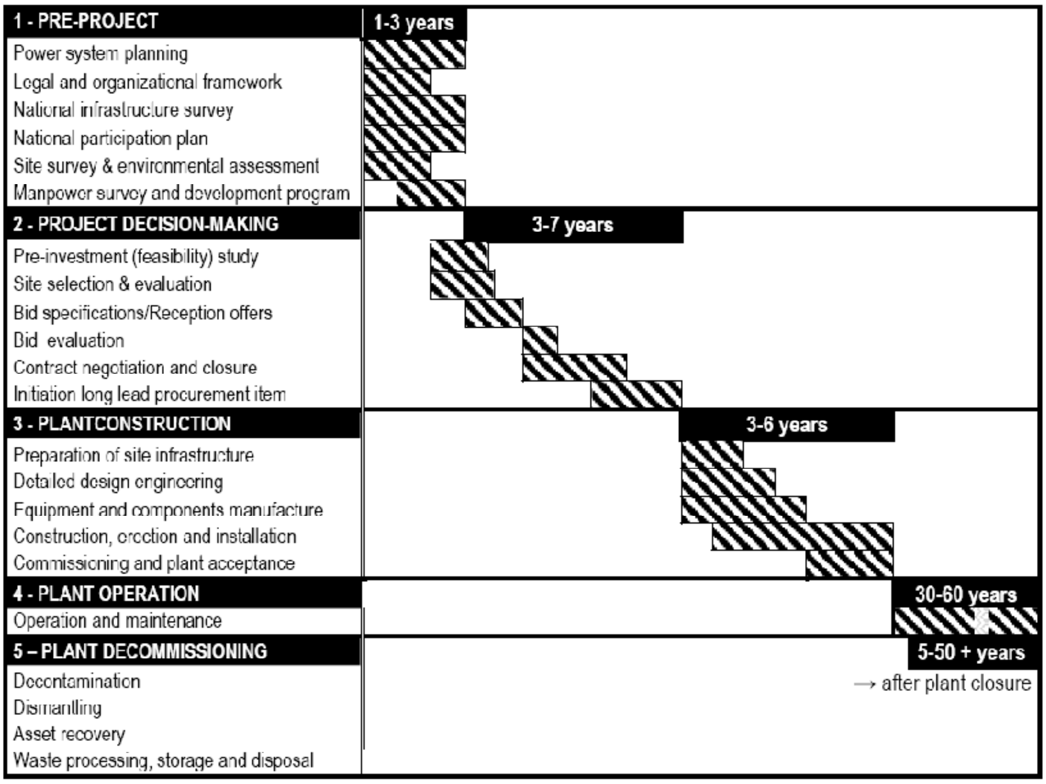

Fig. 1.6: Generic implementation stages of a nuclear power plant project (IAEA, 2007)

These NPP phases are briefly introduced at follow.

2.1.2.1. Pre project phase

Pre project activities are emphasized before the construction of first NPP; this phase is characterized by the initial planning action made by Government in order to prepare the country and the national industry to afford the pending decision: promoting or not the nuclear program.

The main activities undertaken by the Government (mostly) in this phase are (§3.1.4.):

"- National energy supply planning

- Electric power system planning

- Cost estimation

- Nuclear power programme planning

-National infrastructure survey

- National participation plan

---

i This is consistent with the leading countries of the "nuclear renaissance" scenario. From one hand there are some developing countries that are starting now to develop the first nuclear programme (e.g. China, India, Brazil, etc.); on the other hand there are the occidental countries that are planning to replace some of their base load generating facilities due to the need to shout down some of these in the next future. A third category of leading country, in the scenario under discussion, are the oil exporter countries (e.g. Saudi Arabia, Venezuela, Libya, etc.) that prefer to sell their oil than use it for electricity generating purposes. (Locatelli, et al., 2011)

- Long term nuclear power programme policy and commitment

- Organizational structure

- Management systems

- Industry

- Science and technology

- Human resources development

- Legal framework

- Financing

- Sites survey

- Reactor technology survey

- Environmental assessment

- Public acceptance

- Selection of a consultant or consultants" (IAEA, 2007)

2.1.2.2. Project decision-making phase

The project decision-making phase starts with the initiation of the pre-investment study and ends at the closure of the contract awarding route. During this period, some of the most important milestones, for the development of the nuclear infrastructure, shall be achieved; especially the intangible safety infrastructure need to be settled down (§3.2.), (IAEA, 2010).

The main activities performed during this phases are listed at follow.

"- Completion of a pre-investment study

- Site evaluation and qualification

- Evaluation of the nuclear power supply market

- Establishment of a management system

- Completion of implementation of the conformity plan related to legal framework

- Implementation of all international conventions and agreements

- Regulatory requirements

- Selection of a contractual approach

- Preparation of bid invitation specifications (if competitive bidding process is used)

- Bid evaluation

-Financing plan

- Negotiation and closure of a contract or contracts

- Technology transfer and training requirements

- Public acceptance

- Owner's management organization" (IAEA, 2007)

2.1.2.3. Plant construction phase

Construction lead time CLT starts from the preparatory works at the site[i] and finish at the end of the commissioning program[ii] when the plant starts the operating phase. The CLT is stressed in this thesis work due to its importance in the eyes of project management. A basic feature of the CLT is long duration and its susceptibility to delays. Large project are usually affected by long time lags with respect the original estimation (Flyvbjerg, et al., 2002), in addition, the nuclear projects usually met further complications derived to the political, social and technical sensitiveness of the nuclear safety. These "further complications" take the form of further delays and plant modification-rework (§2.1.6).

The CLT estimation is a controversial matter like to the cost one (§2.2.1); Fig.2.4 shows the CLT achieved worldwide. The statistical trends shows how in Asia the construction performance has being quite stable, in contrast with the occidental courtiers that suffers delays.

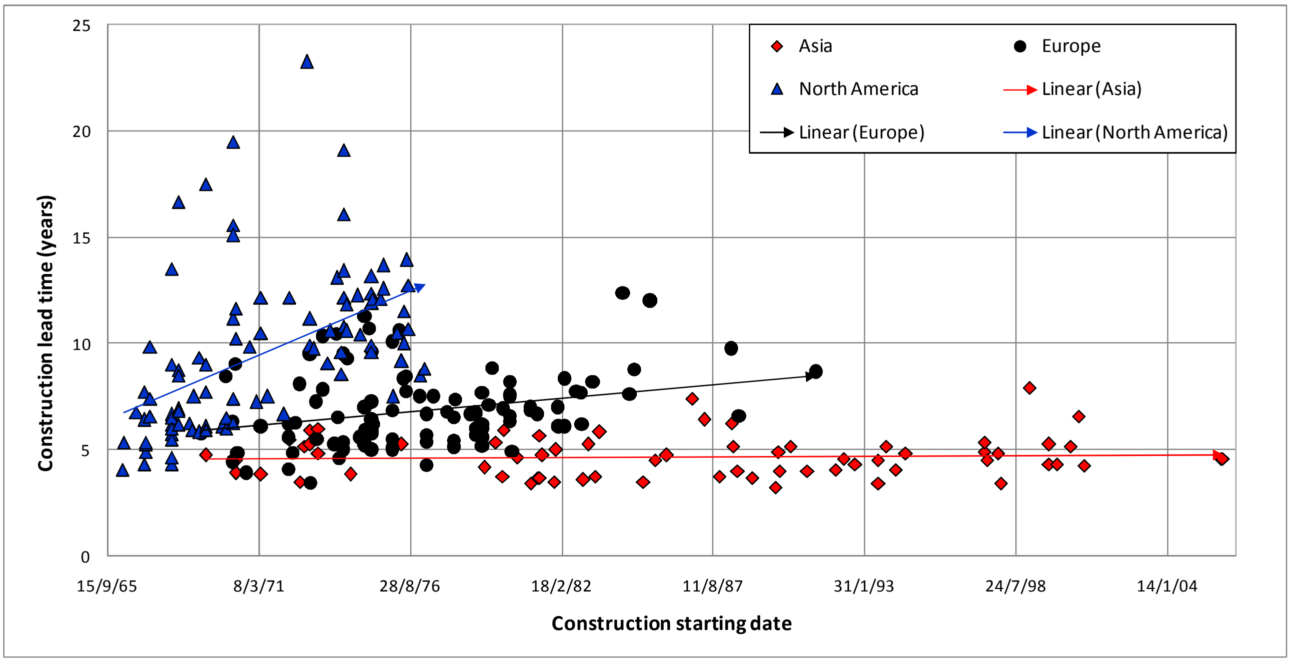

Fig. 1.7: Construction lead time of existing and shouted down large NPP in North America, Europe and Asia. Data provided by (World nuclear association, 2011).

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[i] Usually some activities are anticipated with respect the construction permit or license; hence the construction schedule could result fragmented: the preparatory works (site preparation, some basic civil works, auxiliaries services: road, water, electricity, etc.) from one side and the effective construction and manufacturing to the other one. These work phases could be divided if occurs long time lags in granting the construction permit or license.

[ii] Usually at the end of the commissioning tests the regulatory body assesses the results; then if the commissioning reports accomplish all related safety prescriptions the licensing process continue until when the operating license is granted. If something goes wrong, the regulatory body may prescribe modification of the facility.

2.1.2.4. Plant operation phase

The duration of the operational phase may change significantly due to the actual tendency to postpone the definitive shout down of the nuclear facilities (e.g. some USA's NPP have extended its life from forty years to over eighty years). The actual nuclear power plants of III+ generation use as reference lifetime sixty years (De Rosa, 2009), nevertheless is really probable that their life will be extended in the future[i].

2.1.2.5. Plant decommissioning

The decommissioning lead time may change significantly depending on the approach adopted. There are three basic decommissioning strategies: Immediate dismantling (5-10 years), deferred dismantling (equal to the previous approach plus 5-10 years, or more) and entombment (indefinite time) (IAEA, 2005).

2.1.3. Complexity of the nuclear projects

Indeed the sentence "the nuclear project is complex" could appear obvious for some lectors this section has been provided for uniformity with respect the large project framework (§1.4.3).

Nuclear projects can be considered inherently complex.

The complexity of these projects can be explicated considering the three dimension of complexity: organizational, technical and resource related one (Maylor, 2003).

Organization complexity is high due to the vast number of elements describing project organization and its related interdependencies (between subsets).

Organizational complexity can be represented in bottom up manner: at the lower level there are individuals who represent the basic elements of the organizational framework.

Individuals may be integrated vertically and horizontally within their relative business organizations; these groups become to be complex due the number of individuals and for their interdependences.

These interdependences are differentiated for their nature and represent lines of: control, information flows, physic flows, etc.

Furthermore the concept of distance between individuals enhances organizational complexity; the distance can be physic, cultural, behavioral, social, etc.

This second step (of organizational complexity) is typical of every business organization.

Then the basic groups identified interact with the others within the business organizations; from this point the interdependences acquire a further dimension: interdependences between individuals (as before) and between groups.

Project organization (single business organization) adds a further level of complexity because individuals belong to the project organization and to the business organization at the same time.

[i] This is my personal expectation

New group of individuals are identified (temporaries) and new interdependences between and within: business groups, project groups and individuals ones are formed.

As result the project business organization can be considered in general more complex than traditional business firms.

Furthermore the nuclear project organization (and more generally large one) consists in a network of several business organizations.

Again the organization become more complex and the distance, between the sets identified, grows depending on the network attributes; firm attributes and project ones (Ruuska, et al., 2009).

Large engineering projects, such as chemical facilities, require a broad range of expert firms operating in specific field, such as project management, design engineering, manufacturing, constructing, etc.

The project organization usually complains with a broad range of contractor and suppliers operating in specific field plus an organization operating as system integrator (Brusoni, 2005).

The system integrator is the main contractor and usually is also the holder of the core technology adopted into the chemical project (this can be a group of business organizations such as a joint venture).

As result, large engineering project organization is more complex due to the high differentiation in number of firms and because of the great distance between these (further than the typologies of interdependence).

Indeed the construction field is characterized for its higher recourse of external suppliers (in terms of percentage of project scope) (Clough, et al., 2005)the high tech. industrial projects are usually characterized for its higher organizational complexity. First the distance between firms is higher (in the second case) because of the vast number of specific disciplines required.

This discipline differentiation implies also higher number of specific organizations involved into the project which implies higher number of interdependences greater distance between "groups".

The project network identified for nuclear project is also affected by further level of complexity because of the peculiarity of field.

First Operator and regulatory institutions acquire a more pervasive role into the project development, and then shall be considered into the organizational complexity.

Second the project environment is deeply constrained[i] (because of the safety concerns) (§3.2.3.), and this have direct effect on the degree of prescriptiveness that documents, management systems and quality assurance programs must accomplish (IAEA, 2002).

As result the level of complexity grows again because of the growth of documental, information and control flows; which lets' grow the interdependences between groups and individuals.

Technical complexity can be explicated in a similar manner (with respect the previous case) and refers to reactor design technology and on project execution.

Reactor design numerosity refers to the number of items, subassemblies and assemblies.

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[i] Some authors include the constraining environment and conditions into the definition of complexity (Gidado, 1993).

The interdependences between these elements are differentiated: for example functional groups or physical location groups (Sosa, et al., 2004), (Pimmler, et al., September 1994).
Technical complexity also refers to the number of relevant features (and their interdependencies) associated to the project scope; such as: neurotics, safety related, thermodynamics, metallurgic, hydraulics, etc. With respect the project execution complexity shall be considered in terms of: differentatiation of input-output-mechanism (characterizing the project activities), and the related interdependences; number of task/activities (and related interdependences); and the number of specialties required (Baccarini, 1996).
Nuclear projects are characterized for a vast number of elements (for example for safety purposes the critical equipment have high level of redundancy) which interact complexly due to heterogeneity of technical features associated to its.

Finally resource complexity refers primarily to the economic-financial ones (Maylor, 2003).
Personally I think that the broad typologies of resources shall be contemplated into the complexity analysis, such as: intangibles resources (knowledge based resources and capabilities, intellectual rights, patents, licenses and permits, etc.), human resources, tools and equipment, materials, etc.
As before resource complexity refers to numerosity and interdependence of these.
A Nuclear project is complex considering the resources implied; furthermore vast economic dimension (§2.2.1.) and financial risks (§2.1.6.) suggest the use of a wide variety financial and contractual instruments (such as insurances, project bonds, clauses for transferring risk, financial derivates, incentive contracts, etc.). Government subsidies co tribute to enhance economic-financial complexity.
On the other hand, technical complexity affects the resource related one; because of the capabilities and knowledge based resources required. At this point it's clear how a nuclear project accomplishes extensively all typologies of complexity described.

2.1.4. Strategic importance of nuclear projects

Nuclear energy generation is one of the most critical problems affecting countries, societies and industry.
Global warming, pollution, wars and crisis, resource scarcity, rapid growth of developing countries and safety risks are some of the most important problems affecting the modern electricity generating paradigm.
Electricity generation system represents an element of primary importance for the development and wellness of countries. Governments play a central role in regulating and implementing national electricity strategy (including the nuclear program) (IAEA, 2001), (§3.1.4).

Furthermore the nuclear sector is politically sensitive because of the social, environmental, economic and strategic importance. Society is deeply affected by electricity availability, safety and cost.

Finally globalization contributed to enforce the competition between business organizations; cost and availability of resource play a central role on the industrial competition.

Especially electricity, which affects practically all industrial fields, is considered of special relevance with respect the competiveness and development of national industry.

As result the nuclear project itself have a strategic relevance in the eyes of government, society and industry.

2.1.5. Physicality of the nuclear project scope

Large nuclear facilities are physic infrastructures.

The impact into the environment and landscape is characterized by the following attributes: extension of the nuclear site (and related emergency planning zone EPZ), radioactive discharges (during the entire lifecycle of NPP including incident scenarios), thermal discharges and impact of the related infrastructures (such as electricity greed, emergency centers, cooling infrastructure and transportation one).

Thermal discharges are especially critical for countries having reduced water resources (including access to the sea coasts) because of the high sensitivity of the ecosystems (both in terms of fauna and flora) with respect changes of temperatures.

This problem is especially emphasized due to the large sizes characterizing the majority of NPPs built around the world and for the common practice of grouping many nuclear facilities into a reduced number of sites.

A peculiar feature of dynamic facilities (such as industrial plant) is the stochastic impact onto the environment. This attribute refers to the possibility that incidents, or adverse circumstances, may pose significant impact into the environment. The case of nuclear incidents is one of the most severe, due to the vast potential effects (understood as detrimental) for long periods.

The stochastic impact also characterizes oil platforms and hydroelectric and dam infrastructures.

On the other hand, nuclear projects have indirect effect, into the environment, because of the national infrastructure related to the nuclear system.

This systemic infrastructure deal with: research centers, training centers, reactor spare part inventories, waste infrastructure, reprocessing facilities, enrichment facilities, fuel fabrication facilities, mines, milling facilities, national greed and national transportation infrastructure[i].

Nuclear industry representatives claim the reduced environment impact of nuclear facilities with respect other generating technologies (AREVA, 2006): traditional fossil technologies have a great impact into the environment due to the chemical pollution (especially coal technologies); on the other hand renewables

[i] Greed and transportation infrastructure have being mentioned two times: one for the systemic infrastructure and one for the project related one. If the infrastructural elements refer to the specific nuclear project or site then can be ascribed to it (e.g. site access is specific to the project).

impact on landscapes (especially wind and solar technologies) and on the hydrologic systems (hydroelectric).

As result nuclear facilities can be considered a large project for its physicality and for its impact into the environment and landscapes.

2.1.6. Large nuclear project risk

In this paragraphs, the definition of risk is applied to the nuclear projects (§2.1.61); then a risk taxonomy (complaining with the most relevant typologies of risk, affecting large and nuclear projects) is presented (§2.1.6.2). Finally a ranking of risks is provided in connection to the large project field (§2.1.6.3.); and the financial implication of high risk (affecting nuclear projects) is presented.

2.1.6.1. Definition of risk applied to the nuclear project

One of the most popular definitions of risk is: *"Un uncertain event or condition that, if it occurs, has a positive or negative effect on project objective"* (Project Management Institute, 2000)

As already mentioned, the nuclear project is instrumental (§1.1); then there are different perspectives and objectives that project shall satisfy, as showed in the Fig. 2.5.

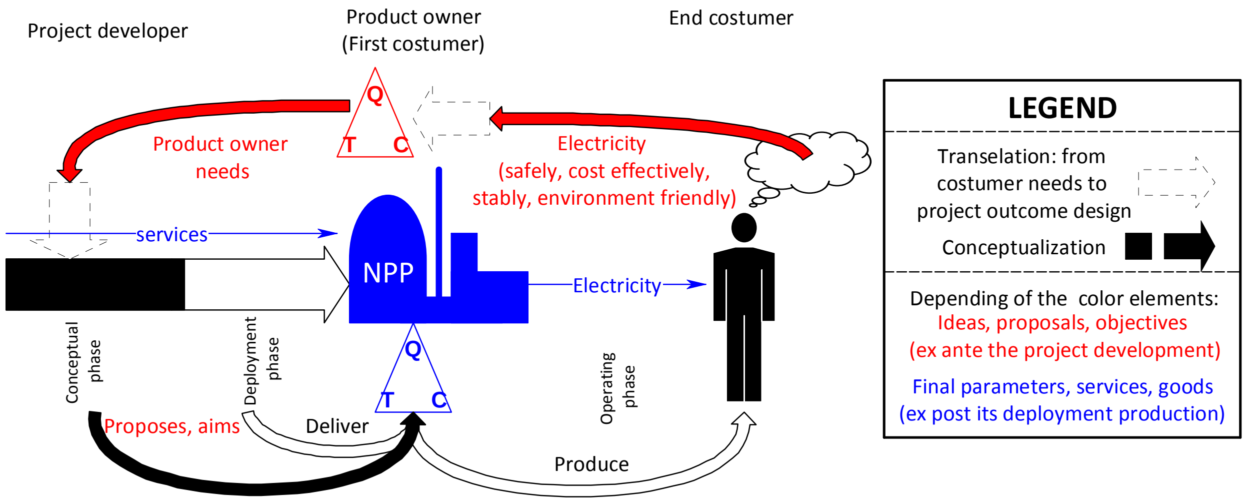

Fig. 1.8: Nuclear project objectives

Fig. 1.9 presents the relevant areas dealing with risk, in connection to the actors sets affected by these areas identified.

Finally Table 2.3 shows the different point of views concerned with the typologies of risk identified.

This work thesis is mostly focused on project management perspective; hence the concept of risk is understood as: uncertain events or circumstances that affect the project objective in terms of Time, Cost and Quality.

On the other hand the others typologies of risk are partly treated by this thesis work, especially the safety risk due to the connection with the licensing process objectives (§3.2.3).

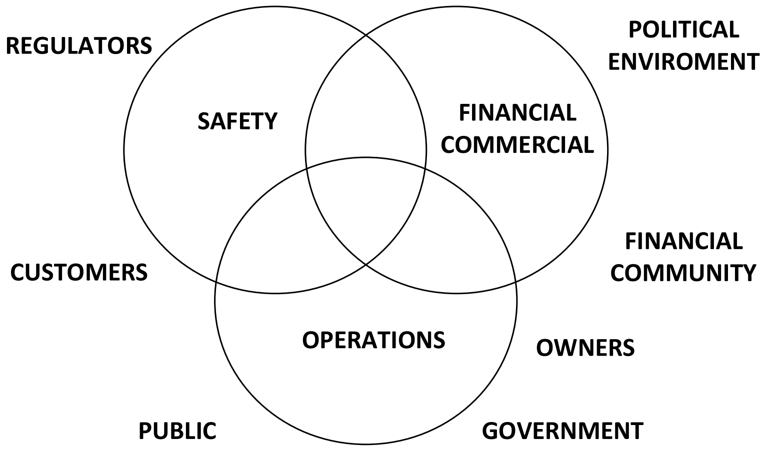

Fig. 1.9: Nuclear project risk: affecting areas (IAEA, 2001),
Page 5, revised figure

Point of view	Focused on these risks:	
Nuclear safety analyst	Nuclear safety and related risk	the relevant risk is the potential for ending up with a system that can demonstrate a frequency of radioactive release that satisfies established institutional and regulatory goals
Financial analyst	Financial risk	the relevant risk is the potential that the cost of the investment will not be recovered over the life of the investment
Plant operation	Operational risk	the relevant risk is that the installation and operation of the new system may introduce operational difficulties
Project manager	Budget and schedule risk	the relevant risk is the probability that the project will be completed on schedule and within budget along with the associated cost impacts

Table 3.3: Different typologies of risk in nuclear project (IAEA, 2001)

2.1.6.2. Large nuclear projects risk taxonomy

Risks affecting nuclear project are diversified because of the different sources, typologies of impact and probabilities associated to its.

An extensive categorization of risk is made introducing "the taxonomy of risk affecting large nuclear projects" showed by Table 2.4. This taxonomy the synthesis of two risk framework:

-*"A risk based taxonomy of large engineering projects"* (Miller, et al., 2001): the risk framework is focused on large project;

Taxonomy	Typology	Sub typology	Group	Sub typologies of risk	Code	Risks affected	Affected by risks
RISK TAXONOMY FOR LARGE NUCLEAR PROJECTS	(§2.1.4.2.1.) Technical risk [LN]	(§2.1.4.2.1.1.) Reactor design difficulty LN]		Level of novelty of the project [LN]	1	4-9,12-14	36
			Difficulty	Complexity [LN]	2	4-9,12-14	36
			Difficulty	Scope specification prescriptiveness [N]	3	4-9,12-14	36
		(§2.1.4.2.1.2.) Project execution [LN]		Contracting [LN]	4	5-6,12-14,19-29	1-3,32-35,36
				Construction [LN]	5	6,12-14,19-29	1-4,32-35,36
				Commissioning [LN]	6	12-14,19-29	1-5,32-35,36
		(§2.1.4.2.1.3.) Operational risks [LN]		Safety related [N]	7	8-9,16-25,37-40	1-3,36
			O&M [LN]	Changes in resources required [N]	8	16-25	1-3,7,36
			O&M [LN]	Changes in output produced [N]	9	16-25	1-3,7,36
	(§2.1.4.2.2.) Market related risk [LN]	(§2.1.4.2.2.1.) Demand [LN]		Change in demand quantity [N]	10	16-25	
				Change in demand price [N]	11	16-25	36
		(§2.1.4.2.2.2.) Resources Supply [LN]	Constr. [LN]	Raw materials [LN]	12	19-29	1-6,32,34-35,36
			Constr. [LN]	Equipment [N]	13	19-29	1-6,32,34-35,36
			Constr. [LN]	Others resources [LN]	14	19-29	1-6,32,34-35,36
			Oper. [LN]	Fuel, spare parts and others resources [N]	15	16-25	32,35,36
		(§2.1.4.2.2.3.) Financial risk [LN]	General [LN]	Tight money [LN]	16	19-29	7-11,15,30-31,36,39,41
			General [LN]	New liquidity requirements [LN]	17	19-29	7-11,15,30-31,36,39,41
			General [LN]	High-risk premiums [LN]	18	19-29	7-11,15,30-31,36,39,41
			Operating organization finance [LN]	Increased nuclear operating exposure [LN]	19	20-29	4-18,20-31,36,39,41
			Operating organization finance [LN]	Existing debt and need to refinance [LN]	20	19,21-29	4-19,21-31,36,39,41
			Operating organization finance [LN]	Financial ratio deterioration [LN]	21	19-20,22-29	4-20,22-31,36,39,41
			Operating organization finance [LN]	Rising cost of debt [LN]	22	19-21,23-29	4-21,23-31,36,39,41
			Operating organization finance [LN]	Limited & declining cash & equivalents [LN]	23	19-22,24-29	4-22,24-31,36,39,41
			Operating organization finance [LN]	Weak balance sheets [LN]	24	19-23,25-29	4-23,25-31,36,39,41
			Operating organization finance [LN]	Underfunded pension plans [LN]	25	19-24,26-29	4-24,26-31,36,39,41
			Project finance [LN]	High hurdle rate for risky projects [LN]	26	19-25	4-6,12-14,16-25,30-31,36,39,41
			Project finance [LN]	Impact of large project [LN]	27	19-25	4-6,12-14,16-25,30-31,36,39,41
			Project finance [LN]	Debt load and service burden impact [LN]	28	19-25	4-6,12-14,16-25,30-31,36,39,41
			Project finance [LN]	Capital structure distortion [LN]	29	19-25	4-6,12-14,16-25,30-31,36,39,41
		(§2.1.4.2.2.4.) Technological [N]		Competiveness electricity tech. [N]	30	16-29,37-41	36
				Competiveness nuclear tech. [N]	31	16-29,37-41	36
	(§2.1.4.2.3.) Socio-political risk [LN]	(§2.1.4.2.3.1.) Legal-regulatory [LN]		Ineffective regulation [LN]	32	4-6,12-15	36
				Inefficient regulation [LN]	33	4-6	36
				Licensing risk [N]	34	4-6,12-14	36,34
				Inspecting risk [N]	35	4-6,12-15	36
				Change in regulatory framework [LN]	36	1-9,11-35,37-38	40
		(§2.1.4.2.3.2.) Social [LN]		Directly [LN]	37	39-40	7,30-31,36
				Indirectly [LN]	38	39-40	7,30-31,36
		(§2.1.4.2.3.4.) Political [LN]		Change in supports and subsidies [N]	39	16-29,34	7,30-31,37,38
				Change in regulation [LN]	40	36	7,30-31,37,38
				sovereignty risk [LN]	41	16-29	30,31

Table 2.4: Large Nuclear risks taxonomy

- *"The types of risks affecting new nuclear reactor projects"* (Ross, 2006): the framework deal specifically to nuclear projects.

As some terms contained into these frameworks differ, (§ANNEX II) permits to connect bi-univocally the different taxonomies.

The risks presented are partly applicable to all large project categories and partly specific to the nuclear one; Table 2.4 deals with two cases, indicating the following acronym within squared parenthesis:

LN: the risk is typical of every large project

N: the risk is peculiar to the nuclear sector and can't be extended to the large project field

Table 2.4 shows only the different typologies of risk and their relative interdependences: three macro areas of risk are identified: technical, market related and socio-political.

Every risk typology (showed by rows) is presented in connection to the others ones: from one hand the risk identified may influences others risky events; to the other one, the risk identified may be influenced by other risky events.

Linkages between risky events permits to understood the high complexity of the risk framework, affecting large and nuclear projects, and also permits to identify domino effects; for example after an incident, public attitude may change, affecting policy which affects legal and regulatory changes which affect the operator finances.

On the other hand (§ANNEX III) shows the entire risk framework, including the following risks features: uncertainty associated to its, level of probability, impact (during project delivering, operating and decommissioning phase).

The typologies of risk just introduce are further discussed in the following sub-paragraphs.

2.1.6.2.1. Technical risk

Technical risks deals with those risks of technical nature; these are partly endogenous to Owners' group and partly induced by the specific context (e.g. blinding safety specifications affecting the reactor design).

The risk taxonomy considers three main subsets of technical risks:

- Reactor design difficulty (§2.1.6.2.1.1.)
- Project execution risks (§2.1.6.2.1.2.)
- Operational risks (§2.1.6.2.1.3.)

These three typologies of technical risk are presented at follow.

2.1.6.2.1.1. Reactor design difficulty

The reactor design difficulty is explicated by three main sources of risk: level of novelty of the project, complexity and constrained environment.

First, the level of novelty and experience associated to nuclear project is one of the main drivers affecting the time and the cost of the nuclear project; many studies emphasized how the FOAK[i] projects have longer lead time and higher cost, e.g. (University of Chicago, 2004), (EMWG, 2007).
This side of technical risk is stressed considering the national or utility strategy in developing nuclear program (§3.1.4.3.): measures for the reactor design standardization are usually taken into account, e.g. France (Sasrty, et al., 2010) and Korea (Choi, et al., 2009).

Second, technical risk is strongly influenced by complexity (§2.1.3.); the high complexity implies high level of epistemic risk[ii].

Third, the nuclear project is deeply constrained because of the prescriptive specifications[iii] affecting: reactor design, nuclear related organizations and sites. These prescriptive specifications are issued by requirements contained into the legal framework[iv] .
The project elements primarily constrained are:
“- Codes and standards
- Design
- Construction and commissioning
- Operation and maintenance
- Safety and licensing
- Quality assurance
- Training
- Project schedule
- Documentation management” (IAEA, 1987)

As result, requirements constrain the project resources (e.g. in terms of organizational capabilities), mechanism (e.g. tools and techniques, quality assurance methodologies, etc.) and objectives.
Adopting the project management perspectives, the project objectives can be grouped in three main set: quality, time and cost (§1.1); on the other hand the IAEA guidelines stress the prioritization of the safety objective with respect the others one (IAEA, 2006), principle 5.

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[i] first of a kind: FOAK
[ii] The epistemic risk derives to the lack of knowledge, it is also called risk “reducible”
[iii] The nuclear sector deeply constrained because of the high safety expectations that national institutions require. The technological features and the history characterizing the nuclear field contribute to explicate why it is deeply regulated. From one hand, the nuclear technology rise risk on people and environment for the high detrimental effect that its unsafe use could lead. On the other hand the history (of the nuclear sector) has showed how an effective legal and institutional framework is a prerequisite to assure the highest level of safety (IAEA, 1997).
[iv] The terms legal framework, as understood into this thesis work, considers the broad set of requirements (mandatory and not) referred to laws, degrees, regulation guidelines, international standards etc. (§3.2.1.3.)

Safety can be considered a project objective or a or just a requirement to accomplish (hence a constrain rather than an objective) depending on the safety culture of the implementing organization. When the safety culture is well developed, the safety represents, for the nuclear organizations, an objective itself (IAEA, 2002).

The safety provisions may be grouped in three main set: technology, organization and resources.

Fig. 2.7 shows the relationship between the project objectives, mechanism, resources and safety requirements.

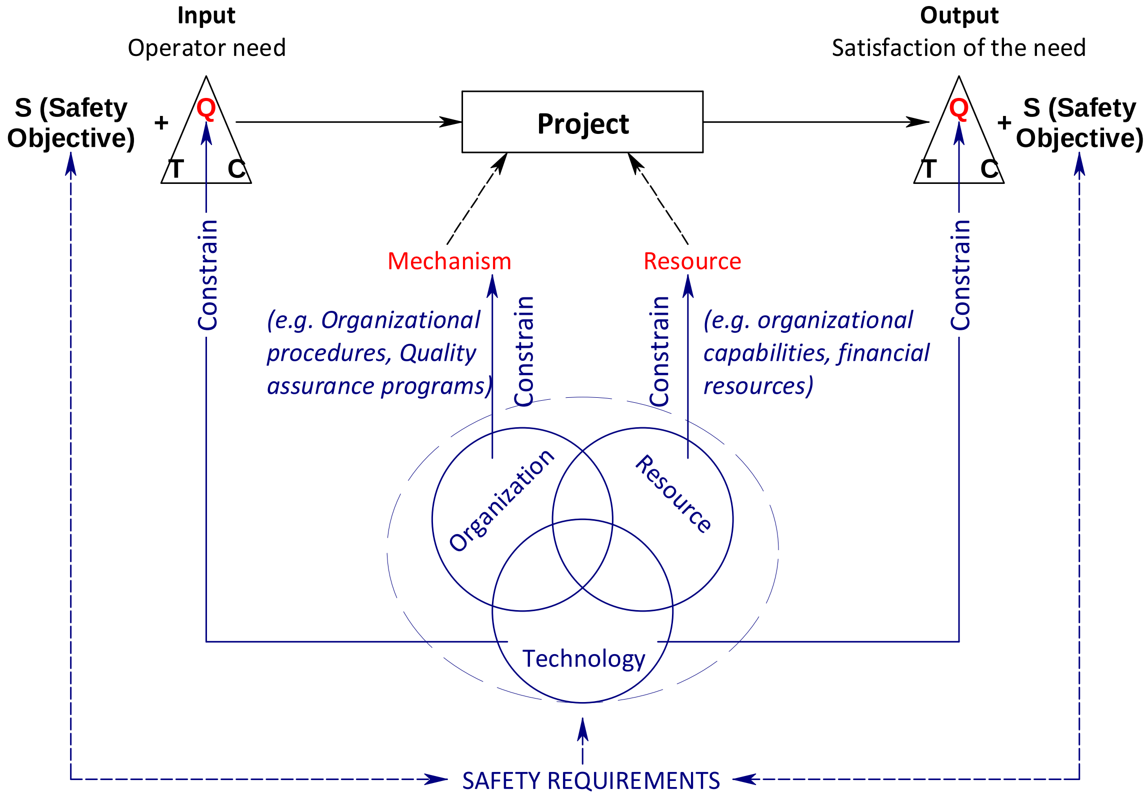

Fig. 1.10: effects of safety requirements into nuclear projects mechanism, resources and objectives

The quality objective can be measured considering measures of tolerance, resistance, reliability, etc. of the nuclear facility elements. This typologies of constrains are typical of the deterministic safety approach, in particular the so called: “safety margins” (§3.2.3.2.2.).

In definitive, these constrains contributes to raise the level of technical risk.

2.1.6.2.1.2. Project execution risks

This risk typology considers three main activities associated to the project development: contracting, construction and commissioning.

Contracting activities can be understood adopting two main perspectives:

- Systemic with respect project network organization

- Specific to the organization which implement contractual relationship with other parties.

Adopting the first perspective, the source of risk is the adoption of ineffective and inefficient contractual measures. These measures can lead to opportunistic behaviours, inefficient and inflexible project development.
Furthermore, contractual arrangement suffers the great uncertainty in considering all possible scenarios and circumstances affecting the project implementation.
A key concern is the experience maturated by implementing organizations and the level of collaboration within the Owners' group (Jarillo, 1988), (Poppo, et al., 2002). Special measures must be addresses when the project complains with international organizations; in these cases (typical of nuclear field) the reference to a uniform language and law framework must be taken into consideration (IAEA, 1987).
Some of the worst scenarios are: parties' litigation, judicial reviews or recourse to arbitration.

Adopting the perspective of a single party, contractual risks consist to the acceptance of aversive contractual measures (in terms of clauses, conditions, specifications, etc.). This may led the organization to bear extra risk. A typical problem is the lack in addressing the contracting responsibilities adopting the endogeneity criteria; in these cases the organization is liable for risk out of its control.

Construction risks are typical of large and nuclear projects.
The sources of risk are diversified in terms of organizational, technical (§2.1.6.2.1.1.), financial (§2.1.6.2.2.3.) and socio-political (§2.1.6.2.3.).
The effects considered are time, cost and quality related (§ANNEX III).

Commissioning is considered especially risky in relation to the licensing process.
The commissioning of industrial facility is itself considered risky because is considered the final check on the facility performances. In some cases, this check may lead to the adoption of claims because the facility performances don't met the reference values reported within contracts (Titolo, 2005).
The nuclear sector is especially affected by the commissioning risk due to the vast potential impact (negative) on project performances. The emphasis on safety implies significant RB' power (in issuing licensing activities); and the achievement of the operating license is of special importance for project success (IAEA, 2007).
As result if commissioning fail to met safety specification, RB have full powers in proposing plant modifications and this scenario is one of the most negative for operator. The assurance on compliance with requirements is of primary importance and must be addressed trough opportune margins.

2.1.6.2.1.3. Operational risks

This section is introduced with lower extent because it doesn't affect directly the project management perspective.

Technical operational risk considers the safety related risk and the technical problems occurring during operation (called in this paragraph: “O&M risks”) such as: plant unreliability, shut down, low efficiency, etc.

Safety related risks deals with scenarios and circumstances that could have impact on the safety of: people, environment and goods. This definition deals with any damage and incident occurring during operating phase of NPP. This risk may have wide range of likelihood and potential impact associated (§3.2.3.2.). The most severe scenario is the core damage and release of radioactive material into the environment. This rare scenario can affects the operators in terms of:

Reimbursement of the damage caused to people, environment and goods (because of the strict and exclusive liability; the reimbursement is most of time covered by the insurance and can be limited in amount by legislator §3.2.1.2.2.), drop of the operator stock price on exchange, loss of credibility and strong public opposition, economic and financial implication due to the early shut down of NPP, high burdens associated to the emergency and post emergency conditions.

On the other hand a minor incident could have effects only into the O&M performances.

Note that the safety related risk, as understood in this section, doesn’t considers the risk of enforcement actions and inspection: these are treated in law and regulatory risks (§2.1.6.2.3.1.).

The O&M risks deals with technical scenarios and circumstances affecting the operating performances of NPP, such as: maintenance delays, plant unavailability, extra costs, etc. These risks are considered mostly endogenous to the operating organization.

The whole set of these risks may have two typologies of impact: on the output sold and on the resources implied for its production.

With respect the first set: thermal efficiency and availability factor (also called capacity factor) are ones of the most important drivers, and may be affected by operating conditions, maintenance, safety related incidents, etc. The success of nuclear project, considering the whole lifecycle, is quite sensible to these typologies of risk (Locatelli, et al., 2010).

The electricity transmission availability is also considered a source of operational risks indeed it’s exogenous with respect operator.

The second set deals with extra cost or low efficiency associated with the operating activities (endogenous to the operator). The extra cost associated to fuel, spare parts and other equipments, purchased from external organizations, are considered resource supply risks (§2.1.6.2.2.2.)

2.1.6.2.2. Market related risks

Market related risks are characterized for the vast uncertainty and exogeneity with respect the organization considered. The sources of such risk can be grouped into four main sets:

- Demand risk (§2.1.6.2.2.1.)
- Resource supply risks (§2.1.6.2.2.2.)
- Financial risks (§2.1.6.2.2.3.)
- Technological risks (§2.1.6.2.2.4.)

These sub typologies of market risks are briefly introduced in the following sub-paragraphs.

2.1.6.2.2.1. Demand risk

(Miller, et al., 2001) refer to the demand risk as forecasting errors (both in terms of quality, quantity and prices) with respect the end products or services of the project.

(Miller, et al., 2001) framework is based on large engineering projects and presents demand risk especially high for large infrastructural projects. For example in transportation projects is difficult to address the demand of services because are specific to the context and few data and decision tools may be available; in these cases the demand quality risk is especially high.

(Miller, et al., 2001) consider the electricity generating technologies with the same demand risk; I personally disagree with this assumption for two main reasons:

First the electricity is a commodity but need to accomplish tree main quality aspects: it must be supplied at the required time, at the required geographical areas and at the required voltage. NPP usually operates on base-load basis and the risk associated to the electricity demand quality is low. By contrast some renewable generating technologies may be affected by discontinue availability (e.g. wind) or periodic cycles (e.g. solar). These features can be considered technical operative risk (§2.1.6.2.1.3.) but at the same time affect the quality of electricity services provided. As result these later technologies may find more difficult to match electricity demand, enhancing higher demand risk with respect nuclear technologies.

Second the impact of the demand risk, for generating technologies, is not uniform and mostly depends on the cost structure.

Nuclear technology is capital intensive and the greatest portion of cost, associated to the electricity production, derives from the initial investment. As result the nuclear cost structure is more "rigid" with respect the other technologies because the greatest portion of the costs is not evitable in function of the output produced; as showed in Table 2.5.

	Nuclear	Gas CCGT	Coal	Wind
Investment	50-60%	15-20%	40-50%	80-85%
O&M	30-35%	5-10%	15-25%	10-15%
Fuel	15-20%	70-80%	35-40%	0%

Table 2.5: Generation cost splitting of different generating technologies (AREVA, 2006)

Hence when the price of the electricity (sold in the market) is lower than his cost (or when the electricity demanded is lower than the one produced), the nuclear plants can't avoid most its costs; the same doesn't happens to others generating technologies where the cost mostly depends on fuel (e.g. combined cycle gas turbines).

These latest technologies are more flexible and then are lesser affected by the demand risk (for this reason are usually included into the generating mix on base line basis).

As result electricity generating technologies are not affected by the same level of demand risk.

2.1.6.2.2.2. Resource supply risks

Resource supply risks derive from lack of access or availability of required items and materials or for the change in supplying conditions (such as change in prices).

This typology of risk affects all phases of NPP, especially the construction and operation phases.

During construction, the unavailability of some equipments, machines or items may cause schedule delays.

Especially the manufacturing and transportation of reactor vessel and others major equipments may require several months; most of times these activities are close to the critical project paths[i] and their delays may cause the delay of the entire project.

Another supply risk consists to the change of prices of raw materials (such of steel and concrete); these risk need to be addressed by opportune financial and contractual instruments.

The most important typologies of supply risk, affecting the NPP operation, are: rise of fuel cost and unavailability of spare parts.

The first risk have moderate impact into the nuclear project as whole (Locatelli, et al., 2010), (AREVA, 2006) and can be secured trough long terms contract.

The unavailability or delays in purchasing of spare parts may have significant effects (on financial performances), if the absence of these causes the lowering of electricity produced.

2.1.6.2.2.3. Financial risks

Financial risks are grouped into three main sets: general, utility finance and project finance.

General financial risks deal with the ones generated by financial markets; these are considered exogenous with respect Owners' group. For example the volatility of interest or currencies may affects the nuclear project in terms of final cost and financial performances.

[i] Or few slacks are associated to its.

Utility finance deals with financing risk affecting the operator: most of these are the consequence rather than initiating risks (as showed in the §ANNEX III).

One of the most important effects is the impact on the operator's credit metrics (Moody's, 2009).

Finally the project finance risks affect the project implementation, like the previous typology can be seen more as effects rather than an initiating risk.

It considers the impact on the project finance and not on the operators one, hence may affect all or a part of the organizations involved into the project (depending on the contractual approach put in place).

2.1.6.2.2.4. Technological risks

Technological risks deal with the competiveness between electricity generating technologies.

The risky events considered is: "new generating technologies (nuclear technologies or others generating ones) achieve better performances (in terms of efficiency, cost, availability, environment and safety)".

This event shall be understood in connection to a specific reactor design which compete with others standards and technologies

The consequences of such risk must be evaluated in parallel with the socio-political risks (§2.1.6.2.3.): e.g. change in regulation, subsidies and public attitudes.

These typology of risk is not considered into the general risk taxonomy applied to large project (Miller, et al., 2001).

2.1.6.2.3. Socio-political risk

After the Chernobyl accident in 1986 a fundamental change of mind was made by Governments and citizens because they clearly recognise the potential detrimental effect of the nuclear power[i] (IAEA, 2002); as result some countries has introduced a moratoria for the construction of new nuclear facilities[ii] (e.g. Spain), others enforced their law and regulatory framework to improve the level of safety system (e.g. USA).

Today the global scenario is facing similar conditions because of the Fukushima accident.

The socio political risks are ones of the most incisive, to nuclear projects, for three main reasons:

- After the Chernobyl accident the legal requirements has become of primarily importance (§3.2.1.) and deeply affect the nuclear project (§2.1.6.2.1.1.).
- After Chernobyl accident the public must be heard and correctly informed before the NPP deployment (IAEA, 2002).

[i] The history of the nuclear development is presented in the section (§3.2.1.)

[ii] The most severe action was undertaken in Italy, where the Government forbids use of the nuclear energy

- Nuclear technology need to be supported by governments: directly through the instauration of subsidies (Thomas, 2010), (Paterson, 2003)and indirectly through the implementation of part of the nuclear infrastructure (§3.1.4.2.).

The paragraph is divided into three sub paragraphs dealing with specific socio-political categories of risks:

- Legal-regulatory (§2.1.6.2.3.1.)
- Social (§2.1.6.2.3.2.)
- Political (§2.1.6.2.3.4.)

These are briefly introduced at follow.

2.1.6.2.3.1. Legal-regulatory risks

Legal-regulatory risks deals with those risks generated within the legal framework and could have a wide range of effects on nuclear projects.

The main sources of risk identified are: ineffective regulation, inefficient regulation, licensing risks, inspecting risks and change in regulatory framework.

Ineffective regulation may pose risk on project due to the lack of appropriate regulating measures or due to the inexistence of opportune legal and contractual instruments (e.g. propriety rights).

Countries, which embark a nuclear program for the first time, may find problematic settled down an entire legal infrastructure and then may adopt a grating approach (§3.1.4.3.), in such cases the legal framework, early drafted, may lack on some elements.

Inefficient regulation may impose vast bureaucratic effort in terms of cost and time and consequently deteriorate some project performances.

Licensing risks affect the early phases of the nuclear project implementation and could have severe impact on project development.

Usually RB has full power to request modifications of: organizational procedures, reactor design documents, etc. Severe problems arise when the request of modification is issued after the deployment of the related scope.

On the other hand the delays, in issuing documents and permits, may have impact on the project schedule and costs.

The worst, quite rare scenario, is when the license never occurs and the plant need to be decommissioned before entering into the operating phase.

Licensing risks are further discussed in (§4.2.4).

Inspecting risks arisen when the RB, during its inspections, find lacks in compliance with safety principles (and others requirements) (§3.2.3) by operator (or others actors).

This risk is mostly referred to operating and decommissioning phase of NPP (because during the early phases the regulatory control is mostly based in licensing issuance).

It's a common practice that RB personnel have full access to every facility and documentation; furthermore, in some countries, the RB personnel may be located within the nuclear sites on permanent basis (this case refers to the resident RB inspectors) (IAEA, 2002).

The inspections may be more pervasive during: safety reviews, temporary shutdown, maintenance periods, refueling and after incidents or emergency conditions.

The effect of this risk is based on the enforcement actions put in place by RB; these measures consist on: civil sanctions, imposed safety measures or plant modification, early shut down (on permanently or definitive basis); in the most severe cases RB may appeal on penal court.

The civil sanctions, license suspension, modification and revocation are instruments by which RB imposes the enforcement actions to operator[i].

Changes in legal and regulatory framework are a dangerous risks for every organization operating in nuclear field.

This risk may have a wide range of effects on nuclear project, and the probability it takes place is very high, in some cases is certain[ii] during operating and pre project phases. During the project implementation is possible that RB and Government take measure for mitigate the level of uncertainty associated to the legal environment, including the reducing regulatory activities.

Furthermore RB have limited resources and, during the project implementation phase, may have not sufficient resources to carrying out the entire sets of its duties (§3.2.2.1.) and then licensing ones may take the precedence.

Generally, new regulatory requirements consist on: elevation of safety levels (associated to the activities regulated), compliance with the technological advances[iii], compliance with new legal requirements, compliance with international instruments (such as international conventions, agreement, treaties, etc.; (§3.2.1.3.3.), and measures to rend more effective and efficient the activities related to the nuclear organizations and RB.

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[i] Civil sanctions may be imposed to actors different to the operator. On the other hand the issuance of license modification, suspension or revocation may be applied only to the operator which is the license holder (licensee).

[ii] There are countries where regulation is amended on periodic basis, e.g. USA. Indeed the probability that a regulatory change is certain its consequences remains uncertain then even these cases must be considered as typologies of risk.

[iii] Nuclear laws, regulations and statutes usually refer to terms such as: "highest level of safety", "as low as reasonably possible" ALARP (in considering the safety risk). Then new safety and technological advances may force (in theory) changes on requirements to accomplish the previous principles. The problem arises in considering the "old" existing facilities that don't accomplish the new, more severe, requirements (this risk is derived from technological risk §2.1.6.2.2.4.). A similar scenario affected all existing RBMK NPPs after Chernobyl accident (§3.2.1.). In these cases, usually legislator and regulator apply different level of prescripteneвess for new and old generating technologies (this is made through the use of appropriate instruments such as license conditions §ref license conditions). On the other hand, the old facilities may be affected by other crafted prescriptions for upgrade the level of safety such as plant modification.

Apart to the last measures, the others could effects negatively on specific nuclear project because of the embitterment of legal and regulatory prescriptions.

Finally changes in regulatory framework pose significant risks because of the vast uncertainty affecting the nuclear field.

2.1.6.2.3.2. Social risks

Social risks are typical of large project and more in particular nuclear ones.

This source of risk is explicated by two main factors:

- degree of acceptability or opposition of citizens
- effect that these could have into the nuclear project

The term citizen is understood in double sense: as people living within the country (where the nuclear project is deployed) or as subset of these, such as group of citizens (e.g. opposition groups).

The degree of acceptability of citizens depends on the historical period and on the country considered (because of the citizen's: culture, attitude on nuclear technology, trust on institutions, etc.).

This typology of risk is considered mostly exogenous to government(and to nuclear organizations) but can be partly affected trough appropriate measures; such as modifying the level of transparency, communicating strength or weakness[i] of: nuclear technology, implanting organizations and related performances; or implementing other measures for enhance or reduce public confidence. With this respect media play a central role.

Indeed studies advocate how the nuclear confidence is grown over the time (after Chernobyl accident), e.g.(Herbst, et al., 2007), Fukushima incident lets drop again the confidence on nuclear technology worldwide, especially in those countries where citizens have traditionally being lowly confidents on that.

A typical public behaviour consists on the: "not in my back yard" NIMBY syndrome; which consist on the public reluctance (with respect the nuclear project) for citizens who live into the nuclear site vicinity.

On the other hand the degree of public involvement, on nuclear project choices, distinguishes between the direct and indirect impact that citizens could have on it. Direct effects can be contemplated or not by the legal framework: the first case deals with public inquiries, the second with opposition groups affecting the project development[ii] (e.g. interference at the nuclear site made by nuclear opponents).

[i] Influencing the public attitude on nuclear power is understood in both senses (enhancing and reducing confidence on nuclear technology or specific nuclear project), depending on the objectives of the implementing actors. For example German government is showing its reluctance to nuclear energy; on the other hand Italian one is trying to support the nuclear choice.

[ii] This risk is considered to have moderate impact on nuclear project but high uncertainty associated to it.

The IAEA suggest at minimum two point of connection between the institution and the public opinion (IAEA, 2010): first, in the early phases of the nuclear program, when the government is deciding to embark, or not, the nuclear option; second during the licensing process for the construction of any nuclear power plant[i].

On the other hand indirect effect of social risk refers to the citizens rights to influence the national or local policy trough elections, this case deal with the political risks (§2.1.6.2.3.4.).

2.1.6.2.3.4. Political risks

Political risks refer to changes on nuclear policy.

The source of such risk may be different, the most important are: nuclear incidents (§2.1.6.2.1.3.), new technological discover (§2.1.6.2.2.4.), social related risks (2.1.6.2.3.2.) or changes on national electricity strategy.

The possible effects relate to changes in legal framework (§2.1.6.2.3.1.) and changes on subsidies affecting nuclear sector[ii], such as tax: loan guarantee, direct loan, limited nuclear liability in amount (§3.2.1.), minimum electricity price and quantity guarantee, etc.

Government plays a central role in the nuclear program (such as nuclear infrastructure development §3.1.4.2.); without its support nuclear program never occur.

Furthermore government power is connected to licensing decision in most countries (Bredimas, et al., 2008).

As result the political risks have great effect on nuclear project (and more generally on nuclear sector) due to the vast uncertainty and due to the potential impact that these could have.

2.1.6.3. Ranking of risk for large and nuclear projects

This paragraph is spitted into two parts: first the main measures implied to rank risk are introduced ad discussed (§2.1.6.3.1.); then a generic ranking of risks, affecting nuclear and large project, is argued (§2.1.6.3.2.).

2.1.6.3.1. Measures implied for ranking risks

The different typologies of risk are characterized by probabilistic attributes: probability of occurrence, severity of consequences, level of uncertainty associated and correlation with others sources of risks. These features represent the basis which permits to ranking the risks.

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[i] In the simplified framework I'm considering only the NPPs; in reality the nuclear program contemplate different types of nuclear facilities.

[ii] Indirectly even subsidies to others electricity generating technologies may impact on nuclear sector; e.g. subsidies on renewable technologies.

Others measure such as: level of control (in terms of endogeneity) of risk, or measures reflecting the available protective and preventive actions may be considered as well for ranking risks.

Some authors suggest to ranking risk using the expected value (§1.4.6.) of the probability distribution describing risks (Zhi, 1995).
This approach is incomplete and may led to incorrect risk ranks because it doesn't considers, for example[i], a a measure of dispersion of the probability distribution describing risk (Williams, 1996).
The concept of uncertainty is of primary importance in characterizing risks.
The assumption made, for introducing the quantitative risk, is the knowledge about the probability distribution describing it; in the better cases the probability distribution is estimated, most of time no or few data are available for infer a probability distribution (Chapman, et al., 2003).
These real cases underline how the previous definition of risk lacks in a fundamental element: the level of knowledge and confidence associated to the risk under evaluation.
Lack of knowledge means uncertainty then risk.
There are two main typologies of uncertainty: epistemic and aleatoric one (§1.4.6.).
Epistemic uncertainty is reducible due to the growing of knowledge associated to the phenomena under study. In the nuclear project field, the epistemic uncertainty is strongly connected to the level of novelty and experience maturated (by the implementing organizations) on the specific reactor design and project; complexity also deals with of epistemic uncertainty.

On the other hand aleatoric uncertainty refers to the permanent uncertainty, not reducible, explicated by natural phenomena.

In operative terms, it's difficult to find a measure describing the level of epistemic and aleatoric uncertainty; this can just be addressed trough expert judgments.

Correlation between risks is a fundamental element to be considered in raking risks. For example may existing risks with low probability of occurrence, low impact and with high degree of confidence on its; if independently assessed these risks may be considered insignificant.
But considering the holistic view of project risk, these may give a greater contribute to total risk due to the high correlation (positive and/or negative) with others risks.
Most of time correlation between risks is not implied for ranking risk due to the lack of data (a part for the safety related risk, §3.2.3.2.2.).

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[i] Assumed that the probability distribution describing the risk is well known; this happens in rare cases in project management, especially for large project (Chapman, et al., 2003). The expected value and the variance associated to the risk curve are not the only measures that can be implied. For example the Skeweness and Kurtosis or others measures may be contemplated as well (Bramanti, 1997).

Finally the possible measures to avoid or mitigate risks may be considered as well, because these change the sensitivity that project, and implementing organizations, have with respect risks (and then affect the risk ranking).

2.1.6.3.2. Large and nuclear project risk ranking

Fig 2.8 shows a complete ranking of risk affecting nuclear project in United States; the data implied derives from two WNA surveys, carried out through the use of qualitative analysis (ref to the studies) (Paterson, 2003).

These studies have been undertaken trough interviews to senior managers operating in the nuclear field.

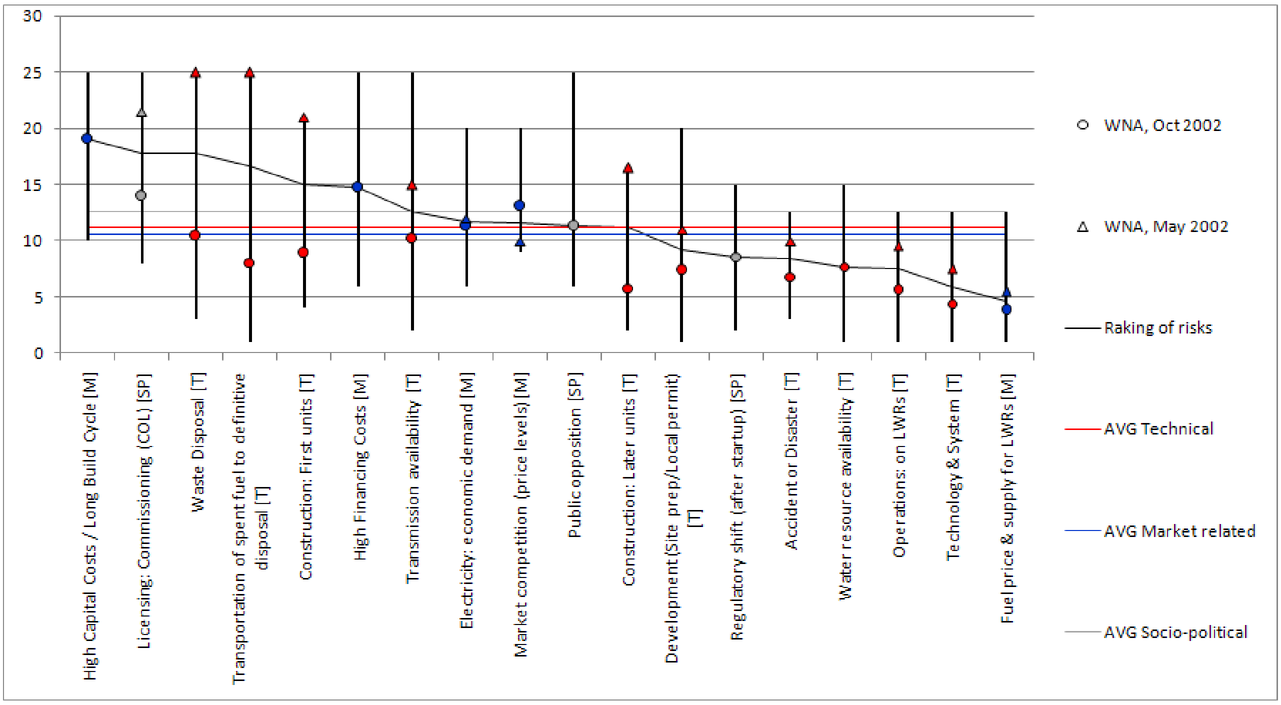

Fig. 1.11: Nuclear project risk ranking

Fig. 2.8 show the different sources of risk on the horizontal axe and the risks score by vertical one.

The risk sources are catalogued trough the taxonomy adopted by this study (§2.1.6.2.); every source has associated an acronym (enclosed within squared parenthesis) indicating the set of reference:

T- Technical risks

M- Market related risks

SP- Socio-political risks

The colour of the markers also refers to these three sets: red for the first, blue for the second and grey for the third.

The risk scores dominium belongs to the interval: zero/ twenty-five, extremes included.

The scores obtained, by the two surveys, are identified by the marker shapes as showed into the legend; and the vertical lines indicate the risk ranges (indicating the minimum and the maximum scores values of the risks; the ranges can be considered rouge measures of dispersion).
Some risks have associated the score of only one study (the later one) because the other one did not addresses such source of risk.
The risks are ranked trough the average of the score obtained by the two studies; black line indicate these score values.
Finally the horizontal and coloured lines show the average score obtained for the three macro sets: technical market related and socio political risks.

The figure shows how the licensing risk is perceived one of the most important risks affecting the nuclear projects. Many others risks refer to the operating phase of the nuclear facility; these are less interested adopting the project management perspective.

Fig. 2.9 shows the risk ratings trough its two dimensions: probability of occurrence and severity of consequences (this figure refers to only to the second survey: WNA Oct, 2002).

The marker shapes and colours indicating the main risk sets as reported into the legend.
Iperbolic lines indicate the iso-risk curves, passing through the risks identified; these permits to ranking the risk in the severity/probability plot.
Furthermore the plot is divided into four quadrant by the lines called:
- AVG probability
- AVG Severity
These lines indicate the average level of probability and severity of the whole set of risks presented.
Finally the average risk is showed by solid line and divides the risk plot into two sets: higher risk and lower ones.

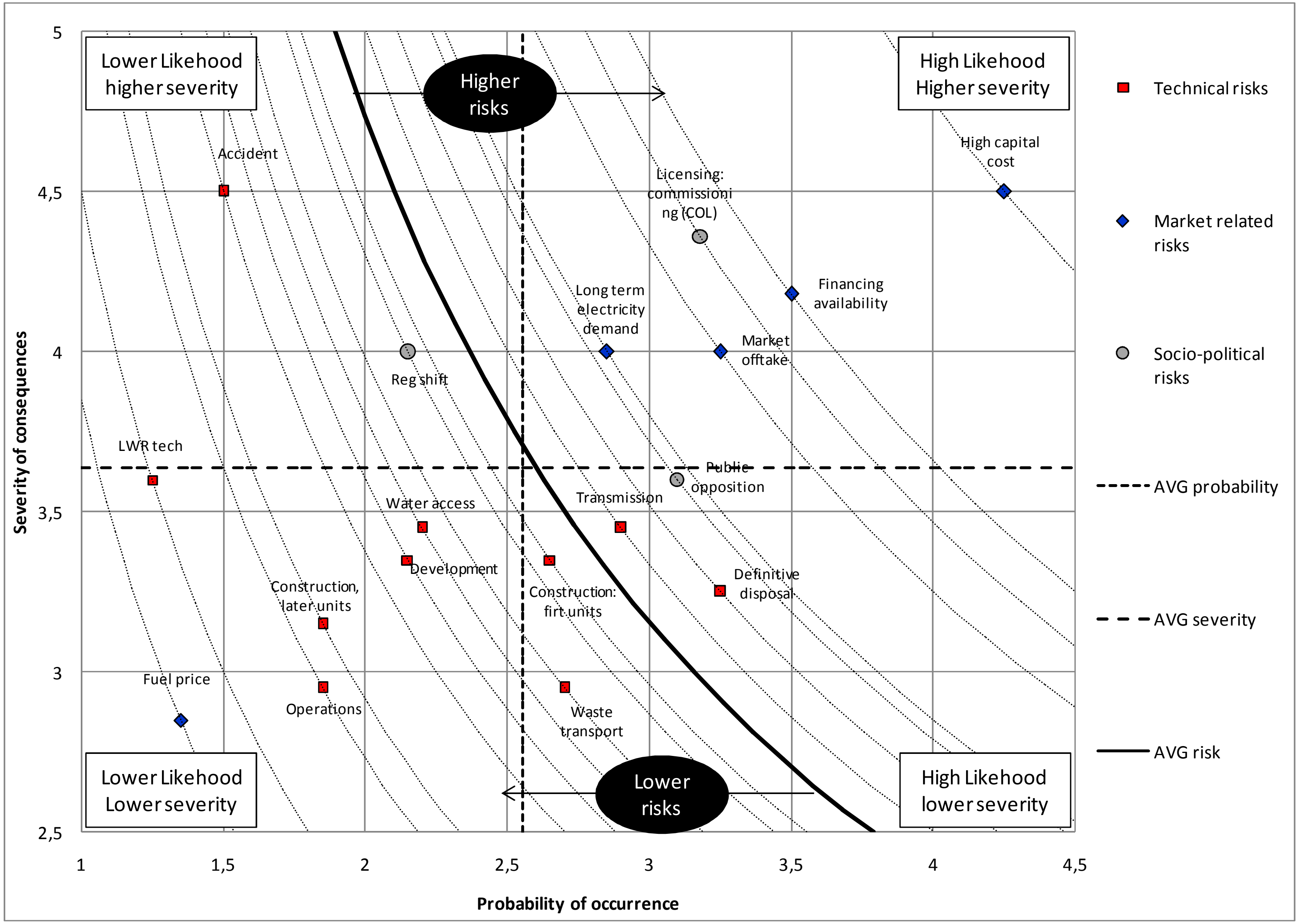

Fig. 1.12: Nuclear risk plot (Paterson, 2003)modified figure

Fig. 2.10 shows a comparison, of the risk' ranks, between large project (Miller, et al., 2001) and nuclear ones (Paterson, 2003). The risks belonging to the two studies have being opportunely grouped adopting the risk taxonomy introduced by this study (§2.1.6.2.).

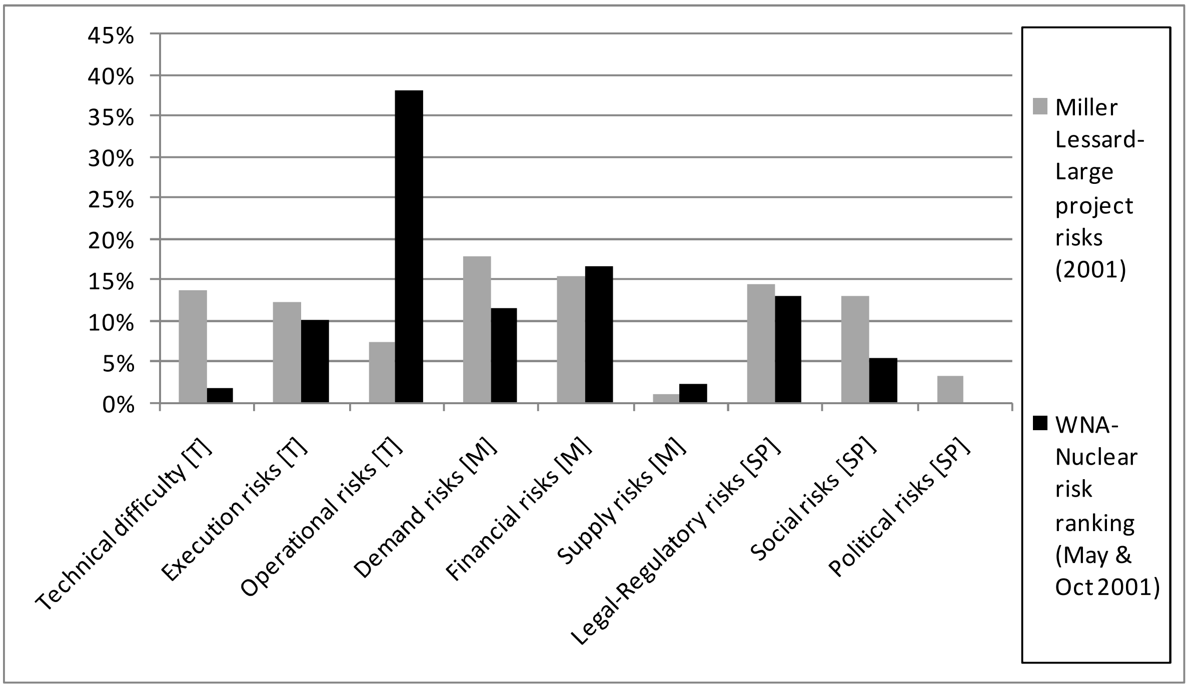

Fig. 1.13: relative comparison between risk typologies affecting Large and nuclear projects

The graph adopts relative data; then the two distribution must be compared in relative sense. For example the technical difficulty of nuclear projects may be higher with respect the large project ones indeed the graph show the contrary; the information deducible from the graphs is that the technical difficulty of nuclear reactor is lower than operational risks, the same doesn't happens to large project.

In general the level of complexity and the operational risks are higher for those projects producing dynamic outcomes (such as industrial facilities) with respect the project producing static outcomes (such as roads, building, etc.) (Titolo, 2005).

Fig.2.10 permits to have a general view of the comparison between nuclear and large project risks, but it is not so specific with respect the project management purposes.

Fig.2.11 shows a relative ranking of risks affecting large projects and nuclear ones. The graph is obtained through a subset of data adopted by Fig.2.10.

The subset is chosen eliminating all risk referred to the operational phase projects, and permits to focus on relative risk distributions affecting project management.

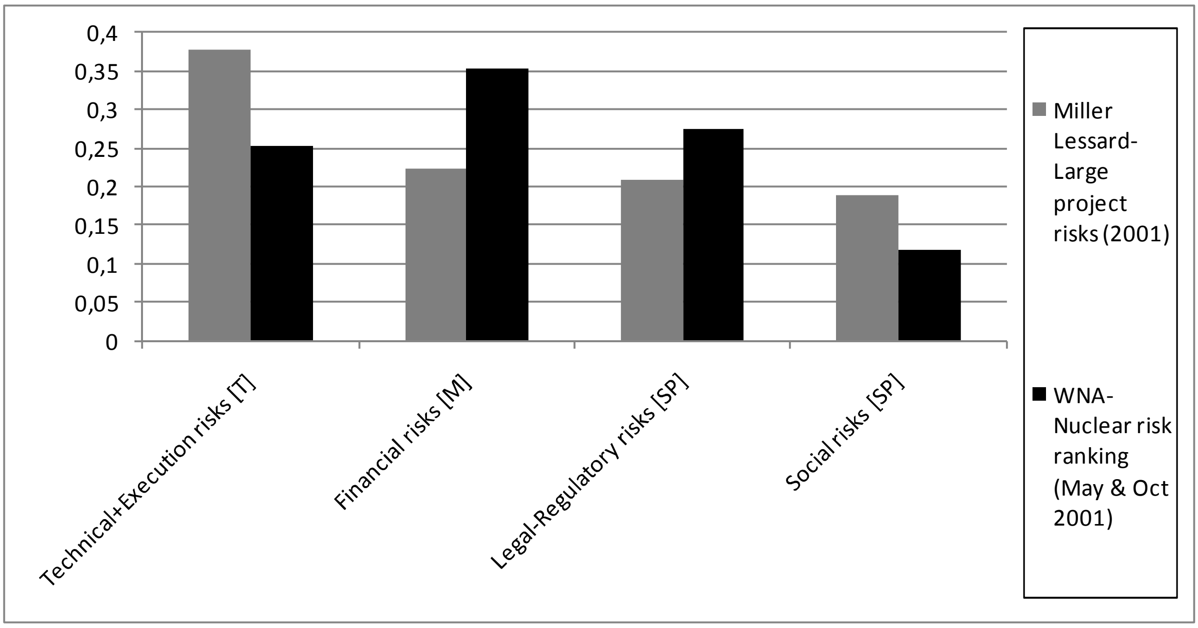

Fig. 1.14 relative comparison between project development risks affecting large and nuclear projects

Fig 2.11 permits to underline the main differences between risk patterns affecting large projects. Large projects are, in general, affected by higher technical and execution risks; by contrast the large nuclear projects are affected by financial and legal-regulatory risks.

In presenting this distinctions shall be underlined that the risk ranks have been obtained trough qualitative surveys, hence may exist discrepancies between the risk perceived and the real ones (especially in large field characterized for the vast uncertainty and scarcity of data).

Finally an absolute comparison between large projects and nuclear ones is showed in the Fig.2.12
The three axes (technical difficulty[44], market related risk and socio-political risk) are consistent with the taxonomy discussed in this chapter (§2.1.6.2.).

This last figure emphasizes the greater risks that nuclear projects have, in absolute terms, with respect the other large projects.

The previous rankings presented lacks in issuing measures of uncertainty and correlations (2.1.6.3.1.); a qualitative consideration of these is issued within the complete risk taxonomy (§ Annex III).

[44] Technical difficulty is a sub set of technical risks ((§2.1.6.2.).

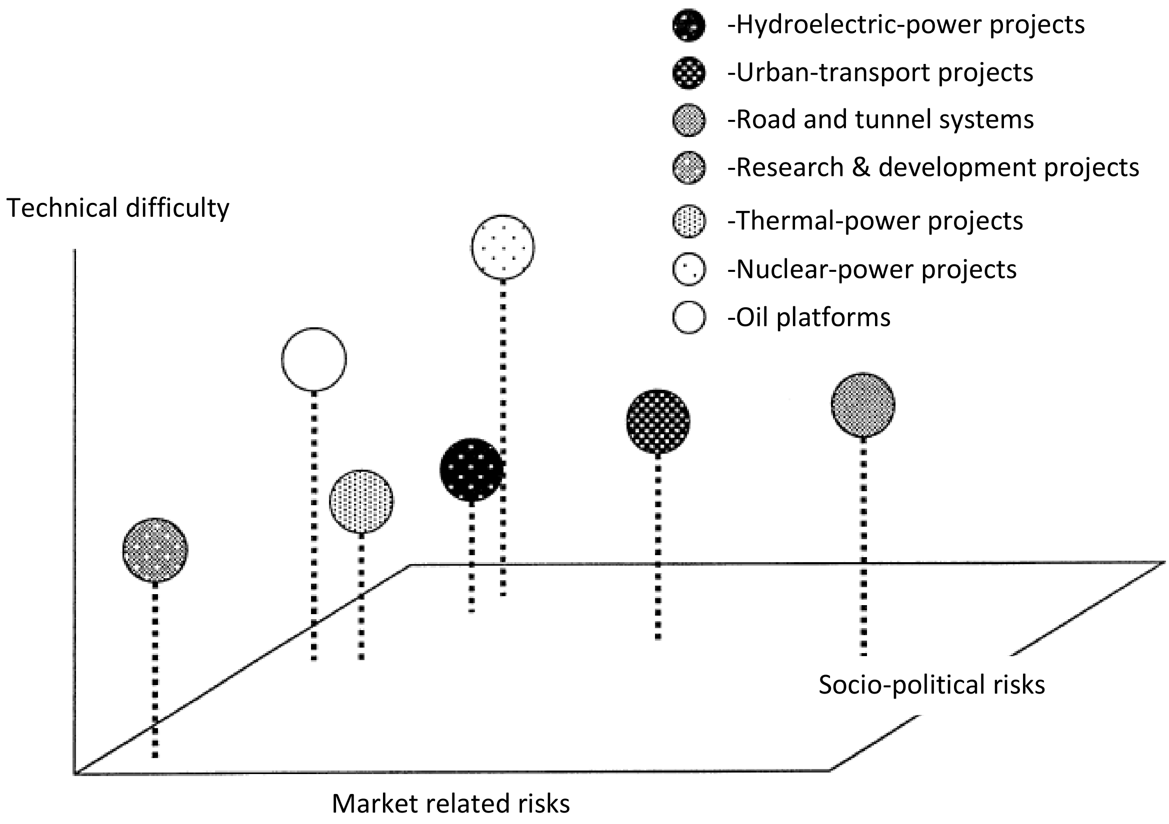

Fig. 1.15: A risk-based taxonomy of large engineering projects (Miller, et al., 2001), revised figure

2.1.6.4. Financial implication of nuclear project risks

The financial implication must be addressed considering the electricity price market and the generating technologies; this is in contrast with the structure of the chapter, because focuses on nuclear project as electricity generation technology and not as large project.

Nuclear investment (large NPP) is characterized, by its intrinsic nature, for:

- High up front commitment (because is capital intensive, §2.2.1.)
- Long lead time for recover the initial investment (long payback time, §2.2.2.)
  - Vast risk, especially during the early phases of project where there is vast uncertainty associated to the investment scenarios (§ANNEX III).

For these reason, nuclear investment is perceived more risky, with respect the others generating technologies, by investor (Moody's, 2009).

Table 2.6 present some estimations of the weighted average cost of capital WACC components; It shows risk premium of 3-4% required from interest rate, furthermore other studies also suggest that, in the nuclear project, is required an higher percentage of equity, which further push up the WACC (AREVA, 2006).

Plant	Source	D (%)	Kd (%)	E (%)	Ke (%)	WACC, before tax
Coal	MIT (2007)	55%	7%	45%	12%	9%
Coal/CCGT	NETL (2007)	45-50%	9-11%	50-55%	12%	10,1-12,1 %
	EPRI (2006)	45%	9%	55%	12%	10,7%
	MIT (2003)	60%	8%	40%	12%	9,6%
Coal/CCGT/Nuclear	Ayres et al. (2004)	50%	8%	50%	12%	10,0%
Nuclear	University of Chicago (2004)	50%	10%	50%	15%	12,5%
	MIT (2003)	50%	8%	50%	15%	11,5%

Table 2.6: Comparison between WACC of electriciyu generating technologies (Locatelli, et al., 2010), revised table

These financial consequences contribute to reduce de competiveness of the nuclear technology with respect others technologies.

Government usually may find appropriate the adoption of appropriate subsidies (such as direct loan, loan guarantee, carbon tax, electricity price floor, etc.) to incentive the deployment of nuclear facilities.

As government may put in place the subsidies with different extent usually some studies ((Sustainable development commission, 2006) refer to two possible cases:

- Supported: which implies vast participation of the government into the project through direct loan (for vast percentage) with low interest rate: the resulted WACC is in these cases in the order of 5-7%
- Market free: the resulted WACC is in the order of 9-10% as showed by Table 2.6.

2.3. Conclusion

This paragraph presents three main remarks:

First: nuclear projects are large projects from all point of views.

Second: nuclear projects are characterized for peculiar risks due to the constrained environment.

Third: nuclear project require an opportune infrastructure to be developed.

Nuclear project can be considered a large project from all points of view

- Is capital intensive (§2.2.1.)
- Is characterized for the long time horizon (§2.2.2.)
- Is a complex project (§2.2.3.)
- Is a strategic and sensitive project for governments, societies, and industry (§2.2.4.)
- Is a physic infrastructure having relevant impact on environment and landscapes (§2.2.5.)
- Is characterized for the high risk, especially in the early phases (§2.2.6.)

Nuclear projects are characterized for the higher complexity and risk with respect the others typologies of large project.The safety significance of nuclear technology imposes prescriptive specifications constraining the project environment.

From project management point of view this implies rigid and unbalanced project objectives (understood as triad TCQ).

Fig. 2.13 shows the nuclear project risk paradigm: distinguishing between the common large project features and the peculiarities of the field.

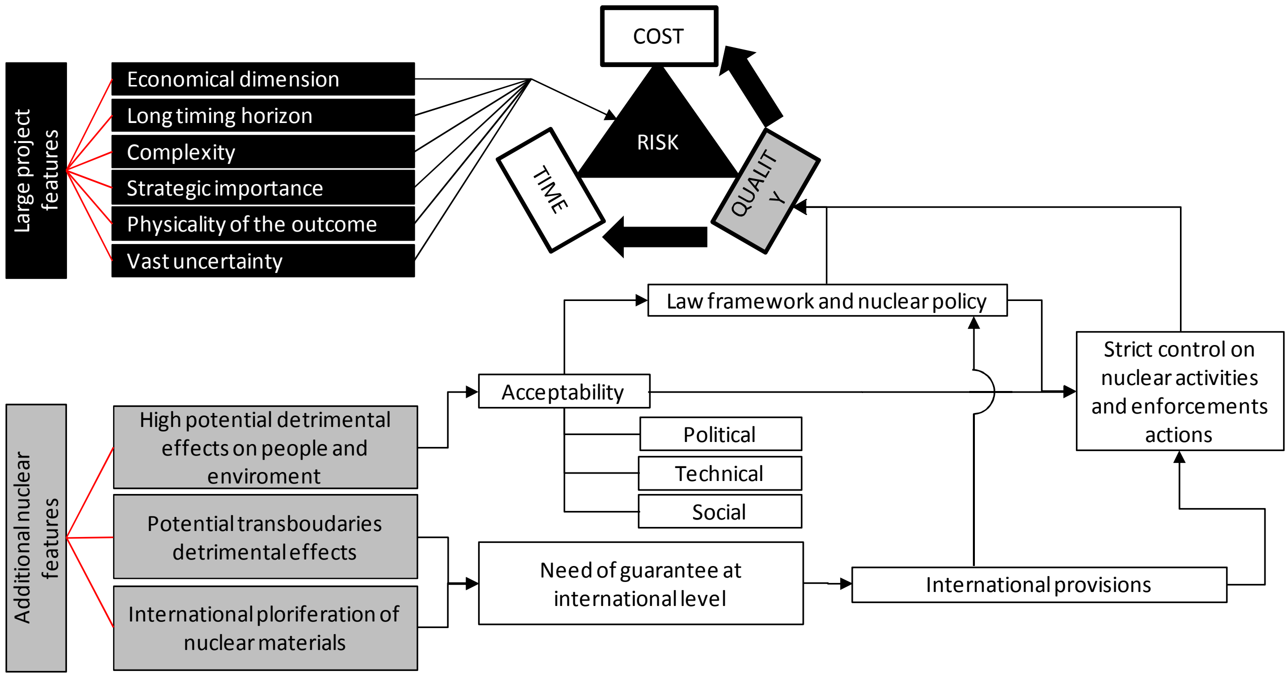

Fig. 1.16: effects of specific nuclear project features on project objectives

Figure 2.13 shows that the quality (the safety related elements) is constrained; and the cost and schedule objectives are of secondary importance (then can be scarified with respect the first one).

The emphasis on safety concerns, and the nuclear project features in general, require the development of appropriate infrastructure (especially the safety one).

Regulatory body, legal frameworks are fundamental elements of such infrastructure and must be developed before the construction of any nuclear project.

The nuclear infrastructure is a central element connecting the single nuclear project with the licensing process (as argued in the next chapter).

Outline of the chapter

- Nuclear projects are large projects from all point of views
- The peculiarity of nuclear project relates to the safety concerns which require a special legal and institutional regime. This implies a deeply constrained project environment.
- The project triad objective (TCQ) resulted unbalanced because of the safety significance and constrained environment.

3. The nuclear programme and infrastructure

This chapter deals with the nuclear program as development of the nuclear infrastructure; it represents a fundamental point of connection between the nuclear project and the licensing process. From one hand the licensing process is supported by the nuclear infrastructure: its rules, procedures, capabilities and institutions are developed in the early steps of the nuclear programme.

On the other hand the licensing process becomes a fundamental piece of the nuclear infrastructure and supports the development of the nuclear project.

The chapter is divided into two main paragraphs: the nuclear programme (§3.1) and the nuclear infrastructure (§3.2).

The first introduces the main concepts: the nuclear programme definition (3.1.1), its objectives (§3.2.2), its steps (§3.1.3) and the actors role into its deployment (§3.1.4).

The second paragraph presents the main infrastructural elements affecting the licensing process: the legal infrastructure (§3.2.1), and the specialized nuclear institutions (§3.2.2) and the safety principles, tools, criteria and Requirements (§3.2.3.).

3.1. The nuclear program

In this paragraph the nuclear program is presented in connection to the nuclear infrastructure (§3.1.1). Second the main steps of the nuclear program are introduced (§3.1.2) and finally the actors role into the nuclear programme is argued: the presentation of these actors (§3.1.4), their involvement into the nuclear programme (§3.1.4.1), their role in terms of responsibilities and functions undertaken (§3.1.4.2) and the possible approaches that differs due to the actors leaderships (§3.1.4.3).

Most of the bibliographical founts are contained into the "IAEA framework" which consists on the whole set of publications, representing the institutional and technical best practices (especially for safety purposes).

The IAEA framework is contained into the "safety standards" (hierarchical representation consisting in three sets: "safety fundamentals", "safety requirements" and "safety guides"), technical guides, books and other publications; which are consistent among them.

3.1.1. Nuclear programme definition

A nuclear programme consists to the planning and development of large scale (at country level) of nuclear activities. There are two main typologies of nuclear programs: civil program and defense related one; indeed, in some countries, these two typologies of nuclear programs are partly overlapped, this thesis work considers only the first one: the civil nuclear programs. The distinction between the civil and military field is also stressed into the international legal framework (IAEA, 2010) and consequently in all the national ones (§3.2.1.).

The main activity related to the civil nuclear programs is the generation of electricity (in conjunction with other ends product[45], e.g. remote heating).

Other typologies of nuclear activities, like the scientific research, the medical one or other minor industrials application (e.g. industrial radiology) don't connoted itself a nuclear program.

The training and research can be understood as part of the nuclear program when are instrumental to its development.

The IAEA framework emphasizes the supporting role of the nuclear infrastructure with respect the deployment of the NPPs (IAEA, 2006), especially in nuclear safety terms (IAEA, 2010).

The basic[46] elements of the nuclear infrastructure are:

"- National legal framework and international agreements

- Nuclear safety regulatory body and environmental regulatory authority

- Physical facilities

[45] Comprising whole, or a subpart, of its related supply chain; e.g. fuel enrichment and fabrication, mining and milling, reprocessing, etc.

[46] The "basic" infrastructure elements are the minimum elements required for the deployment of the first NPP

- *Finance/ Economics*

- *Human resources, education and training*

- *Operational practices and processes to assure safety and performance throughout the life of the facility*

- *Public information and acceptance"* (IAEA, 2006)

As previous argued, the definition of nuclear infrastructure takes into account also the nuclear facilities and all elements necessary to the safely generation of the electricity derived from the nuclear fission.

3.1.2. Nuclear programme objectives

The nuclear programme is an instrumental project associated with two typologies of aims.

The first typology consists to the nuclear infrastructure development.

The second aim typology consists to the achievement of the following objectives (IAEA, 2009):

- Allowance of and economic, safe and reliable electricity source
- Geopolitical electricity generation independency (or diversification)[47]
- Country's economic development
- Employment
- Technological growth

3.1.3. Main steps of the nuclear program

The nuclear programme consist to the implementation of the nuclear infrastructure; during the pass of time the scope of the nuclear infrastructure change as change the extent by which the main actors are involved. The IAEA framework presents the nuclear porgramme steps in connection with the NPP lifecycle (§2.1.1) as showed in the Fig. 3.1.

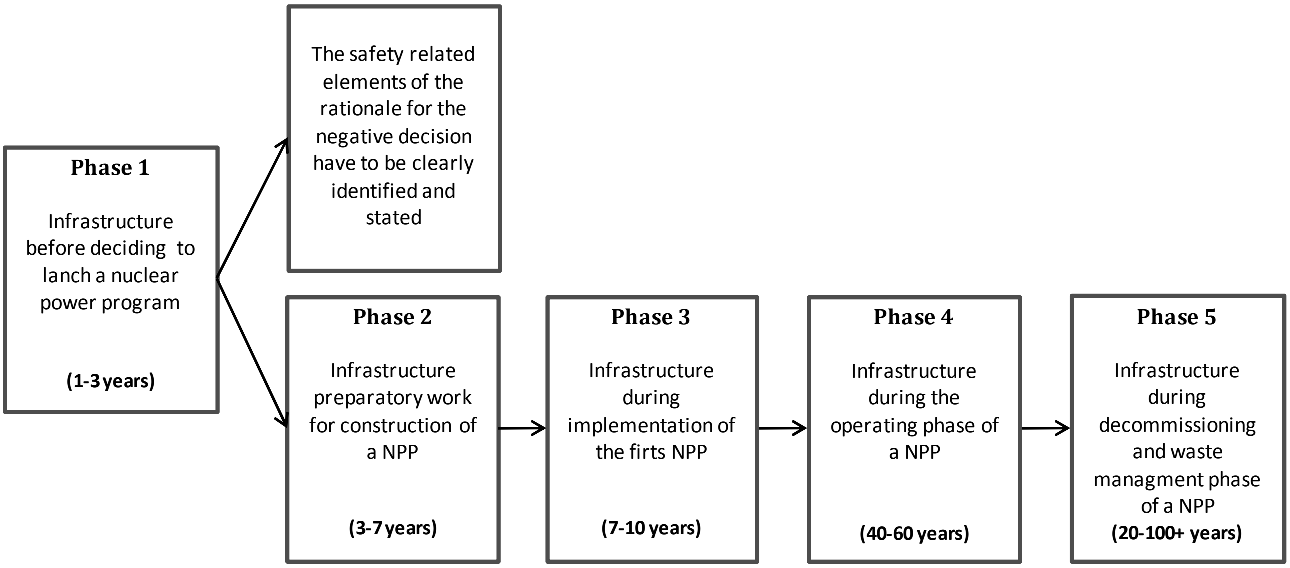

Fig. 1.17: Nuclear programme steps (IAEA, 2010), revised figure

[47] This most depends on the availability of the uranium ore and fuel facilities (enrichment, fabrication, assembling) within the country.

The nuclear programme steps correspond to the ones of the first NPP, this framework emphasized the supportive role of the nuclear infrastructure. In reality some pieces of the nuclear infrastructure are out of phase with respect the lifecycle of the first NPP, an example is the development of the waste infrastructure: indeed there are 185 commercial NPPs shout downed, cancelled or suspended (around the world) (World nuclear association, 2011), in no country exists a definitive solution, for the high level waste[48], yet.

The nuclear programme deployment can be divided into two macro phases, chronologically separated by a fundamental milestone: the achievement of the first NPP operating license (by operator).

The early three phases are critical for the development of the basic infrastructure needed for the construction and operation of the first NPP (IAEA, 2006). Especially the development of the intangible infrastructure is needed (Knowledge based and human capabilities, implementation of the required nuclear authorities, legislative and regulatory framework, etc.) (IAEA, 2010).

When a country decide to embarks the nuclear programme, may find problematic to settle down an entire and comprehensive infrastructural framework because it necessitated log lead times and great efforts. Hence, usually countries adopt a grating approach: first deploy a basic infrastructure and then update and further develop it (IAEA, 2007). A typical approach consists to the sharing of a part of the nuclear infrastructure with countries or organizations already "experts" in the nuclear field (IAEA, 2006), this approach is especially emphasized for technical standards and regulation.

During the latest two phases: 5,6 the basic infrastructure has been already settled down; in this long phase the infrastructure need to be updated and upgraded for taking into account: the technological advances, the most advanced practices (especially the safety ones) and for cover all aspects not explicitly treated in the early phases of the nuclear programme.

The waste[49] and decommissioning infrastructure is one of the latest elements developed, due to the high socio-political sensitivity and the long time available for its deployment (typically the entire lifetime of the first NPP[50])

3.1.4. Actors role into the nuclear programme

The actors involved into the nuclear program may change significantly, between countries, mostly depending on legal and administrative traditions.

[48] Nuclear waste can be categorized considering three main sets: the first set comprise with waste having low radioactivity content which decays in months or, at least few years (e.g. minor industrial applications, radiology, etc.); this set is called: "low level waste".
The second set comprise with waste having medium level of radioactivity which decays in centuries to reach radioactivity concentrations (around some hundred of Bq/g), this set is called: "medium level waste".
Finally high level waste comprise with waste which require thousands of years to reach radioactivity concentration levels in the order of hundreds of Bq/g. (Troiani, 2009)

[49] This sentence is satisfied only for the high level waste. On the other hand the temporary storages for medium and low level waste needs to be developed in the early phases of the nuclear programme. This because the NPPs could store an elevate number of fuel assemblies.

[50] Under the assumption that oldest NPP is the one first shouted down and decommissioned.

The IAEA framework presents a reduced set[51] of actors, generally applicable to all countries, and permits to draft the general areas of competence.

This framework adopts two main sources of information: the international prescriptions[52] and the nuclear safety best practices.

Furthermore, the nuclear programme can be treated with different level of depth, due to the vast complexity associated to it. This paragraph introduces the different actors' roles using a gradual approach: First are introduced the macro areas of competence and then these are detailed (this representational choice has being made to enhance the "understability" of the framework).

The main "macro-actors" of the nuclear program are: the Government, the Regulatory body RB, the Owners' group[53] and citizens (of the country where the nuclear programme is implemented). A more detailed framework considers further actors, as showed in the Table 3.1. This differentiation is consistent with the IAEA guidelines, e.g. general representation: (IAEA, 2010) Vs detailed representation (IAEA, 2006).

IAEA guidelines, sometimes, refers to the term "Operator" as substitute of the Owner's group, e.g. (IAEA, 2010). The author think that a substantial differentiation shall be underlined for avoid confusion; especially the legislative regime emphasizes the prime responsibility of "license holder" (also called operator) and the first principle of the safety fundamental (IAEA, 2006) states: "*The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks*". This pervasive principle highlights the need to clearly distinguish between the Operator and any other actors (or actors set), because of its high relevance in the eyes of nuclear laws, regulations and standards.

1.Macro Actors	**Government**		**Regulatory Body**	**Owners' group**	**Citizens**
2.Further detailing in the representation	• Ministers • Nuclear Power implementation Agency NPIA	• Regional or Federal Councils / Governments • Local Councils	• Environment Agency • Others Independent administrative authorities • Waste management and Decommissioning Authority	• Operator • Reactor Vendor •Contractors • Credit institutions • Other private actors that supports the NPP deployment	
Actors' linkages (1->2) & (2<->2)	Administrative hierarchy	Partition of Institutional Powers	Competence area partition	Contractual agreements	

Table 3.1: General Vs Detailed representation Actors in the IAEA framework

[51] With respect the real nuclear programs, where are usually involved a vast number of: commissions, agencies, contractors and subcontractors, governmental authorities, regional and local authorities, etc.

[52] The international prescriptions are the ones that come from the ratification of legal international instruments. The contracting parties, of these instruments, are the countries who are embarking a nuclear program. The main international instruments are the: "conventions", "treaties" and "agreement". The international provision are treated in the section (§3.2.1).

[53] "Owners' group" is the cooperation project network comprising with: reactor vendor, operator, contractor and suppliers (World nuclear association, 2007).

3.1.4.1. Main actors involvement into the nuclear programme

This section analyses only the three early phases because, as mentioned before (§3.1.4), are the most critical phases affecting the licensing process.

Fig 3.2 shows the level of involvement for the Government, RB, Operator and Contractors-suppliers.

The driver chosen for represents the actors involvement is presented by the following equation.

$$\underset{i}{\text{Involvement}}\%(\text{t}) = \frac{\underset{i}{\text{Resources implied}}\ (\text{t})}{MAX\left[\underset{i}{\text{Resources}}\ \text{implied}(\text{T})\right]}$$

$$T = [Phase_1(begin); Phase_3(end)];\ \ t \in T$$

$$Dom(i) = \{Government; RB;\ Operator; Vendor/Contractors\}$$

The resources implied consist with: financial resources, human resources, physic resources and knowledge based resources.

The assumption made is the independence between Governemnt, RB, operator and Vendor/contractors network; this consists in considering only the resources implied into the project (and not the ones received by other actors).

This assumption lies in the real scenario because of two main reasons:

First the Government resources contribute to the development of the institutional framework (including RB), as result the RB and government are not independent in the early phases of nuclear program).

Second the resources implied by the Vendor/contractors are financed by the Operator[54]. As result the Operator resources are not independent with respect the Vendor/contractors ones.

On the other hand the assumption made permits to consider the relative contribute, of different actors, in terms of involvement (independently to the others ones).

As result the curves plotted I the Fig. 3.2 are standardized with the same adimensional scale, showing the level of involvement with respect theirself.

The actors' role is argued at follow.

In the first phase the Government has the leading role: promotes the nuclear option (also in the eyes of citizens), settles down the energetic and nuclear policy, implements the international conventions, treaties and agreements; establishes the statutory framework (supported by Parliament), promotes the nuclear research and development, establishes the needed authorities (in the simplified framework the RB). Its involvement rapidly decreases during the second phase.

In the second phase, the RB becomes rapidly full involved because of its staff recruitment (considered part of the human and knowledge base infrastructure) and the establishing of the regulatory framework.

[54] In this simplified nuclear progamme scenario, Governemnt subsidies are assumed equal to zero (in accordance with the IAEA framework: "safety standards"); nor Credits and financial institutions are considered because indirectly involved into the nuclear program (and then don't represent a key nuclear programme actor).

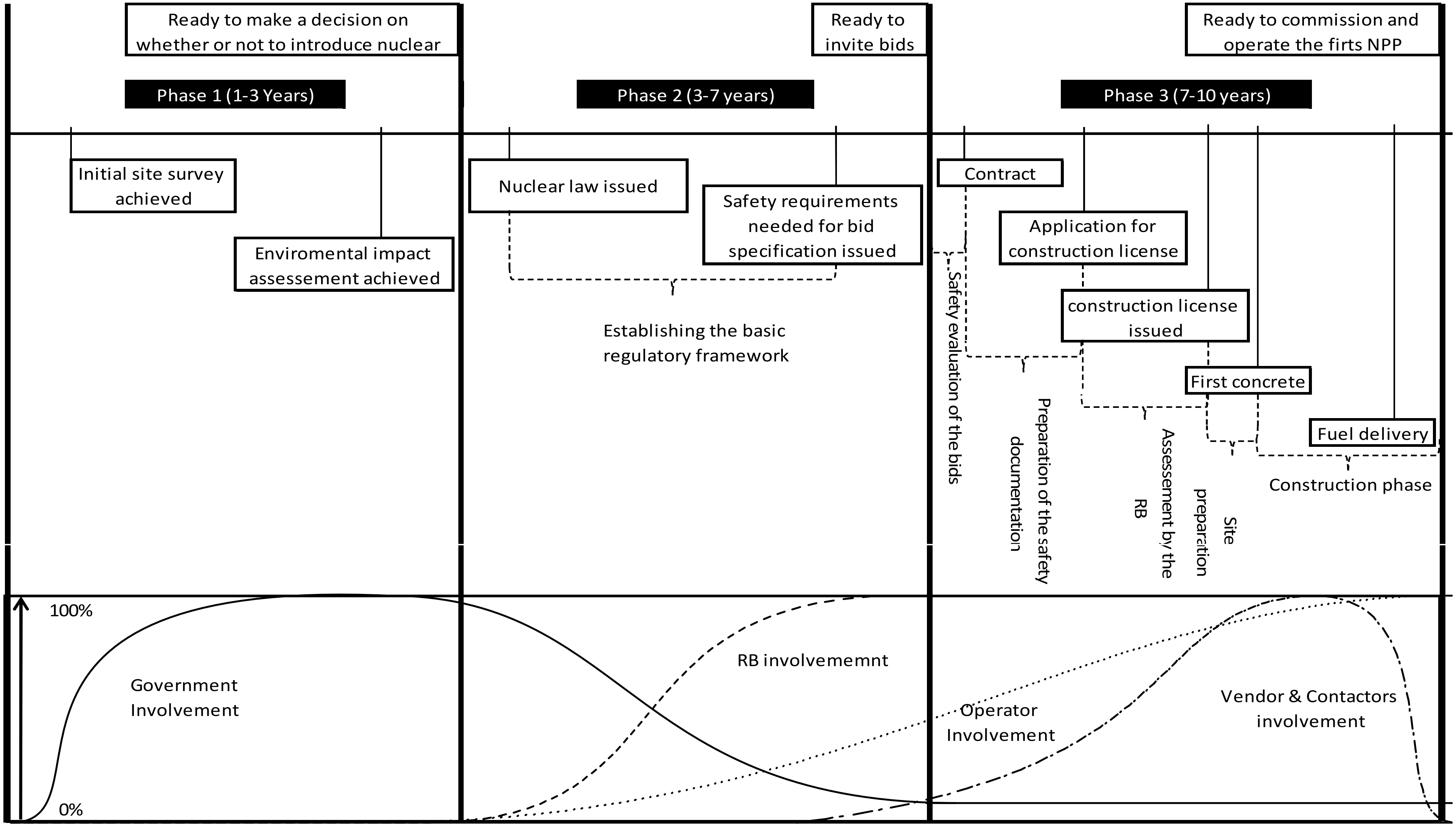

Fig. 1.18: Actors involvement in the early phases of the nuclear programme (IAEA, 2010), Deeply modified figure

The Operator starts to be involved into the nuclear program trough two ways: from one hand, begins its personnel recruitment and knowledge development (mostly depending on its strategy and the NPP scope of work that directly deploys[55]); on the other one it carries out the contract awarding route. This later activity in inherently linked to the licensing process because from one hand the contract awarding route constrain and determines the NPP feature; on the other ones these NPP features (in conjunction with the Operator and the Nuclear site ones) are assessed by RB. Hence when the contract is awarded directly begins the licensing process[56].When the necessary permits are granted, starts the site preparation phase[57] and follow the construction of the NPP[58]. During the NPP construction, the Operator is deeply involved because: it supervises construction, continue to be involved into the licensing process and continues its personnel training. The highest level of involvement begins in the commissioning phase, and continues in the operating one.

Finally, in the third phase is showed the involvement of the NPP constructing actors: reactor vendor, contractors, etc. In this case the involvement representation looks like an asymmetric "bell-courve". The Left tail is predominant due to the partial involvement into the contract awarding route and the licensing process. On the other hand, after the construction phase (where contractors are totally involved) the workforce decreases rapidly when commissioning starts (IAEA, 1988). Fig. 3.2 emphasizes how some actors are transitory with respect the nuclear infrastructure, others are not. The human and knowledge based capabilities of both Operator and RB are parts of the nuclear infrastructure; then RB and Operator are presented emphasizing the cumulative effects of its development.

On the other hand, vendor and contractors' involvement is totally transitory with respect the nuclear infrastructure: when the NPP is finished they are not involved anymore.

Government is partly transitory, because of its ministers, commissions directly joined with the nuclear field.

3.1.4.2. Actors role into the nuclear programme

This paragraph presents a set of table and figures that itself synthesizes the nuclear programme in a more detailed manner with respect last paragraph (§3.1.4.1).

[55] Usually the first NPP is developed shifting maximum level of efforts and responsibility to an expert organization in the field of engineering and construction of NPP. This is made possible through contracts: EPC (Engineering, Procurement and Construction) on lump sum basis. In every cases (even when an external organization carry out all works) The Operator need to recruit personnel to: supervise the NPP construction, afford the licensing process (where its responsibility can't be shifted to anyone), and to operate with the plant after its construction.
In the case under discussion (Fig. 3.2) is assumed the lowest involvement of the Operator (EPC lump sum).

[56] Sometimes these two phases are partly overlapped in the "early meetings" of the licensing process (IAEA, 2010).

[57] Even when the NPP is purchased under lump sum-EPC contractual basis, usually the site preparation is underpinned by the Operator, or by indigenous firms. This because this task doesn't require specific nuclear skills and one of the prerogatives of the nuclear proramme is the national participation and the creation of jobs. The example provided in the Fig. 3.2, emphasize the distinction between the Operator role and the Contractors ones; hence is assumed that the site preparation is undertaken by the Contractors.

[58] Usually the Construction of a NPP requires a specific license (e.g. France). In some countries the license typologies doesn't cover explicitly the NPP construction. In every case, a permit for the NPP construction is needed; in the IAEA framework this permit is granted by the RB (IAEA, 2010).

The main actors and their responsibilities are listed at follow.

Government

"(*a) Create a State organization to perform a prospective analysis of the need for nuclear power and to manage political and public consultation on a potential nuclear power programme.*

(b) Establish the national policy and strategy for ensuring long term safety of the nuclear power programme.

(c) Make a decision on launching the nuclear power programme.

(d) Establish an educational programme and scientific institutions to develop and sustain national knowledge in all areas of nuclear safety. Create a State organization for programme management and oversight.

(e) Consult or submit the nuclear power programme for approval.

(f) Create or enhance and maintain a basic nuclear legal system that provides licensing and regulatory framework.

(g) Establish an independent regulatory body that is dedicated to safety evaluation and oversight and is effectively separated from bodies involved in promotion of nuclear power or in energy policy decisions or their implementation.

(h) Establish a national strategy for radioactive waste final disposition.

(i) Become a party in the major international conventions" (IAEA, 2010)

Operator

"(a) Develop specific projects within the framework of the national nuclear programme.

(b) Ensure the technical capabilities and economical capacities for the development and execution of the specific projects.

(c) Enter into negotiations with reactor suppliers and architect engineers.

(d) Arrange maintenance of the knowledge of the plant safety design basis.

(e) Ensure the competence and skills for operation and maintenance of all plant systems and equipment for the entire lifetime of the plant.

(f) Become a member of international nuclear associations of nuclear operating organizations.

(g) Participate in safety related peer reviews to maintain safety.

(h) Establish a strong commitment to safety by developing an advanced safety culture.

(i) Share construction and operating experiences." (IAEA, 2010)

Regulatory Body

"(a) Establish an efficient methodoly for overseeing safety during design, construction, commissioning and operation.

(b) Build up sustainable competence in all areas of nuclear safety.

(c) Ensure availability of independent expert knowledge as needed to support safety evaluations and inspections.

(d) Develop and adopt a complete and satisfactory set of nuclear safety regulations and guides.

(e) Maintain close cooperation with regulatory bodies that have licensed similar nuclear power plants and with international safety organizations.

(f) Request assistance from international organizations when needed." (IAEA, 2010)

Contractors-Vendor

"(a) Offer proposals based on proven technologies and complying within internationally accepted safety criteria.

(b) Design, construct and commission the plant in accordance with internationally accepted safety criteria and with the safety requirements arising from the specific local conditions.

(c) Support the plant owner in the long term by planning or verifying safe implementation of the plant modifications and by sharing the operating experience and information on equipment ageing." (IAEA, 2010)

Public

"(a) Participate in the decision making concerning plant licensing and the application of safety principles in national safety regulation." (IAEA, 2010)

Furthermore the following table and figures define more precisely the actors' role into the nuclear programme: Table 3.2 shows the relationship between the nuclear programme actors and the implementing infrastructure elements; Fig.3.3 shows the sequence of the action undertaken by the different actors.

Finally, Fig.3.4 pones in relation: the actors' role[59], the infrastructure pieces, and the timescale.

[59] In this figure is used the "macro-actors" taxonomy (§3.1.4).

		Funding and Implementing Organizations	
Infrastructure Issue	**Responsible**	**Primary**	**Supporting**
Nuclear Power Implementation Agency	Government	Ministry of Energy	Other Ministries and Existing Nuclear R&D Institutes
Nuclear Power Policy	Government	NPIA[60]	Ministry of Energy
Nuclear Related Laws	Government	NPIA	Ministry of Justice
Regulatory Body RB	Government	Government	NPIA
Educational institutions	Government	NPIA	Ministry of Education
Economic Assessment	Operator	Operator Finance and Commercial Department	NPIA
Financing Assessment	Operator	Operator Finance and Commercial Department	NPIA, Ministry of Finance, Consultants
Public consultation	Operator	Operator Public Relations Department	Consultants, Ministry of Environment
Siting and Site Infrastructure	Operator	Operator Technical Department	Consultant, Ministries of Energy and Industry
Grid Strengthening	Operator	Transmission Utility	Department of Energy
Transportation Means	Operator	Operator Technical Department	Ministry of Transport
Environmental Assessment	Operator	Operator Technical Department	Consultants, NRB, Ministry of Environment
Bid Request, Evaluation and Vendor Selection	Operator	Operator Technical and Commercial Departments	Consultant, Ministry of Energy
Licensing[61]	Operator	Operator Technical Department	RB, Consultant
Emergency Planning[62]	Operator	Operator Technical Department	RB, Consultant
National Laboratories	Government	NPIA	Ministries of Industry, Science and Technology
Engineering	Operator	Private Sector Companies	Operator, Ministries of Industry and Energy
Project Management and Commissioning	Operator	Private Sector Companies	Operator ,Ministries of Industry and Energy
Fuel Supply	Operator	Operator Through International Suppliers	RB, Ministries of Energy and Foreign Affairs
Waste Management[63]	Operator	Operator	NPIA, RB, Waste Management and Decommissioning Authority

Table 3.2: Division of Responsibility for the Establishment of Basic Nuclear Power Infrastructure, (IAEA, 2006), revised table

[60] Nuclear Power Implementation Agency, NPIA

[61] The licensing responsibilities could change depending of the perspective adopted in the analysis. In this table responsibility of the operator is understood as: "the responsibility to achieve all the legal and regulatory prescriptions". This point of view lies in the international legal framework: the actor who carries out the licensing duties is the RB (CNS I Art. 7.2.ii in conjunction with the Art. 8). In all countries, the licensing decisions may be appealed in administrative or special court of justices, this emphasize the RB prime responsibility with respect the licensing process.

[62] This refers to the in-site emergency infrastructure. Usually the responsibility of built the emergency infrastructure is shared between the Operator and the national and local institutions. Further then the Operator staff, the police department, fire service, emergency medical responder are part of the off-site emergency infrastructure (IAEA, 2002)

[63] Waste management is an Operator duty until when the NPP released of its control. When this step is passed, the waste management duties are carried out by Government. Furthermore the Waste infrastructure is usually financed by Operator but deployed by specialized Actors under the supervision or control of the Management and decommissioning Authority

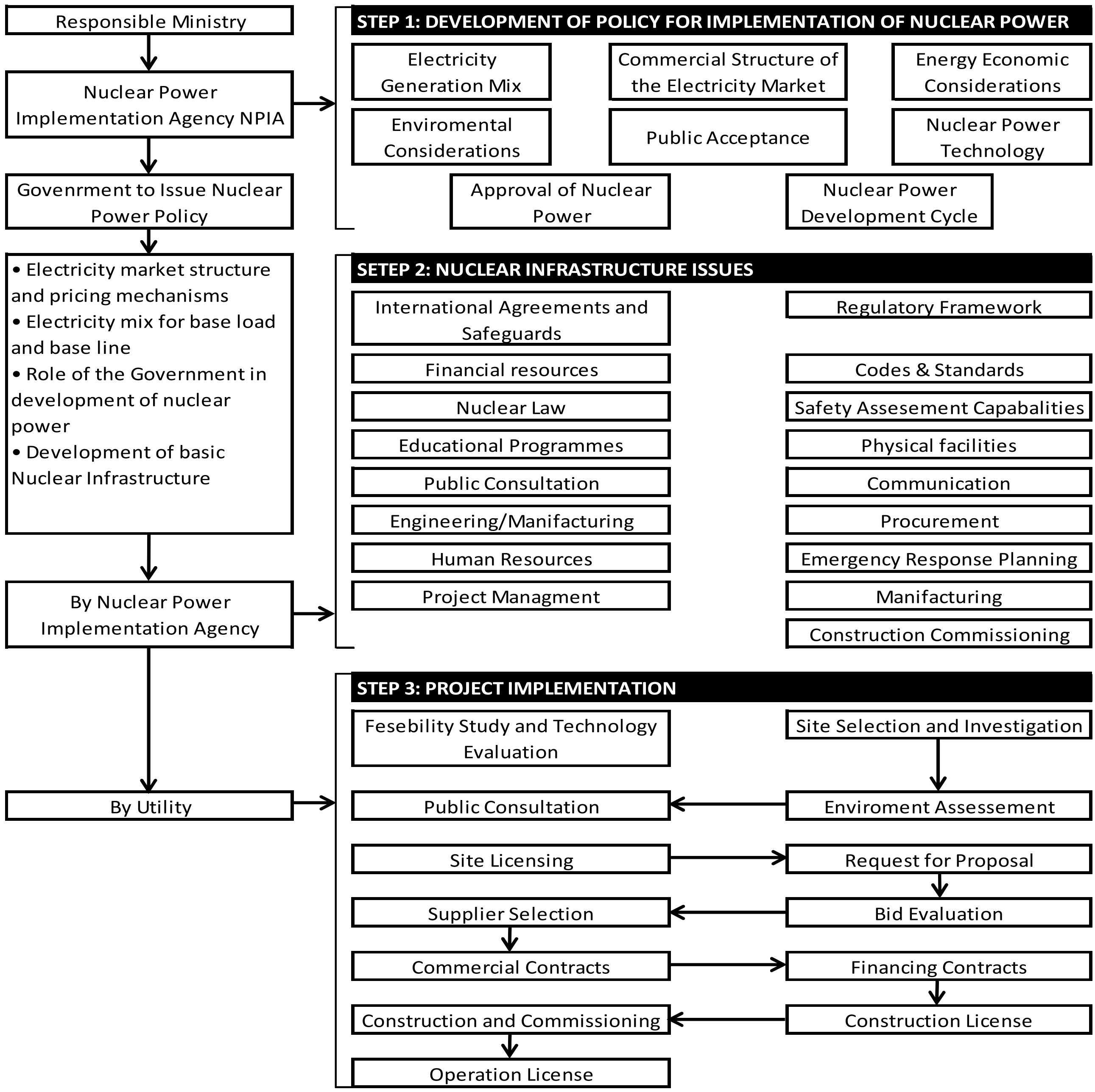

Fig. 1.19: Nuclear power development cycle (IAEA, 2006), revised figure

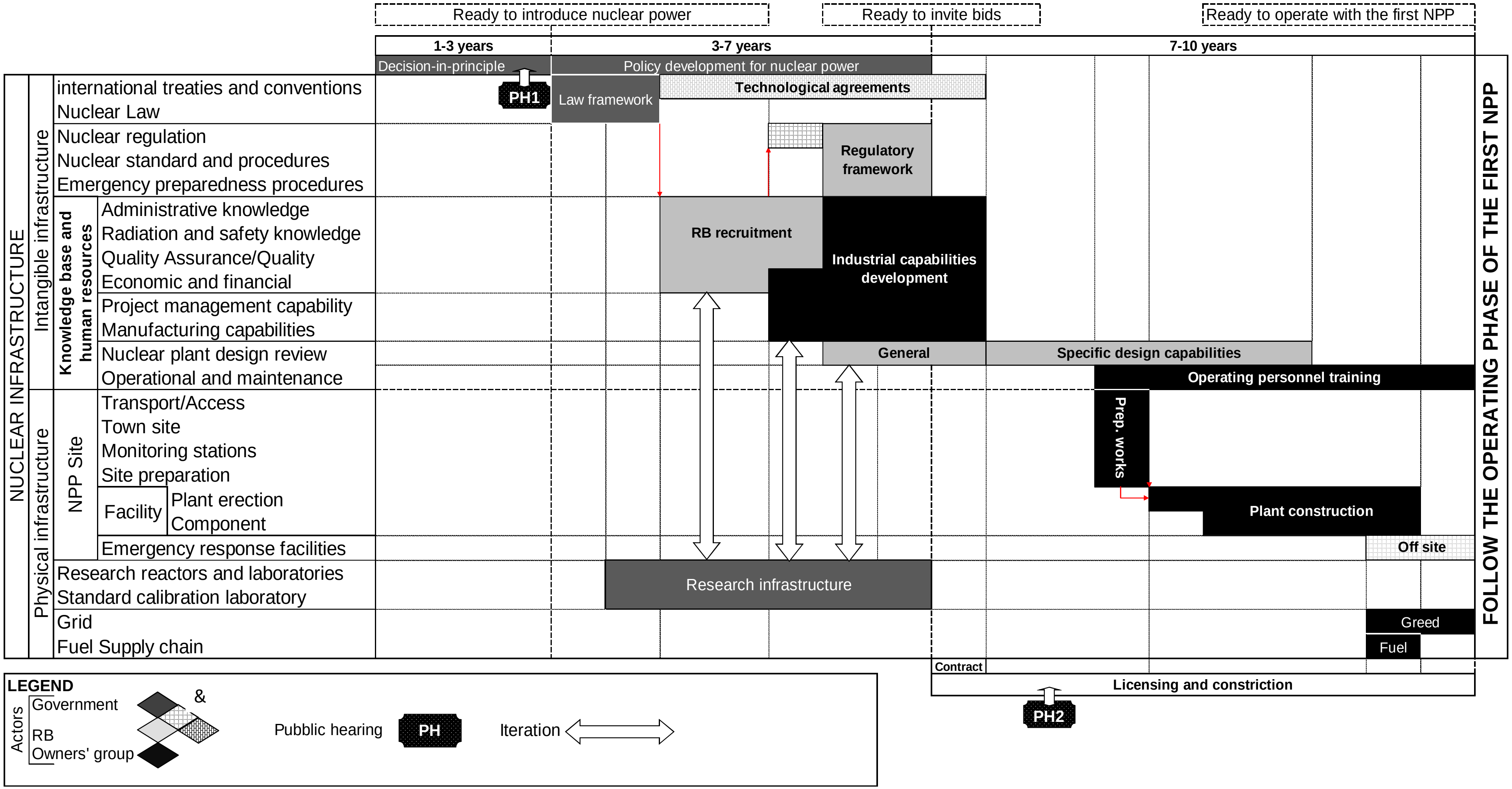

Fig. 1.20: The nuclear program & the nuclear infrastructure (Locatelli, et al., 2011), revised figure

3.1.4.3. Nuclear programme approaches

The real nuclear programme practice overcomes the ones presented in the IAEA guidelines. Especially the function of the government may change significantly depending on the country considered.

There are three main approaches to nuclear programmes that differ depending on the leadership of its:

a) Government leadership
b) Market-free oriented
c) A mix of the previous

a) In the first approach the government has the leading role of the nuclear programme, in these context usually the nuclear industry, especially the Electric utility/utilities (Operator/operators) are under the governmental control (directly or indirectly).

The industrial strategy is led by the politic powers: Government and the devoted Ministers.

The typical features of this approach are: pervasive role of the governments, vast national incentives and systemic pacification of the whole nuclear supply chain within the country (reactor design standardization, economies of scale, rationalization of the fuel supply chain, etc).

Under the government leadership approach, the nuclear programme is also characterized for the strong incentives to export the national reactor technology (strong support in the technological agreement, export credit, etc).

The degree of openness of the nuclear market, with respect foreign firms, depends on the maturity of the national industry.

In the early phases, Government usually incentives the importation and the construction (usually under turn-key basis) of foreign nuclear technology.

During the development of the nuclear program national industry become more expert, then start to be involved into the nuclear programme with greater extent, in this phase the reactor design remain unchanged.

Finally when the nuclear industry is enough mature, usually starts the technology design diversion considering the lessons learned in the construction and operating phases of NPP[64].

When this milestone is achieved the national nuclear industry becomes extremely closed and autarchic.

The establishment of design capabilities requires high degree of collaboration between the different industrial actors: contactors, reactor vendor and operator. This collaboration is facilitated when the comprehensive national strategy is led by a unique actor: the Government.

Examples of countries which adopt this approach are: France (Sasrty, et al., 2010) and South Korea (Choi, et al., 2009).

[64] Usually the technology diversion starts before the decommissioning of any nuclear facility within the country.

b) Market free oriented is typical for the Anglo-Saxon countries, and the leadership is left to the nuclear market, then to the private nuclear industry.

This approach is characterized by the moderate degree of involvement[65] of the government, the pervasive role of the regulatory body, the high degree of openness of the market and the information transparency.

This approach is usually more respectful of the basic principles of the global economy, the international (and regional) cooperation is emphasized, the dynamic and development with respect the most updated safety practices and technologies are also stressed.

On the other hand the nuclear programme usually results more fragmented and less efficient: lower degree of overall planning, national collaboration and the lack of a unified strategy within the country.

This lower efficiency and lower degree of synergy usually led this typology of nuclear programme to be more expensive. Especially the lack of a uniform strategy led to and lower economies of learning and scale that are essential elements in the nuclear programme (due to the vast influence of the construction cost into the whole nuclear investment).

Examples of countries who adopt this approach are: USA (Sasrty, et al., 2010) and UK (Thomas, 2010).

c) An intermediate approach consists in the mix of the previous ones; this case is typical for most of the European countries, for example: Finland and Italy.

In this case the relative advantage and disadvantage of the previous approaches are mixed.

The effect of these approaches on the licensing framework are discussed in the section (§4.2.4)

3.2. Nuclear infrastructure

The nuclear infrastructure is characterized by two main features:

- Is the nuclear programme scope of work
- It's supporting role with respect the typical nuclear programme objectives (electricity generation, geopolitical independence, etc.) (§3.1.2).

The nuclear infrastructure can be divided into two main sets:

- The intangible infrastructure
- The physic infrastructure

The distinction between these two sets takes into account the intrinsic nature of the infrastructural elements in terms of their physicality.

Although some infrastructural elements can be understood in the middle between these two sets (e.g. human resources, Institutions, etc.); Table 3.3 presents the Work Breakdown Structure of the nuclear infrastructure with a net distinction of the two sets[66].

[65] The same presented in the section §3.1.4.1

[66] I this case, the physical elements are strictly characterized by its material nature; their nature is considered the prerequisite for their infrastructural role. The intangible infrastructure considers all the remained elements (including

This paragraph represent the connection between the nuclear programme (§3.1.) and the licensing process (§4.).

Most of the infrastructural elements are behind the topic of this thesis work, hence are not explicitly treated in the following paragraphs[67]; on the other hand there are some infrastructural elements that deeply affect the licensing process. These lasts are deeply treated in the following paragraphs emphasizing their role into the licensing process.

the ones that overlap these two sets). A document for example, is sometimes characterized for its physic support (e.g. paper); nevertheless its support is not the feature that better emphasize the infrastructural role of documents. On the other hand a road is strictly characterized for its physicality (then is considered a physic infrastructure element).

[67] These elements are just listed in the general Work Breakdown Structure WBS infrastructure showed in Table 3.3.

NUCLEAR INFRASTRUCTURE				§3.2
	Intangible infrastructure			
		Legal infrastructure		§3.2.1.
			International Legal Regime	§3.2.1.2.
			Extent and distribution of prescriptive norms into the legal hierarchy	§3.2.1.3.1.
			Relationship with non-nuclear laws	§3.2.1.3.2.
			Openness and dependence to foreign and international provisions	§3.2.1.3.3.
			Centralization of the legislative body	§3.2.1.3.4.
			Framework dynamics	§3.2.1.3.5.
		Specialized nuclear Institutions		§3.2.2.
			Nuclear Regulatory Body RB	§3.2.2.1.
			Nuclear power implementation agency NPIA	§3.2.2.2.
			Waste and decommissioning authority	
		Safety principles and criteria		§3.2.3.
		Knowledge based and human capabilities		
			Administrative knowledge	
			Nuclear plant design review capability	
			Quality Assurance/Quality Management capability	
			Project management capability	
			Operational and maintenance capability	
			Radiation knowledge and awareness among the workforce	
			Economic and financial knowledge	
		Documental, Financial, Contractual infrastructure		
			Technological agreements	
			Contracts	
			Financing instruments	
			licenses and permits	
	Physic infrastructure			
		Research infrastructure		
			Universities, training centers	
			Research reactors and laboratories	
			Standard calibration laboratory facilities	
		Nuclear site		
			Water supply	
			Power supply	
			Transport/Access	
			Micro earthquake monitoring station	
			Meteorological and hydrological station	
			Town site and administration facilities	
		Nuclear Power Plant		§2.
			Reactor building	
			Component manufacture and material supply	
		Safety and Security based infrastructure		
			Physical protection facilities	
			Safeguards plan and equipment	
			Emergency response facilities	
		Greed infrastructure		
		Fuel supply chain		
			Uranium ores	
			Milling facilities	
			Enrichment facilities	
			Fuel fabrication and assembly facilities	
			Fuel logistic	
		Waste infrastructure		
			Storage/Disposal of low and medium radioactive waste	
			Spent fuel storage and disposal facilities	
			Reprocessing facilities	
			Waste Logistic	

LEGEND

- Infrastructure chunks (black)
- Ifrastructure elements inherent to the licening process (grey)

Table 3.3: The nuclear infrastructure Work Breakdown Structure

3.2.1. Legal infrastructure

Legal and administrative traditions are the most important factors affecting the licensing process (Bredimas, et al., 2009), (Bredimas, et al., 2008) and their prime impacts results in legal, regulatory and institutional framework.

This traditions differentiation (at international level) is perceived as one of the most influencing factors with respect the complexity and uncertainty, affecting the owners' group during the nuclear project development.

From one hand, legal and regulatory issues are perceived as ones the most influencing risk factors affecting the owners' group during the NPP development (§2.1.6.3.).

On the other one, the international reactor market is characterized for the contraposition of few vendors that operate in many countries[68]: this implies that the reactor vendors use to face really different legal systems and licensing practices. As result, their scarce knowledge, associated to the different legal-regulatory environments mostly contributes to the high risk (the epistemic side) incurred by the Owners' group[69].

Following paragraphs introduce: the history of the nuclear discipline (§3.2.1.1.), the some basic principles applicable worldwide because implemented at international level (§3.2.1.2.), and a general framework applicable to different countries (§3.2.1.3). This last include the principal drivers which permits to compare really different law systems.

3.2.1.1 International development of the nuclear discipline

The history of the nuclear power has deeply influenced the actual legal scenario (IAEA, 1997).

The first experimentation of nuclear fission (and its applications) starts in parallel with the development of the World War Second (WWII); from the beginning the nuclear challenge was perceived critical for the sort of the international war, as result the conflict was extended even in terms or nuclear research.

Indeed the fission reaction was discovered by German-Austrians Scientist[70], the USA's research program (Manhattan project[71]) rapidly achieve fundamental milestones[72] in the arms race. At least USA won the

[68] Actually there are twenty-six countries where NPPs are planned and thirty-seven where NPPs are under proposal. On the other hand the nuclear vendors (that could undertake an international selling campaign) are in the order of ten and come from a reduced number of courtiers: Canada, France, Japan, Russia, South Korea and USA (World nuclear association, 2011). In the next future is expected that some nuclear importer will becomes exporters: especially China and India. In every case the number of importing courtiers is always greater than the ones which exports.

[69] The owners group is affected (as whole) by the epistemic risk derived from the reactor vendor lack of knowledge. This because rarely the responsibility and the liability (associated to a specific activity or scope; in this case the reactor design) are bi-univocally linked; this because of the legal constriction and the contractual arrangements between Owners' group parties.

[70] 6 January 1939 the German chemist O. Hahn, F. Strassman discovered the Nuclear fission; their Austrian colleague L. Meitner noted that this reaction would release energy

[71] On August 1939 E. Teller and A. Einstein wrote to President Roosevelt that Germany was trying to produce enriched uranium, and urged him to make sure that the USA could arm itself with nuclear weapon before Germany did so; this

research and development competition (and the military conflict as well): The first atomic device was experimented at Alamogordo, New Mexico; atomic bombs were then used in Hiroshima and Nagasaki.

The nuclear field was initially driven by Governments who mostly concentrated on the military application of this (and operated secretly); as result no statutory framework was settled down during WWII.

During the last years of WWII many scientist and politics[73] start to put pressure on the American Government about the sort of the international safeguards; indeed USA was the only country capable to develop atomic devices, a set of the ruling class perceived great uncertainty about the future regime of nuclear armaments. A first concern was the relationship between USA and URSS; this last starts a military nuclear programme on 20 August 1945 under the prime responsibility of Lavrenti Beria (Chief of the Soviet secret police: NKVD).

These first attempts (about the global safeguard regime development) start to become concrete after the end of the global conflicts[74]; On 24 January 1946 was settled down United Nations Atomic Energy Commission (UNAEC); this international organization was subject to the direction of the Security Council.

UNAEC was also joined by URSS under Veto Right[75].

On 13 June 1946 was reported to the United Nations Security Council a proposal made by American secretariat: the "Baruch Plan"; this last reported the creation of a new international organizational (called: "International Atomic Development Authority" IADA) empowered to:

- Controls and operates all nuclear activities related to the production of fissile material;
- Licensing and regulating duties related to the remained nuclear activities;

---

persuaded the president to start the Manhattan Project (the vast research project carried out in USA with the aim to develop the nuclear bomb)

[72] The research development gives, in these years, important results: in late 1939 was discovered the plutonium (G. Seaborg) and on 2 December 1942 was achieved the criticality (E. Fermi)

[73] Some examples this are presented at follows:

On 3 July 1944 N. Bohr sent a memorandum of understandings to Roosevelt for convincing him to take USSR into their confidence about their progress they were making toward the manufacture of the nuclear weapon (Roosevelt and Churchill refuses).

On 25 April 1945 H. Stimson (secretary of war) wrote to President Truman about the control of the atomic safeguards: "the question of sharing it with other nations [...] becomes a primary question of our foreign relations." (Stimson, et al., 1947).

On June 1945 a group of Manhattan Project physics (chaired by J. Franck) appealed for an international demonstration of the power of the bomb before using it against Japan and pressed for an international agreement or agency to prevent its further use.:

[74] On 15 November 1945 was implemented and international treaty between USA, UK and Canada: "Three Nation Agreed Declaration on Atomic Energy"; with the aim of scientific cooperation (in the nuclear field) and mutual enforceable safeguards.

[75] On 27 December 1945, American and British Governments proposed to URSS the creation of UNAEC. During this meeting URSS Government made clear that the UNAEC work must be subjected to its veto right, USA and UK accepted this conditions.

- Enforcing activities;

- Foster the scientific research related to the peaceful purposes of nuclear activities.

The American proposal was then rejected by the Soviet Veto right[76].

On 11 June 1947 the Soviet Union proposed a different inspection system, this was considered inadequate by USA and its allies.

Finally UNEC concluded its work at the end of 1949.

As the international safeguards problem remains unsolved USA attempted to maintain its nuclear monopoly: at the end of July 1946 the US Congress adopted the McMahon act ; this contained provisions that avoid the exchange of scientific information in the nuclear field. Furthermore USA, UK and Canada tried to build a monopoly of fissile raw material to reduce the access to it.

In September 1949 Soviets carried out their first nuclear tests; UK achieved this milestone on October 1952.

The end of the US monopoly let growing the tension of the Cold War (1947-1989) between the Russian federations (Warsaw pact) and the US's alliance (North Atlantic Treaty Organization NATO).

A fundamental step forward was made in 1953-54 by the Eisenhower Administration[77] which promotes the nuclear for peaceful purposes and a new private regime associated to it: trough the Atomic energy Act, 1954. With respect the law framework, other countries started to regulate the nuclear sector to deploy commercial nuclear facilities (for electricity generation purposes). During this period, all nuclear programs were led by Governments.

The secrecy regime (e.g. McMahon Act) and international competition (for both civil and military field) led the nuclear sector to be highly fragmented in terms of: technologies[78], engineering standards, safety standard, etc.

After the Eisenhower Speech, new countries started civil nuclear programmes: importing the nuclear technology from abroad. As result, in these years started a political and commercial competition, between nuclear exporting countries[79] which aimed to affirm their technological standard.

Some countries imported only a type of reactor technology for geopolitical reason, e.g. all countries belonging to the Warsaw pact imported the Soviet Standards (RVMK and VVER).

Others importing countries[80] tried to develop first different typologies of reactor technology for experiments their effective advantages and disadvantages (e.g. Italy).

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[76] After Hiroshima and Nagasaki, URSS federation undertaken significant effort for the development of the nuclear arsenal; few days after the Security Council meeting Andrei Gromyko achieve the first soviet nuclear criticality.

[77] On December 1953 Eisenhower met Roosevelt for discuss about the future regime of nuclear power; on 8 December 1953 President Eisenhower promotes the peaceful purposes of atoms ("Atoms for peace") at a plenary meeting of United Nations. On 4 December 1954 a new international organization was settled down: "International Atomic Energy Agency" IAEA.

[78] E.g. LWR, Magnox; CANDU, RBMK, etc.

[79] Considering the scenario where the reactor vendor comes from a different country with respect the site where nuclear project is being developed; exporting country: is the country where the foreign reactor vendor comes from.

Furthermore a common trend, adopted by European importing countries, was to modify the initial reactor technology for adapts it to the national needs; this was made possible only after a transient that permitted (to those importing countries) to acquire sufficient design capabilities (e.g. France). This common trend led to the growing of the nuclear standards, emphasizing the legal and regulatory fragmentation of the nuclear sector.

On 1986 Chernobyl accident[81] showed, to the entire world, the potential detrimental effects of a severe nuclear incident. This event shocked the public opinion worldwide and indirectly forced the politic class to make changes to the safety regime or, in the worst cases, stopped (e.g. Spain) or abandoned the nuclear program (e.g. Italy).

A first concern was the over-boundary effects of severe nuclear accident; that required the implementation of appropriate international measures (IAEA, 2002).

On September 1991 started the negotiation of the Convention on Nuclear Safety CNS I: IAEA supported an open-ended working group comprising representatives of the nuclearized countries (technicians, diplomats, lawyers, etc); the aim of CNS I was to raise the level of nuclear safety worldwide[82].

After some years of intense work, CNS I was finally ready for signature by contracting parties' representatives[83] from June 1994. The Convention primarily contributes to the harmonization of the basic safety principles, and forced the contracting parties to implement its. The consequence was the modification of the institutional assets (in general terms the Regulatory body acquired more duties) and the law framework. One of the points of greater discussion was the treatment of the existing facilities (e.g. the RBMK designs showed their inconsistency with respect the new standards, especially the defense in depth principle §3.2.3.1.2.2.). From one had there were experts that advocates that the new principles shall be applied only for the new facilities; on the other ones, most contracting parties felt that the such an

[80] Importing Country is the country where the operator intends to develop the NPP importing the reactor design from abroad.

[81] During the night of the 26 April 1986 at the Facility Chernobyl IV (situated at Chernobyl, Ukraine close to the Byelorussia), an unconventional safety training led the operating personnel avoid some safety procedures (the operating procedures lack to the specific prioritization of the conflicting objectives tradeoffs affecting the NPP management) that led quickly to an uncontrolled overheating of the reactor core. Soon the core was subjected to a double explosion: first for the steam overpressure inside the vessel and then the hydrogenous explosion for its contact with the incandescent graphite. After the second explosion (that damaged part of the building containment) a vast amount of radioactive material was discharged into the atmosphere (this dispersion was emphasized by a fire).At the same time the nuclear core meltdown was passing and melting the pipes system. In the days (and months) after the accident, cities in the vicinity (of the site) were evacuated; furthermore the facility was entirely covered with a new building and underground was excavate a tunnel that permits to deploy a concrete basement for protect the layer from the core meltdown.. The post accident investigations showed many lacks in the safety system in terms of: Plant design, Safety procedures (especially the need of prioritization of the safety objective); Man-Machine interfaces, etc. (IAEA, 1992)

[82]CNS I has a reduced scope, (Article 3) comprises with: *"land-based civil nuclear power plant […] including handling or treatment facilities for radioactive materials as are on the same site and are directly related to the operation of the nuclear power plant"* (CNS I, Article 2). In other words the scope of the CNS I are the NPPs (§2.1). The defense- related facilities are out of the international accounting and control.

[83] The contracting parties are the countries that agreed to the International Convention

approach would be inconsistent with the original objective of CNS I (raise the level of nuclear safety) (IAEA, 2002).

The tradeoff was found in Article 6 of CNS I, which recites:

"Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact."

Article 6 falls into four categories (IAEA, 2002):

1) State party revises, as soon as possible, the existing reactors (the article doesn't detail how this must be done; nevertheless it must be based on up-do-date standards).
2) State party must ensure all the "reasonably practicable" improvement to upgrade safety (practicable in technical, economic, etc. terms)
3) If state party cannot upgrade its installations, it has to make a plan for shout them down.
4) The timing of the shout down takes into account various factors: social, environmental, economical, the energy context, etc.

The result of these prescriptions was that the countries, who didn't implemented the new safety measures, were constrained to justify their decisions to the others contracting parties.

After the achievement of this fundamental milestone (CNS I implementation) others important international convention were implemented to cover some specific subjects that are, for their nature, of international interest: International safeguards (Non proliferation of nuclear material), nuclear liability (especially third party liability); import/export controls; transportation of nuclear material; waste management; etc (IAEA, 2003).

Nowadays the international regime is characterized for the vast cooperation between overseas institutions: IAEA and Nuclear Energy Agency NEA (OECD branch) Promotes and support the international cooperation between nucelarized courtiers. On the other hand the country's institutions are directly connected each other trough bilateral agreements and specific networks[84].

3.2.1.2 International Legal Regime

Nowadays, the most important international instruments[85] are presented in the Table3.4

[84] E.g. the western regulatory bodies support each other trough "Western European Nuclear Regulators Association" WENRA. This has significant beneficial effects on licensing and regulating activities.

In general terms, all these impact on the licensing processes for their prescriptions, implemented at country's level and applied trough the regulatory body action.

On the other hand there are international instruments that introduce pervasive prescriptions, in terms of: institutional framework and responsibility/liability allocation; these have a deep impact on the licensing framework and on project management perspective, as result are discussed at follow.

Main Subject	Convention Title	Year
Safety fundamentals	Convention on Nuclear Safety (CNS I)	1994
Nuclear Incidents	Second Convention on nuclear safety review meeting (CNS II)	2002
	Convention on Assistance in the case of a Nuclear Accident or Radiological Emergency	1986
	Convention on Early Notification of a Nuclear Accident	1986
Nuclear Liability and Coverage	Paris Convention on Third Party Liability in the Field of Nuclear Energy (the Paris Convention)	1960
	Brussels Convention Supplementary to the Paris Convention (the Brussels Supplementary Convention)	1963
	Protocol of 12 February 2004 to the 1960 Paris Convention (2004 Paris Convention)	2004
	Protocol of 12 February 2004 to the 1963 Brussels Supplementary Convention (2004 Brussels Supplementary Convention)	2004
	Vienna Convention on Civil Liability for Nuclear Damage	1963
	Protocol to Amend the Vienna Convention (1997 Vienna Convention)	1997
	Convention on Supplementary Compensation for Nuclear Damage (CSC)	1997
	Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention of 21 September 1988 (Joint Protocol, 1988)	1988
Waste	The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management	2001
Non- Proliferation	Treaty on the Non-Proliferation of Nuclear Weapons (NPT)	1970
Nuclear Security, Physical protection and Illicit trafficking	Convention on the Physical Protection of Nuclear Material	1980
	International Convention for the Suppression of Terrorist Bombings (hereinafter the Terrorist Bombings Convention)	1997
	United Nations Security Council resolution 1373	2001
	United Nations Security Council resolution 1540	2004
	Code of Conduct on the Safety and Security of Radioactive Sources	2004
	Convention on the Physical Protection of Nuclear Material (CPPNM)	2005
	Protocol to the Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation (SUA Convention)	2005
	Protocol of 2005 to the Protocol for the Suppression of Unlawful Acts against the Safety of Fixed Platforms Located on the Continental Shelf	2005
	International Convention for the Suppression of Acts of Nuclear Terrorism (hereinafter the Nuclear Terrorism Convention)	2005
	International Convention for the Suppression of Acts of Nuclear Terrorism (hereinafter the Nuclear Terrorism Convention) (2005)	2005

Table 3.4: International legal regime: main instruments

3.2.1.2.1. Convention on Nuclear Safety, 1994 (CNS I)

[85] The international instruments can be categorized in four basic sets: conventions, treaties; agreement and United Nations Council resolutions

CNS I pones the basis of modern licensing processes in terms of safety principles, institutional architecture and nuclear liability.

First it introduces highlight the basic elements of the nuclear law (Article 7);

Second it underlines the Regulatory Body' features (Article 8) and its duties (article 7).

Third it introduces the principle that the Operator is the prime responsible of the nuclear risk (Article 9).

Forth it introduces the general safety considerations: Priority to safety (Article 10), Financial and Human resources (Article 11), human factors (Article 12), quality assurance (Article 13); assessment and verification of safety (Article 14); radiation protection (Article 15) and emergency preparedness (Article 16).

Fifth it reports the safety of installation principles underlining the lifecycle steps: siting (Article 17), design and construction (Article 18), operation (Article 19).

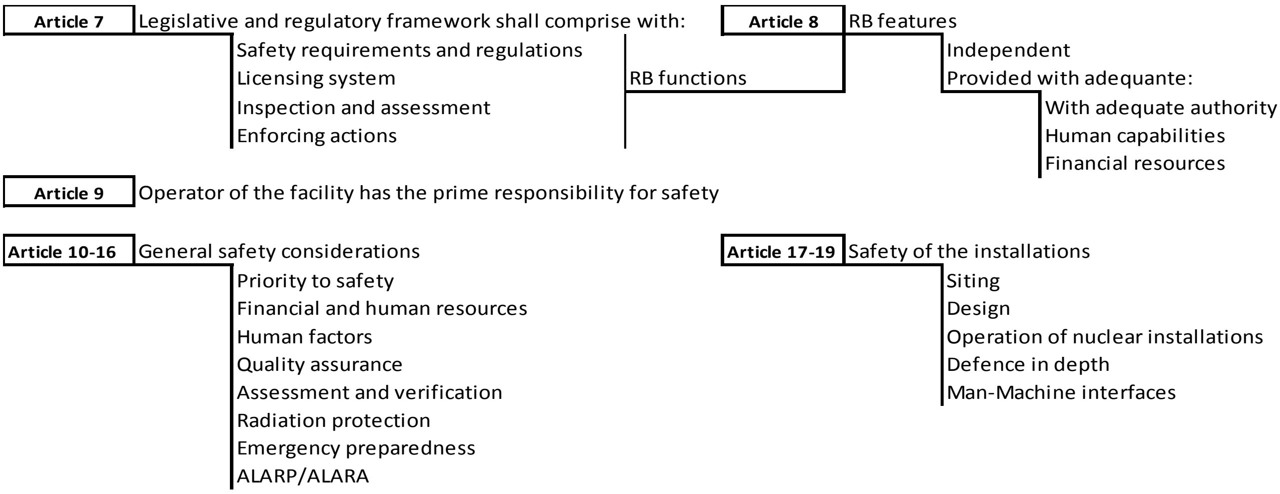

Fig. 1.21: Principles of the CNS I

3.2.1.2.2. Nuclear Liability and coverage, the legal international regime

Traditional laws were considered inadequate to handle nuclear damages; especially for its over-boundary and long term detrimental potential.

There are two main set of international instruments that deals with the nuclear liability:

-International ones (open to every country):

- 1997 Vienna Convention, 1997
- CSC, 1997
- Joint Protocol, 1988

-Regional one, open to OECD countries (with the possibility to open the convention to others countries upon consent of the contracting parties):

- The Paris Convention, 1960
- The Brussels Supplementary Convention, 1963.

The implementation of these instruments into the national framework is argued in the paragraph §3.2.1.3.3.

In every case, the key elements that characterize the international nuclear liability regime are defined by the following elements (IAEA, 2003):

a) A defined liability scope

Nuclear installation definitions (CNS I, Article 2.i):

"Nuclear installation means for each Contracting Party any land-based civil nuclear power plant under its jurisdiction including such storage, handling and treatment facilities for radioactive materials as are on the same site and are directly related to the operation of the nuclear power plant. Such a plant ceases to be a nuclear installation when all nuclear fuel elements have been removed permanently from the reactor core and have been stored safely in accordance with approved procedures, and a decommissioning programme has been agreed to by the regulatory body."

Any nuclear installation must have a legal person in charge: the operator.

In the conventions the operator has legal personality and can be both: physic person or organization; usually the operator is the license holder (also called licensee).

Nuclear incident means: *"any occurrence, or any series of occurrences having the same origin, that causes nuclear damage or, but only with respect to preventive measures, creates a grave and imminent threat of causing such damage."* (IAEA, 2003)

Nuclear damage means:

"(i) loss of life or personal injury;

(ii) loss of or damage to property; and each of the following to the extent determined by the law of the competent court;

(iii) economic loss arising from loss or damage referred to in subparagraph (i) or (ii), insofar as not included in those sub-paragraphs, if incurred by a person entitled to claim in respect of such loss or damage;

(iv) the costs of measures of reinstatement of impaired environment, unless such impairment is insignificant, if such measures are actually taken or to be taken, and insofar as not included in subparagraph (ii);

(v) loss of income deriving from an economic interest in any use or enjoyment of the environment, incurred as a result of a significant impairment of that environment, and insofar as not included in subparagraph (ii);

(vi) the costs of preventive measures, and further loss or damage caused by such measures;

(vii) any other economic loss, other than any caused by the impairment of the environment, if permitted by the general law on civil liability of the competent court." (Protocol to amend Vienna convention, 1997)

Finally the casual link between the nuclear damage and its source must be demonstrated by the person claiming compensation. The conventions don't contain any provision related to the causality; this matter is treated the national law framework: in most countries not all causes of damage are legally relevant (remote causes are not considered) and the laws requires "adequate causality" (a cause is only legally relevant if is generally linked to the cause of damage) (IAEA, 2003).

b) Strict liability imposed on the operator of a nuclear installation

The definition of strict liability is:

"Strict liability is liability without regard to fault

[…]

In general if a party is aware of the abnormally dangerous conditions or activity, and has voluntarily engaged in or permitted it, that party accepts that it will be liable for resulting damage even trough it has taken every reasonable precaution, was not negligent, or was not a fault in any moral sense." (Kelleher, et al., 2009)

Strict liability is also called: "no fault liability", "absolute liability" or "objective liability", this special liability status is usually applied to those organizations or persons engaged in dangerous activities because facilitate the bringing of claims by or behalf of the victims of the damage.

c) Exclusive liability of the operator

Exclusive liability (also called: "legal channelling of liability onto one person") prescribes the operator is the sole liable, and no other person may be liable; the operator cannot be held liable under other legal provions. This feature is typical of the nuclear laws and results unmatched with others branch of law (IAEA, 2003).

The justification of this principle is reported at follow:

"Two primary factors have motivated in favor of this channelling of all liability onto the operator as distinct from the position under the ordinary law of torts. Firstly, it is desirable to avoid difficult and lengthy questions of complicated legal cross-actions to establish in individual cases who is legally liable. Secondly, such channelling obviates the necessity for all those who might be associated with construction or operation of a nuclear installation other than the operator himself to take out insurance also, and thus allows a concentration of the insurance capacity available." (The Exposé des Motifs of the Paris Convention (as revised and approved by the OECD Council on 16 November 1982).

All states that enacted nuclear liability laws adopt the legal channeling principle with the exceptions of USA[86] and Austria.

The uniform adoption of this principle enables the harmonization and the simplification of the international regime. It deeply affects the activities or events that have an over-boundary effect, like the transport of the nuclear material and the nuclear incidents.

[86] USA adopts the concept of "economic channeling" who produces substantially the same results of the legal one (IAEA, 2003)

Another advantage "legal certainly" who affect the operator, this avoid disputes that are time and cost expending activities.

The main dis-advantage of this principle is the exemption of the vendor, contractor and supplier nuclear liability.

Hence this principle has important repercussions on contracts and on the divisions of responsibility due to the asymmetry in assigning the overall liabilities between the project partners (Owners' group).

d) Exonerations of the operator from liability

The operator is liable even if the cause of the incidents is ascribed to "force majeure causes". Only some specific circumstances exempt the operator to its nuclear liability: the operator "MUST PROVE" that the nuclear incident is caused by conflicts, hostilities, civil war, insurrection or from an act/omission committed by the victims with the intent to cause the damage (IAEA, 2003).

e) Limitation of the liability in amount

Without express limitation the nuclear liability is unlimited for the Operator, the limitation amount must be expressed by the national legislations.

Few states adopt the unlimited liability: Austria, German, Japan and Switzerland.

On the other hand the international conventions fix the minimum limitation amount that contracting parties can impose at national level:

-the minimum limitation of the Vienna revised convention is 300 Million SDRs[87]

-the minimum limitation of the revised Paris Convention is 700 Million Euros.

The limitation in liability has always been a critical issue at the international debate; because in the case of catastrophe the potential effects are higher than these limits and the State must inevitability pay additional compensation, giving a clear advantage to the Operator (IAEA, 2003).

On the other hand Operators shall not be exposed to financial risks that could entail its immediate bankruptcy. Even because of the strategic importance of the Electric Utilities in the national systems and for its nuclear liability (in the case of bankruptcy the States must acquire the nuclear liability associated with the operator).

The Brussels Supplementary Convention, 1963 and the CSC, 1997 provide additional founds (out of public ones) to cover additional compensation if the damages excess the limitation in amount.

f) Limitation of liability in time

All legal system fix a limited period for the submission of claims: in most case this is 30 years for the personal injury and 10 years for other damages.

g) Mandatory financial security of the operator to meet liability

[87] Special drawing right (SDRs) is a special unit of measurement adopted by the International Monetary Fund IMF, its value with respect the currencies is consultable at the internet site: www.imf.org; at the present 1 SDRs correspond to one dollar.

Nuclear liability conventions prescribe that operator provides insurance or other security financial forms for cover its liability until the limited amount.

The states adopting the "unlimited liability in amount" must assure security financial solutions for the minimum amount prescribed in the Conventions adopted.

The nuclear insurance industry is usually organized in "nuclear insurance pools" in order to achieve the needed synergies and to reduce the operator fees. Furthermore these pools usually make use of instruments provided by international insurance market; as result the contract are usually re-insurance.

In some countries the insurance industry may have not sufficient capabilities to cover the risk of "claims for compensation"; in these cases, the revised Vienna Convention gives two options (Vienna Convention, 1997). The first option prescribes that operator must cover not less than 150 million SDRs and the State cover the difference (between the operators' amount and the 300 Million SDR). The second one permits to the operator to cover 100 Million SDRs rather than 150 Million, under the same conditions of the first options. This additional advantage for the operator is limited in time: at least 15 years from the entry into force of the (Vienna Convention, 1997) within Operators' State.

h) Non-discrimination and equal treatment of victims

The non discrimination principle implies the national law is applied to all victims without discrimination based on "*nationality, domicile or residence*" (IAEA, 2003).

This provision recognizes directly the over-boundary potential effects on the nuclear incidents and contributes to harmonize the nuclear discipline at international level.

i) Exclusive jurisdiction of a single competent court;

In the case of incident, and subsequent claims by the victims of the nuclear damage, is applied the general rule that only one jurisdiction is applicable: the one of the State where the incident take place.

Furthermore is applied the obligation to recognize and enforce final judgment entered by the competent court in other contracting States without re-examination of the merits.

This provisions enforce the principle of "legal certainly" and avoid the risk incurred by the operator to compensate the same damages more than a time (IAEA, 2003).

Finally Fig.3.6 show the comprehensive compensation process derived from the various conventions on nuclear liability. This permit to understand the status applied to the operator that deeply affects the division of responsibilities associated with the development of the nuclear project.

These principles are applied to every licensing process.

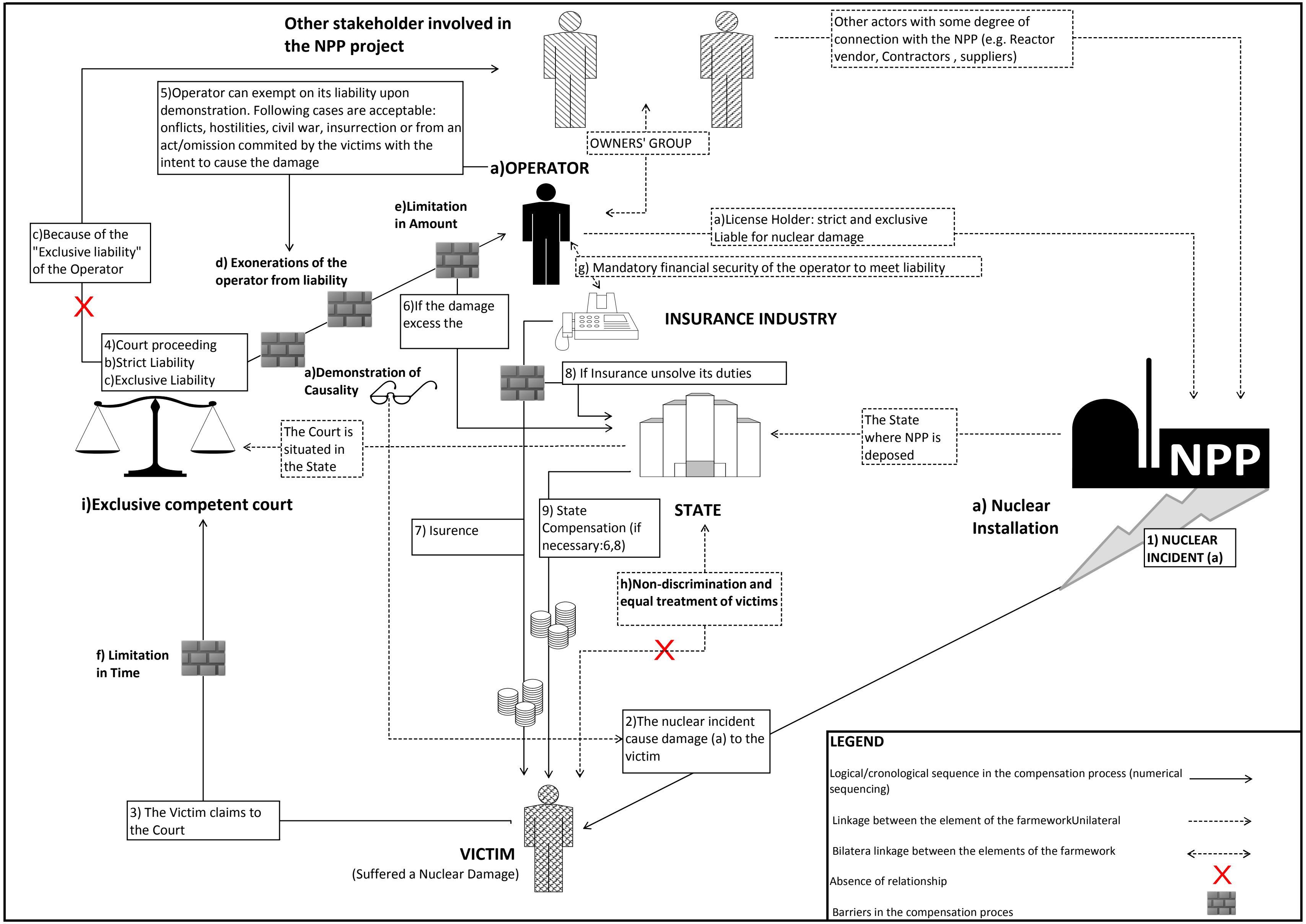

Fig. 1.22: Compensation process for victims of nuclear damage

3.2.1.3. Law framework

Law frameworks may change significantly, between countries, depending on the approach and traditions considered; this paragraph aims to present a general framework applicable to different legal systems. Furthermore the framework permits to consider some basic drivers affecting the licensing process, in terms of: complexity, amenability/flexibility, stability/predictability, detail extent of prescriptions and level of harmonization with respect the international practices.

The elements of the law framework are: extent and distribution of prescriptive norms into the legal hierarchy (§3.2.1.3.1.), relationship with non-nuclear laws (§3.2.1.3.2.), openness and dependence to foreign provisions (§3.2.1.3.3.), Centralization of the legislative body (§3.2.1.3.4.) and framework dynamics (§3.2.1.3.5.). These elements are discussed in the following sub-paragraphs; the comprehensive framework is showed in the Fig.3.7.

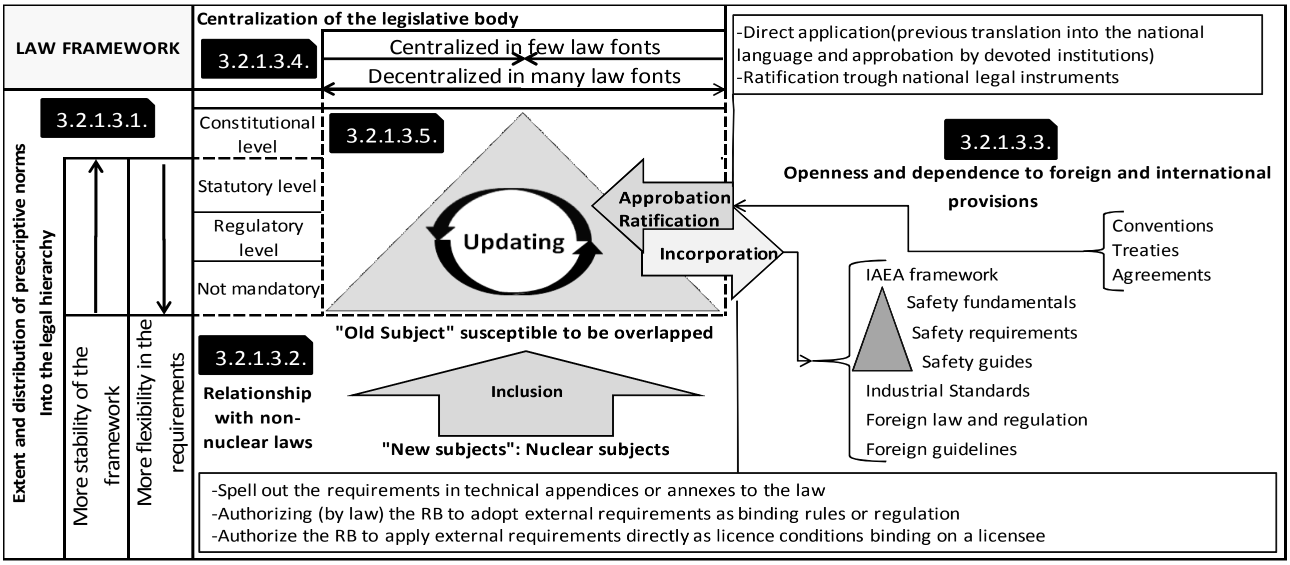

Fig. 1.23: Law Framework

§3.2.1.3.1. Extent and distribution of prescriptive norms into the legal hierarchy

In the constitutional-occidental legal systems the legal fonts are, in general terms, ordered in a top down manner: the most important principles are settled down in the higher level of the framework. At the bottom, the norms becomes more prescriptive, detailed and specifics; furthermore, these norms, must be consistent with the ones at the top. Table 3.5 presents the law hierarchy levels (rows) in conjunctions with the implementing institutions (columns).

As the level of specification and detail grows at the bottom levels, the number of norms is not uniformly distributed between the different hierarchal levels. Hence the legal framework is usually represented as triangle: few norms at higher levels and many norms at the lower ones.

One of the most important drivers, which permit to differentiate the law frameworks, is the level of specification of the norms and their distribution within the legal hierarchy.

		INSTITUTIONAL LEVELS			
		Parliament	Government	Regional, federal and local Council	Administrative bodies
LAW FONTS HIERARCHY	Constitutional level	Constitutional laws			
	Statutory level	Ordinary laws	Others acts with the force of law[88]		
	Regulatory level		Regulations		
	Not-mandatory level				Guidelines[89]

Table 3.5: Law hierarchy and implementing institutions

There are three basic legal approaches that differ due to the level of detail and specification of its norms (IAEA, 2002):

1) Prescriptive base approach
2) Performance base approach
3) A balanced mix of the previous

1) In the first approach, the legislator emphasizes the level of detail and specification of the norms contained into the law framework. Form one hand the resulted framework is understandable, clear (if correctly structured and if it is assured the consistence between the different norms) and prescriptive.

To the other one it's rigid: difficult to amend and to modify.

In licensing context, every "rule" and "parameter" (that applicant must accomplish for achieve the license) is defined into the law framework.

The actor empowered to grant the license need to assess the consistence between the proposed facility (an all documents associated to it) and the "rules" and "parameters" defined in the law framework; when the law framework is performance-based, he doesn't' need to interpret anything because all is clearly defined, as result his confidential power is low.

The nuclear sector is characterized for the continuous improvement in terms of safety practices, technological advances, etc. As result, maintain a prescriptive law framework in line with the modern practices requires great efforts to the legislator and regulators: this fact represent one of the main weaknesses of the approach.

Another concern is the distribution of the detailed norms into the legal framework; in general terms, higher the hierarchy level and more difficult is the modification of the norms belonging to this, as showed in Fig 3.8.

In real cases, the prescriptive based approach lead to higher level of complexity even due to the lack of an opportune overall structure because of the decentralization of law fonts (IAEA, 2002). Furthermore the Higher complexity usually led to problems in terms of consistency between different norms.

[88] Decrees, ordinances (in some countries, e.g. France); regional, federal, local laws.

[89] Indeed all institutions can develop not mandatory documents; sometimes the administrative bodies have also the duty to develop these.

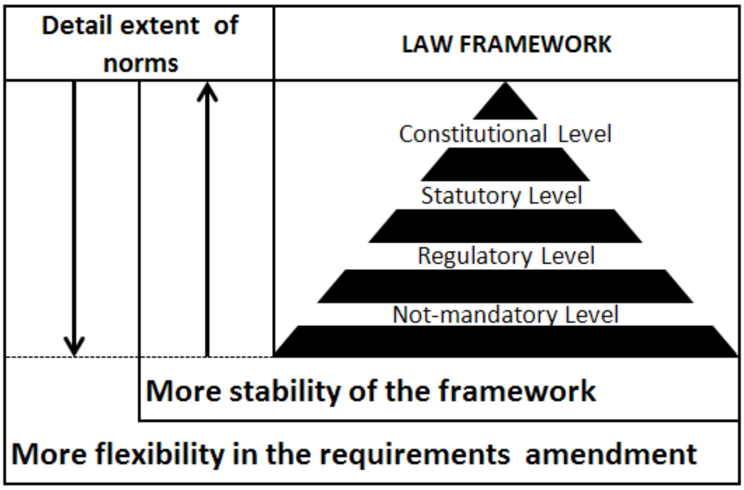

Fig. 1.24: Detail extent of the norms into the legal hierarchy

Finally the legislator, in the application of such approach, should consider all possible scenarios and circumstances affecting the subject of its interest: this is only theoretically possible, in real cases is not.

2) The Performance Based approach is characterized to the low level of detail and specification of the norms contained in the law framework; this is the opposite case with respect the previous one.

In this case, law framework reports only the basic principles that shall be persecuted.

In licensing contexts, these led to high confidential powers associated to the actors devoted to granting the license. The advantage is the low efforts needed in maintain the framework in line with the best and modern practices because it doesn't need to be amended.

On the other hand applicants usually perceive great licensing process uncertainty because it is difficult to forecast the interpretation of the actors empowered to grant the license.

In these cases, the guidelines are vast and detailed. In this way is possible to maintain the flexibility required (because the guidelines are not mandatory) and furnish to the applicants proven and detailed licensing approaches that improve its understood and forecast with respect the licensing process (IAEA, 2002)

In every case the detailed examples reported in the guidelines are not mandatory and the applicant can anytime furnish a new safety approach to the actor devoted to grant the license (IAEA, 2002).

Another typical tools, extensively used in the performance based approach, are the license conditions; these are prescriptive norms crafted to the specific site and design subjected to be licensed.

In most countries the license conditions have the force of law (e.g. UK).

The license conditions permit to maintain the level of flexibility required until the license is granted; after that point, prescriptive norms are written into the license and must be satisfied during the operating phase of the facility (these can be modified, suspended, amended by the institutional actor empowered to do that) (IAEA, 2002).

3) In this last case the legislator tries to combine the previous approaches to compensate the relative advantages and disadvantages of these. Indeed legislator always adopts a combined approach (because the previous approaches are more theoretical extremes), this category deals with those national approaches not directly linked to the previous ones (§4.3).

§3.2.1.3.2. Relationship with non-nuclear laws

The nuclear legislation has much degree of connections with other branches of law because when the nuclear program is implemented many fields have already been regulated; then nuclear laws are included into a broader law framework.

Table 3.6 presents the existing subjects susceptible to be overlapped by the nuclear laws, and the subjects that characterize the nuclear laws (IAEA, 2003).

Higher is the overlap, between the nuclear and remained field, higher is the level of complexity of the resulted framework.

Usually the development of the nuclear law is characterized for a grating approach (IAEA, 2006): the legislator usually prefers to concentrate its effort on the most critical matters and takes advantage of the existing law framework who support the remained ones. Hence the most important principles are regulated by specific nuclear laws and the secondary matters are mostly treated by regulator which refers extensively to the existing non-nuclear laws. This approach emphasizes the dependence of the nuclear field to the whole law framework.

The main weakness of this approach is the level of complexity and fragmentation associated to the nuclear law framework; especially for the oversea actors involved into the nuclear project (that are not familiar with the extensive law framework adopted within the country).

Regulated subjects susceptible to be overlapped by the nuclear subjects	**Nuclear subjects**
Local land use controls	Radiation protection
Environmental matters	Sources of radiation and radioactive material
The economic regulation of electric power utilities	Safety of nuclear facilities
The occupational health and safety of workers	Emergency preparedness and response
General administrative procedures	Mining and milling
Transport	Transport of radioactive material
The export and import of nuclear material	Radioactive waste and spent fuel
Intellectual property rights	Nuclear liability and coverage
Liability for non-nuclear damage	Safeguards
Emergency management	Export and import controls
Taxation	Physical protection

Table 3.6: Nuclear law subjects and overlaps with the existing law framework

§3.2.1.3.3. Openness and dependence to foreign and international provisions

The term “openness” refers to the degree of permeability of the legal context with respect foreign or international provisions.

The term “dependence” has two main facets, first the external effects of the international instruments[90], second the extent by which the law framework incorporates foreign provisions[91]; this thesis work refers to the second meaning “dependence”.

In licensing contexts, the degree of openness and dependence of the law framework affect primary the oversea actors (involved into the nuclear project): higher is the common legal base between the importing and exporting country, higher is the level of understood of the foreign actors. As result this driver have significant effect on the epistemic risk affecting foreign actors.

There are two basic typologies of instruments which permit to incorporate foreign provisions into the national law framework (IAEA, 2003):

1) First the “international legal instruments”: conventions, treaties, agreements, and UN Security Council decisions (§3.2.1.2).
2) Second: standards, foreign laws, regulations and guidelines.

1) The first instruments have two effects into the law framework: internal and external one:

- Internal effects refer to the efforts and techniques needed for the incorporation of the international prescriptions into the national law framework.

- External effects refer to the obligation that the state acquires with respect the other contracting parties of the international instrument.

- There are two basic methods for incorporating the international instruments into the national legal framework: the direct approbation and the ratification.

The first method permits the direct application of the international prescriptions previous the approbation by the devoted institutions, and after its translation into the national language (if needed).

The second method consists to the incorporation, of the international prescription, into national laws.

The advantage of first method is the “self-executing” feature that implies fewer legislators’ efforts.

On the other hand, second method enables a better inclusion of the international prescription because of the higher consistency and respect of the national legal traditions.

[90] When an international instrument is implemented, the contracting party acquire duties with respect the others contracting parties of such instruments; these duties are underlined into the international instrument body.

[91] E.g. an extreme case is when all norms contained into the framework are imported; in this case the framework has a high dependence with respect foreign provisions.

Most of time the choice (between these two methods) is constrained by the degree of openness of the legal systems: some constitution forbids the direct implementation of foreign provisions; hence these need to be ratified by appropriate tools.

- The external effects are written into the international instrument document text; usually every contracting party has the duty to approve/ratify the provision in a limited time under certain conditions.

2) The second typology of foreign provisions has only internal effects: there is not any obligation affecting the implementing State.

There are two basic categories of foreign provisions:

2.a) Requirements

2.b) Standards

2.a) The incorporation of foreign requirements into the national framework is typical for those countries that are developing the nuclear program (second step, §3.1.3). In this case legislator develops the basic legal infrastructure (IAEA, 2006)and "imports" some prescriptions from abroad with four main objectives: first facilitating the foreign reactor vendor and contractors[92], second to reduce the legislators' efforts, third harmonizing the country's law framework with the international practices, forth take advantage of technical and legal expertise of experienced organization (IAEA, 2006), (IAEA, 2003). Foreign requirements can be imported from law frameworks of overseas country's[93] (laws, regulations, guidelines) or publications made by no-governmental organizations which promote the development of nuclear programs, e.g. IAEA[94] [95].

2.b) On the other hand, standards permit to take into account the modern practices (in terms of safety procedures, quality assurance, etc) and technological advances (the advantage derived to the implementation of foreign requirements

Especially the "performance based legal approach" (§3.2.1.3.1.) takes into account this typology of foreign prescriptions (IAEA, 2002).

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[92] For the first nuclear project is typical the extensive use of foreign contractors and vendors (under turn-key contract). This because of the low maturity of the national nuclear industry (IAEA, 2007).

[93] Usually the ones of contractors and vendor.

[94] IAEA promotes the peaceful use of nuclear energy and assist the countries who implements a civilian nuclear program (Statute IAEA, Article2).

[95] The IAEA publications are structured in a hierarchical manner: safety fundamentals (that reports the most important principle contained in the international conventions); safety requirements (written using legal terminology; this intermediate level contain the prescriptions easily implementable into national law framework); and safety guides (detail and enable a better understood of the previous typologies of documents).

Furthermore IAEA public also technical guides, studies, books, etc. Some of the implementing prescriptions are also contained in these further typologies of documents, e.g. (IAEA, 2010).

Standards are mostly developed by professional and no-governmental organizations; some of the most important (affecting the nuclear field) are: IAEA, International Organization for Standardization (ISO); International Electrochemical Commission (IEC), American Nuclear Standards Institute (ANSI), American Society of Mechanical Engineers (ASME), German Nuclear Safety Standard Commission, Association Francaise de Normalisasion (AFNOR), (IAEA, 2002).

The implementation of the foreign provisions (both foreign requirements and standards) is undertaken by three basic methods (IAEA, 2003):

-Authorizing (by law) the RB to apply external provisions as binding rules or regulation;

-Spell out the provisions in technical appendices or annexes to the law;

- Authorizing (by law) the RB to apply external provisions directly as license conditions.

External provisions may be subjected to periodic reviews; these three methods enable a simplified modification of the existing linkages trough the RB action (avoiding the government and parliament action).

A first concern is the consistence between the foreign provisions and the states' legal structure (e.g. institutional structure and procedures, terminology, etc.).

Finally, Table 3.7 summarizes the variables affecting the degree of openness of the law framework.

<table>
<tr><th colspan="2">Typology of international/foreign instrument</th><th>Implementation into the national law framework (internal effect)</th></tr>
<tr><td>1)International instruments (internal and external effects)</td><td>Conventions
Treaties
Agreements
UN Security Council decisions</td><td>-Direct implementation (after the translation into the national language and the approbation by the devoted institutions)
-Ratification (using national legal instruments)</td></tr>
<tr><td rowspan="2">2)Foreign provisions (only internal effects)</td><td>a)Foreign requirements (laws, regulations, guidelines)</td><td rowspan="2">-Authorizing (by law) the RB to apply external provisions as binding rules or regulation;
- Spell out the provisions in technical appendices or annexes to the law;
- Authorizing (by law) the RB to apply external provisions directly as license conditions.</td></tr>
<tr><td>b)Standrds</td></tr>
</table>

Table 3.7: Variables affecting the Degree of openness and dependence of the law framework

§3.2.1.3.4. Centralization of the legislative body

Centralization of the legislative body is a measure of fragmentation of the law framework.

Some advanced countries have undertaken, in the ten last year, reforms for: reducing the number of laws, enhancing the simplicity, coherence and clearness of the resulted framework.

This driver has strong degree of connection with the "relationship with non-nuclear laws" (§3.2.1.3.2.).

(Bredimas, et al., 2008) argue how the nuclear framework should be contained in ten or less law fonts.

§3.2.1.3.5. Framework dynamics

Dynamics refers to the frequency by which the law framework is revised, modified and amended; this driver is strongly dependent of the "extent and distribution of prescriptive norms into the legal hierarchy" (§3.2.1.3.1.), and the "openness and dependence to foreign and international provisions" (§3.2.1.3.3.).

Usually, norms contained into the lower levels, of the law hierarchy, changes more frequently with respect the higher ones.

The "performance based legal approach" (§3.2.1.3.1) is more flexible and amendable, and then dynamic (IAEA, 2002).

Law frameworks are highly dependent to foreign standard and requirements are also dynamic.

On the other hand the "prescriptive based" (§3.2.1.3.1) framework are static, especially when the detailed norms are contained into the higher level of the legal hierarchy.

Furthermore the framework dynamics depends significantly to the legal traditions; some of the most critical subjects are the administrative procedures and the extent by with judicial and administrative reviews influences the law framework.

Finally framework dynamics impacts into the licensing contexts in terms of predictability and stability of the procedures and conditions that applicants must fulfill.

3.2.2. Specialized nuclear institutions

The institutional framework comprises with administrative bodies devoted to the nuclear sector.

The degree of fragmentation of these bodies mostly depends on the national and administrative traditions of the country considered. A uniform perspective (at international level) is provided by the IAEA framework[96] that delineates three main administrative bodies: Regulatory Body (RB) and Nuclear power implementation Agency (NPIA) and decommissioning authority (IAEA, 2006). Furthermore other administrative bodies usually overlap the nuclear sector, the most important agency; with this respect is the Environmental Agency (EA).

The first two institutions are presented in the following subparagraphs; the decommissioning authority is not specifically treated due to its scarce influences into the licensing process. Finally EA is presented only in the detailed nuclear programme framework (§ ANNEX IV), because is not a specific nuclear institutions and then doesn't need to be developed because already exists.

3.2.2.1. Regulatory Body RB

Nuclear Regulatory body has four main functions (CNS I, Art 7,8):

- Regulating the nuclear sector
- Carrying out the licensing activities for: the NPP construction, exercise; for the transportation and holding of nuclear materials, etc.

[96] Safety fundamentals, safety requirements and safety guides, §3.2.1.3.3

- Inspecting/Assessing documentation and activities related to: the NPP constructions/operations, transport and holding of radioactive material, etc.
- Enforcing actions: RB has the power to make civil sanctions and to suspend, revoke or modify the license or a part of it.

These are the ordinary duties of the RB; in addition, during the development of the nuclear programme (transient), RB must develop the appropriate capabilities for carrying out its duties.

As result, RB functions have internal and external effects.

Form on hand RB must satisfy the highest standards in terms of internal procedures, quality assurance, ect.

On the other hand RB regulates licenses, inspects and enforces the nuclear sector, as result deeply affects all stakeholders involved in it.

In carrying out its functions, RB needs to accomplish some basic features; these are mostly determined by the Government action in the second step (§3.1.3) of the nuclear programme: e.g. financing, staffing, legal status, etc.

With this respect the most important principle is the RB independence (IAEA, 2010); for achieving this RB status there are two main typologies of challenges listed at follow:

1) External challenges: "*may include unwarranted interaction and attempts to influence regulatory decision making by individual politicians and political groups, by licensees and vendors, and by interest groups such as nongovernmental organizations."* (IAEA, 2003)

2) Internal challenges consist with:

- Lack of clearly defined objectives and criteria to persecute
- Insufficient competence of the RB staff
- Too great dependence on few individuals
- Lack of clearly defined procedures

Then to determine the RB independence there are three main tiers to consider:

"- The establishment of the legal framework governing regulatory activities and their associated objectives, principles and values, including the legal basis for adequate and stable financing of regulatory activities;

- The establishment and implementation of clearly defined processes for regulatory decision making;

- The establishment and implementation of a clearly defined competence management programme for the regulatory body which includes an internal management programme for human resources and provides the necessary means to secure independent scientific and technical support for the regulatory activities, with international co-operation as an important component" (IAEA, 2003).

These measures are undertaken by two main typologies of actors: the politic decision-makers (Government and Parliament) which create the Regulatory institution by law and furnish it with financial resources, competences, etc.; and the senior managers of the RB which promote and implement the internal procedures and all necessary measures that enable the quality and independence of the RB activities.

Fig. 3.9 summarizes all influencing factors related to the RB independence.

A detailed list of RB duties is presented in the detailed nuclear programme framework: (§ANNEX IV).

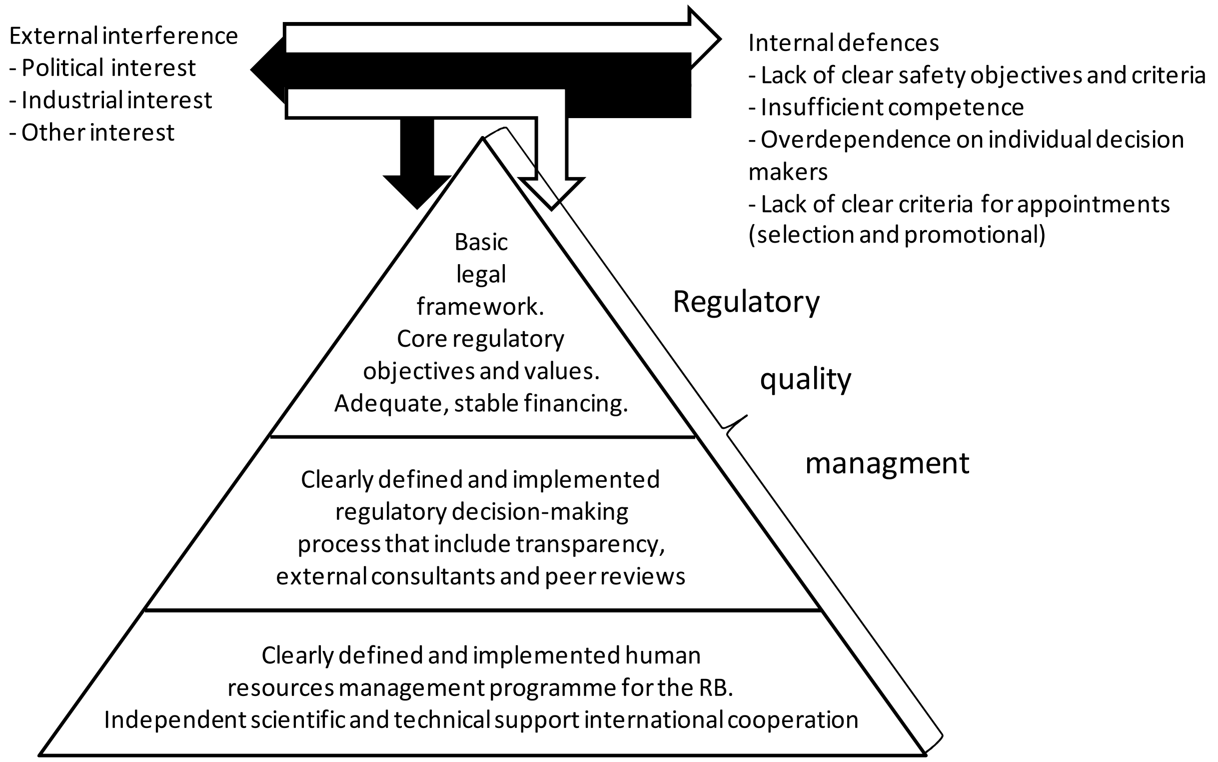

Fig. 1.25: Components of a system for quality management to ensure independence in regulatory decision making. (IAEA, 2003), revised figure

3.2.2.2. Nuclear Power Implementation Agency

NPIA is a transitory organization under the responsibility and control of the Minister primarily devoted to the development of the nuclear programme.

The main activities undertaken by the NPIA are:

- Position of nuclear power in the electricity market and generation mix.
- Economics of nuclear power.
- Legal, regulatory and legislative aspects of nuclear power.
- Environmental and siting aspects of nuclear power.
- Nuclear power technology.
- Nuclear fuel cycle including waste management and decommissioning.
- Expected role of the government and the private sector in the development of the nuclear programme.
- Extent of availability of the industrial base and of the human resources needed for the nuclear programme in the country.
- Extent of the uranium resources in the country and its impact on the fuel supply policy.
- Public acceptance.

The an example of organizational structure of the NPIA is showed in the Fig. 3.10.

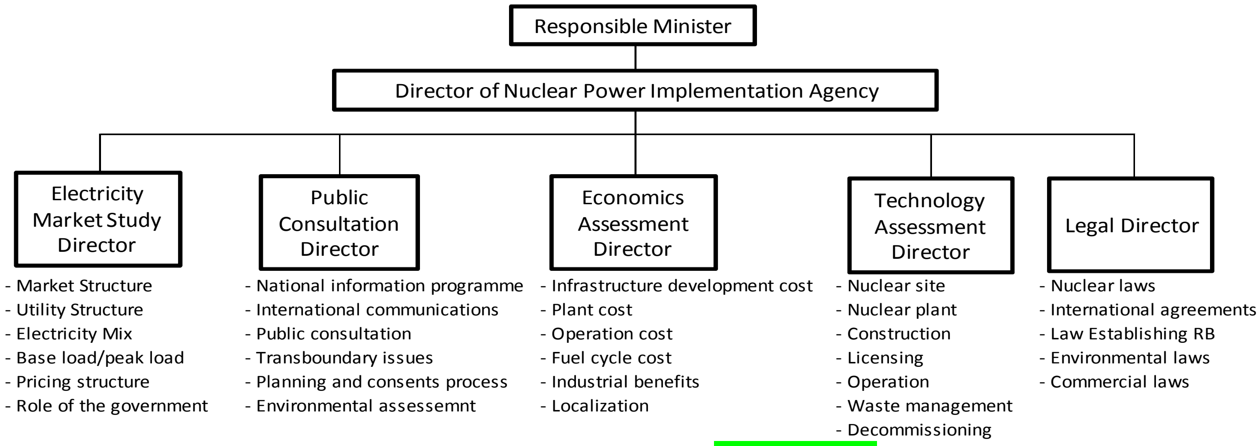

Fig. 1.26: General organization of NPIA (IAEA, 2006), revised figure

3.2.3. Safety Principles, tools, criteria and Requirements

The concept of safety encompasses all potential activities which could have potential negative effect on people or environment and is applied to all industrial activities.

Safety concerns are especially emphasized in the nuclear sector due to the performing of dangerous activities and handling radioactive source; these have high potential detrimental effect on people and environment, and then require special care to be managed.

The concept nuclear safety is especially stressed (in the nuclear field) and considers only the nuclear risk[97] (§3.2.1.2.2.a.).

On the other hand the nuclear activities and installations are affected also by broader typologies of risk, which are systematically taken into account during the safety demonstrations or assessment.

This section deals only with the concept of nuclear safety because it is the most important aspect related to the licensing decision-making process.

The prime objective, derived to the implementation of the nuclear safety principles, is:

"The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation" (IAEA, 2006)

The demonstration and assessment of the safety of nuclear installations (or related activities) is performed using opportune tools and trough the reference to the safety principles and criteria.

The following paragraphs introduce the general nuclear safety principles applied to the NPP (§3.2.3.1.); and argue how these principles are applied (§3.2.3.2.1.) assessed and demonstrated (§3.2.3.2.2.). Finally the

[97] Nuclear risks consist on event and circumstances tha, if occur, have potential negative effect on nuclear safety. The effect of such risks are the nuclear damages (§3.2.1.2.2.a.).

paragraph (§3.2.3.2.3.) introduce the problems arisen due to the adoption of the safety criteria into the legal infrastructure.

3.2.3.1. Safety Principles

The safety principles are rules (general or specific) by which the concept of safety is developed and applied.
The most common safety principles are documented by the IAEA using a hierarchical structure; at the top: "IAEA fundamentals safety principles" that introduces the basic prescriptions that: nuclear countries, RB and nuclear operator must put in place for enable the effectiveness of the safety measures.
These basic principles are then further detailed by the "IAEA Safety requirements"[98] and by the "IAEA Safety Guides".
The whole set of publications is called: "safety standards".
The IAEA safety requirements and guides are too many and too much detailed to be argued into this chapter, furthermore the whole set of nuclear safety principles are too many as well.
For this reason, this section deals only with the most important and general safety principles.

3.2.3.1.1. IAEA Safety Fundamentals

The Fundamental safety principles (IAEA, 2006)introduce the most important safety roles and philosophies that necessitate to be implemented by the nuclear countries and organizations; Table 3.8 shows the ten principles.

3.2.3.1.2. Basic Safety Principles

The basic safety principles can be grouped in three main sets: management, defense in depth and technical principles (these can be general or specific).
The specific principles take into account also the various phases of the NPP: siting, design, manufacturing and construction, commissioning, operation, Accident-Management, Decommissioning, emergency preparedness (IAEA, 1999)
This section presents at follow only the general basic safety principles.

3.2.3.1.2.1. General Management safety principles:

The three general management safety principles are listed at follow:
- Safety culture: "*an established safety culture governs the actions and interactions of all individuals and organizations engaged in activities related to nuclear power*." (IAEA, 1999)
- Responsibility of the operating organization: (redundant, like CNS I, Art 9 and IAEA Safety fundamental, principle 1)

[98] In this case: "safety requirements" is the name of a set of publications. Note that this paragraph also introduces the concept of safety requirements but using a different perspective: those safety prescriptions contained into the law framework (that are blinding roles for the actors operating in the nuclear field)

- Regulatory control and independent verification (redundant, like CNS I Art 8 and IAEA safety fundamentals, principle 2).

Principle 1: **Responsibility for safety**
The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.
Principle 2: **Role of government**
An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.
Principle 3: **Leadership and management for safety**
Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.
Principle 4: **Justification of facilities and activities**
Facilities and activities that give rise to radiation risks must yield an overall benefit.
Principle 5: **Optimization of protection**
Protection must be optimized to provide the highest level of safety that can reasonably be achieved.
Principle 6: **Limitation of risks to individuals**
Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.
Principle 7: **Protection of present and future generations**
People and the environment, present and future, must be protected against radiation risks.
Principle 8: **Prevention of accidents**
All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.
Principle 9: **Emergency preparedness and response**
Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.
Principle 10: **Protective actions to reduce existing or unregulated radiation risks**
Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

Table 3.8: Fundamental Safety Principles (IAEA, 2006)

3.2.3.1.2.2. General defence in depth safety principles:

The Defence in depth principle stated: “*To compensate for potential human and mechanical failures, a defence in depth concept is implemented, centered on several levels of protection including successive barriers preventing the release of radioactive material to the environment. The concept includes protection of the barriers by averting damage to the plant and to the barriers themselves. It includes further measures to protect the public and the environment from harm in case these barriers are not fully effective.*” (IAEA, 1999)

The objectives of this safety strategy are:

“- compensate for potential human and component failures

- maintain the effectiveness of the barriers by averting damage to the plant and to the barriers themselves

- protect the public and the environment from harm in the event that these barriers are not fully effective.” (IAEA, 1999)

The concept of defence in depth is based five levels of defense, multiple physic barriers and different plant status as showed in the Fig. 3.11.

The concept of defence in depth has e also two further basic general principles as corollary:

- Accident prevention: "*principal emphasis is placed on the primary means of achieving safety, which is the prevention of accidents, particularly any which could cause severe core damage.*" (IAEA, 1999)

-Accident mitigation: "*in-plant and off-site mitigation measures are available and are prepared for that would substantially reduce the effects of an accidental release of radioactive material.*" (IAEA, 1999).

3.2.3.1.2.3. General technical safety principles:

The general technical safety principles are listed at follow:

- Proven engineering practices: "*nuclear power technology is based on engineering practices that are proven by testing and experience, and which are reflected in approved codes and standards and other appropriately documented statements.*" (IAEA, 1999)
- Quality assurance: "*quality assurance is applied throughout activities at a nuclear power plant as part of a comprehensive system to ensure with high confidence that all items delivered and services and tasks performed meet specified requirements.*" (IAEA, 1999)
- Self-assessment: "*self-assessment for all important activities at a nuclear plant ensures the involvement of personnel performing line functions in detecting problems concerning safety and performance and solving them.*" (IAEA, 1999)
- Peer reviews: "*independent peer reviews provide access to practices and programmes employed at plants performing well and permit their adoption at other plants.*" (IAEA, 1999)
- Human factors: "*personnel engaged in activities bearing on nuclear plant safety are trained and qualified to perform their duties. The possibility of human error in nuclear power plant operation is taken into account by facilitating correct decisions by operators and inhibiting wrong decisions, and by providing means for detecting and correcting or compensating for error.*" (IAEA, 1999)
- Safety assessment and verification: "*safety assessment is made before construction and operation of a plant begin. The assessment is well documented and independently reviewed. It is subsequently updated in the light of significant new safety information*" (IAEA, 1999)
- Radiation protection: "*a system of radiation protection practices, consistent with recommendations of the ICRP and the IAEA, is followed in the design, commissioning, operational and decommissioning phases of nuclear power plants.*" (IAEA, 1999)
- Operating experience and safety research: "*organizations concerned ensure that operating experience and the results of research relevant to safety are exchanged, reviewed and analyzed, and that lessons are learned and acted on.*" (IAEA, 1999)

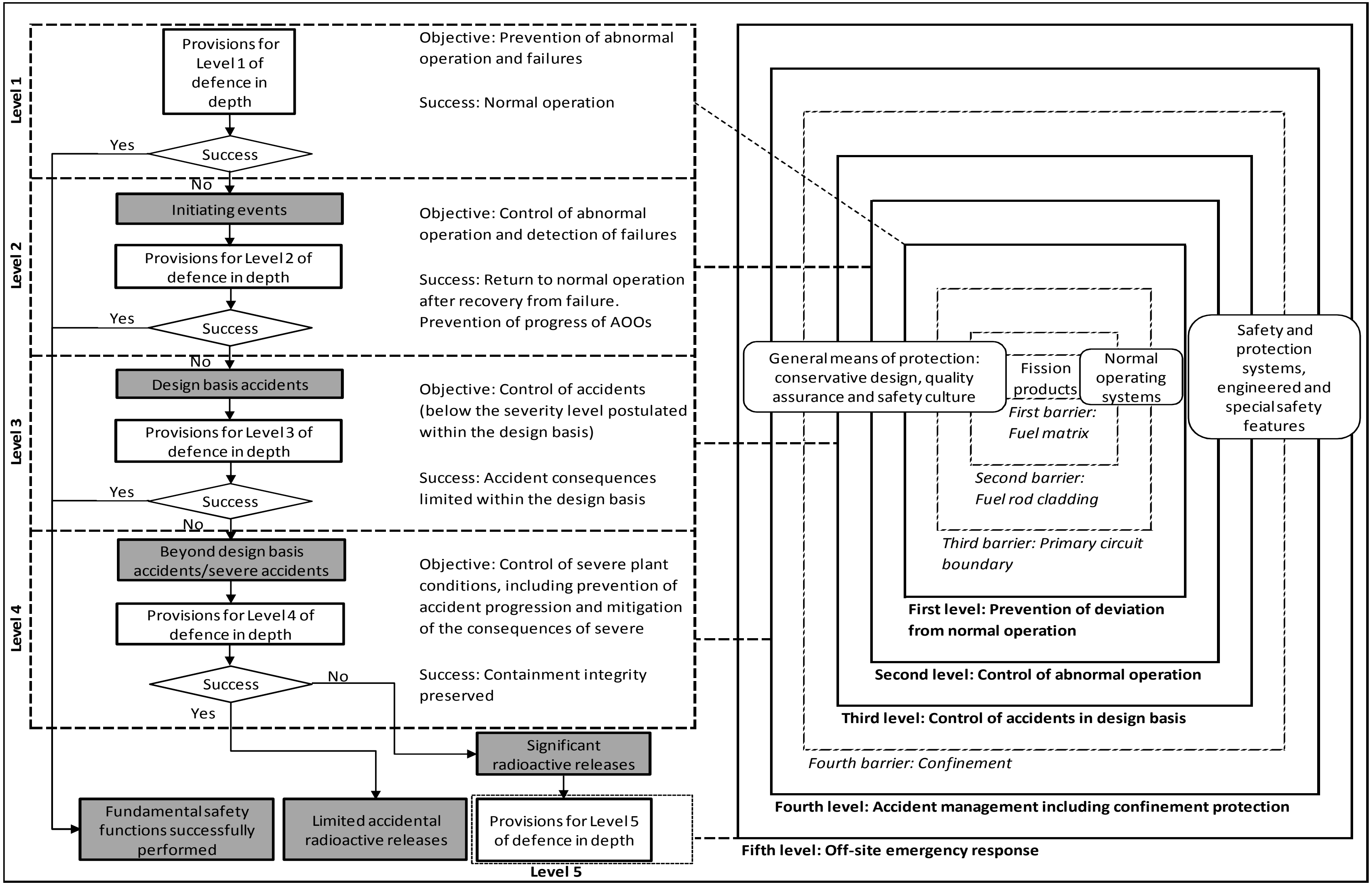

Fig. 1.27: Defence in depth (IAEA, 2005)revised figure

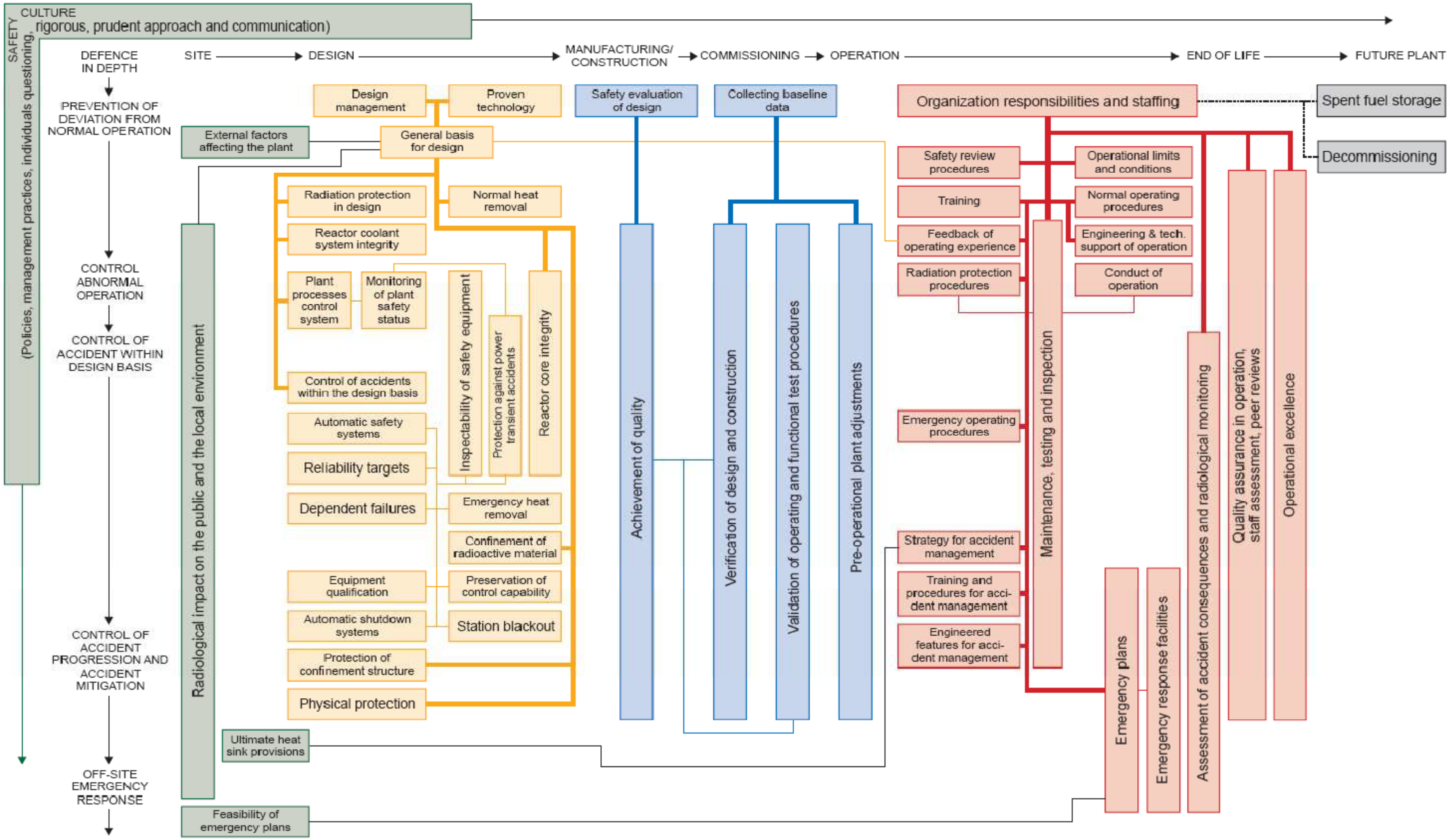

Fig. 1.28: Coherence of the specific safety principles (IAEA, 1999)

- Operational excellence: "*operational excellence is achieved in present and future nuclear power plant operations by: augmenting safety culture and defence in depth; improving human performance; maintaining excellent material condition and equipment performance; using self-assessments and peer reviews; exchanging operating experience and other information around the world; increasing application of PSAs; and extending the implementation of severe accident management.*" (IAEA, 1999)

The connection between the basic principles is showed in the Fig. 3.12.

3.2.3.2. Application, demonstration, assessment and adoption (as requirements) of the safety principles

To be effective, the safety principles need to be:

1) Applied to all pertinent organizations and activities[i]
2) Demonstrated, in terms of compliance with safety requirements, during the licensing process by the applicant[ii], and during the subsequent NPP's phases by the licensee (e.g. periodic safety reviews, inspections, shut down, incidents, decommissioning).
3) Assessed, inspected and monitored, in terms of compliance with safety requirements, during the licensing process and during the subsequent phases of NPP by the RB.
4) Adopted, as requirements, into the legal framework to be blinding roles for all actors operating into the nuclear field.

The real issuance of the safety principles, in the terms just introduced, may require the introduction of special measures, tools, methodologies and criteria as argued by the following sub paragraphs.

3.2.3.2.1. Application of the nuclear safety principles

The application of the nuclear safety principles, in general, passes through:

- Incorporation, of the principles, into all organizations operating in the nuclear field (in terms of safety culture, capabilities, knowledge, procedures, quality assurance programs, training activities, etc.)

- Application to all activities related to nuclear safety functions (using a grating approach depending safety risk significance associated to the different activities)

Furthermore, the organizations need to put in place opportune measures[iii] to rend effective the implementation of the nuclear safety principles. The most important are: measures for the continuous improvement of safety performances, R&D, management of safety related events, experience feedback,

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[i] With different emphasis and extent depending of the actors and activity considered.

From one hand the RB and the Operator must put in place all possible measures for pursue the safety objectives, on the other one may exist sub contractors that, during the NPP construction phase, furnish goods and services that are not critical with respect the nuclear safety. The application of safety principles is emphasized in the first case and is not in the second one.

A similar example can be done with respect the activities: some are critical with respect safety (e.g. the manufacturing, installation and maintenance of the reactor vessel) and some are not or less (e.g. the cleaning services at the offices within the NPP facility).

[ii] The definition of applicant and licensee is argued in the (§4.1.3)

[iii] These measures are considered safety principles as well.

knowledge and information sharing between nuclear organizations (e.g. peer-reviews), self assessment, continuous training, implementation of quality assurance programs, etc. (IAEA, 2002).

These general considerations lie to the real application of the nuclear safety principles that mostly depends on the typology and the content of the safety principle considered.

For example the first IAEA fundamental safety principle (titled: *Responsibility for safety*: assign the prime safety responsibility to the operator) requires the development of opportune articles, settled down into the legal framework by the contracting parties of the CNS I[i].

In particular the legislator must address an unusual liability principle[ii] associated to the nuclear licensee: the principle of strict and exclusive liability.

Furthermore the application of this principle passes also trough the instauration of contractual relationship between the actors belonging to the Owners' group. In this case the responsible operator shall take under control all activities related to safety (because in any case it is liable). Sometimes the operator delegates some of these responsibilities during the early phases of the nuclear project and then gradually acquires the whole set of responsibilities. This case is typical for those operators inexperienced with a particular reactor design, which delegated the NPP development trough the turnkey approach. It is advisable that the operator maintain always some degree of control over all activities related to the nuclear safety.

Furthermore the term responsibility must not be understood just as law prescription, but is especially fundamental piece of the safety culture and approach operator must incorporate; the real application of this principle may require special measure put in place by the operator that must take under control all possible risk associated to the unsafe use of nuclear material or related activities.

This general principle impact to many of the others safety principles.

3.2.3.2.2. Demonstration and assessment of the compliance with nuclear safety principles, criteria and requirements

The demonstration and assessment, of the safety principles, can be argued together because are speculated activities: from one hand the Operator tries to demonstrate, to the RB, the compliance with the safety requirements; to the other hand the RB assesses the demonstration of the operator and carry out its independent assessment as well. Usually the approaches adopted for these two tasks (assess and demonstrate) are the same.

These two activities are typical of the following instant (of the NPP's lifecycle):

- Licensing process
- Safety reviews

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[i] The principle derived from the Article 9 of CNS I, implemented after the Chernobyl accident (§3.2.1.2.1.).
The contracting parties are the countries who agreed CNS I.

[ii] As discussed in the §3.2.1.2.2., the nuclear operator acquire special liabilities that in any other industrial activities don't exist.

- Inspections (independent or related to event concerning safety matters)
- Shut down
- Decommissioning

Fig 3.13 synthesizes the relationship between the application of the safety principles in relation to the demonstration and assessment.

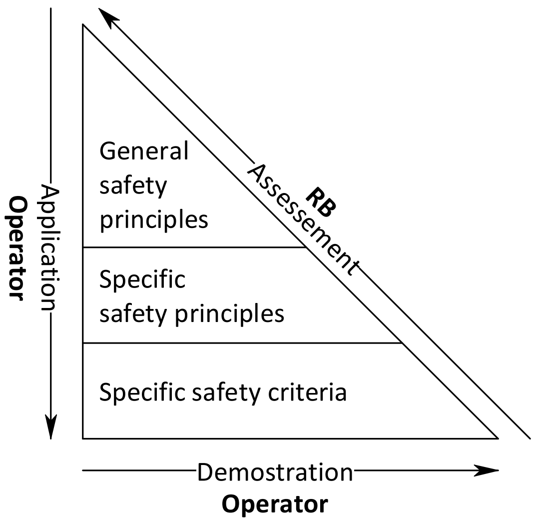

Fig. 1.29 : Linkage between the safety principles application, demonstration and assessment

As argued in the previous section (§3.2.3.1.), the safety principles are organized in a hierarchal manner, Fig.3.13 show a top down application of these.

A key concern is the linkage between the application of the safety principles and its demonstration/assessment.

The safety criteria comply with methodologies and tools opportunely addressed to enable a judgment (more or less objective, depending on the safety criterion considered) on the correct issuance of safety principles and requirements. These criteria may be incorporated into the legal framework as safety requirements (that have a blinding role for the operator) or included into the evaluation (demonstration/assessment) without an explicit request; in every case a detailed definition of the safety criteria is needed and it's usually contained into the detailed guidelines furnished by the RB.

The demonstration of compliance with safety requirements (and more in general with safety principles) consists in documenting the application of the safety criteria with respect the: organization, nuclear site and reactor design features.

On the other hand the assessment of the safety requirements passes through the application of opportune safety criteria, further than an expert judgment made on the overall consistence of the safety principles application.

The safety criteria, adopted for the demonstration/assessment mostly depend on:

- The typology of safety principle (e.g. qualitative, quantitative, etc.)

- The experience and technological advance matured in the application of the principle
- The availability of the methodologies and tools within the organization to carrying out the assessment/demonstration in terms of: capabilities, experience, knowledge, economic resources, instrumentation, etc.
- The requested level of detail, precision, completeness and reliability in the issuance the demonstration/assessment.

Fig 3.14 shows a sample of the most important typologies of tools adopted in the demonstration/assessment of the safety principles, catalogued for their nature, in relation to some safety criteria.

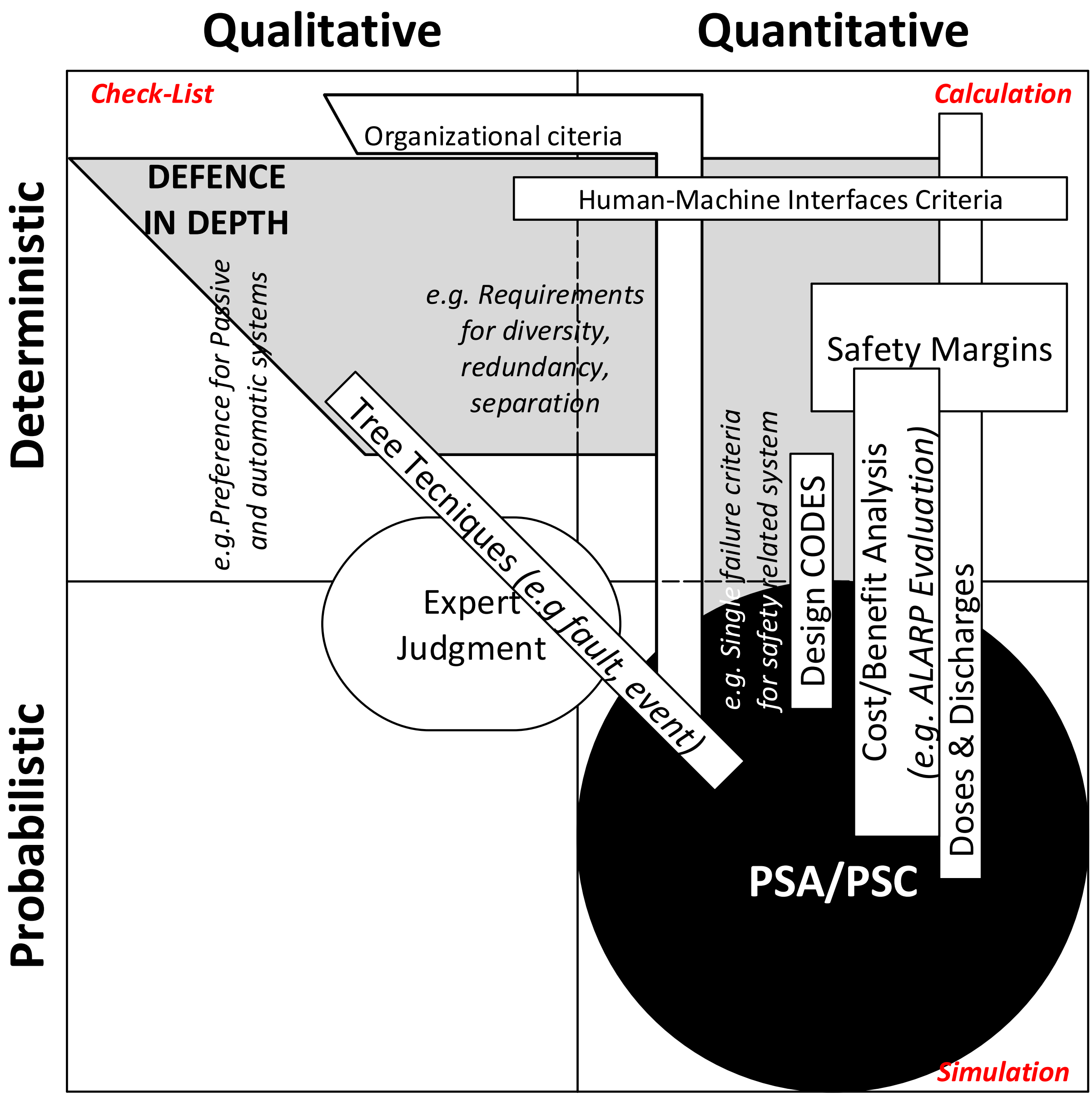

Fig. 1.30: Safety criteria and assessing methodologies

The following subparagraphs introduce the main tools and methodologies associated to the safety criteria.

3.2.3.2.2.1. Deterministic Safety Analysis of Nuclear Power Plant

The traditional approach, adopted for the safety demonstration/assessment, is the deterministic analysis. The prime objective of such approach is the definition of conservative rules associated to the: NPP design, organization and site features, giving high degree of confidence to the effectiveness of the safety measures put in place (IAEA, 2005).

The definition of the conservative and bounding assumption passes through the identification of the pessimistic (in safety terms) scenarios, input and design codes.

Table 3.9 shows the possible options related to the application codes, boundary and initial conditions and assumptions on system availability. On the other hand, Table 3.10 shows a typical subdivision of postulated initiating events, catalogued for their expected occurrences[i] and severity (in safety terms).

Option	*Applied codes*	*Boundary and initial conditions*	*Assumptions on systems availability*	*Approach*
1) Conservative	*Conservative codes*	*Conservative input*	*Conservative assumptions*	*Deterministic*
2) Combined	*Best estimate (realistic) codes*	*Conservative input*	*Conservative assumptions*	*Deterministic*
3) Best estimate	*Best estimate codes + Uncertainty*	*Realistic input + Uncertainty*	*Conservative assumptions*	*Deterministic*
4) Risk informed	*Best estimate codes + Uncertainty*	*Realistic input + Uncertainty*	*PSA-based assumptions*	*Deterministic + probabilistic*

Table 3.9: Options for combination of computer code and input data (IAEA, 2009), (IAEA, 2003)

Occurrence (1/reactor year)	***Characteristic***	***Plant State***	***Terminology***	***Acceptance criteria***
10^{-2}–1 (expected over the lifetime of the plant)	*Expected*	*Anticipated operational occurrences*	*Anticipated transients, transients, frequent faults, incidents of moderate frequency, upset conditions, abnormal conditions*	*No additional fuel damage*
10^{-4}–10^{-2} (chance greater than 1% over the lifetime of the plant)	*Possible*	*Design basis accidents*	*Infrequent incidents, infrequent faults, limiting faults, emergency conditions*	*No radiological impact at all, or no radiological impact outside the exclusion area*
10^{-6}–10^{-4} (chance less than 1% over the lifetime of the plant)	*Unlikely*	*Beyond design basis accidents*	*Faulted conditions*	*Radiological consequences outside the exclusion area within limits*
<10^{-6} (very unlikely to occur)	*Remote*	*Severe accidents*	*Faulted conditions*	*Emergency response needed*

Table 3.10: Postulated initiating events subdivision (IAEA, 2009)

[i] Note that the deterministic assessment requires the use of probabilistic tools as well

The conservative option passes also trough the definition of the most severe initiating and postulated conditions; hence the most pessimistic event path are defined and analyzed in depth.

In recent years there is a tendency to apply the deterministic assessment using the combined or better estimated input options (Table 3.10); this enable to avoid too much conservative assumptions. On the other hand the application of these approaches require: further capabilities, knowledge and data to perform better estimations of the plant equipments codes, operational states, incident paths and related transient (IAEA, 2009).

The most important application, of the deterministic analysis, relies to the calculation of the safety margins associated to the various levels of defence in depth, under conservative assumptions (IAEA, 2005).

The safety margins are defined as: *"The safety margin of operating reactors is defined as the difference or ratio in physical units between the limiting value of an assigned parameter the surpassing of which leads to the failure of a system or component, and the actual value of that parameter in the plant."* (IAEA, 2003).

This definition lies in the real application of the safety margins that take as reference point the parameters values fixed as requirements (and not the critical measures of the physic parameters which lead to the failure of the system or component). Fig. 3.15 illustrates the definition of the safety margins under this later assumption.

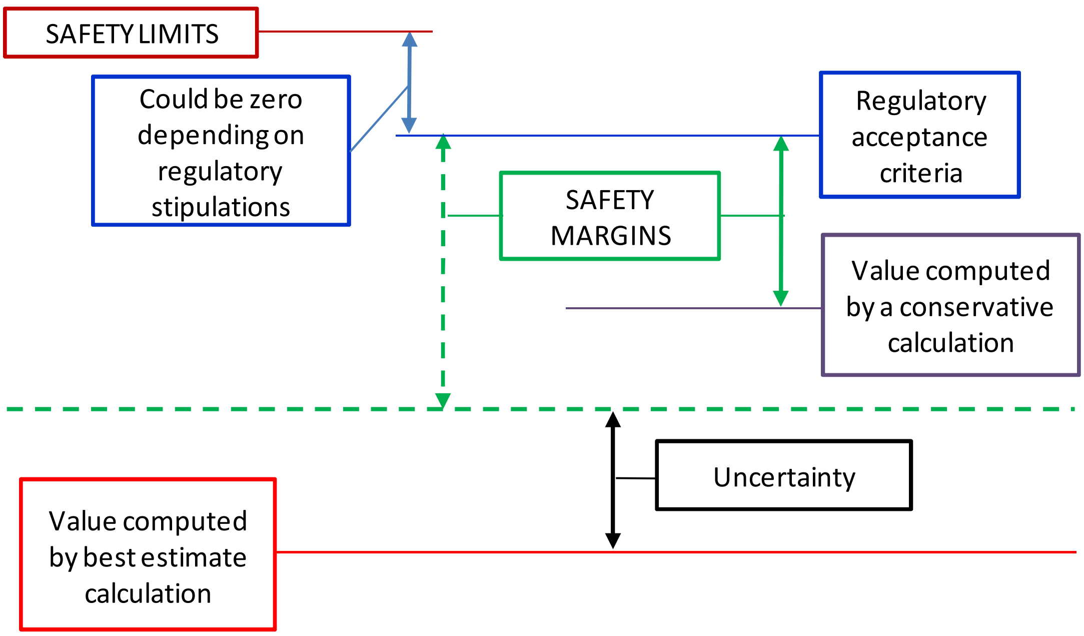

Fig. 1.31: Definition of safety margins, (IAEA, 2003), revised figure

The most common physic measure implemented as safety parameters are: *"reactor coolant system pressure, minimum shut down margins, linear heat generation rate of fuel, fuel temperatures, fuel clad temperatures, departure from nucleate boiling ratio, fuel enthalpy, fuel clad strain and extent of oxidation, percentage of fuel failure, hydrogen generation, containment pressure and temperature, and radiation dose to plant personnel and the public"* (IAEA, 2003)

On the other hand the deterministic analysis permits to (IAEA, 2005):

- Checking the single failure criterion: this criterion prescribes that no single failure prevents the effectiveness of the safety functions. The satisfaction of this requirement is assured by opportune safety margins associated to the NPP design (in addition to opportune organizational measures) that gives high confidence that the single failure doesn't implies the failure of any safety functions.

The conservative assumptions rely to the definition of the worst single failure affecting the reliability of the safety functions.

-Indentifying/preventing common causes of failures: this application is founded on the defence in depth principle, in assuring that the reliability of the safety functions trough the implementation of redundant and diversified safety functions (physic barriers, organizational measures, etc.).

-Providing equipment qualification: the aim of this application is to provide that equipments are able to perform its functions in relation to the occurrence of some defined typology initiating events, in terms of environmental and loading conditions (e.g. definition of the Design basis earthquake).

-Limiting operator claims: the deterministic safety requirements (and the related development/calculus procedures) give are sufficient objective to avoid possible minus understanding between the operator and the RB. This feature permits to incorporate explicitly prescriptions in the la law framework (e.g. maximum radiation dose assumed by a worker within a year) and to avoid operator's claims.

The deterministic safety criteria (high level) typologies are listed at follow (IAEA, 2009):

-People (workers and public, with different reference values) receives lower, individual and collective, radioactive doses with respect the reference requirement[i].

- Integrity of safety barriers should be maintained

- The operator should ensure required capabilities (with special emphasis to maintenance and emergency personnel and procedures)

- It's practically excluded the case of large radioactive releases into the environment.

The achievement of the integrity of barriers passes through the definition of variables that describes the physical process; this indirect reference is called surrogate criteria.

More generally the compliance with single failure criteria, usually considers the following acceptance criteria (IAEA, 2009):

- Achievement of surrogate criteria
- Definition of plant stated conditions
- Safety performance requirements
- Operators' action requirements

[i] The requirement also considers the incident scenario and assign to this different reference values.

3.2.3.2.2.2. Probabilistic Safety Analysis of Nuclear Power Plant

The Probabilistic safety assessment PSA consists in the application of tools and methodologies to analyze the risk associated to the plant, people and environment (IAEA, 2001)

PSA is mostly[i] based on best estimate assumptions (input) and gives as output probabilistic measures associated to events and scenario.

Table 3.10 shows the possible input data and model assumption options.

The scope specification for the PSA includes (IAEA, 2002), some or all of the, following elements:

- Initiating events (internal and external)
- The NPP operational modes considered
- The scope of the human reliability analysis
- Post-trip repairs and return into service of safety functions, equipments, etc.
- Management measures implemented during the accident events
- Operational states beyond the prescribed conditions (e.g. lack of application of the correct procedure)
- Sensitivity studies
- Uncertainty analysis
- Levels of PSA (0, 1, 2, 3)
- Living PSA (LPSA)
- Presentation of the PSA results and risk monitors

Some of these elements require a further explanation: the levels of PSA, the LPSA and related risk monitors.

The levels of PSA represent a sub division of the PSA scope, adopting the defence in depth concept:

- Level 0: identifies the reliability of the various safety systems and functions (IAEA, 2001).
- Level 1: indentifies the potential risk that could lead to the core damage. Depending of the extent of the analysis the PSA tools could provides further insights in addressing the strengths and weakness of the safety functions (in physic and organizational terms) considered.

  The most representative measure is the core damage frequency CDF (referred to an operational year). A further in depth analysis could considers the sequencing events after the core damage is occurred; this is the case of the "Level 1+".
- Level 2: indentifies the risk (in terms of occurrence and severity) of radioactive releases into the environment. The most representative measure is the large early release frequency LERF.

[i] In reality, the application of the PSA methodologies, is founded on the best estimate with respect the most critical assumptions, codes and input data. On the other hand conservative assumption and data are still used for those model elements where not sufficient data are available due to: the low safety priority of the object treated, the lack of knowledge associated to these or the excessive cost associated to its measurement.

- Level 3: indentifies the public health and social risk after the radioactive releases into the environment. It considers the contamination of land, food and people surrounding the NPP site, taking into account the possible meteorological scenarios and off site emergency measures put in place.

The most used level is the first one[i] and only some advanced countries adopt the second level as requirement. Finally the use of the third level is rare.

The Living probabilistic safety assessment is and advanced application, of PSA methodologies, during the operating phase of NPP. The formal definition of LPSA is reported at follow:

"*A "living PSA" (LPSA) can be defined as a PSA of the plant, which is updated as necessary to reflect the current design and operational features, and is documented in such a way that each aspect of the model can be directly related to existing plant information, plant documentation or the analysts' assumptions in the absence of such information. The LPSA would be used by designers, utility and regulatory personnel for a variety of purposes according to their needs, such as design verification, assessment of potential changes to the plant design or operation, design of training programmes and assessment of changes to the plant licensing basis."* (IAEA, 1999)

The application of LPSA permits the implementation of risk monitor which permits, to the operating personnel, to have a real time analysis tool (considering the various plant configurations and operational states).

The main applications of the PSA approach are:

"- Optimizing the technical specifications

- Identifying accident management measures

- Determining the change to the risk from the effects of ageing

- Controlling equipment outages for maintenance

- Supporting plant modifications

- Evaluating operational events from a risk based perspective

- Introducing graded QA[ii]" (IAEA, 2002)

In every case the use of the PSA approach is not sufficient complete itself to enable the demonstration /assessment of the NPP site, design and related activities; these methodologies are characterized for their supporting role with respect the traditional deterministic approach (in the licensing context). Different is

---

[i] The level 0 is necessary for calculate the measures associated to the first level of PSA.
Nevertheless the level 0 doesn't permits to compares different design models and technologies because the safety functions and systems may be different. On the other hand the level 1 of PSA enable the comparison between different reactor designs and then is more frequently reported as reference criteria.

[ii] A quality assurance program is put in place to ensure, that all safety related functions and activities, gives sufficient confidence over its performances. The PSA methodologies can assist the prioritization of the functions and activities related to safety. With this perspective is possible to develop the QA programs with different extent depending on the safety significance addressed by the PSA measures (IAEA, 2001).

the case of plant modification, where the PSA and cost benefit analysis play a central role in demonstrating the feasibility of a possible plant modification (IAEA, 2002).

Furthermore the PSA methodologies require the introduction of reference criteria to be implemented for decision-making purposes; these criteria are called: probabilistic safety criteria PSC.

The simplest PSC assign to the various risk measures a reference value; table 3.11 reports the target values of CDF and LERF adopted by the IAEA, (IAEA, 2001).

	PSA Level 1: CDF (year)	PSA Level 2: LERF (year)
Existing plants	$< 10^{-4}$	$< 10^{-5}$
Future plants	$< 10^{-5}$	$< 10^{-6}$

Table 1.3: Reference values of annual CDF and LERF (IAEA, 2001)

Example of modern reactor show the compliance with these last reference values: EPR (CDF: 5,8 10^{-7}; LERF: 8,4 10^{-8}), AP1000 (CDF: 5,1 10^{-7}; LERF: 5,9 10^{-8} (De Rosa, 2009).

More complex consideration are adopted in the cases of plant modification; with this respect the various national practices differ with great extent.

3.2.3.2.2.3. Comparison between the deterministic and probabilistic approach

Table 3.12 show a comparison o the two approaches considered.

Deterministic approach	Probabilistic approach
Usually uses a conservative/bounding assumptions approach to address uncertainties in the models and data	Usually uses a best estimate approach in all aspects of the modeling; sometimes conservative assumptions are used to determine the success criteria
Addresses a limited subset of initiating events and fault sequences that are chosen as the bounding ones	The starting point is a comprehensive set of initiating events and hazards (including those that are within and beyond the design basis) and they are all included in the analysis
Accident conditions are addressed separately	The PSA model integrates all initiating events and safety systems in the same model
Initiating event frequencies and system/ component failure probabilities are taken into account in an approximate way	Initiating event frequencies and system/ component failure probabilities are included explicitly in the PSA model
Uncertainties are addressed by making conservatisms assumptions, or using best estimate codes and models with associated evaluation of the uncertainties in the results	Many of the uncertainties can be addressed explicitly in the PSA models. The capabilities to address parameter uncertainties are included in modern PSA software
Gives a rough indication of the relative importance of systems/structures/components	Modern PSA software provides a wide range of information on ways to measure the importance of all the systems/structures/ components that are included in the analysis

Table 1.4: Comparison between deterministic and probabilistic approach, (IAEA, 2005)

Finally table 3.13 present the relative strengths and shortcomings of the deterministic and probabilistic method.

	Relative strengths	Relative shortcomings
Deterministic approach	- Well developed and applicable due to the large experience cumulated by Utilities, reactor vendors and RB -Requires less data and assumptions as input due to the implementation of the conservative hypothesis.	- The method doesn't consider (extensively) the probability of the various events affecting safety -The method itself tends to concentrate the in depth analysis over the most severe accidents, neglecting some others less severe accidents. The fact that the method doesn't consider their respective occurrences led to sub-optimization in the eyes of the overall risk affecting the NPP. (exist less severe accidents that have greater contributes to the overall risk due to the higher occurrence) -The method considers only the initiating events frequencies approximately (and for example it doesn't considers the postulated initiating conditions frequencies), then can't demonstrate itself the balancing design. -It can't serve to improving the safety performances because it doesn't consider the probability of the various safety related events.
Probabilistic approach	-Takes into account the comprehensive set of initiating events and fault sequence affecting the various levels of PSA -Enable to quantify the plant risk -Address explicitly the uncertainty associated -Enable to address sensitivity studies associated to the different parameters significant to the risk -Enable to determine the level to which the deterministic requirements have been met -Enable to identifies and ranks the plant modifications that gives greatest reduction to the safety risk -Enable to compares relative risk -Provides advanced tools that permits to monitor the risk affecting the NPP (e.g. LPSA)	-Is not possible to demonstrate the PSA is complete -Is difficult to address large uncertainties associated to some PSA areas -Is difficult to justify the input data and assumption made as input into the PSA model -The model incorporate a degree of subjectivity -Difficult to address the Human behavior

Table 1.5: Comparison between strengths and shortcomings of the probabilistic and deterministic approaches, (IAEA, 2005)

3.2.3.2.2.4. Integrated decision-making process

Due to the relative strengths and weakness of the safety approaches considered, an integrated decision making process represents the more effective approach in considering the compliance with safety principles, requirements and criteria. This approach is also called risk informed approach and consists to a balanced judgment with respect the various safety demonstration and assessment approaches.

Fig. 3.16 shows the risk informed process using as input four main set of safety criteria and giving as output a balanced decision trough the use of opportune weights. Finally the decision made must be implemented and monitored.

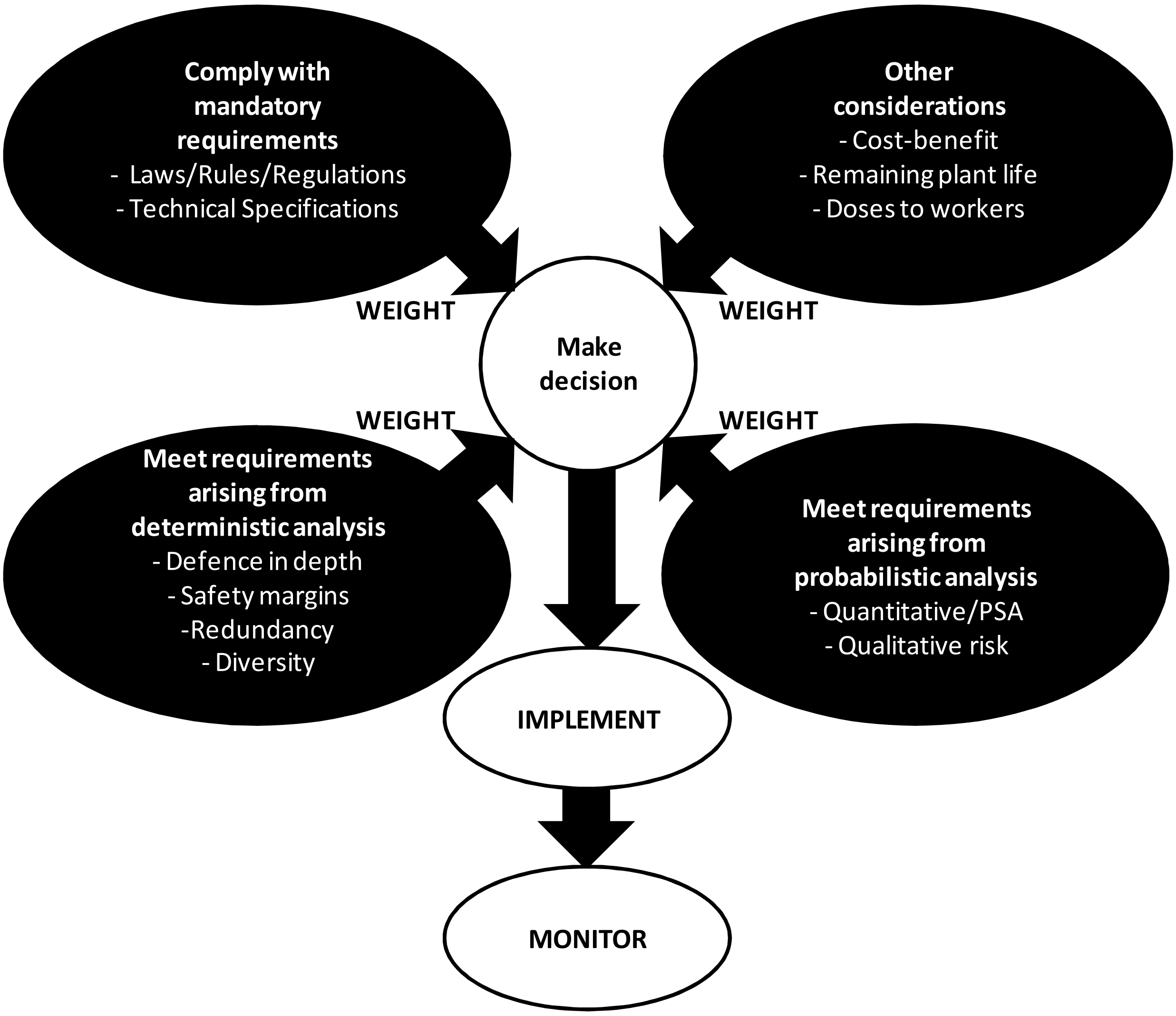

Fig. 1.32: integrated decision making approach, (IAEA, 2005)

This general decision making approach can be implemented for various purposes and by different actors. A sample of some typical decision that can be implemented trough this approach is showed in the Table 3.14.

The most interesting decisions, due to the scope of this thesis work, are the ones concerned the licensing process; especially with respect the demonstration and assessment of the safety principles.

3.2.3.2.3. Adoption of the safety principles as mandatory requirements

The adoption of the safety principles as requirements may change significantly, mostly depending on the:

-Legal and administrative traditions concerned the application of the safety principles

-RB knowledge and capabilities with respect the use of advanced assessment methodologies

	Operator	RB
Licensing	-Decisions concerning the licensing application and the related safety demonstration	-Decisions on the acceptability of the proposed design, site, staffing, procedure, etc. -Decisions on the proposed modification or plant rework -Decisons on license conditions
Plant Modification	- Decisions on the feasibility of the proposed modification	-Decisions on the acceptability of the proposed modification
Periodic Safety review	- Decisions on periodic safety review application and implementing measures	-Decisions on the acceptability of the safety status of the NPP -Decisions on the further implementing measures
RB inspection		-Decisions on the acceptability of the safety status of the NPP -Decisions on implementing possible enforcing actions
Accident scenario	- Decisions on implementing extraordinary emergency measures	- Decisions on implementing extraordinary emergency measures -Decisons on implementing possible enforcing actions
Shut down	-Decisions on implementing safety measures	-Decisions on further safety measures
Decommissioning	- Decisions on the decommissioning plan and implementing measures	- Decisions on the acceptability of the proposed plan - Decisions on prescribing further safety measures

Table 3.14: Sample of some decision that can be implemented through the use of the risk informed approach

The traditional mandatory approach is based on the deterministic assessment criteria.

This because the deterministic approach is:

- The first method introduced for the assessment of the safety principles
- Adopts well developed tool and tecniques
- Requires less validated input data
- Requires less experience and capabilities for both the RB and the Operator
- Is easiest to be implemented by mandatory requirements (the probabilistic measures require a degree of subjectiveness to be implemented; this means that the numerical probabilistic criteria can't be implemented at high level of the legal framework)

The recent tendency has showed the progressive adoption to a risk informed regulation and decision-making regulatory process (IAEA, 2005).

The way by which the risk informed law framework is implemented may change significantly depending on the national approach. With this respect a key driver is the level of delegation power that the RB acquires in issuing the PSC.

Fig. 3.17 shows the two possible extremes cases in adopting the PSC into the law framework: from on hand some PSC criteria are included as regulatory requirements, to the other hand the PSC are just presented by detailed guidelines (for assist the licensing applicant in developing the appropriate demonstration experiments and documentation, and giving him sufficient predictability of the decision-making process). In the later case the PSC is assessed by the RB who detains high discretionary powers.

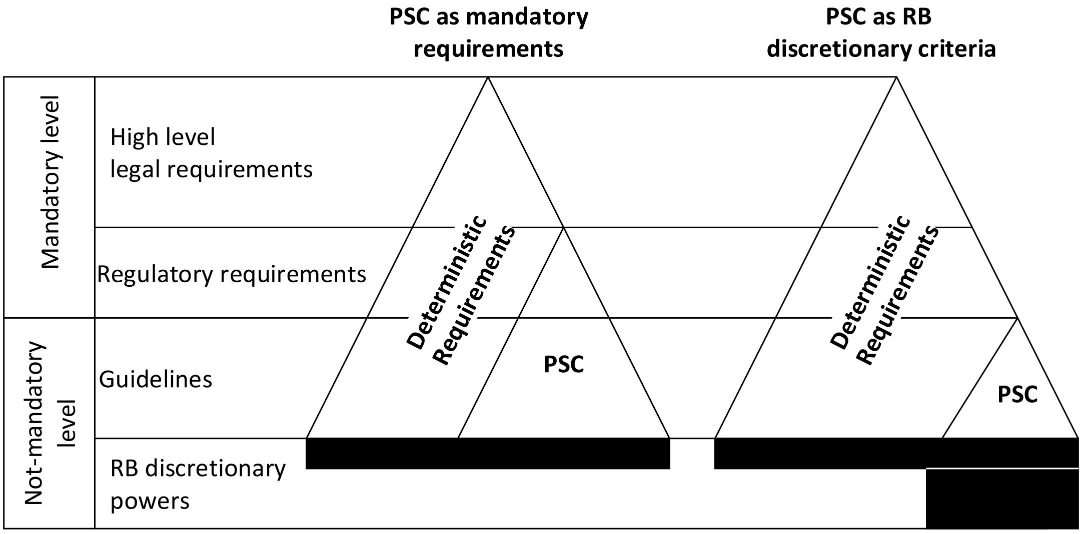

Fig. 1.33: Approaches in adopting the PSC as requirements

The relative comparison between these two cases is presented at follow.

The relative advantages of the first approach, with respect the second one, are:

- It enables the issuance of claims by the licensing applicant
- It permits a better comprehensibility and predictability of the licensing decision-making process

On the other hand the disadvantages of the first approach, with respect the second one, are:

- The first method requires frequent updating of the regulatory requirements
- The first method is less flexible with respect the application of advanced PSC criteria and safety concept design.

Outline of the chapter

- The nuclear programme outcome is the nuclear infrastructure
- The nuclear infrastructure groups the nuclear project and the licensing process.
- The infrastructural elements which affect the licensing process are: Law framework, institutional framework and the safety framework (safety principles, criteria and requirements).
- The infrastructural elements, critical to the licensing process, are some of the basic drivers which permits to categorize the different typologies of licensing process approaches and effects, as discussed in the following chapter.

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4. Licensing framework

This chapter deals with the licensing of NPP. The chapter is structured in the following paragraphs: **§4.1.** Introduces the main definitions associated to the licensing, **§4.2.** Presents a licensing model that permit to evaluate the tradeoff between public and private objectives considering the main licensing parameters (which determine the possible licensing approaches).

§4.3. Introduce a comparison between six licensing practices: Finland, France, Italy, Republic of Korea, United Kingdom and United States of America. The comparison is undertaken taking advantage of the licensing framework previously introduced.

4.1. Preliminary definitions and licensing paradigm

The current paragraph define and introduce the basic licensing mechanism (§4.1.1.), and principles (§4.1.2.). Finally a subparagraph introduces a documental framework related to the licensing process(§4.1.3.).

4.1.1. Licensing process definition and mechanism

The term "licensing process" refers to the bureaucratic proceeding by which the applicant tries to obtain a license.

In most of nuclearized countries, is required an opportune license for undertake the following activities: construction of a nuclear facility, operation of the nuclear facility, transporting and handling of radioactive sources, materials or wastes (IAEA, 2003).

This thesis work considers the licensing process in terms of: bureaucratic proceeding required to obtain the necessary permits (and licenses) to construct and operate with a NPP; the transport and handling of dangerous material are considered of secondary importance.

There are two main typologies of actors involved into the licensing process: public actors (which incorporate public objectives §4.1.2.2.1) and private ones (Owners' group).

From one hand private actors aim to obtain the necessary permits (and licenses) to undertake the required activities (construction, operation of NPP).

To the other one, public actors want assure that the activity under review doesn't let rise unacceptable risks for people, environments and goods.

The demonstration and assessment of the risks (affecting the activity under review) is performed trough appropriate tools and criteria which permit to evaluate the compliance with safety principles and requirements (§3.2.3.).

The IAEA framework emphasize the independence of RB (§3.2.2.1.) in carrying out its duties, including the licensing ones; as result RB is the only public actor considered.

In introducing the licensing subject, this chapter adopts the IAEA framework for two main reasons:

- It presents the general principles applicable to every country
- It Incorporates the best practices (especially in considering the safety concerns)

By contrast the complete licensing model (presented in this chapter) takes also into account divergent national practices (with respect the IAEA assumptions) to be more complete and realistic.

For example the RB is not the only public actor devoted to the licensing functions because, in most countries, Government and other institutions acquire licensing functions and duties (Bredimas, et al., 2009). In every case, RB is the technical expert organization which address a complex judgment (due to the raise of special political, social and technical issues) on the: operator documents, site and design proposed within the licensing application.

Fig.4.1 shows the most important actors involved into the licensing process (Simplified IAEA framework) and the possible difficulties that could rise during such process.

Furthermore Fig. 4.1 presents the definition of applicant, licensee (which are the licensing status of the operator) and license.

From one hand there is the regulatory body (showed in grey color) that exercise its licensing duties: acquires all the needed information for deciding about the safety and security (associated to the activity under evaluation, decides if the proposal made by the applicant is feasible or request to modify it, attach the license conditions and finally grants the license to the applicant.

To the other one, there is the applicant who must demonstrate, to the regulatory body, which its application satisfies all requirements and not give raises risk to the workers, to the citizens and to the environment.

Furthermore the applicant need to modify part of the work done (in documental or physic terms) if imposed by the RB.

Fig. 4.1 shows the possible paths generated within the licensing process:

- In the better scenario the RB decides that the license application is complete and consistent with the law / regulatory requirements and the safety /security principles.

This scenario is described by the path: A-B-D-E-F[i].

The only negative effects that could raises from this scenario are delays (§4.2.4.1).

- A possible complication could derive due to the lack of completeness or clearance of the application (or documentation associated to it); in this case the RB requests further information and demonstrations.

This scenario is described by the backward circle: B-C-X-B in the Fig. 4.1.

This scenario implies licensing delays.

- Finally the worst case is when the RB finds discrepancies within the proposal, made by the applicant, and requests him to modify part of the: documentation, procedures, organization or work performed. The modifications can be classified into two main sets: intangible modifications and tangible (physic) ones.

The first set comprise with modification of documents, plans and procedures.

[i] The capital letters refers to the licensing activities presented in the Fig.4.1.

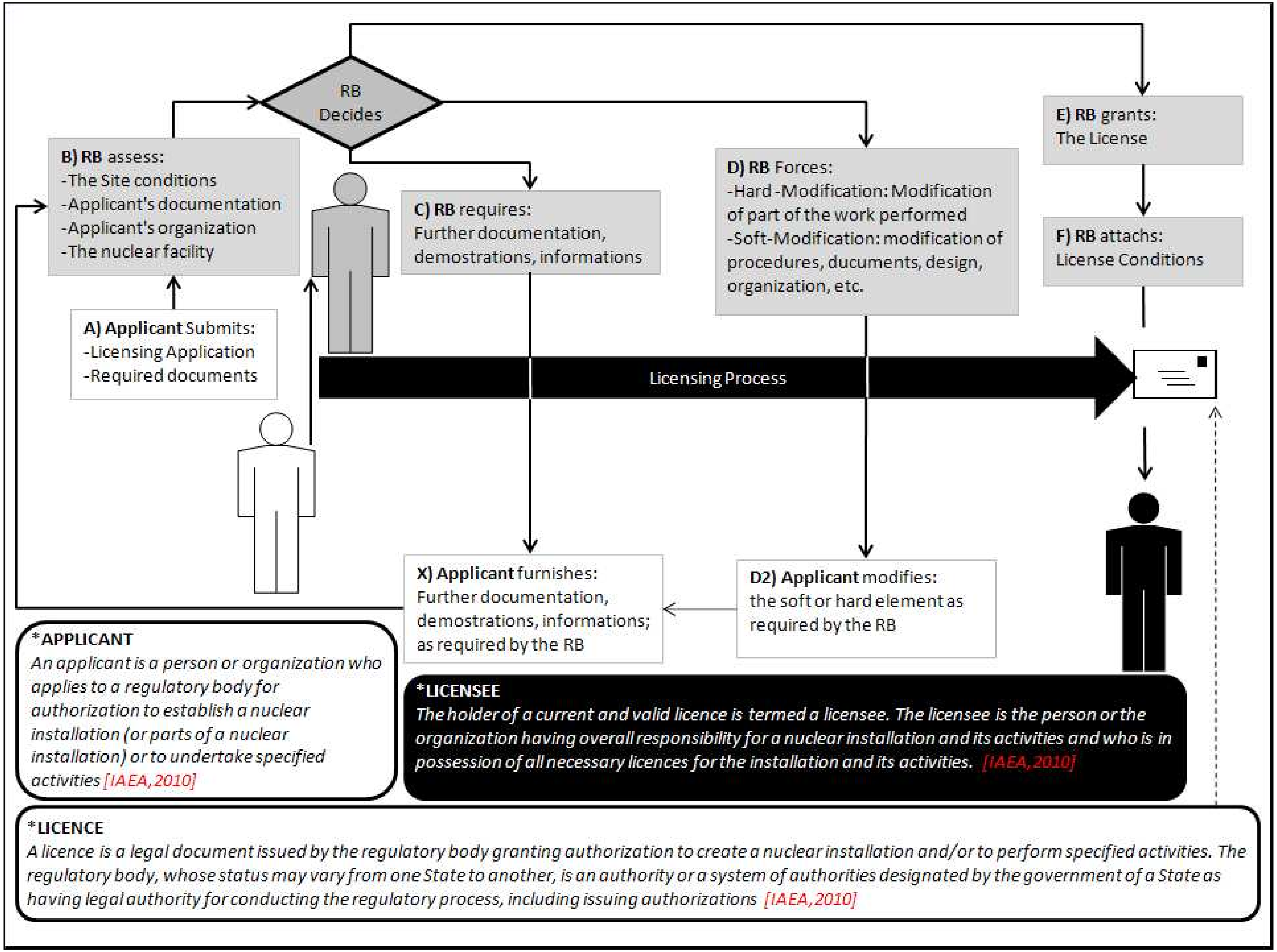

Fig. 0.1: The simplified licensing paradigm

On the other hand, tangible modification deals with the rework of part of the facility constructed, this is the most severe case because is both time consuming and expensive (§4.2.4). This case is showed, in the Fig.1, by the backward circle: B-D-D2-X-B activities.

4.1.2. Licensing paradigm

The basic licensing principles can be synthesized using the six Ws framework (Chapman, et al., 2003).

The framework is defined by six question which permit to introduce the general meaning of the licensing process as showed in the Table 4.1.

Six Ws	Extensive question	Answers
Who	Who are the parties involved?	Parties
Why	What do parties want to achieve?	Motives
What	What are the parties interested in?	Licensing scope
Whichway	How is it to be done?	Activities
Wherewithal	What resources are required?	Resources
When	When does it have to be done?	Timeframe

Table 4.1: six Ws framework (Chapman, et al., 2003), revised table

The answers to the questions just introduced are answered at follow.

4.1.2.1. Who- Who are the parties involved?

The main licensing actors are presented into Fig 4.2, showing the degree of involvement of the actors considered and the typology of actor.

The level of involvement is understood in terms of resources, the responsibilities and the power associated to the different organizations; and it’s expressed qualitatively and heuristically.

The table shall be understood as not prescriptive because, depending on the national administrative and legal tradition, the institutional actors can have different levels of involvement (with respect the ones presented). On the other hand, depending on the contractual arrangements, Owners’ group parties could be different with respect the ones presented.

Critical suppliers are the ones which manufacture, assembly and install the critical equipment (with respect the nuclear safety; e.g. reactor vessel, control rod, vaporizer, steel liner, core catcher critical pipes, valves, pumps, etc. ,auxiliary electricity generators, critical heat exchanger, fuel and waste pools, control room and other safety systems) and nuclear fuel.

On the other hand the non critical suppliers are the ones which carry out non critical works with respect nuclear safety; e.g. site preparation, early civil works, office building, some turbine island components, greed connection and other non critical equipments or buildings.

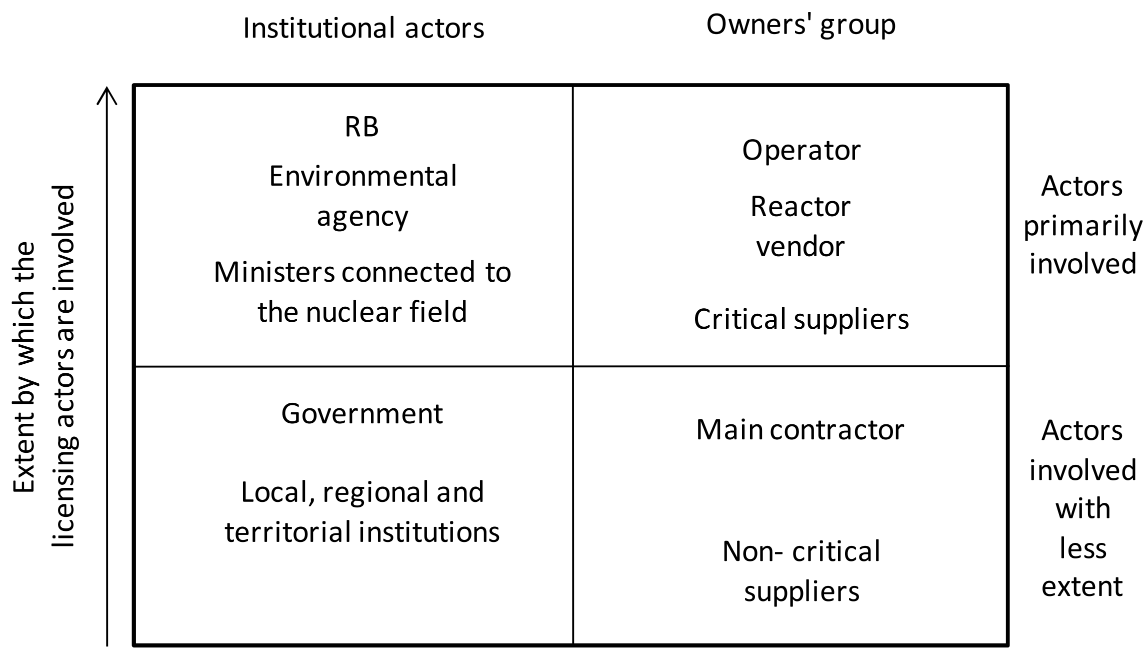

Fig. 0.2: Actors involved into the licensing process

The IAEA framework (IAEA, 2010)represents the RB and the operator as the most important licensing actors: the first is the regulator and the most important institution which carry out the licensing function; the second is the only liable, with respect the nuclear safety, and it's the applicant and license holder.

Finally the public is also involved into the licensing process (CNS I); considering the information transparency and power in affecting the licensing proceeding.

Public hearings and inquiries are the most important activities by which the public opinion could affect the licensing process and decision-making.

Depending on the national traditions, the citizens empowered to participate to the public hearing and inquiry can be: national citizens, people living in the federal state, region, district, etc (where the NPP is going to be deployed); and citizens living in the vicinity of the nuclear site (including citizens of other countries if the nuclear site is close to the national boundary).

4.1.2.2. Why- What do parties want to achieve?

There are different typologies of objectives in considering the multiple actors involved into the licensing process; these can be grouped into two main categories: public objectives and private ones. The first are usually endorsed by the public and institutions; the second are typical of the Owners' group parties.

These two typologies of objectives are usually conflicting as discussed in the following sub-paragraphs.

4.1.2.2.1. Public objectives

The main typologies of public objectives are: regulatory control, nuclear safety, nuclear security and public acceptance.

- Regulatory control objective: “*The objective of granting authorizations in the licensing process is […] to establish regulatory control over all activities and facilities*” (IAEA, 2010).
- Nuclear safety objective: “*The achievement of proper operating conditions, prevention of accidents or mitigation of accidents consequences, resulting in protection of workers, the public and the environment from undue radiation hazard*” (IAEA, 2010).

A more general perspective shall considers also the wide concept of safety; nevertheless this thesis work mostly refers to the nuclear safety because is the predominant concept considered the nuclear field, especially in licensing contexts (IAEA, 2002), (IAEA, 2010), (IAEA, 1999).

- Nuclear security objective: “*The prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or malicious acts involving nuclear material, other radioactive substances or their associated facilities*” (IAEA, 2010).
- Compliance with legal and regulatory requirements objective: one of the principal aims of the licensing process is to assure the compliance with legal and regulatory norms constraining the activities to be licensed and related implementing organizations.
- Public acceptance objective: a further indirect objective of the licensing process is reinforcing credibility on the nuclear project, implementing organization and institutional ones.

A key concern is the mutual overlap and interference between the different public objectives; most of these can be considered as complementary as showed in the Fig. 4.3.

On the other hand the interference that security objective has with the safety[i] and the public acceptance[ii] ones may be divergent is some circumstances (IAEA, 2010), (IAEA, 2002).

When the objectives considered are divergent, an opportune tradeoff must be addressed by law and regulatory framework and by regulatory decisions.

4.1.2.2.2. Private objectives

The main public objectives are: time efficiency, cost effectiveness, low regulatory risk and regulatory constrain.

Time efficiency objective: the licensing lead time shall be as short (and less interdependent to the project path) as possible because of its impact on project schedule and cost.

Cost effective objective: the cost of the licensing proceeding shall be as low as possible.

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[i] “*For example the introduction of delay barriers for security reason can limit rapid access to respond to the safety event or can limit emergency egress by plant personnel*” (IAEA, 2010).

[ii] For example confidential information (concerning security) could pone the basis of objectives between public acceptance and security. From one had the information transparency is one of the measures for enhance public confidence and acceptance; on the other hand the publication of security information could entail security effectiveness.

Usually the direct licensing cost (direct fees) is not perceived as a great obstacle in licensing contexts , for this reason this thesis work refer to this objective with lesser extent.

	Regulatory control	Nulear safety	Nuclear security	Compliance with legal and regulatory requirements	Public acceptance
Regulatory control					
Nulear safety	Compl.				
Nuclear security	Compl.	Partly compl. and partly divergent			
Compliance with legal and regulatory requirements	Compl.	Compl.	Compl.		
Public acceptance	Compl.	Compl.	Partly compl. and partly divergent	Compl.	

Table 4.3: Connection between public licensing objectives

Low regulatory risk objective: afford as low licensing risk as possible.

The impact that, adverse circumstances, could have on project execution are delays, modification and rework (of documents, procedures, management system, plant design etc.) (§2.1.6.2.3.1.).

The main sources of licensing risk are: the high complexity (of the regulatory framework) affecting the level of understood by applicant and the unpredictability of the RB decision-making.

This objective is treated with special emphasis because it represents the most critical with respect licensing system.

These three private objectives can be considered conflicting because, in most situations (e.g. decision-making), a tradeoff between these need to be issued.

Finally Fig 4.4 shows the endorsement of the different public and private objectives considering the RB, the operator and the public (which are the most important licensing actors).

		RB	Public	Operator
Public Objectives	Regulatory control	++++	+	
	Nulear safety	+++++	+++++	+++
	Nuclear security	+++	++	++
	Compliance with legal and regulatory requirements	++++	+	
	Public acceptance	++	++++	+
Private objectives	Time effective	ind.		+++
	Cost effective	ind.		++
	Low regulatory risk	Ind.		+++++

Table 4.4: Endorsement of public objective by devoted actors

The emphasis by which the objective is pursued is showed by the "+" symbols adopting a qualitative scale (from zero to five). The suffix "ind." means "indirectly" because RB also need to consider the licensing effects on private objectives in regulating and licensing activities.

4.1.2.3. What-What are the parties interested in?

The objectives previous presented refer to the following licensing scope.

The public objective[i] refers to the scope of the licensing process as showed in the table 4.5.

		Licensing scope
Public Objectives	Regulatory control	Nuclear site, facility design, formal documents, management system, operating procedures, operating organization.
	Nulear safety	
	Nuclear security	
	Compliance with legal and regulatory requirements	
	Public acceptance	

Table 4.5: Licensing scope.

4.1.2.4. Whichway- How is it to be done?

The most important typologies of licensing activities, undertaken by the RB, Operator and public are showed in the table 4.6.

RB	Operator	Public
Manage the licensing proceeding		
Exchange of documents and information with operator	Exchange of documents and information with RB	
Exchange of documents and information with others institutions (including international and foreign organizations)		
Assess the licensing scope	Demonstrate the safety, security and compliance with requirements of the proposed application (considering the overall scope)	
Coordination of public Hearings and inquiries		Partecipate to public hearings
Publication of public information	Publication of public information	Inquiry and ask relevant information
Decision making activities		
Editit of License conditions		

Table 4.6: Licensing activities

4.1.2.5. Wherewithal- What resources are required?

The main resources directly involved are listed at follow.

Physic resources: testing tools materials and buildings, communication technologies and calculating ones

Intangible resources: knowledge based capabilities, assessment procedures, licensing procedures, ect.

[i] By contrast the private licensing objectives refer to the performances of the licensing process itself; in term of efficiency and effectiveness.

Other resources: economic resources and human ones[i].

These resources mostly belong to the RB and Operator.

4.1.2.6. When- When does it have to be done?

The licensing process usually starts immediately after the end of the contract awarding route (when the project network is consolidated by contractual relationship) and finish immediately before the operating phase of the NPP.

As result the licensing process encompasses the whole construction and start up phases of NPP as plus a period before (usually around an year: for the issuance of the construction license) and after (Around six months, during this period RB assesses the commissioning results, enacts its decision on the plant acceptability and licenses conditions).

Further details about the timeframe, such as the licensing steps are treated in the paragraph: (§4.2.1.4).

4.1.3. Documental framework

The licensing process is mostly based on documental activities: exchange, submission, creation, assessment, control, publication and modification.

From one hand licensing rules and administrative procedures are contained in official documents.

To the other hand, licensing process is itself document based; and all physic activities such as inspection, equipment testing and calibration, etc. are reported by opportune documents.

As result the documental perspective permits to consider all licensing activities in connection to the nuclear programme and the nuclear project.

This paragraph introduce a general framework reporting the main typologies of documents (and related scope), produced by the RB and by the operator, during the entire nuclear programme lifecycle (§4.1.3.1.). The most important documents are then presented in detail: Contractual documents (§4.1.3.2.), license application (§4.1.3.3.) and the license (§4.1.3.2.).

4.1.3.1. Typologies of documents produced by RB and Operator

Table 4.7 and Table 4.8 present the main typologies of documents formulated by RB and operator during the entire lifecycle of a nuclear facility.

The most important documents, with respect the licensing process are presented in the following paragraphs (the project contract, the licensing application and the licence).

4.1.3.2. The contract

The contract is: "*A contract may be defined succinctly as a set of promises. If a contract is enforceable, the law requires the performance of these promises and provide a remedy if they are not performed. Every contract must satisfy these five conditions to be enforceable:*

[i] Some licensing processe anticipate the bidding process, e.g. Finland.

<table>
<tr><th colspan="3">Typologies of RB's documents</th><th>Main content</th></tr>
<tr><td rowspan="16">Documents related to specific a nuclear project</td><td rowspan="13">Results of review and assessment</td><td rowspan="4">Records of information exchange between the RB and the operator</td><td>Requests for additional information by the RB</td></tr>
<tr><td>Questions formulated by the regulatory body</td></tr>
<tr><td>Responses by the operator and other parties</td></tr>
<tr><td>Records of meetings between RB staff and operator</td></tr>
<tr><td rowspan="9">Documentation of review and assessment</td><td>Reference to the documentation submitted by the operator</td></tr>
<tr><td>Basis for the evaluation</td></tr>
<tr><td>Evaluations performed</td></tr>
<tr><td>Conformance with regulatory requirements and guides</td></tr>
<tr><td>Comparison with similar (reference) facilities</td></tr>
<tr><td>Independent analysis performed by the RB or consultants</td></tr>
<tr><td>Conclusions with respect to nuclear safety</td></tr>
<tr><td>Reasons for the decisions made</td></tr>
<tr><td>Additional conditions to be fulfilled by the operator</td></tr>
<tr><td colspan="3">Records of inspection activities</td></tr>
<tr><td colspan="3">Records of enforcement actions</td></tr>
<tr><td colspan="3">Licence document</td></tr>
<tr><td rowspan="6">Internal guides and procedures</td><td colspan="3">Review and assessment procedures</td></tr>
<tr><td colspan="3">Inspection procedures</td></tr>
<tr><td colspan="3">General procedures for the development of regulations and guides</td></tr>
<tr><td colspan="3">Procedures for issuing, amending, suspending, revoking and terminating licences</td></tr>
<tr><td colspan="3">Enforcement procedures</td></tr>
<tr><td colspan="3">Procedures for issuing public information</td></tr>
<tr><td colspan="4">Documents and reports of public domain</td></tr>
<tr><td colspan="4">Regulations and guidelines (external)</td></tr>
<tr><td colspan="4">Documents produced in relation to other institutional actors</td></tr>
</table>

Table 4.2: Main typologies of RB's documents and related subject treated, (IAEA, 2002)

- *There must be a real agreement between the parities - that is a true "meetings of the minds" on the contract's subject matter*.
- *The subject matter of the contract must be lawful*.
- *There must be valid consideration for each promise*.
- *The parties must have the legal capacity to contract*.
- *There must be compliance with legal requirements, regarding the form of the contract (e*.g., some contracts must be made in writing)." (Kelleher, et al., 2009).

Construction and industrial contracts can be grouped into two main typologies: competitive contracts and negotiated ones. In the first case the owner select a contractor trough a competitive bidding; in the second case the contractor is predefined.

In the first case the contractual approaches usually adopted are: Lump sum (the total cost is fixed and cover the whole scope of work) and unit price (based on estimated quantities, the contract fixes the unit prices of the different activities undertaken during the project implementation).

Typologies of Operator's documents		Main content of documents
Formal documents required into the licensing process	Project description	Description of the site
		Description of the facility
		Safety concepts and criteria used in the design of the facility
		Applicable safety regulations, guides and industrial standards
	Organizational aspects	Management structure and resources
		Quality assurance arrangements
		Organizational structure for each stage of authorization
		Qualification and training of personnel
		Development of procedures
		Documents and records control
	Plans and programmes	Radiation protection programme
		Environmental monitoring programme
		Emergency preparedness
		Physical protection
		Fire protection
		Waste management
		Research and development
		Feedback of operating experience
		Decommissioning strategy
Reports submitted to RB on periodic basis	Site evaluation & construction	Progress of site studies
		Progress of construction
		Results of the pre-operational environmental monitoring programme
	Commissioning & operation	Results of commissioning tests
		Operational data
		Modifications
		Results of the radiation protection programme
		Results of the environmental monitoring programme
		Radioactive waste management
Reports submitted to RB on factual basis	Notification of incidents	
	Reporting of changes and modifications	
	Reporting of others events	
	Release from regulator control	
Internal documents	Contractual documents	
	Records of site evaluation and construction	
	Commissioning records	
	Operational records	
	Records of modifications to the facility	
	Records and evaluation of events	
	Decommissioning and license termination records	

Table 4.3: main typologies of operator's documents and related subject treated, (IAEA, 2002)

On the other hand, negotiated contracts may adopt a further contractual approach: cost plus-fee (in this case the contract fixes the scope of work and the contractor is reimbursed; contractor revenues are also fixed: constants, as percentage of the final cost of the project, or identified through an equation including relevant drivers associated the project performances[i]) (Clough, et al., 2005).

The modern industrial scenario is characterized to the high competition, and the procurement of complex industrial products (such as industrial facilities) is mostly based on competitive contracts (Titolo, 2005).

The contracts stipulated for the construction of a nuclear facility may be awarded on competitive or negotiated basis depending on the nuclear programme approach. In the later case, the contractor is preselected for political or strategic reasons. (IAEA, 1987).

Some nuclear programme approaches[ii] emphasize the need of a uniform strategy to enhancing the required synergies and learning economies. Usually the first NPPs are imported from abroad on lump sum basis and the first NPP (which defines the reactor technology to be reproduced within the nuclear programme) can be selected by politic choice or competitive bidding.

On the other hand the "market oriented" (and some "mixed approach") nuclear programmes usually deal with the competitive bidding in the selection of the contractor §3.1.4.3.

Nuclear programme scenarios and contractual approaches affect the whole documental framework.

From on hand the competitive bidding can be understood as documental proceeding, hence the documental framework shall consider the vast amount of documents generated within this.

On the other hand, the negotiated contracts require a series of further agreements stipulated between countries (implemented by the Governments) and between industrial organizations (especially the operator, the main contractor and the reactor vendor)[iii].

In every case the contract awarding route terminates with the entered into force of the contract (for the implementation of a nuclear project).

The final contract includes a vast amount of annexes and related documents describing in detail: the scope of work (e.g. specifications), the resources implied, the project schedule, the responsibilities and liabilities of the contracting parties (in relation to the project performances), manuals and instruction (describing in detail the procedures to be applied during the project execution) and the role governing the contract itself (language, applicable law and regulatory framework, framework dealing with claims, judicial reviews, arbitration, contract modification, etc.).

Fig. 4.3. Present a general overview of the contract in relation to the whole set of annexes and related documents.

[i] The introduction of a sophisticated equation for determining the contractor revenues deal with concept of: "incentive contracts".

[ii] This case refer to the "(a) governemnt leadership" or the "(c) mixed approach" presented in the paragraph: §3.1.4.3.

[iii] The typologies of document to be considered are: international agreement (especially the technological and commercial agreements), treaties and memorandum of understandings and contracts. The first three can be implemented by the Governments, the latter two by Industrial organizations.

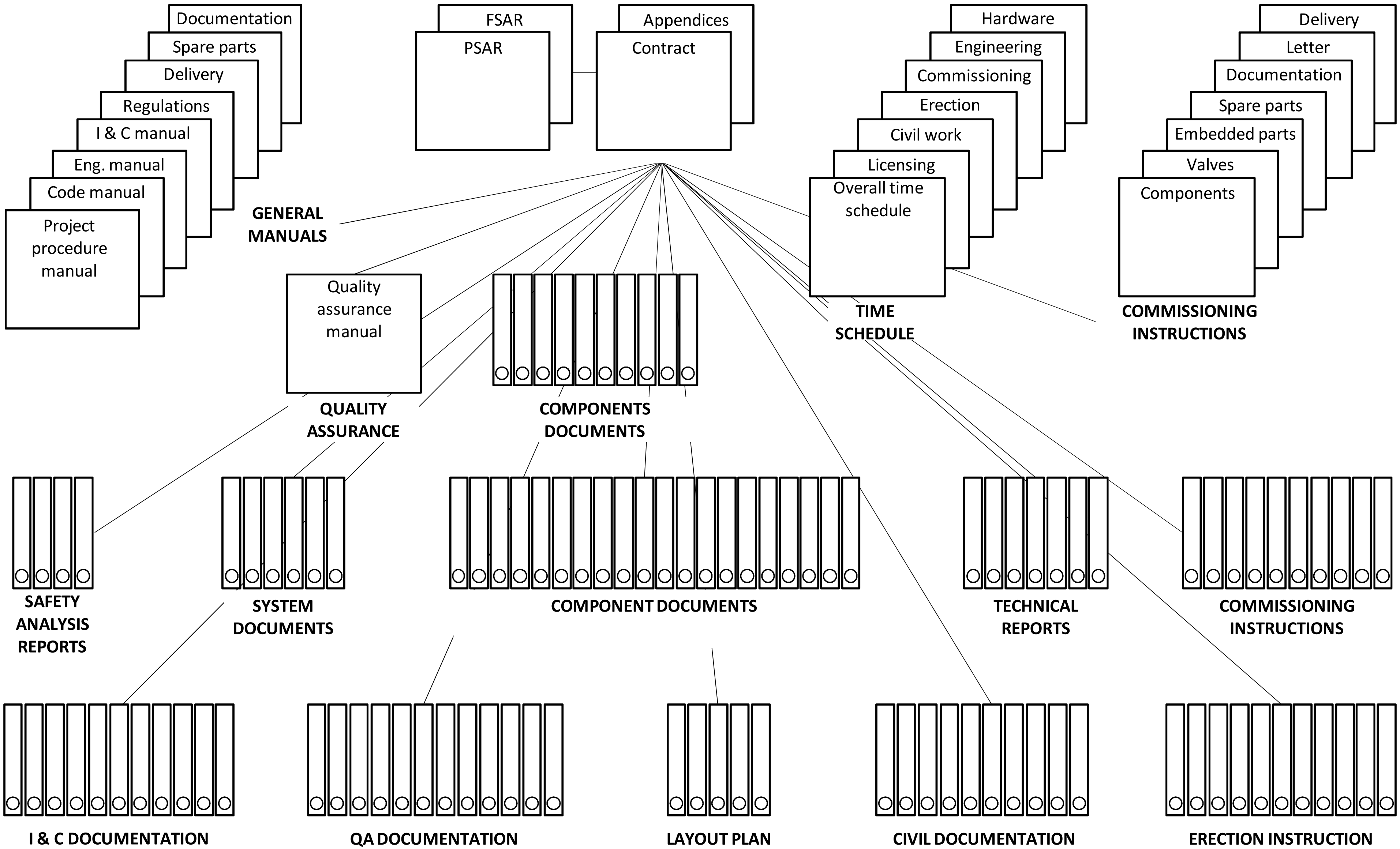

Fig. 0.3: The contract and the related documentation, (IAEA, 1988), revised figure

Some contractual documents and clauses establish a linkage with the licensing process, the most important are:

a- Applicable law and regulation

b- Safety analysis reports

c- Quality assurance manual

d- Licensiablility clauses

e- Transfer of technology and training services.

a- Applicable law and regulation

The contract may be subjected to the law into force in the country where the project is executed or not (atypic contract) (Titolo, 2005).

In the nuclear field, national[i] legal (and regulatory) framework has a pervasive role on the project execution and this reduces the flexibility in the adoption of foreign or international requirements.

As result, most of time the contract is entirely subjected to the national law.

On the other hand, there are scenarios where the nuclear programme is in the early steps and the law and regulatory framework may result not well defined.

In such cases the legal and regulatory framework may refer (in some parts) to foreign provisions even to facilitate the work foreign reactor vendor and contractors (§3.2.1.3.3).

The adoption of foreign requirements may come from to a unified strategy adopted by the RB and the Operator. Form one hand the RB reduces the regularly functions and assure an efficient and effective regulatory framework importing proven requirements and practices (IAEA, 2006).

To the other one, the operator reduce the regulatory risk because is assisted by experienced organizations (with respect the foreign requirements).

b- Safety analysis reports

The licensing process is performed to assure the safety of the nuclear installation.

Safety analysis and reports are core documents to be provided into the license application.

c- Quality assurance manuals

The purpose of the QA programme is to ensure that the facility is designed, deployed and tested in a satisfactory manner (IAEA, 1988); hence the QA manuals (which contains management tools and procedures to undertaken the QA programmes) play a central role in demonstrating the NPP safety (IAEA, 2002). QA manuals are included into the licensing application (IAEA, 2010).

d- Licenziability clauses

[i] The term "national" refers to the country where the NPP is deployed.

The operator has the prime responsibility in assuring the installation safety; and then is the prime licensing actor.

On the other hand the operator may have reduced capabilities, experience and knowledge with respect the reactor technology to be licensed. In these cases the rector vendor need to assist him, during the licensing process, delivering the required documents in accordance with the contracted schedule.

If the reactor technology fails met the regulatory requirements, the project is susceptible to suffer delays and modifications.

If this risk is not opportunely addressed (on contractual basis) the operator is liable for a risk out of its control; for this reason, the licensing risk may be shared with the others contracting parties.

It's a common practice to include the fulfillment of the regulatory requirements (of the proposed reactor technology) as qualifier performance, during the bidding phase[i].

Furthermore the bid evaluation consist on raking the proposals received, on multi-attribute basis: the safety assurance and regulatory acceptability are attributes, of primarily importance(IAEA, 1987).

On the other hand, even when the contractor is not selected on competitive basis; the correspondence with regulatory requirements needs to be evaluated.

The contract awarding route, itself, doesn't protect the licensing applicant (operator) to the risk of regulatory refusal (with respect the reactor technology), and special clauses shall be put in place, such as the "licenziability clause", which permits to shift the risk to the other contracting parties. The reactor vendor-contractor assure the licienziability of the reactor design proposed, if problems arise (during the licensing process) the clause indentifies the responsibility, penalties, claims and compensation measures dealing with the scenario described.

By contrast such clause has only effect on economic domain, because the civil and penal liability can be transferred to others parties.

e- Transfer of technology, domestic participation and training services

The transfer of technology is a subject of paramount activity for the effective implementation of nuclear programme and project (IAEA, 1988).

In general terms, the transfer of technology requires a series of agreement between government (importing and exporting countries), regulatory bodies and industrial organizations (IAEA, 1999).

A key concern in developing the nuclear programme is the domestic participation[i] in terms of suppliers, research and testing centers, academics , etc.

[i] The bid invitation is correlated to a series of documents specifying the scope of work required, the contractual conditions, and other specifications. In the nuclear sector is of primarily importance to attach a complete and updated legal and regulatory requirement into the bidding specification (IAEA, 1987). As result the bidding invitation itself can be understood as vehicle by which the foreign contractor is informed on the actual legal and regulatory scenario. Due to the criticality of this information, the operator may be assisted by the RB (e.g. during the early meetings §REF).

The level of involvement of national industry mostly depends on the level knowledge and experience with respect the all activities required for the implementation of the nuclear project. (IAEA, 2001).

Chemical, construction, metallurgic, mechanical[ii] and industry may acquire a role in the development of the nuclear project. On the other hand training services are usually required for both operator and domestic contractors (IAEA, 2007).

Especially the operator requires appropriate training services for carrying out operating and maintenance activities of the nuclear facility (IAEA, 1987).

Reactor vendor is usually the prime actor which furnishes training services: at the training centers, similar nuclear facilities, trough simulators, etc.

The commissioning of the NPP is critical with this respect; the operating personnel require to be trained and involved into this (IAEA, 2007).

Apart to the governamental and regulatory agreements, the transfer of technology is also considered into the bidding process (if is contemplated) and on project contract.

From one hand, the transfer of technology and training services are parts of the project; the domestic participation could be a part of the scope, a criteria adopted for ranking the proposals or both. (IAEA, 1987)

To the other one, the contract specifies the scope of such services, the resources implied and the implementing organizations.

These contractual specifications have effect on licensing process: first the reactor vendor is obligated (by contractual clauses) to deliver the documentation to the RB, in accordance with the agreed schedule. Second the reactor vendor, contractor and suppliers need to assist the operator in delivering the required documents (to RB) and in demonstrating that he has sufficient knowledge and capabilities to carrying out the operating activities.

Third the national suppliers involved, must be supported in demonstrating (in the eyes of RB) that have sufficient knowledge and capabilities to implement their NPP work scope.

These obligations are specified into the contract, and the operator remains the prime licensing responsible. As result the contract must address the appropriate division of responsibilities including clauses and penalties.

4.1.3.3. The licensing application

The licensing application includes at minimum:

"- The name, address and any additional contact information of the applicant

- The site for which the application is being made, if required

- The nature of the activity that the applicant wishes to undertake

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[i] The industrial development, employment and national participation are some of the most important objectives associated to the implementation of the nuclear programme (§3.1.2.).

[ii] List not exaustive.

- Details of any relevant existing licence

- Any environmental assessment report, if required by national legislation

- Information on whether the installation or activity is fully or primarily owned or controlled by a person from another State or by a foreign corporation, and, if so, details of the ownership structure." (IAEA, 2010)

On the other hand the application is correlated by a series of documents, describing in detail the technological features, the organizational features, the project features, the site condition, etc.

The operator must demonstrate, trough the submission of application and related documents, a series of prerequisites required for the construction, operation and decommissioning of the NPP.

In particular the documentation provided shall demonstrate to RB (IAEA, 2010):

- The applicant met legal and regulatory requirements
- The documentation is complete and consistent
- The NPP to be implemented, deals with the safety objectives, principles, requirements and criteria (§3.2.3.)
- The Operator, and in cascade the others Owners' group parties, have sufficient capabilities to carry out the activities to be licensed and authorized.

Table 4.8 shows the content of the document to be provided to RB in supporting the licensing application.

Project description	Description of the site
	Description of the facility
	Safety concepts and criteria used in the design of the facility
	Applicable safety regulations, guides and industrial standards
Organizational aspects	Management structure and resources
	Quality assurance arrangements
	Organizational structure for each stage of authorization
	Qualification and training of personnel
	Development of procedures
	Documents and records control
Plans and programmes	Radiation protection programme
	Environmental monitoring programme
	Emergency preparedness
	Physical protection
	Fire protection
	Waste management
	Research and development
	Feedback of operating experience
	Decommissioning strategy

Table 4.4: scope of the formal documents required during the licensing process, (IAEA, 2002)

The matters just presented are reported into the following documents:

“(1) A descriptive construction report (including a quality manual), which consists of a description of the fundamental elements including basic information on the nuclear installation, the process and technologies used, justification of related activities and provisions for decommissioning;

(2) References to and benchmarks against other relevant nuclear installations, including those in other States, if any, and a summary of the most significant differences between the installations;

(3) A draft plan for the project, including phases and anticipated schedule (including technical research and development, if necessary), a prior economic study regarding the necessary financial investments and the expected costs;

(4) A site evaluation report, which may include a report on the environmental radiation monitoring programme;

(5) Reports on the use of cooling sources and discharges into the environment, and a report on the environmental impact assessment;

(6) Public inquiry strategy plans and reports according to each State’s framework and practices;

(7) A report on the management and organization of the design and construction project, including responsibilities and a list of contractors;

(8) A report on the acquisition programme, including a list of the structures, systems and components and their origin, and, as applicable, details of the manufacturing process for structures, systems and components important to safety;

(9) The strategic plan for the licensing process, including the set of requirements, guides, codes and standards to comply with, which may be partly adopted from the vendor State (if any);

(10) A preliminary safety analysis report before authorization to begin construction, which may include information on site evaluation, the design basis, nuclear and radiation safety, deterministic analyses and complementary probabilistic safety assessment;

(11) Plans relating to the operating organization and its management system for all licensing steps;

(12) Technical design documents;

(13) Physical protection plans prepared using design related threat analyses, and especially interfaces with safety measures;

(14) Fire protection plans;

(15) Plans for accounting for and control of nuclear material;

(16) Training and qualification plans for operations personnel;

(17) Proof of trustworthiness of all staff who will be engaged in responsible or sensitive positions;

(18) Commissioning programmes and reports;

(19) Final safety analysis report; (20) Ageing management plans;

(21) General operating rules;

(22) Technical specifications, including all operational limits and conditions (may be included in the general operating rules);

(23) A plan for collecting and applying feedback on operating experience;

(24) Plans for evaluating and improving safety performance;

(25) Operating procedures for accident management;

(26) Emergency preparedness and response plans;

(27) Reports and manuals on the radiation protection programme;

(28) Reports on radioactive waste and spent fuel management, including a description of the system for the classification and characterization of waste, and rules and criteria to release waste;

(29) Modification rules (may be included in the general operating rules);

(30) Details of the maintenance programme and the periodic testing programme;

(31) Reports of periodic safety reviews or other safety reviews;

(32) Decommissioning plans and reports, including details of final shutdown, and decommissioning substages, actions and safety analyses." (IAEA, 2010)

The content of these may be divided or combined into different documents depending on the national requirements and the RB or actors' consuetude.

4.1.3.4. The license

This paragraph consider only the license to construct and operate with the NPP; the license required for handling, transporting, exporting or importing nuclear material are not directly considered[i].

The license is the legal document granted by the RB which empowers the licensee[ii] to carry out the activities specified into the license[iii].

The licence usually includes:

"(a) A unique licence identification.

(b) The issuing authority: the laws and regulations under which the licence is issued; the official designations of those who are empowered by those laws or regulations to issue the licence and whose signature and stamp should appear on the licence; and the authority to which the licensee will be accountable under the terms of the licence.

(c) Identification of the individual or organization legally responsible for the licensed installation or activity.

(d) A sufficiently detailed description of the nuclear installation, its location and its activities, including a clear depiction and description of the site boundaries, and other drawings, as appropriate.

(e) The maximum allowable inventories of sources covered by authorizations.

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[i] In general terms most of the license features, following introduced, may have some degree of similarity with the others typology of liceces not specificately treated.

[ii] The licensee is, in general terms the operator.

[iii] And indirectly all others parties involved into the activities to be licensed.

(f) The requirements for notifying the regulatory body of any modifications that are significant to safety.

(g) The obligations of the licensee with respect to both safety at the installation and the safety of its equipment, radiation source(s), personnel, the public and the environment.

(h) Any limits on operation and use (e.g. dose limits, discharge limits, action levels, limits on the duration of the authorization, permit or licence).

(i) Any separate additional authorizations that the licensee is required to obtain from the regulatory body.

(j) The requirements for reporting events and incidents at the installation.

(k) The requirements for providing routine reports to the regulatory body.

(l) The requirements for retention of records by the person or organization responsible for the nuclear installation and its activities, including the time periods for which records should be retained.

(m) The requirements for arrangements for emergency preparedness.

(n) The means and procedures for changing any information stated in the licence.

(o) The documentary basis: the documents in support of the application and those prepared and used by the regulatory body in the review and assessment process, which together form the basis for issuing the licence.

(p) The relationship to other licences; that is, whether the licence is contingent upon a prior authorization or is a prerequisite for a future authorization.

Mechanisms should be established so that expiry of an authorization is avoided (if an expiry date is established by the regulatory regime).

(q) Procedures for, information about and identification of the legal framework for challenging the licence or part of the licence.

(r) Licence conditions dealing with safety aspects of the installation and its activities." (IAEA, 2010)

The letter "r" identifies the licence conditions which are additional obligations with the force of law; these permits to introduce specific requirements applicable only to the licensed activities[i].

The license conditions can be amended, modified, suspended and attached (new license conditions); this permits to the RB to maintain a specific regulatory control on the nuclear activities. Indirectly the licence conditions enhance the discretionary powers of the RB and are especially used in the "performance based legal approach".

The requirements contained into the licence conditions usually cover the following areas:

"design, radiation protection, maintenance programmes, emergency planning and procedures, modifications, the management system, operational limits and conditions, procedures and authorization of personnel." (IAEA, 2010)

The licence conditions can be grouped into the following categories (IAEA, 2010):

[i] Depending on the country considered the licence conditions may be addressed by law, regulation or specified into the licence. On the other hand, the term "licence conditions" is internationally understood deals with the last definition. The previous two definitions are considered as legal and regulatory requirements. (IAEA, 2002)

-Technical limits

- Safety procedures and operation modes

-Administrative proceedings and procedures

-Inspection and enforcement actions

- Response to abnormal circumstances

Usually the licence conditions are attached during the whole licensing process, at every step the RB formulates license conditions affecting the following phases (e.g. in parallel with the early licensing approvals, such as site and reactor design, the license conditions are formulated and affect the construction and the commissioning of the nuclear facility)[i]; these licence conditions are mostly transitory. On the other hand, when the operating licence is granted the definitive[ii] conditions are attached to it.

4.2. Licensing process model

This paragraph introduces a heuristic and qualitative model which permits to classify the different licensing conformations (applicable to every country), underlining the resulted licensing risk for the Owners' group parties.

Firts the licensing process is represented by the licensing parameters.

The "licensing parameters" permit to classify the possible licensing conformations and approaches in terms of: law framework (4.3.1.1), institutional actors involved (4.3.1.2), safety criteria utilized (4.3.1.3), licensing steps (4.3.1.4), public involvement and information transparency (4.3.1.5) and nuclear programme approach (4.3.1.6).

Second, the objectives associated to the licensing process are identified, distinguishing between the public objectives and private ones (4.2.2).

Third, the linkages between the licensing parameters and objectives are identified (on qualitative basis).

Forth, the potential effects on the nuclear project objectives are identified in terms of time lags and extra costs (on quantitative basis).

As result, the model permits to identify the critical areas associated to different licensing process.

The licensing risk is partly identified on quantitative basis (the impact side) and partly indentified on qualitative ones (the critical aspects enhancing the licensing process uncertainty).

This would provide the basis to consider mitigating actions in terms of protection (mostly endogenous to the Owners' group) and prevention ones (partly endogenous to the RB and partly to owners' group).

Furthermore this study would provide useful insight (for the RB and legislator) in considering the relative advantages and disadvantages of the licensing approaches in the eyes of the Industrial organizations.

[i] This contributes to emphasize the regulatory complexity.

[ii] These can be amended, suspended, modified, etc. at any time by RB. Usually the licence conditions are revised during safety reviews and during or after the occurrence of abnormal circumstances (e.g. incidental scenarios).

The following subparagraphs present: the licensing parameters (§4.2.1), briefly recall[i] the licensing objectives (§4.2.2.), the linkages between licensing parameters and objectives (§4.2.3) and finally the potential impact on project performances.

4.2.1. Licensing parameters

The licensing parameters permit to underline the relevant licensing process attributes and form the basis by which the potential effects on project objectives are identified.

All these are endogenous to the public institutions, especially: parliament, government and RB.

The licensing parameters considered are: legal framework (understood in broad sense: including regulations, guides, etc.); institutional actors involved, safety criteria, licensing steps and nuclear programme approach (which the single NPP units belongs to).

Most of these elements have been already introduced in the chapter (§3.) and in the current one (§4.)[ii]. For avoid redundancies, the following subparagraphs don't reargue the licensing parameters already explicated in the previous section.

4.2.1.1. Law framework

Legal traditions are one of the most discrepant elements in considering licensing processes adopted into different countries (Bredimas, et al., 2009).

The difference between legal frameworks is explicated by: the legislating approach, the implementing institutions and for the specific norms contained into it.

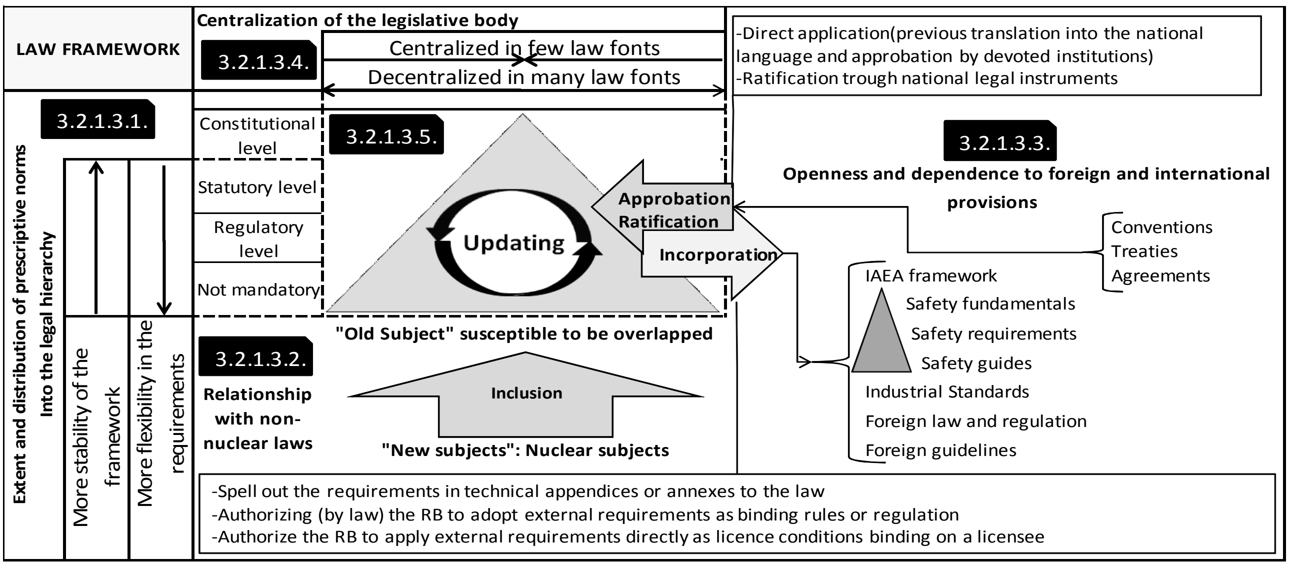

Fig. 4.4: Law Framework

[i] The general licensing objectives have been already presented in the paragraph (§4.1.2.2).

[ii] Legal framework (§3.2.1.), institutional actors involved (§4.1.2.1.), safety criteria (§3.2.3.) and nuclear programme approach (§3.1.4.3.).

This thesis work considers five basic drivers which permit to explain the possible legislative approaches and its consequences on licensing objectives; these are briefly reported on Fig. 4.4.

The explication of these five drivers is reported into the paragraph (§3.2.1.3.); Fig4.4 also reports the number the related subparagraphs.

The five drivers are considered licensing parameters, the possible effect on licensing process objectives are treated on paragraph (§4.2.3.).

4.2.1.2. Institutional framework

The term "institutional framework" refers to the division of powers and duties between institutions involved into licensing process; this refers specifically to the administrative proceeding: others related activities (such as legislative or regulatory) are not directly considered.

The IAEA framework emphasizes the independent role of RB in carrying out its licensing functions, (IAEA, 2003): this case is considered the best approach in pursuing the safety objective (§4.1.2.2.1.); for this reason the RB is the sole institutional actor considered into the licensing process (IAEA, 2010).

This simplified framework lies in the existing licensing practices were several others institutions are also involved; first the Government which, most of time, is the sole institutions devoted to grant the license. Furthermore the Environment agency, decommissioning authority, parliament and others administrative bodies and ministers are also involved into the licensing process. This because the nuclear safety is not the sole objectives associated to the licensing process.

This thesis work considers four main typologies of institutional approaches showed in the Table 4.9.

Case	Number of critical decision points	Responsible institutions
a	One check	RB
b		Government, RB gives its opinion/option
c	Double check	Rb and Government
d	Multiple check	Government, RB and other institutions

Table 4.5: Institutional approaches in licensing decision-making

Case a is consistent with the IAEA framework. This approach is considered the best with respect the safety objective but may have negative impact on public perception because the RB is usually perceived as an "obscure" organization by citizens (Bredimas, et al., 2009).

Case b considers the Government as the sole licensing decision makers; the RB is the technical bodies which assist the licensing decision. This approach affects positively the public perception because Government has the politic responsibility of its decision; but may have negative impact on safety objective prioritization because Government may pursue different objectives at the same time (e.g. employment, country development, etc.)

Case c is one of the most common approach because combines the advantages of the previous ones. By contrast this approach may affect negatively on private objectives because enhance the complexity of the licensing framework and the unpredictability of critical decisions.

Finally the Case d is similar to the previous one: the public objectives are assured with greater extent because more institutions and decision points are incorporated into the licensing process.

By contrast this approach may have significant negative impact on licensing efficiency,clearness and on predictability of licensing decision-making. As result this approach increase the licensing risk considering the Owners' group point of view.

4.2.1.3. Safety criteria

The safety criteria consist on the methodologies adopted by the RB in assessing safety of the nuclear installation in connection to the implementing organization and the proposed site (§3.2.3.2.2.).

Every licensing process need to incorporate opportune safety criteria; the same are also used by the applicant for demonstrating the safety of its proposal.

The safety criteria can be grouped into two main families: deterministic criteria and probabilistic ones.

Fig. 4.5. compares these two approaches considering the regulating process and the licensing one.

During the regulating process, the starting point is the risk considerate acceptable by the RB.

In the deterministic approach the risk framework is just draft, and gives and order of magnitude of possible events (initiating and postulated) considered risky I the eyes of the safety.

The output of the regulatory process is the definition of prescriptive criteria of deterministic nature (including qualitative criteria) which are directly assessable and measurable.

The definition of these "constrains" passes trough modeling of the behavior of the nuclear installation, operating personnel (and relating procedures) and site conditions.

The model is based on conservative codes, input data and bounding conditions.

The question the RB try to answer, in carrying out its regulatory functions, is: "which measurable criteria assure that the safety risk, of the proposed installation (in connection with the operating organization and the specific site), is at least equal to the risk considerate acceptable?"

In answering to this question RB need to consider the specific reactor design technology.

This approach has been traditionally used by nuclearized countries in carrying out the licensing safety assessment, and nowadays is still the most common used (IAEA, 2005).

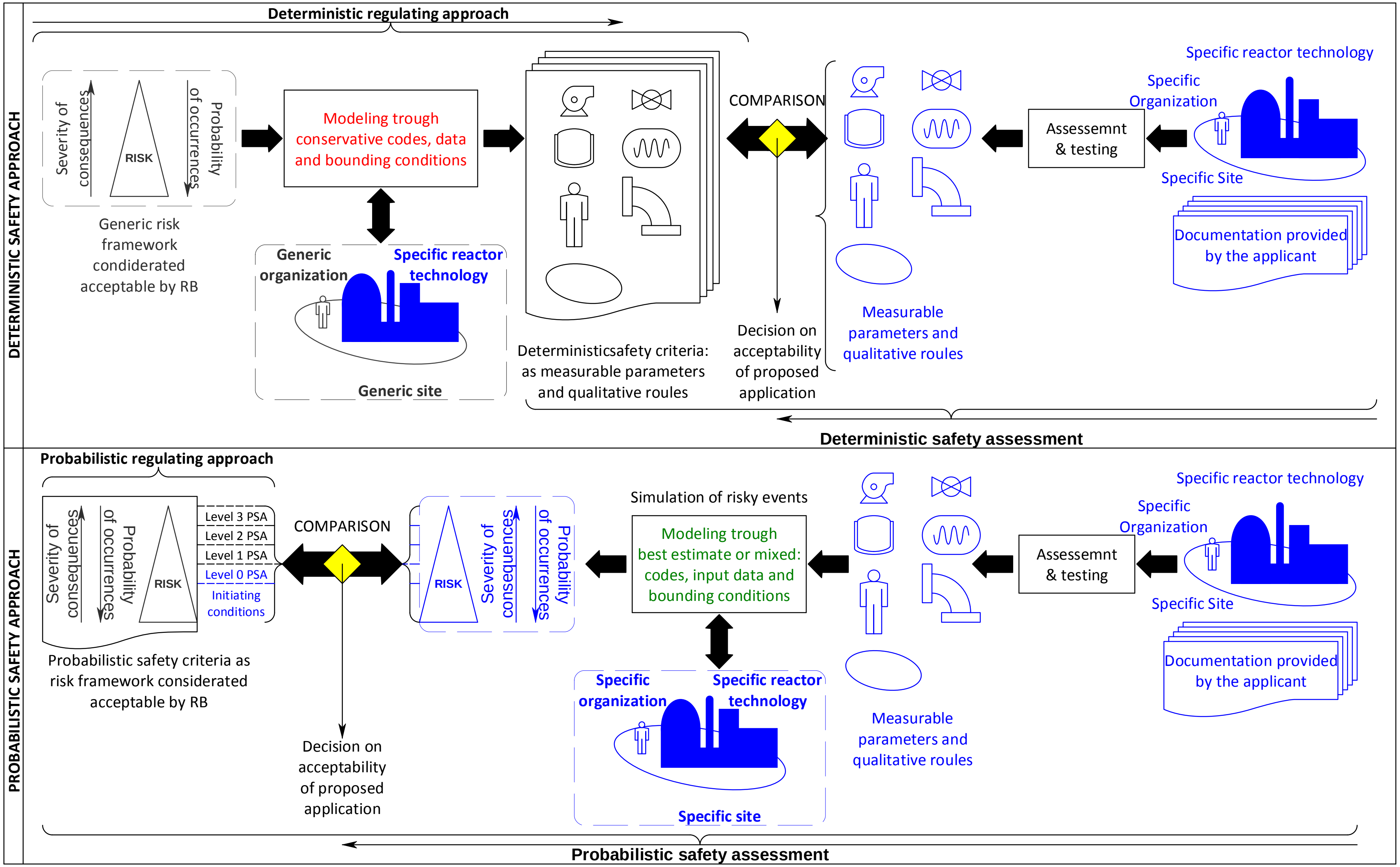

Fig. 4.5: Comparison between deterministic and probabilistic approaches

The main advantage of the deterministic approach (with respect the probabilistic one) is that the resulted prescriptions are clear, directly measurable (then predicable by Owners' group), and can be incorporated into legal documents (and don't require degree of subjectivity to be applied). On the other hand the deterministic safety criteria contribute to enhance the complexity of regulatory framework because the provisions, necessary to assure the safety of the nuclear installation, are many and interdependent.
Another strength of the deterministic safety criteria is that require lower experience and capabilities to be assessed and applied by RB and Operator.
Especially in the case of new nuclear programmes, the deterministic criteria can be directly incorporated (into the regulatory framework) considering those countries already experienced with the specific reactor design technology (usually is chosen the reactor vendor's country).

The probabilistic approach also starts from the definition of the risk framework considered acceptable by RB. In this later case, the risk framework need to be more precise and specific to the reactor technology considered (especially for the lower levels of PSA).
The resulted probabilistic safety criteria are really simple: for every risky event is fixed a maximum level of probability.
The levels of probabilistic safety assessment are internationally codified considering four main levels: from level zero to three (§3.2.3.2.2.2.).
Level 0 is specific to the rector technology considered[i] because require a detailed specification of the safety functions and related operating modes.
Level 1 is uniforms for every light water reactor and indicates the probability that the core damage takes place.
Finally Level 2 and 3 are uniform to every nuclear technology.

The intrinsic simplicity of the probabilistic safety criteria lies in the real application of these, which requires a vast amount of data, advanced software tools, experienced personnel and capabilities for both the applicant and RB.
In this case the question that applicant and RB try to answer is: "which is the real safety risk that the specific site, implementing organization and nuclear technology, give rises?"
In answering to this question, RB and applicant usually find the following difficulties:
First the risk that the nuclear installation let rises is not directly assessable and requires extensive simulations.

[i] Note that Fig. 4.5. distinguishes between specific and generic consideration showing the chart objects in blue or grey colors.

Second the data required for carrying out such simulations may be not available, especially for new generating technology (which for example have never been definitively deployed yet). In this cases the best estimating models, input data and bounding conditions can't be used and some conservative hypothesis need to be introduced (the resulted model partly incorporated best estimate hypothesis and party conservative ones: this is called combined approach).

Third the model requires degree of subjectivity, especially in considering the mutual interference between safety functions, initiating and postulated conditions.

Forth is not possible demonstrate that the probabilistic model is complete.

Fifth the probabilistic prescriptions can't be directly incorporated into the legal framework as requirements[i]. Hence the licensing decision-making let raise the risk perceived by Owners's group.

Sixth the application of PSA requires vast experience for both RB and applicant, as result can't be applied for novel nuclear programmes.

Seventh the PSA requires long lead times to be developed, and can't be implemented during the licensing processes. Usually the reactor vendor furnishes its PSA estimation before the licensing processes (especially for levels zero and one) and the RB assesses these results during the licensing processes.

For these reasons, the licensing process is mostly based on deterministic safety approach.

Probabilistic safety approach is more common used during the lifetime of the nuclear facility, especially for maintenance, safety reviews and proposed plant or procedure modifications (IAEA, 2002).

On the other hand the risk informed approach combines deterministic and probabilistic safety approaches together.

This approach is more common used in the advanced nuclearized countries and assure higher level of safety with respect the previous two.

4.2.1.4. Licensing Steps

The licensing process is structured into steps; these take the form of regulatory holding points where the devoted institutions grant (or not): licenses, permits and authorizations required for constructing and operating with the nuclear facility.

These holding points can be regrouped into different ways depending on the licensing contexts considered; as result, the licensing frameworks is characterized by two tiers of steps: from one hand the basic decisional points, on the other hand the macro-phases (consisting on the aggregation of the previous). The macro-phases are also characterized for the critical decisions consisting on granting (or not) licenses and major authorizations.

[i] At least is possible to set down a general and qualitative objective (such as ALARP), issuing specific guidelines on PSA application and leaves to the RB the discretionary powers in deciding about the acceptability of nuclear project adopting the probabilistic criteria.

The licensing steps are programmed regulatory holding points[i]; Fig. 4.6 and Table 4.10 show the most important of these affecting the entire lifecycle of the nuclear facility.

Letters a-g indentify the licensing steps, the remained ones (h-j) are not proper of the licensing process but are affected by the authorizations generated within it.

Furthermore Fig. 4.6 (and Table 4.10) shows the most common approaches in aggregating the basic holding points into licensing macro-phases: traditional approach and combined one.

[i] Exist also un-programmed regulatory holding points, such as: inspection and enforcing actions, accident investigation, request of plant modification (e.g. up-rating), legal and regulatory reviews, politic changes, long term shutdown.

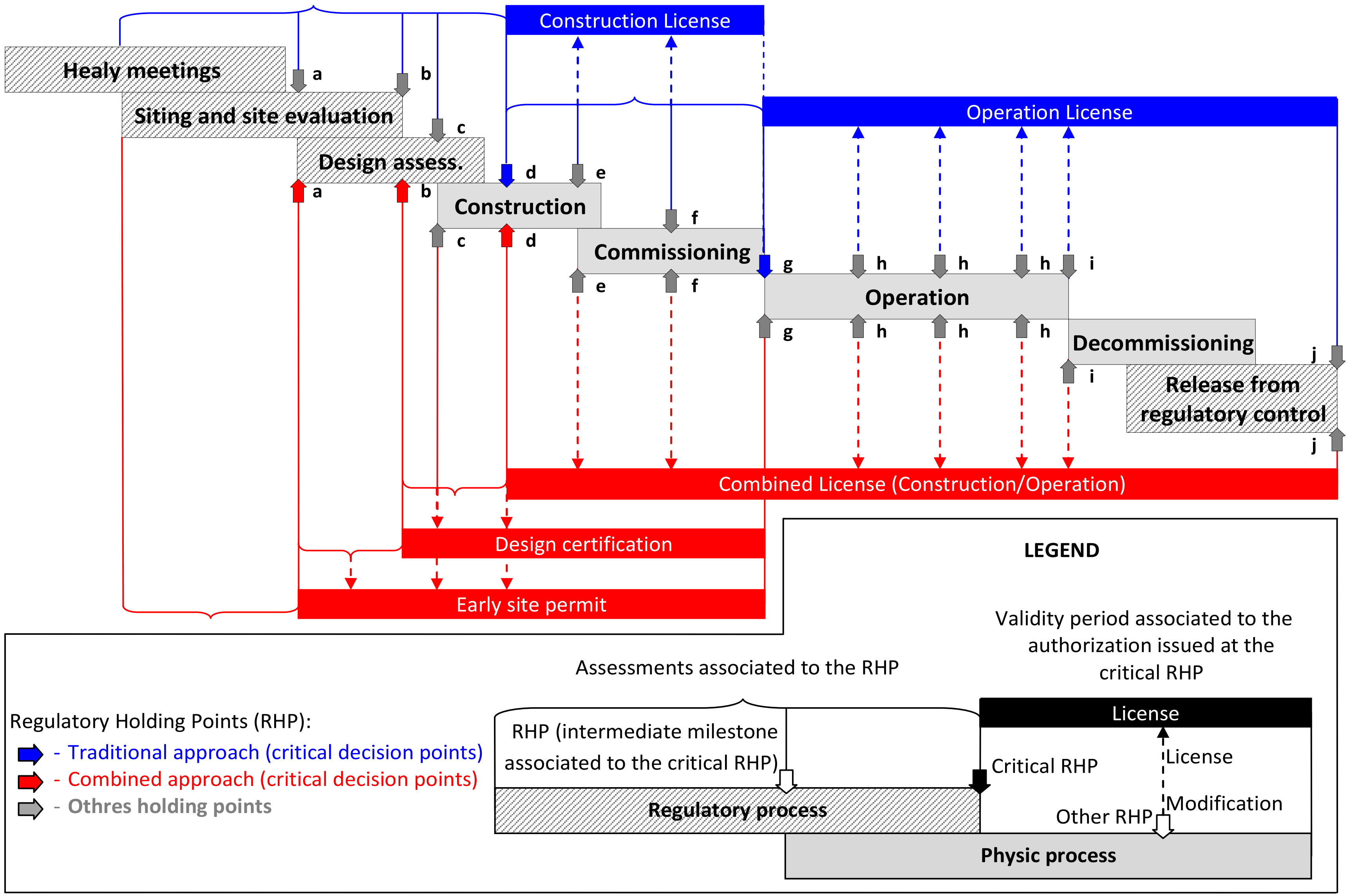

Fig. 0.6: Programmed regulatory holding points, (IAEA, 2010), revised figure

Licensing process dedicion points			Scope of the regulatory assessment
Cod	Traditional approach	Combined approach	
a	Site approbation: as part of construction application	Early site permit	Environmental impact assessment and radiological study: risk of nuclear installation: natural conditions, human induced risks, possible domino effects, use of the land around the site boundary; risk for people and environment: population density in the vicinity of the site, impact on arrangements for emergency preparedness, site security, existing environmental conditions, ecology, operating discharges, heat dissipation effects.
b	Design approbation: as part of construction license	Design certification	Design analysis: deterministic safety assessment, PSA, operating limits/conditions and procedures, QA and management system, ergonomics, maintenance, internal handling, pool storage, safe shutdown, waste management, decommissioning.
c	Early site permit: as part of the construction (or combined) license		Preliminary safety report, definitive site approbation, design modification (do adapt the facility design to the specific site), security during construction, certification of contractors (if required).
d	Constraction license	Constraction and operation license	Application (§4.1.3.3.): framework and schedule for construction and acquisition of structures, systems, and components, operator financial capabilities, planned design deviation, physical and fire protection, radioactive monitoring equipment and devices, upgrading of the radiological study, industrial codes, standard and rules, applicant control over the contractors
e	Non nuclear testing approval		Construction report, commissioning programme and any other relevant document produced in the previous stages (especially any modification affecting the previous regulatory holding points).
f	Fuel load and nuclear testing approval		Status of the nuclear installation (especially in the eyes of safety and security): as-built design, results of non nuclear commissioning tests, storage facilities ; management aspects: management system, organizational structure (especially training and qualification of personnel), arrangements on periodic testing, maintenance and inspection; Organization and modification procedures, reporting system; Operational provisions: operational limits, commissioning programme, environment discharges (and related conditions), adequacy of operating instruction and procedures, on-site emergency preparedness, physical protection, accounting and control for nuclear material, waste management programme.
g	Operation license	Operation approval	Results of commissioning tests, Operating limit and conditions, Arrangements for emergency preparedness, safety analysis report and other programmes: access authorization, fitness for duty, training and qualification of licensed personnel, maintenance, pre-service inspection and testing, surveillance (especially the environment and safety functions), environmental qualification, monitoring of effluents, management of spent fuel, ageing management, feedback for operating experience.
h	Safety review		Actual service conditions, compliance with requirements, safety and security principles, programme for equipment qualification, mechanical thermal loadings, ageing management programme, any necessary safety improvements, maintenance programme, proposed plant modification, license renewal application
i	Decommissioning authorization		Decommissioning programme, operational decontamination programme, waste storage and removal and transportation, fire protection, radiation exposure of workers, non-radiological hazards, supply systems to prevent failures, integrity of hosting devices
j	Release from regulatory control		Responsibility shift (from operating organization to the devoted institution), institutional controls, final radiological status of the site (and of the facility if not already decommissioned), radiological history of workers and contractors.

Table 4.6: Programmed regulatory holding points, based on (IAEA, 2010)

The main advantage of the traditional licensing approach (showed in blue color in the previous figure and table) is long experience maturated by the industrial organizations and institutions.

On the other hand, combined approach (showed in red color in the previous figure and table) reduces the regulatory risk (AREVA, 2006) and enable more effective synergies especially for uniform nuclear programmes (IAEA, 2010).

First the regulatory risk is reduced because the design certification and site permit can be understood as real options for industrial organizations: especially the reactor vendor and the operator.

Rector vendors' competition is mostly based on: politic support, experience maturated, financial and contractual condition, project performances, reactor design features (including safety and security) and standards, training support, transfer of technology, and ability to met licensing requirements.

With respect the last element, the design certification permits lesser effort and risk during the project implementation; when the certification is achieved is easier to implement the same design and the Utilities are encouraged to replicate the same reactor design.

Furthermore the certification in one country can simplify the certification in other countries because of the collaboration between regulatory institutions (e.g. WENRA).

As result the reactor vendors are encouraged to apply for the certification design even in the absence of a planned project, but just for enhance a competitive strategy.

Operating organizations can also beneficiate to the lower risk.

When the nuclear site is certificated and approved, is easiest to construct other facilities within this (the site permit need to be amended considering the cumulative effects and the interdependences with other installation at the same site). Siting synergies[i] are typical for the nuclear projects and even the traditional licensing approach may include mechanism dealing with this aspect.

The Operator can apply the real option logic to the design certification.

The modern scenario is characterized for the absence of nuclear project for long time (especially occidental countries) and for the return of nuclear investment by some occidental countries, and developing ones (mostly inexperienced with the nuclear technology). Furthermore the reactors of III+ generation have maturated low or no experience with respect the construction and operation. As result, Operator may find problematic choose between different reactor technologies because no performances evidences are available.

In this uncertain context, Operator can apply for the certification of more reactor designs before the effective construction of these. Trough this licensing strategy, the operator takes time in deciding about the reactor technology to be implemented, but proceed with early steps of licensing process; when sufficient information is available he can choose the preferred design and proceed with the later licensing phases.

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[i] Especially for the constrained environment conditions required (in terms of population density, greed supply, hydrologic, seismic, geologic, meteorology, etc.), and for the vast effort needed to convince local population.

The reactor design certification is a real option also considering the subsequent nuclear projects which adopt the same reactor technology; this encourages the replication of the same reactor technology for subsequent projects by implementing organizations.
The international (and regional) harmonization of reactor design also beneficed of design certification because of the extensive cooperation between oversea RBs (CORDEL group, 2007).

Finally should be underlined that the two approaches presented have been originally designed for large and medium light water reactor concepts. From one hand there are licensing phases that anticipate the construction of the nuclear facility; to the other one some licensing phases proceed in parallel with its implementation. The firsts may take from two to four years on averages; the seconds are consistent with the large project schedule. This context mitigates the potential beneficial features of small and modular reactor concepts because is time consuming (Reynolds, et al., 2010). The effective implementation of such reactor concepts requires a substantial rethink of licensing practices to considering the peculiarities of these both in term of licensing schedule and safety requirements (Bagnal, et al., 2010).

4.2.1.5. Public involvement and information transparency

The success of the nuclear project passes through the public acceptance which is a prerequisite.
The IAEA guidelines suggest two formal hearings for enable the public to formulate the questions and comments: the firs at the beginning of the nuclear programme, the second in the early phases of licensing process (IAEA, 2010).
The formal hearing may also deals with relevant stakeholders (e.g. industrial organizations).
The openness of the public hearing vary significant between existing regulatory contexts; the most common approach are: citizens who live in the vicinity of the nuclear site[i], citizens living into the related federation region or country.
Public hearings can be also categorized in function of the degree of power left to the public; the most common approaches are: the public comments require only to be answered, the comments arisen must be taken into account: any refuse must be motivated by devoted institutions, public opinion has a blinding rule on project (e.g. referdum about the opportunity to implement the nuclear project) (Bredimas, et al., 2008).
Especially where the public influence is high, experience suggest to pose the hearings as early as possible for mitigate potential negative effects on project performances (Golay, et al., 1977).
Public information transparency is required for enhance the public acceptance.
The transparency must be balanced with the security and confidential information, RB or other devoted institutions are responsible to find the appropriate tradeoff between these conflicting objectives.
Additional complications derive from technical language and specification characterizing nuclear subject.

[i] Consider also foreign citizens if the nuclear site is close to the national boudaries.

Furthermore public information is especially stressed during operating phase (e.g. notification of unusual events).

4.2.1.6. Nuclear programme approach

The nuclear programme approaches have been already argued on paragraph: (§3.1.4.3.), these can be regrouped into three main sets:

d) Government leadership
e) Market-free oriented
f) A mix of the previous

a) In the first approach the Government is usually involved into the licensing process. In this case the Government incorporates more objectives and responsibilities on the sort of the nuclear programme and project itself.
This approach enhances the national barriers with respect foreign reactor technologies because Government also endorse the development of national ones.
During the early phases of nuclear programmme, national capabilities and experience on nuclear sector mat be inadequate: in such case Government may support the importation of foreign reactor technology (usually under turnkey basis for the first units and gradually iincreaisng the national participation of project development).
When sufficient experience is gained by national organizations, the Government has the power to maintain effective barriers against international competitors: the energy policy and the licensing process play a central role with this respect.

b) Market free oriented approach is characterized to be open with respect international competitors. To maintain an effective open market approach the licensing process shall be structured in a way that it's partly (or totally) independent with respect political powers.
In this contexts the information transparency and public participation is especially emphasized during licensing process.

C) the third category deals with the balancing of the two previous approaches.

4.2.2. Licensing objectives

As discussed on paragraph (§4.2.), the licensing process model attempts to exemplify the connection between the licensing parameters (already introduced: §4.2.1.) and the licensing objectives (described in this section).
Furthermore paragraph (§4.1.2.2.) has already drafted the licensing objectives framework.

The licensing objectives can be regrouped into two main sets: public objectives (endorsed by public and institutions) and private ones (considering the Owner' group interests).

The most important public objectives are:

- Regulatory control objective: "*The objective of granting authorizations in the licensing process is […] to establish regulatory control over all activities and facilities*" (IAEA, 2010).

- Nuclear safety objective: "*The achievement of proper operating conditions, prevention of accidents or mitigation of accidents consequences, resulting in protection of workers, the public and the environment from undue radiation hazard*" (IAEA, 2010).
- Nuclear security objective: "*The prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or malicious acts involving nuclear material, other radioactive substances or their associated facilities*" (IAEA, 2010).

- Compliance with legal and regulatory requirements objective: one of the principal aims of the licensing process is to assure the compliance with legal and regulatory norms treating for the activities to be licensed and related implementing organizations.

- Public acceptance objective: a further indirect objective of the licensing process is reinforcing credibility on the nuclear project, implementing organization and institutional ones.

A further public objective is the licensing efficiency which can be negatively affected by complex, costly licensing frameworks.

The minimization of resource required for the licensing issuance is transversal objective: affecting the RB and the Owners' group (then is considered and overlap between public and private objectives). Furthermore the cost of licensing services is usually covered by fees (partly or totally) on applicant; then the inefficiency of licensing process may result on more expensive fees.

The "cost effectiveness" objective (as introduced at the section §4.1.2.2.2.) is included into the licensing efficiency one.

The most important Private objectives (excluding the efficiency one because already presented) are briefly listed at follow.

Time effective objective: the licensing lead time shall be as short as possible because of its impact on project schedule and cost.

Low regulatory risk objective: afford as low licensing risk as possible.

Regulatory risk can be explicated by estimation uncertainty, probability of occurrence of scenarios, affecting project performances, and associated severity.

The next paragraph considers the linkages between licensing parameters and objectives considering the level licensing uncertainty generated by the: level of clearness and understability of the framework, predictability of licensing decision-making, degree of freedom left to the Owners' group.

The probabilities of occurrence of scenarios, generated into the licensing process, and affecting the nuclear project, are not directly addressed; these estimations require expert judgment and are difficult to quantify.

Finally the impact of such circumstances on project performances is addressed quantitative heuristic simulation as argued on paragraph (§4.2.4.).

4.2.3. Linkage between the licensing parameters and objectives

One contribute of this thesis work is the systemic identification of the licensing approaches.

Table 4.11 indicates the potential effects that licensing approaches (indentified trough licensing parameters §4.2.1) have on private and public objectives (§4.2.2.), using a heuristic and qualitative scale.

This provides the basis to understand how the different approaches met the tradeoff between conflicting objectives.

Licensing parameters are heterogeneous and then the scores showed in Table 4.11 are not directly comparable but enable a systemic understood of licensing framework.

Most of the effects on project objectives have been already argued in the licensing parameters paragraph (§4.2.1) and then are not discussed again.

Table 4.11 shows also notes (by letters A-J) indicating peculiar approaches and special cases; these are discussed at follow.

A -Shows the legal framework implemented into the early phases of new nuclear programme.

The grating approach in developing law framework is characterized for:

- Inclusion of oversea standard and regulation: considering the best international practices and the regulation country where the reactor vendor comes from)

- High degree of "shared subject" with respect the non nuclear laws (§3.2.1.3.2.), because legislator and regulator concentrate their efforts on critical nuclear issues and left the remained ones to the normal legal (and regulatory) regime.

- Decentralized framework as consequence of the previous two elements.

LEGEND

-3	Vast negative impact	1	Moderate positive impact
-2	medium negative impact	2	medium positive impact
-1	Moderate negative impact	3	Vast negative impact
N.D.	Low or no impact		

				Public Objectives						Private objectives			
											Low licensing uncertainty		
				Regulatory control	Nulear safety	Nuclear security	Compliance with legal and regulatory requirements	Public acceptance	Licensing efficiency	Time effective	Cleareness and understability of licensing framework	Predicability of licensing decisionmaking	Degree of freedom left to the Owners' group
Law framework	rel. with non-nuclear laws	Many shared subjects							-2		-3		
		Few shared subjects							2		2		
	openness/dependence to external linkage	Ratification of treaties and conventions		1	2	1	1				2		
		International standards linkage		1	2	1	1				2		
		Foreign Law, regulation, standard (§1)		-1					1		2		
	distribution of prescriptive norms into the legal hierarchy	Low detailment							1		-2		3
		High detailment	At statutory level	2	1	1	2	2	-2		2	2	-3
			At regulatory level	2	1	1	2	2	-2		2	2	-3
			At not-mandatory level								2	-3	
	legislative body centralization	Centralized framework in few fonts		1					2		3		
		Decentralized framework							-2		-3		
	Dynamic	Revised Sometimes											
		Revised periodically		3	3	3		1	-2		-2	-2	-2
Institutional framework	One check: RB			1	1	1	1	-1	2	3	3		
	One check:Gov., RB gives its opion/opinion			1		1	1					3/-3	
	Double checks: RB and Gov.			2	1	1	2	1		-1	-1	2/-2	
	Multiple checks: Gov., RB and other institutions			3	1	2	3	2	-3	-3	-3	1/-3	
Decision making safety criteria	Deterministic safety assessemnt			2	2	2	2		-1		3	3	-3
	Probabilistic safety assessemnt			1	1	1	1		-2				1
	Risk informed decisionmaking			3	3	3	3		-3		-1	-1	
Main Steps	Early meetengs							1	-1	2	3	3	
	Site:	First site certification		1					-1	-1			
		The site has already certified		-1					1	2	2	3	
	Design:	first design certification		1					-1	-1			
		design has been already certificated		-1					1	2	2	3	
	Construction			2	1	1			-2			-1	-1
	Commissioning tests			2	2	2			-2			-2	-2
	Operating			2	3	3			-2			-3	-3
Public	Transparency	High transparecy				-2		3	-1				
		Low transparecy				3		-3					
	Pubblic involvement	Public opinion has blinding rule						3	-2	-2		-3	
		The main comments arisen must be taken into account						2	-1			-1	-3
		The comments require only to be answered						-2	-1				
Nuclear program	Gov. Leadership	the Gov. support the nuclear project		-1	-1				2	3		3	
		The Gov. Doen't support it											
		The Gov. Opppose to specific nuclear project							-2	-3		-3	
	Free market oriented (operators)							2					1

Table4.7: Effects of licensing approaches on objectives

B – Performance based legal approach (§ref):

-The level of prescriptiveness of the legal framework is low;

-The RB has high discretionary powers in deciding about the acceptability of the license application;

- The safety assessment and demonstration is flexible: it can be based on different safety principles and criteria (because mandatory requirements are not prescriptive). The applicant can propose particular demonstration/assessment safety approach in accordance with RB;

-The RB usually adopts the "risk informed" approach in licensing decision-making to enhance the effectiveness of performance assessment and to enhance the flexibility of the framework;

- The predictability of the licensing decision-making is low because of the vast discretionary powers associated to RB. To enhance the predictability detailed guidelines specify one, or some, possible safety approaches and the decision-making criteria. These are not mandatory requirements (then enhance flexibility) but prescriptive (then enhance the predictability).

- The regulatory control is assured trough prescriptive license conditions.

C - Note: the vast detailing at regulatory and statutory level may enhance the inefficiency of the licensing process because is bureaucratic based leaving low degree of flexibility to RB and Operator.

D - "Prescriptive based" legal approach (§ref):

- High level of prescripteveness and specification of mandatory requirements (which indirectly leave few discretionary powers to RB)

- Usually based on deterministic safety criteria

- The previous affect positively on predictability of the licensing decision-making and negatively on the degree of freedom left to RB and Operator.

E - Note: the RB is usually perceived as an "obscure" organization by citizens, when it is the only licensing decision-maker the public may be low confident on that (mostly depends also by the public attitude and traditional confidence on politics, institutions, science and technology) (Bredimas, et al., 2009). On the other hand the presence of multiple instructions (including politic ones) affect positively on public perception. The case "one check: Government decides and RB gives its option" is considered the neutral case.

F - Note: as discussed in the paragraphs (§3.2.3.; §4.2.1.3.) deterministic safety approach gives higher safety assurance with respect probabilistic one: the previous is based on conservative assumptions and the later introduce higher levels of subjectivity.

On the other hand the "risk informed approach" is more complete and effective with respect of the previous.

These features affect at the same time the regulatory control, security and compliance with mandatory requirements objectives.

The assumptions on licensing efficiency are: deterministic safety assessment affects negatively efficiency objective because is prescriptive and bureaucratic activity. The real application of PSA is more complex, with respect of the previous, and requires much more capabilities and resources; hence the negative effect on efficiency objective is higher.

Finally risk informed decision-making combines both the previous approaches hence require much more resources with respect of these.

G - Note: early meeting affect positively (and indirectly) licensing schedule because the agreement between RB and Operator enhance the understood and the predictability of licensing decision-making.

H - This case is typical for the "Government leadership nuclear programme approach" (§3.1.4.3.):

-With respect the institutional framework, Government acquire full powers in licensing decision-making

- If the Government supports the specific nuclear project, the predictability of licensing decision is affected positively. The Government powers, associated to the different conflicting objectives who endorse, affect negatively the regulatory control and the safety objectives. By contrast the efficiency of the framework is affected positively because of the government support.

- If the Government doesn't oppose the specific nuclear project it has the full powers to abort it, especially before the licensing process.

If the applicant applies to the licensing process he affords high risk because the final licensing decision is addressed by Government who can refuse it; as result the predictability of the framework is affected negatively. In this scenario, even the efficiency and time effectiveness of the licensing process result negatively affected.

I-Combined approach (construction and operation license) (§4.2.1.4.):

-The early site permit becomes to be efficient and time effective only after the first certification. By contrast the regulatory control may be affected negatively when the permit is reused.

-Design certification has the same features of the previous.

J-Note: the high transparency affect negatively on security objective because are conflicting objectives. Usually the relevant security informations are obscured and a totally transparent licensing process can be considered as utopia.

4.2.4. Impact of the licensing process on project performances

The licensing effects on project performances can be catalogued into two main sets: planned effects and stochastic ones; as showed in the table 4.12.

The planned effects are consist on the basic resources required to undertaken the licensing proceeding by both the RB and Operator.

The regulatory fees are usually well defined in advance with respect the licensing proceedings; by contrast the other resources required (e.g. in terms of required capabilities, economic resources, etc.) can be only estimated in accordance with the previous experience and reasonable expectations.

	Controlling actors	Affecting actors	Licensing effects	
Planned effects	Government, RB	Owners' group	Regulatory fees	
	RB, Owners' group	RB, Owners' group	Resources required	Financial resources
				Knowledge based capabilities
				Human resources
				Hardware based capabilities
	RB	Owners' group	Planned licensing lead time	
Stochastic effects	RB, Citizens	Owners' group	Additional project development constrains	
	RB	Owners' group	Licensing process delays	
	RB	Owners' group	Modifications	Soft modification
	RB	Owners' group		Hard modifications
	RB	Operator	Operating constrains	

Table 4.8: Categorization of the licensing effects on project performances

In every case the licensing process requires a minimum amount of resources that can be considered mostly deterministic and depends on the regulatory system, reactor design and experience of both RB and Owners' group.

This typology of licensing effects are not considered in depth because don't affect the regulatory risk (which is the main subject treated in this thesis work).

The second category deals with those effects generated during the licensing process; these mostly affect the owners' group because every RB operates on fixed resource basis.

The concept of regulatory risk is based on the stochastic effects on project performances.

At every licensing step, the RB issues its decision on the acceptability of the work previously performed, and on the plans concerning next project development; these regulatory decisions represent the typical source of uncertainty and licensing risk.

Delays, project modification and additional constrains (e.g. license conditions) are the basic effects that the licensing decision-making may implies.

Fig. 4.7. synthesizes the mechanism by which these effects are generated during every licensing phase; this considers only the most important actor involved into the licensing process: RB and operator.

The Licensing process starts at the early meetings phase where, in general terms, the regulatory body and the applicant made deals about the documents form, the basic requirements and other organizational details concerning the application issuance.

The formal start of the license awarding route starts with the submission of the application by the applicant (Fig. 4.4, phase. A).

When the RB receives the formal application, and the other related documents, starts to make its formal assessments (Fig. 4.4, phase. B) and makes a judgment on the proposed plans, reactor design features, operating organization and selected site.

The work performed by the RB is mostly cyclical[i], at every sub step, of the licensing process, it: assesses, makes a judgment and eventually prescribes further measures which represent the roots of licensing process path diversion; the scopes of these activities are the work previously performed and the plans concerning the next project development.

Fig 4.4. Shows these cyclical activities: the black arrows underline the planned development of the process (by letters: B-C-D-E-F-B), and the red ones the licensing paths diversion (by letters: B-Del1-Del2-B for the regulatory delays and B-Mod1-Mod2-Del2-B for the soft and hard modifications).

When every licensing step is performed, the RB makes its judgment on the acceptability of the work previously performed and on the operating organization; if the nuclear project is considered acceptable it releases the formal license (Fig. 4.4, phase. H).

In parallel, with development of the project, the applicant also submits further documents and intermediate applications to undertake the next steps of the licensing process and the RB decides on the acceptability of these.

The licensing process implies also the generation of further regulatory norms which blinds the activity performed by the applicant/licensee, both during the project implementation (Fig. 4.4, phase. C) and the operating phase (Fig. 4.4, phase. G).

As result the basic stochastic effects generated by the "licensing risk" consist on project delays, project or document modification, project rework and unexpected regulatory constrains as discussed in detail in the following sub-paragraphs.

[i] Some activities performed by the RB may be not cyclical especially when serious safety problems are detected. The nuclear laws prescribe that the RB has the power to issue a decision and impose enforcing actions at any time during the licensing process and the operating phase of the nuclear facility. As result the RB decision-making activities are not performed only on the planned decisional points but can be issued at any time. Fig.4.4. shows a simplified framework under the assumption that the licensing decisions are issued only at the planned stages.

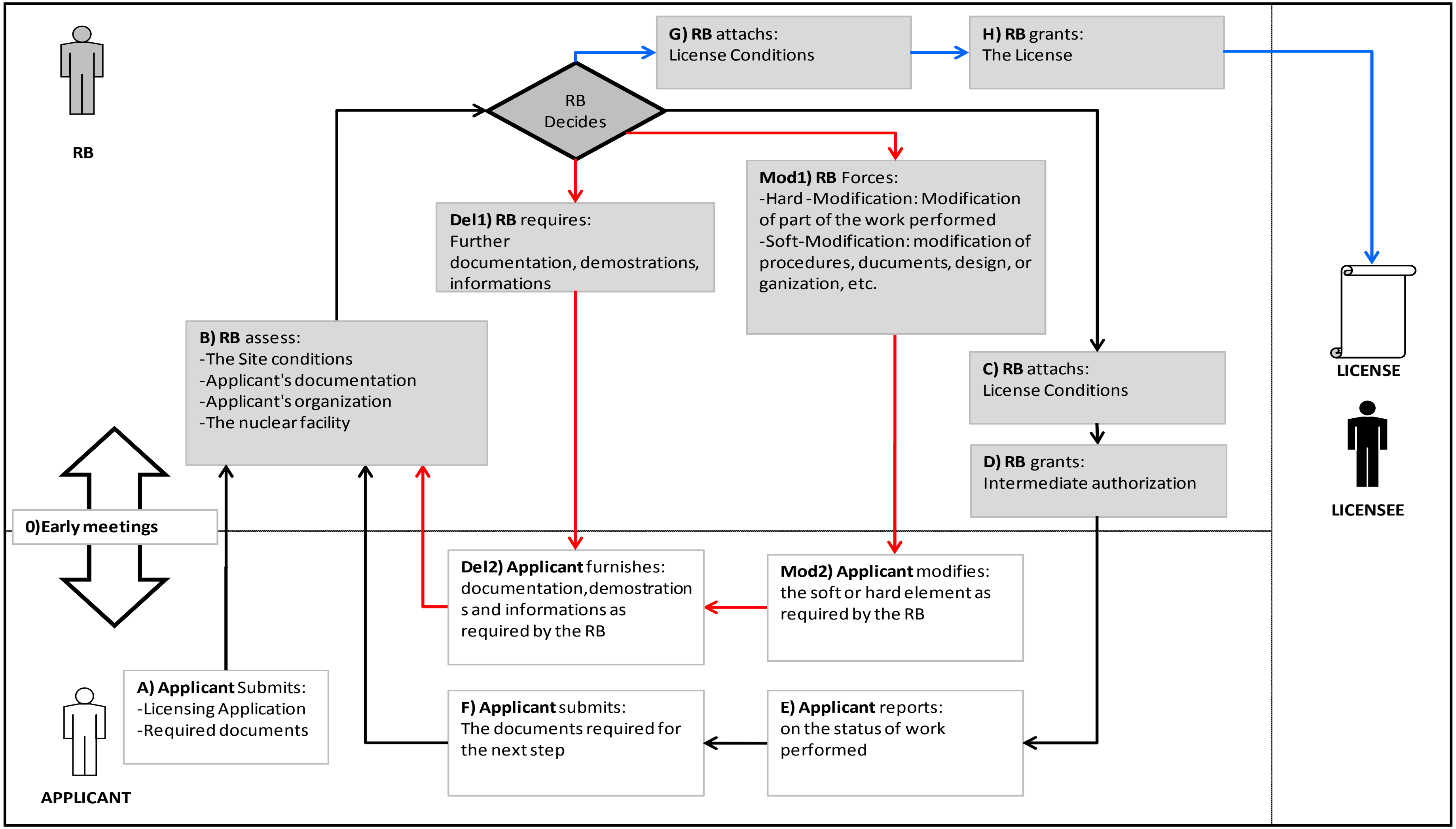

Fig. 4.4: The Simplified licensing paradigm

4.2.4.1. Project delays generated by the licensing process

The licensing delays can be generated trough three main mechanisms as described by the Table 4.14.

Delay mechanisms	Responsible Actors	WHY
1)The licensing assessment or decision-making activities takes more time than expected	1A) RB/Government	The RB resources and/or personnel is not sufficient to undertake the whole set of regulatory activities
	1B) RB/Government	The experience maturated within the regulatory institution is not sufficient to assure a fast licensing decision-making and assessment
	1C) Applicant	The documents, submitted by the applicant, doesn't respect the format usually adopted by RB
2)The RB requires further information and demonstration to undertake the licensing decision-making	2A) Applicant	The content of documents submitted is not clear or doesn't contain sufficient information to demonstrate the compliance with requirements and safety principles
	2B) RB	The RB personnel are not experienced with advanced assessing/demonstrating methodologies
3)The Applicant submits the licensing documents beyond the original schedule	3A) Applicant	The reason beyond the submission delays can be caused by a broad range of reasons; e.g. project delays, low experience of contractors, weak project organization and parties litigation, optimistic estimates, etc.

Table 4.14: Principal licensing delays mechanisms

The mechanism "1A" can be generated in the following scenarios:

- The government, of the country who embarks a new nuclear programme, doesn't assign the sufficient resources, required by the RB, to undertake its regulatory duties.

  This scenario might take place both for experienced countries, with respect the nuclear programme, and for inexperienced ones.

  In the first case the RB already exist and performs the periodic activities concerning the issuance of new regulation, the surveillance of the operating installations status, safety reviews, etc.

  Especially in the era of "nuclear renaissance", a country who decides to re-embark a nuclear programme shall take into account the destination of new resources to regulatory organization because of the extra-work required to it.

  On the other hand, the inexperienced countries may develop the regulatory organization for the first time under the "grating approach" (§3.), and this may conflict with the need of a prompt and experienced RB, ready to issue the firsts license issuances.
- The exhalation of new legal or regulatory requirements let grow the resource required to assess and control its compliance.
- The RB receives more applications than supportable considering its available resources.

Especially in the "nuclear reinassence era", under the "combined licensing approach" (ref licensing steps) the several issuances[135] for deign certification may cause a peak of regulatory resources required.

The mechanism "1B" is typical for those countries that embark the nuclear programme for the first time.

To prevent the mechanism "1C" the applicant and RB usually make deals about the document format at the early meetings stage.

This fact may complicate the knowledge management activities for those industrial actors that operate on international scale; this because the documented information must be conforms to different standard: one for every country where they operates.

To be effective, the enterprise data base must be organized using a uniform standard; as result the internal applicant's records (ref documental analysis) could be stored using two different standards: first the one required by RB to enhance the licensing efficiency and effectiveness, and second the internal standard to assure the effectiveness of the knowledge management measures adopted by industrial operators.

The mechanism "2A" may not imply licensing delays only if the RB requests the further information well in advance with respect the regulatory holding point.

This may be difficult during the early phases, of the licensing proceeding, because the regulatory assessment is critical with respect the project schedule: a delay of the assessment cause a delay of the entire project.

The mechanism "2 B" is typical for those countries that embark the nuclear programme for the first time because the RB is not enough mature to carry out its function efficiently.

Finally the mechanism "3" may be cause by a broad range of scenarios.

This section aims to consider when the licensing process causes a delay on the project development and not the reverse case; this because this study want to be focused on the effects that the regulatory proceeding has on project risk.

A licensing delay has different typologies of effects on project performances: especially in terms of project lead time and final cost of the project.

The licensing effect on project lead time requires the formal definition of the relations of precedence between both project development and licensing activities.

The delay of the whole project occurs when the delayed regulatory activity is under the critical path of the project, or when the licensing activity, even if is not initially critical, is delayed enough to become critical.

The licensing effects on the economical performances require, further than the previous elements, the detailed definition of project costs (including the discrimination between avoidable cost and not avoidable

[135] This because the different reactor vendors aim to set their reactor technology as standard.

in the case of delay). Furthermore any other differential cost must be considered as well; e.g. incentive clauses[136], project performance bounds[137].

The economic cost of delay is calculated as not avoidable and not productive[138] costs occurring during the delayed period plus any other differential cost.

The licensing effects on financial performances require, further than the previous element, the formal definition of several financial conditions especially in terms of calendar of payments and capital cost.

As result the correct estimation of the licensing effects, in terms of licensing delay, require the precise definition of several parameters both with all project paths; the resulted framework is characterized to be indeterminate.

To consider the general implication of the licensing delay a simulation is issued.

The aim of this simulation is to draft the general consequences of a project delay, in terms of project performances, and to identify the most influencing parameters on those.

First the general project features need to be considered: table 4.16 summarizes the project assumption, in line with the occidental countries.

An important differentiation is made between the market free approach and the Government supported projects (the incentives considered are only in terms of financial conditions).

Note that some of the parameters presented usually depend on the country considered (e.g. the price of the electricity sold); then the licensing effect shall be crafted to the specific national environment both in terms of project features and licensing ones.

On the other hand, the current simulation consider, for instance, the project features uniformly between countries with the aim of underline only the effect of the licensing process on the project performances.

The advantage of this approach is the general identification of the licensing features permitting a comparison between different licensing systems.

Then the simulation can be considered fictitious and shall not be understood as a real estimation of the licensing process effects, rather an instrument to deduce the strength and weakness of different licensing systems.

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[136] The incentive contracts include clauses that act as bonus or penalties depending on project performances. When the project lead time is considered a critical, the project contract may specify bonus and penalties that depends on the final project lead time.

[137] The performance bonds are a typology of contract surety bonds that serve as protection to the owner of the project. If the project performances don't satisfy the ones indicated into the contract, the performance bonds assure the compensation of the performance weakness burden to the Operator by the responsible contractors, until a specified upper limit. These contractual instruments are linked to the contract trough stay into force until the end of the warranty period.

[138] The not productive costs refer to the ones that, in absence of licensing approbation, occur but don't give any contribution to the project development. These are expenses that reduce the efficiency to the project development.

<table>
<tr><td rowspan="10">Construction cost</td><td colspan="3">Leverized overnight cost:[139]</td><td>4000 ($/Mwe)</td></tr>
<tr><td colspan="3">Inflaction during construction</td><td>2%</td></tr>
<tr><td colspan="3">Amorthization period</td><td>20 years</td></tr>
<tr><td colspan="2" rowspan="7">Overnigh cost distribution[140]</td><td>year</td><td>scheduled cost</td></tr>
<tr><td>1</td><td>-256.410.256</td></tr>
<tr><td>2</td><td>-589.743.590</td></tr>
<tr><td>3</td><td>-897.435.897</td></tr>
<tr><td>4</td><td>-1.025.641.026</td></tr>
<tr><td>5</td><td>-846.153.846</td></tr>
<tr><td>6</td><td>-384.615.385</td></tr>
<tr><td rowspan="8">Operating parameters</td><td rowspan="3">Revenues and operating performances</td><td colspan="2">Nominal electrical power</td><td>1000 (Mwe)</td></tr>
<tr><td colspan="2">Capacity factor</td><td>90%</td></tr>
<tr><td colspan="2">Unit price of electricity sold</td><td>80 ($/Mwh)</td></tr>
<tr><td rowspan="3">Operationg costs</td><td colspan="2">O&M</td><td>6 ($/Mwh)</td></tr>
<tr><td colspan="2">Fuel</td><td>4 ($/Mwh)</td></tr>
<tr><td colspan="2">Decommissioning and waste funds</td><td>0,12 ($/Mwh)</td></tr>
<tr><td>Inflaction during operation</td><td colspan="3">it is assumed that the inflation affecting the operating costs is transferred to costumers trough the electricity price sold</td></tr>
<tr><td colspan="3">Facility lifetime[141]</td><td>70 years</td></tr>
<tr><td rowspan="6">Financing and tax</td><td></td><td colspan="2">“Market Free” Scenario</td><td>“Supported” Scenario</td></tr>
<tr><td>kd</td><td colspan="2">8%</td><td>5%</td></tr>
<tr><td>ke</td><td colspan="3">11%</td></tr>
<tr><td>D/(E+D)</td><td colspan="2">50%</td><td>65%</td></tr>
<tr><td>Direct taxes</td><td colspan="3">34%</td></tr>
<tr><td>WACC before taxes</td><td colspan="2">9,5%</td><td>7,1%</td></tr>
</table>

Table 4.15: basic assumption related to the nuclear project

Second, the simulation identifies the potential delay trough four parameters as showed in the Fig. 4.15

The starting point is the budget fore costs scheduled during the construction time.

Then the date of delay start is identified; this is related to the critical regulatory holding points.

[139] Many studies report this value as average of occidental countries, by contrast the facility developed has shown higher costs (REF CHAP2); as result this estimation can be considered a bit optimistic.
An optimistic assumption is requested because the consumptive costs of nuclear projects include licensing influence.
The starting point of the simulation under discussion is a credible budget cost of the project excluding the licensing influence.

[140] The overnight cost distribution has been drafted considering the cash flows presented in the (REF Moodys).
These cash flows have been modified considering the average of the construction time of occidental nuclear project (The reference study is pessimistic and consider a construction time of more than ten years).
Finally the annual cash flows are interpolated polynomially to reconstruct the overnight cost distribution during the entire project development.

[141] The nuclear facilities of III generation are usually certified with a lifetime of 60 years, by contrast the plants already developed have shown the common tendency to increase the original lifetime.

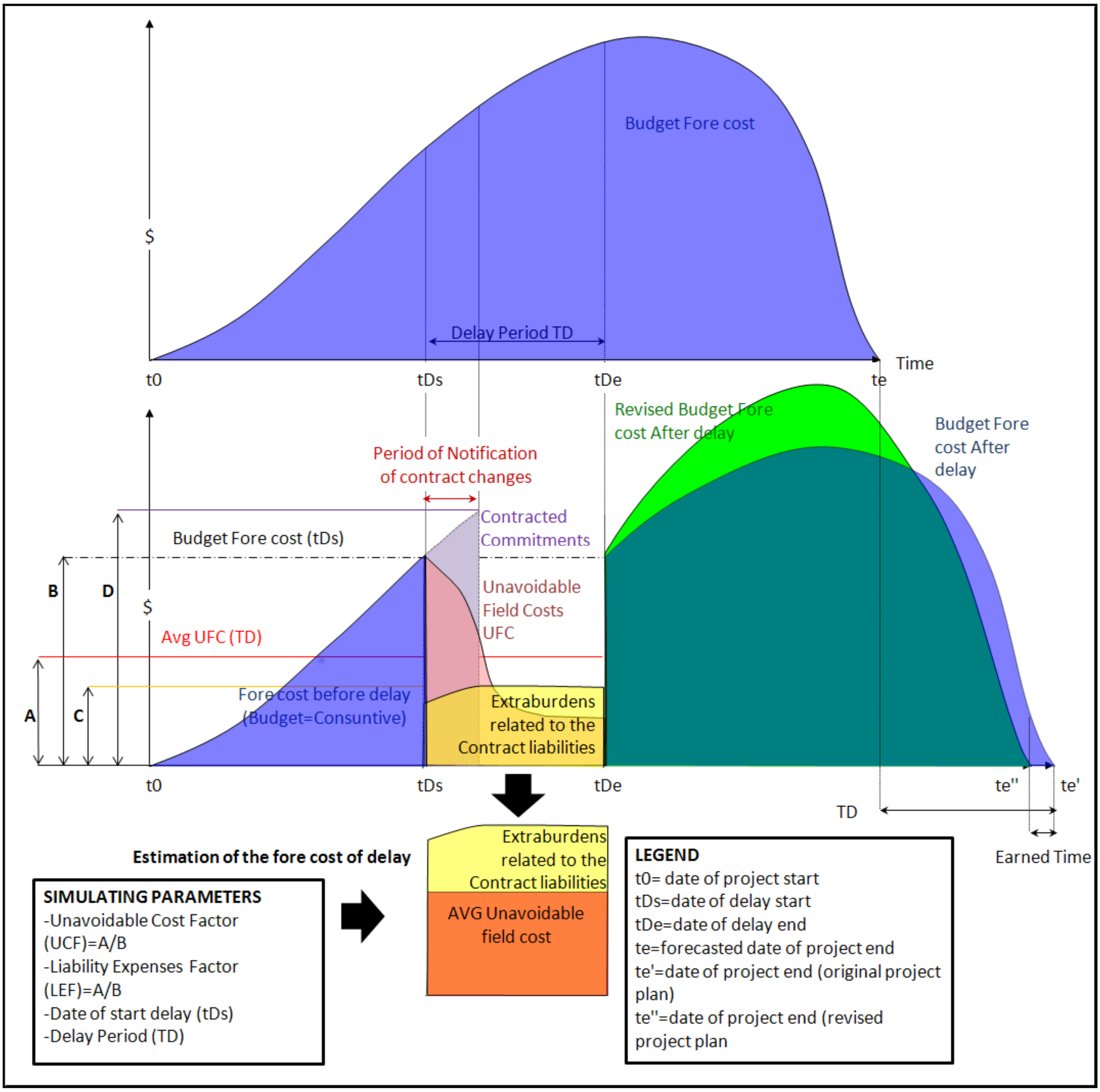

Fig. 4.5: Parameters that exemplify the licensing delay

The regulatory holding points are identified into the licensing procedure and are always critical. Furthermore the delay in issuing the acceptance decision (on specific license applications, e.g. construction, fuel load) inevitably stops the whole project development.

In reality this assumption is pessimistic because some project activities don't require formal approbation for its issuance (e.g. some infrastructural works); by contrast the nuclear facility itself is deeply constrained by regulatory approbations.

As result this assumption can be partially accepted depending on the specific RHP to be considered; for this reason further specification will be addressed in considering each licensing steps.

After the identification of the date of starting delay the duration of this is also necessary.
The duration of delay depends is not known before it takes place; for this reason the simulation consider different values (plausible) of delay period.
Note that this simulation just identifies the potential delays without considering the probability of its occurrence; this is the first step in considering the licensing risk.
On the other hand the probability distribution is not easily determinable because of the scarce availability of the data.

The overnight cost of the project, during delay, mostly depends on the field cost (during the delayed period) and on further commitments concerning the next development of the project.
The field cost can decrease, after a transitory; by contrast there are some typologies of cost that are not avoidable.
Let we define the operative flexibility as the ability to avoid the overnight cost in a given instant on the project development.
This general definition overpasses the detailed definition of the different categories of cost and can be heuristically presented as percentage of the total overnight cost in a given instant.
Of course the flexibility changes during the project development depending on the activities undertaken during the project development.
The activities susceptible to higher level of operative flexibility are the ones related to the development and start up of the facility, having, at the same time, high rate of human work: these are the site preparation, construction, installation, tests, quality assurance and commissioning activities[142].
The costs related to the equipment have also a grade of operative flexibility.
The current simulation considers the unavoidable cost trough a single indicator: "Unavoidable cost factor" that express the average of the not avoidable costs (during the licensing delay) divided by the overnight cost at the instant of the delay start.
This approach leads to consider the unavoidable cost without transitory.
The advantage of this choice is the simplification of the framework; the disadvantage affects primarily the financial performances that require the actualization of the cash flows.

[142] A key concern with respect the flexibility is the contractual relationship with contractors and workforce. In general terms is not correct consider the workforce totally flexible.

On the other hand, the cash flows are actualized on annual basis, then the later disadvantage take place only when the delay is greater than one year (this scenario has low probability of occurrence); as result the assumption made can be considerate acceptable.

The second category of delay cost considered is calculated “extraburdens related to the contract liabilities”.

The contract between the Operator[143] and the main contractor contains special clauses related to the project modification and suspension.

The operator usually has the full power to change the project scope and schedule; on the other hand the contract includes procedures and clauses to related to such scenarios.

Typically these contract changes require a period of notification to the contractor (Clough, et al., 2005).

The same approach usually occurs between the main contractor and the related suppliers and sub-contractors; considering that usually there is no contractual relationship between the sub-contractors/suppliers and the project owner.

Generally such period of notification takes from one to three months.

As result, in the simulation is assumed a further burden proportional to the project commitment, included into the period of notification.

This extra burden is also proportional to a factor called: “Liability Expense Factor LEF” (minor than one), this because during the delayed period no productive activities occur (this is an assumption of the simulation).

This additional cost can be understood as penalty related to the change of project schedule without notification.

Adopting another perspective this cost can be understood as cost of flexibility at the time of delay.

Note that the “extra burdens related to the contract liabilities” continue until the end of the delay (and not just for the notification period), this because is assumed a cost for maintaining ready the various contractors that are waiting for be involved into the project.

This because the duration of the delay is considered totally uncertain, in the eyes of the Owners’ group, and then they need to be ready for the further project development when the application’s acceptance is finally issued by devoted institutions.

This requires implies cost that I have assumed proportional to factor under discussion.

[143] For instance is assumed that the project is developed under a turnkey contract between a main contractor and operator (project owner).

Finally, when the licensing delay terminate, the Owners group may find appropriate to reduce the delay cumulated at expense of the overnight cost.

This tradeoff is not issued into the simulation; then the assumption adopted is that the project continues its development following the original schedule.

This assumption is pessimistic because the project capital cost and financial performances are highly dependent to the construction lead time.

For this reason the result of the simulation shall be understood as conservative especially for the long delays.

The results of the simulation are showed in the annex V; the mitigating actions of delay consequences are discussed at follow.

First, the contractors may consider the possibility to increase the speed of the project development; this choice must be evaluated considering the differential costs.

Form one hand, the increase of speed requires additional labor force or overtime work schedule[144], increasing the cost at the same time.

To the other hand: the financial cost of delay, the contractual incentives/penalty and others avoidable costs can be reduced by the increase of development speed.

Second, the Owners' group parties can increase the project flexibility in correspondence of the critical regulatory holding points.

In presence of a licensing delay, the contractors may find problematic avoid some categories of cost; for example, the labor cost is usually contracted in advance and is not possible to reduce or increase it promptly.

On the other hand, the materials are not consumed during the work stoppage; it is also assumed the absence of its obsolescence (because is assumed that the regulatory delay is not sufficient to reduce the value of the goods).

As result the Contractors need to find the optimal tradeoff between the project exigencies and the licensing risk, considering the constrains affecting this decision (e.g. the minimum lead time for personnel recruitment or the maximum level of personnel flexibility).

Another way to increase the flexibility is the identification of alternative no-critical activities; these works proceed in parallel with the project development and proceed sufficiently slowly to permit

[144] Under the assumption that the labor productivity cannot be easily influenced by the contracting organizations (during the project development).

labor force peaks in correspondence of the RHPs (if a licensing delay occurs). If these additional labor peaks are not sufficient to permit the completion of the alternative activities, sufficient time shall be available to recruits labor force required.
These alternative activities and the delayed ones must be consistent each others, in terms of: knowledge, skill, experience and qualification required; this is particularly difficult in the nuclear field because a big part of the project scope requires special qualifications especially in terms of quality assurance.
With this respect the activities of installation and commissioning are undertaken by highly specialized personnel; the construction and infrastructural work are more easily compatible.

Third the RB can choose the RHP considering the natural project development or to craft it to a specific reactor design technology (this last is especially effective for the nuclear programmes centrally coordinated by government.
The "natural development", of the nuclear project, must be selected in accordance with the reactor size and technology; this emphasizes the need of licensing rethink for the Small modular reactors[145].
Forth, the licensing process can be structured considering more not-critical RHPs; the approach generally consists on the anticipation of these. The delays affecting such RHPs are mitigated by time buffers.
By contrast some critical RHPs are always required like the construction license (or permit), the operating one and the commissioning plan approval (both for the non-nuclear and nuclear tests).
Furthermore the anticipation of some RHPs, and consequently the licensing assessment associated to its, necessitates a vast amount of RB's resources in the early phase. This may conflict with the maximum resource available by the regulatory organization.

Finally the governmental or regulatory institutions may consider the introduction of a sort of "reimbursement" in the case of regulatory delay, only when this is covered by their defined liability. This typology of incentive aims to reduce the regulatory risk and to encourage the nuclear programme development.
The prescriptive definition of the "reimbursement" shall avoid opportunistic behaviors by the Owners' group parties.

[145] Because the large and medium reactor, especially light water reactors, have been traditionally implemented in most nuclearized countries, influencing the structure of the licensing process.

In the project field, the unplanned project conditions are addressed by the contract considering the available information at the moment of the signature. The “unit-price” approach is usually adopted to address the project activities that can’t be planned in advance; like the project modifications or delays. By this contractual approach, the unit price of the activities is fixed in the contract, and the amount of work is determinate during the project development on event-driven basis.

A possible opportunistic behavior consist on the so called “unbalanced- unit prices”[146] that consist on a change of the unit prices in a manner that the planned cost of the project remains unchanged.

If the contractor considers more risky some activities, with respect to the others, could increase their unitary cost (and, at the same time, lowering the unitary prices of the un-risky activities).

Then, when the Operator requests a project modification, or has to reimburse part of the extra cost occurred (due to a branch of contract or a specific liability), he must pay the additional burden derived to the fictitious change of prices.

This measure makes more profitable the activities that are supposed to be over-performed during the project development.

The RHPs can be considered risky milestones and are also known in advance; than are particularly suitable to put in place the described opportunistic behavior[147].

This mechanism can be used to takes advantage of governmental reimbursement if this is calculated trough the unit prices.

Furthermore, the government is not primarily involved into the contract awarding route[148] (under the assumption that the utility is not under governmental control; or under the assumption that the politic directives influence only the general elements of the contract such as: the financing form, the typology of the contract and the technology implied) and then have no, or few, influence of the unit prices settled down into the contract.

As result, it is advisable the introduction of a fixed fee as governmental reimbursement.

[146] The unbalanced unit prices generalize the concept of “unbalanced bids”; this last is an opportunistic behavior that the contractors could put in place against the project owner during the bidding phase of the project. This measure is usually used in the construction field and is considered on the board of legality. In public project, if discovered, it usually invalidates the bid incorporating such measure (Clough, et al., 2005).

[147] For example, considering those licensing phases that require more resources, it is possible to increase the unit cost of the activities susceptible to be affected by the critical RHPs. At the same time, can be reduced the unit prices of the activities that are loosely dependent on licensing process e.g. training activities or infrastructural works.

[148] Under the assumption that the utility is not under governmental control; or under the assumption that the politic directives influence only the general elements of the contract such as: the financing form, typology of contract and reactor technology required.

4.2.4.2. Project rework and modification generated by the licensing process

In this paragraph the modifications considered are only the ones generated trough the licensing process.

A basic classification, of the project modifications, deals with the concept of "soft modification" with the "hard one". As showed in the Table

The first category deals with the modification of documents, procedures and plan ex- ante its development; the second one consist on the modification of part of the physic infrastructure already implemented or organization's feature.

	Typologies of modification	Responsible Actors	WHY
Soft modification	1)Inopportune documentation	1A) Applicant	The documents submitted are not consistent each other's or don't fulfill the mandatory requirements
		1B) Applicant	The plans submitted to the RB gives not sufficient assurance on the fulfillment of the requirements
		1D) RB	New mandatory requirements enter into force, and the documents previously issued are not consistent to this (or the information contained into the documents is not sufficient to demonstrate the compliance with the new requirements)
Hard modification	2)Part of the facility already implemented don't satisfy the mandatory requirements	2A) Applicant	Wrong methods: the quality assurance methods and procedures have not being fully implemented during the project development.
		2B) Applicant	Wrong scope: the facility features don't met the planned specifications or requirements due to a defects of design or to the incorrect project implementation
		2C) RB	The issuance of new mandatory requirements influence the part of the project outcome already implemented
	3)The organizations involved into the project don't satisfy the requirements on capabilities required	3A) Applicant	Insufficient training of the operating personnel
		3B) Applicant	The financial capabilities of the applicant are not sufficient to match the requirements on nuclear liability
		3C) Applicant/ Main contractor/ Suppliers	The construction capabilities of one or more contractors/suppliers are not consistent with the mandatory requirements

Table 4.16 reworking categories induced by the Licensing process

The basic source of a modification (imposed by a licensing decision) is the no compliance with mandatory requirements or RB's expectations; the decision-making approach, adopted into the licensing process, plays a central role.

The prescriptive based approach reduces level of flexibility left to the applicant (in terms of project development and licensing issuance): the licensing criteria are known in advance and a fail, in the fulfillment of some of the requirements, led to a project modification.

Hence, the project modification can be considered soft or hard depending on when the defects are detected by RB, and on the work performed until that instant.

This feature emphasizes the need to anticipate as early as possible the assessment of the critical aspects of the application.

By contrast, the assessment can't be anticipated too much because of the scarceness of the RB's resources and because the impossibility to carry out a safety judgment ex ante the project development.

The modern techniques and methodologies don't permit to give an assurance on safety performances before the effective implementation (and assessment) of the facility and operating organization; with this respect, a substantial rethink is utopian.

The preliminary safety assessments are based on the assumption that: the construction capabilities, experience, programs and quality assurance rules are sufficient to demonstrate the correct development of the facility (in the eyes of the safety objective).

Furthermore, for FOAK project, the previous assumption also include that the modern design and simulating techniques permit to assure the safety performances ex ante the effective development of the of the facility.

These assumptions are weak considering the real cases, especially because the nuclear project is a complex infrastructure and because the human behaviors introduce a vast uncertainty.

As result the licensing process need to incorporate the assessment of the work performed and to issue a judgment on it, this is the root of the hard modifications.

The soft modifications are mostly generated in accordance with philosophy of the preliminary safety assessments.

Another differentiation between the early assessments and the later ones is the approach by which these are conducted.

The early assessments are mostly conduced trough a top down approach in accordance with the legal and regulatory framework structure.

On the other hand the later assessments are conduced trough a bottom up approach: first the various measures and performance indicators are assessed, then formalized, using the licensing forms and methodologies, and finally integrated to the whole application.

This differentiation has twofold: first the licensing consistency is assured during the project proceeding and second the more specific constrains are assessed only during and after the project development.

As result the more specific safety lack are detected only during the development of the project raising the risk hard modification.

This risk is especially high in the prescriptive based approach because the mandatory requirements are vast and detailed.

On the other hand the performance based approach enables a higher flexibility and the decision-making activity is affected by the RB discretion.

From one hand the licensing environment is more unpredictable (but this uncertainty can be reduced trough not mandatory requirements exemplifying a possible safety demonstration), to the other one the project defects can be more easily compensated (because the RB can approve a mitigating action that permits to avoid the project rework).

As result, if sufficient information and experience is available, by the contractors, on the specific licensing framework, the performance based approach might be more suitable (with respect the risk of hard modification) than a prescriptive based one.

Likewise the previous paragraph, a simulation is issued with the aim of estimating the cost of rework in different scenarios.

The simulation of the rework scenarios require the definition of: the economical and financial features of the project, the instant when the modification is issued, the level of parallelization of the modifying activities with respect the original path, the duration and cost of these, the euristic curve describing reworking activities.

First, the economical and financial project's features are the same introduced in the previous paragraph (see Table 4.16).

Second, the project modifications can start any time during the project development; this because is assumed a close cooperation between the RB and the applicant during the licensing proceeding, in line with the recommendations made by the IAEA (IAEA, 2010).

This behavior permits the promptly communication of the defects detected by RB; by contrast the formalization and the formal request of project modification requires an amount of time.

This period can be considered inversely proportional to the level of collaboration, between licensing parties, and to the effectiveness of the RB organization (that depends on the cumulated experience, the assessment methodologies and techniques, the capabilities and resource available during the specific assessment).

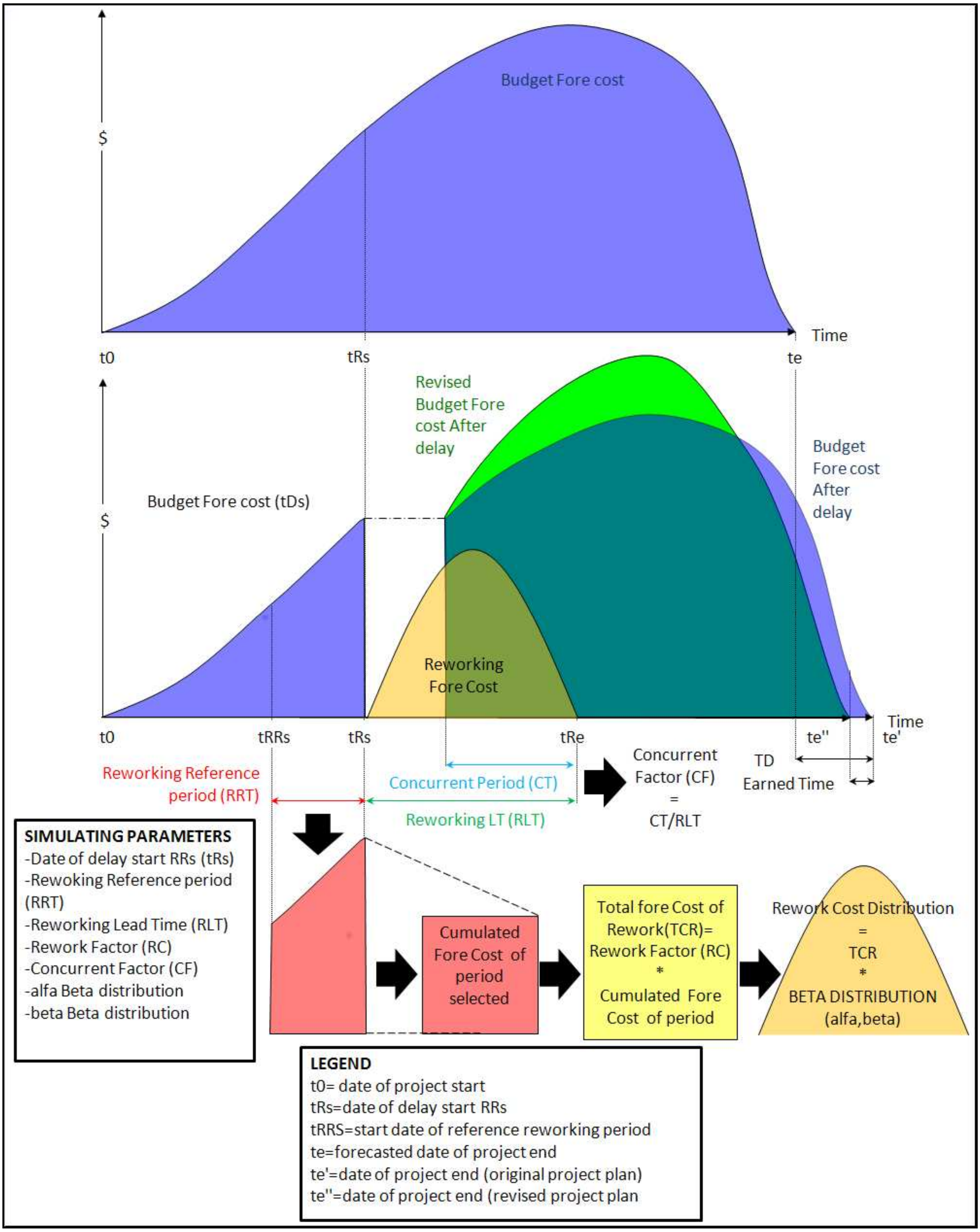

Fig. 4.6 Determination of the overnight cost of rework

In the simulation presented in this paragraph is assumed that when a defect is detected by RB, the applicant is instantly informed on that. This simplified assumption is optimistic, more realistic assumptions are considered in the simulation presented in the paragraph XX.

Third, the level of parallelization, between the modifying activities and the planned ones, mostly depends on: the severity of the modifications, the interdependence between the modified package and the planned ones, the moment of when the activities are performed.

The simulation under discussion considers different levels of parallelization: from the total parallelization (that implies that the project is finished without delay) to the absence of it (the modifying activity is totally performed under the critical path of the project).

Forth, the duration of the modifying activities are proportional to the dimension of work to be performed, and indirectly proportional to the productivity levels and the resources assigned for its development.

The simulation, under discussion, calculates such period as percentage of the planned lead time of the activities performed and dedicated to the scope of modification[149].

This percentage incorporates both the total level of productivity and the lead time required to undertake all additional activities connected to the modification (e.g. the demolishing activities).

Fifth, the direct cost of modifying activities is proportional to the resources assigned to its and to the amount of work to be performed.

The direct cost is calculated as percentage of the overnight cost of the activities, previously dedicated, to the scope of modification.

This parameter incorporates also the direct cost of the additional activities connected to the modification.

The financial cost of the modification is incorporated in the total cost of the project (that is one of the performance indicator considered).

Sixth, the modifying packages depend on the typology of modifications (soft and hard modification), the completeness and the scheduling of licensing assessments, the instants by which the defects are detected and then communicated to the applicant.

The simulation selects the rework packages trough a parameter indicating the modifying period[150].

Considering the date of commencement, of the modifying activities, and a the reference period; the work package is identified percurring backward the cumulative curve of the overnight cost.

[149] E.g. if the modifying activity consists on the rework of a part of the facility, the reworking period is calculated as percentage of the original lead time of the constructing activities dedicated to that facility part.

[150] The modifying activity consist on the

4.2.4.3. Additional regulatory constrains generated within the licensing process

These further constrains are not considered as path diversion because the generation of these is planned and sometimes required by the licensing process (especially the performance based approach ref emphasizes the generation of these trough license conditions).

Indeed the license conditions are fully expected, its' content is not known in advance and it may impact on every aspect of the nuclear project (e.g. administrative aspects, technical ones, etc.).

To reduce the uncertainty generated by the license conditions the RB usually formulates detailed guidelines and furnishes examples of nuclear project previously licensed; furthermore a collaborative relation, between the applicant and RB, is required to estimate in advance the regulatory constrains that will be generated during the proceeding.

On the other hand, the delays, project modification and rework (induced by the licensing process) can be simulated considering a specific project and licensing process. This methodology can help both the RB and Operator to identify the most critical phases and to put in place measure to reduce the licensing risk.

Furthermore this methodology can be used to compare different licensing system in relation to a specific nuclear project: this problem is typical for the nuclear industry (main contractors, reactor vendors and suppliers) which operate on international market but have to face local regulatory environments.

The estimation of regulatory risk using simulation is difficult to issue for two main reasons: first are needed a vast amount of information and data that may be not available; second it's difficult to consider heterogeneous and qualitative information.

As result the most effective approach, in considering the licensing risk, consist on the integration of quantitative simulation with the qualitative methodologies.

As result the next subparagraphs tries to integrate these two methodologies considering the elements that compose the risk: from one hand the severity of consequences that the licensing process may have on project performances; to the other one the probability of occurrence of licensing path diversions.

4.3. Case Study: comparison of international practices

This paragraph introduce a simplified comparison between national practices adopting the framework previously described.

The countries considered are Finlad, France, Italy, South Korea, United Kindgdom and United States of America.

FINLAND	[**1)Law framework**: "prescriptive based": the law establish the general principles and the detailed provisions are establish in the standards and guidelines (YVL)];[**2)Main actors**: system of multiple checks: the main decisions on grant or not the licenses are left to: the government, the parliament and the RB (STUK) for the technical aspect related to the safety];[**3,E)Steps and related time:** two main steps: Construction License (it takes 2-3 years) and the operating one (issued in parallel with the construction)];[**4)Public**: the public hearing are anticipated before the decision-in-principle (only for the stakeholders in the vicinity of the site); the tools to disseminate information are: internet sites, television teletext, the telefax bulletin, television, newspaper];[**5)Nuclear program**: the nuclear program leadership is shared between the government, who operate as energy planner and the utilities];[**A)Country's barriers**: language, cost of workers, detailed and prescriptive rules][**B,C,D,F)Total Risk**: the rules are really prescriptive, and even the subcontractors are checked and inspected by STUK]
UK	[**1)Law framework**: "performance based"; most licensing are settle down by not- mandatory guidelines; important regulating tools are the license conditions that have force of the law];[**2)Main actors** the RB (HSE-NII) has many discretionary powers in granting the license, the government is involved just for the siting policies];[**3,E)Steps and related time:** generic design assessment (Gda, it takes 3 years) promote the design standardization and Site License (it takes 1 year)];[**4)Public**: during the GDA the applicant publishes the safety documents submitted to the RB and answer to the main questions arisen by its internet site. During the Site License, the Secretary of state[151] is empowered to carrying to the public Inquiries.]; [**5)Nuclear program**: the nuclear program leadership is mostly left to the Utilities];[**A) Country's barriers**: the facilities design already approved take really less time for the next licensing process]; [**B,C,D,F)Total Risk**: high risk due to the discretionary powers left to the RB; the licensing system lack of clearness and predictability even due to the extensive use of the license conditions as part of the regulatory framework];
FRANCE	[**1)Law framework**: "prescriptive based ", and fragmented in many fonts];[**2)Main actors**: admistrative framework fragmented; most of the licensing decision are issued by the system of "double check": the RB (NSA) gives its option (on the technical matters) and the government make the decision];[**3,E)Steps and related time:** construction permit an the operating one.(the law set up the licensing lead time of 3 years but there are some example where the period was longer like 4 years)];[**4)Public**: the public inquiry (within 5 Km) is coordinated by the prefect. The Information is controlled by a chain: the RB (NSA) communicates with the local information committees and the Prefect (who coordinate the information provided to the medias). The "High committee for transparency" monitors the level of inf. transparency nevertheless the defence related activities reduce it];[**5)Nuclear program**: the Nuclear program leadership is led by the government. A key feature of the program is the high standardization of reactor design to achieve the economies of scale and learning];[**A) Country's barriers**: the nuclear defence policy; long collaboration tradition of the main actors involved (all owned by the state), reactor standardization];[**B,C,D,F)Total Risk**: the main risks derive to the framework complexity, however it's is perceived low from the main French actors due to its long experience of the system and to their long term partnership strategy]
KOREA	[**1)Law framework**: general law framework, the detailing is issued by regulation, but the institution has a high degree of power flexibility. The regulatory framework results "prescriptive based" due to the detailed technical standards. The fonts are really decentralized];[**2)Main actors:** really concentred administrative framework; the Minister of Science and technology has the power to grant the license and control the inspector department. Other monitoring activities are carried out by the RB (KINS),and expert body that usually assist the Minister in the licensing decisions];[**3,E)Steps and related time:** construction license and operating one; emphasis on the anticipation of civil and preparatory works that are undertaken in parallel with the licensing process];[**4)Public**: Few provisions are made about this matter];[**5)Nuclear program**: The Nuclear program is led by the government ;emphasis on design standardization];[**A) Country's barriers**: nuclear program emphasis on national participation for economic development purposes, standardization of reactor design, language , prescriptive standards];[**B,C,D,F)Total Risk**: Low, due to the fact that the nuclear policy really strong and is strictly under governmental control, and there is an intense collaboration between the main licensing actors]
ITALY	[**1)Law framework**: "prescriptive based" approach, the administrative procedures are really detailed and fixed by law (no regulations are available yet). The law fonts are really concentrated];[**2)Main actors**: The main powers during licensing process are shared between three different ministers (Minister for economic development, Minister for the environment , Minister for infrastructure and transport). The RB (Agency for the nuclear safety) gives it's option on the technical matters related to the safety];[**3,E)Steps and related time:** the main steps are: Site certification (1 year) and design license (2,5 years); this time forecast is present in the legislation (maybe optimistic)];[**4)Public**: the information is disseminate by: media and internet sites ; the transparency is assured by the "Information and transparency committee", present in every nuclear region, must answer to the question arisen from the public]; [**5)Nuclear program**: the government has a main role in the nuclear program leadership: directly (constructing the nuclear infrastructure) and indirectly (it possess the main share of ENEL)];[**A) Country's barriers**: Low, firstly the international agreements established (the most important: ENEL-EDF)];[**B,C,D,F)Total Risk**: involvement of the regional and local authorities into the licensing process, public acceptance, need for rebuilt the nuclear capabilities (especially to set up the RB), political instability]
USA	[**1)Law framework**: vast and complex: a balanced synthesis of the prescriptive and performance based approaches. the prescriptive details are left to the regulations or the standards. the framework is really is revised on periodic basis];[**2)Main actors**: The RB (NRC) is the main institutional actor involved into the licensing decisions];[**3,E)Steps and related time:** Exist two licensing system: the traditional one (10 CFR 50) is divided into two licenses: one for constructing and one for operating ;in the newest (10 CFR 52) the steps are: Early site permit, Design certification and the combined license (for both the construction/operation).];[**4)Public**: Most of the documentation is made available by NRC by internet[152] and the public can assist to the safety meetings between the applicant and the NRC. the mandatory public-hearings are collocated in the early phases of the licensing process.];[**5)Nuclear program**: The leadership is left to the different utilities under the logic of the market freedom];[**A) Country's barriers**: strong nuclear industry , governmental incentives];[**B,C,D,F)Total Risk**: public incontinence, judicial reviews, Antitrust decision. the mitigation actions are: emphasis in the preliminary meetings , the rule: "what is approved in the early steps can't be modified in the latter ones]

Table 4.17: Licensing frameworks applied to the countries under study

[151] Or the Scottish Minister for development, in Scotland

[152] Removing the commercial and security sensitive information

	FRANCE	ITALY	KOREA	UK	USA	
	[**1**) prescriptive based];[**3,E**) construction/operation]	[**2**) strong government role]	[**1**) detailed regulation and guideline];[**3,E**) construction/operation]	[**4**) both high];[**5**) market openness];[**A**) low]**;[B,C,D,F**) high for both countries]	[**1**) detailed standards and guides];[**3,E**) for the traditional USA's licensing approach];[**4**) both high;[**5**) market openness, low standardization];[**B,C,D,F**) both high]	FINLAN D
FRANCE	[**1**) law detailment];[**2**) level of centralization, RB role & Gov. Role];[**4**)]; [A)];[**B,C,D,F**)]	[**1**) prescriptive law];[**2**) system of double checks];[**4**) similar administrative framework]	[**2**) strong government involvement];[**3,E**) construction/operation];[**4**) low];[**5**) strong government role, standardization];[**A**) high];[**B,C,D,F**) low]	[**5**) fuel fabrication, waste reprocessing and military activities (indeed with different extent)]	[**3,E**) just for the old USA's system];[**5**) historical military development]	FRANCE
ITALY	[**1**) law detailment];[**2**) level of centralization, RB powers];[**3,E**) in Italy there is an unified license for both constructing and operating, in Finland this two aspects are covered by two different license)];[**4**) In Finland there is an higher public involvement;[**5**)];[**A**)];[**B,C,D,F**) different kind of]	[**1**) centralization of law];[**2**) centralization/fragmentation of responsibilities];[**3,E**) different approach];[**5**)strongeness of the government, defense related policy, emphasis on standardization];[**A**) the French system is closer];[**B,C,D,F**) really different with respect the experience and stability]	[**2**) level of centralization]	[**2**) centralization];[**3,E**) just for the site license];[**B,C,D,F**) high]	[**A**) low]	ITALY
KOREA	[**1**) Koran law is decentralized];[**2**) stronger role of the Korean government];[**3,E**) lead time, anticipation and parallelization of preparatory works];[**4**) different emphasis];[**5**) different strategy and leadership];[**A**) really different];[**B,C,D,F**)]	[**1**) the Korean law is less detailed];[**2**) centralization/fragmentation of responsibilities]	[**1**)];[**3,E**) different kind of, lead time and level of parallelization];[**4**)];[**B,C,D,F**) really different]	[**1**) law detailment];[**2**) centralization]	[**3,E**) just for the old USA's system]	KOREA
UK	[**1**) really different systems, level of detailment, legal tools used];[**2**) RB role, Gov. involvement];[**3,E**) different sequence construction/operation VS design/site];[**B,C,D,F**) different kind of: low predictability VS detailed provisions]	[**1**)];[**2**) UK centralized, France decentralized];[**3,E**) different sequence construction/operation VS design/site];[**4**)];[**5**) leadership role, extent of standardization];[**A**) really different];[**B,C,D,F**) different level and type]	[**1**)];[**2**) RB and Gov.role];[**3,E**)];[**4**)];[**5**) leadership role];[**B,C,D,F**) different kind of]	[**1**) regulation detailment];[**3,E**)]; [**4**)];[**5**) really different];[**A**) really different];[**B,C,D,F**) really different]	[**1**) Anglo-Saxon-system];[**2**) strong RB role and independence];[**3,E**) license for site and design; the operator has more options in choosing the licensing steps]; [**5**) market freedom leadership role];[**A**) low];[**B,C,D,F**) high]	UK
USA	[**1**) really different legal traditions];[**2**) RB role, Gov. involvement];[**3,E**) different for the newest USA's licensing approach];[**B,C,D,F**) different kind of];[**A**) different kind of]	[**1**) law detailment];[**2**) RB and government role];[**3,E**)just for the newest USA's system];[**4**): really different];[**5**) leadership role, extent of standardization]; [**A**) really different];[**B,C,D,F**)]	[**1**)];[**2**) RB and Gov.role];[**3,E**)];[**4**)];[**5**) government involvement]	[**1**)];[**2**) RB and Gov. role];[**3,E**)];[**4**) really different];[**5**) extent of reactor standardization, leadership role];[**A**) really different];[**B,C,D,F**) really different]	[**1**) Uk's system is more "performance based" oriented];[**3,E**) for the old USA's system];[**4**) higher transparency in USA]	
	FINLAND	**FRANCE**	**ITALY**	**KOREA**	**UK**	

LEGEND	**1)Law framework**	**3,E)Licensing steps**	**5) Nuclear program**	**B,C,D,F) Total Risk**	**DIFFERENCES**
	2)Licensing actors	**4)Public information & involvement**	**A) County's barrier**		**SIMILARITIES**

Table 4.16: Comparison between national practices

5. Conclusions

This thesis work is based on four research questions:

R1- *Which are the main factors affecting the licensing processes worldwide*?

R2-*How can be compared different licensing processes*?

R3- *How to consider the Project management performances in relation to the licensing process*?

R4- *Which measures can be adopted to reduce the regulatory risk*?

The answers to these specific questions are discussed ate follow.

R1- *Which are the main factors affecting the licensing processes worldwide*?

The licensing processes, worldwide, are characterized to have some elements in common and some others completely different.

First the concept of safety and the basic rules governing the licensing process are uniform between countries, especially after the Convention of Nuclear Safety I (REF).

Furthermore some specific regulatory areas are also in common between countries, e.g. nuclear liability regime, safeguards measures, emergency preparedness, etc. (all these specific subjects are covered by international agreements and treaties).

Second, the administrative procedures, the institutional framework, the duration of the proceeding, the cost recovery system, the public involvement measures and the safety criteria are the elements that mostly differentiate the licensing processes worldwide(RFI Licening Process).

Further than the specific licensing approach, the nuclear programme approach, strategy and the nuclear infrastructure (both tangible and intangible) play a central role in differentiating the licensing systems.

In general terms, the nuclear programme is characterized to be: “market-free approach”, “Government leadership” or a mix of the previous (REF).

Finally the reactor design technology to be reproduced within the nuclear project may affect deeply the licensing proceeding, especially in terms of deterministic safety criteria (ref) and schedule (ref steps).

Considering the “market-free approach” the safety criteria need to be open and available for different typologies of reactor and then the “risk-informed” (REF) safety approach result the more common.

On the other hand, when the nuclear programme is highly integrated (“Governement leadership”) the reactor design technology to be developed is mostly the same[153] (or at least the same model available in different sizes); in this cases the licensing assessment and decision-making is mostly based on the deterministic approach, even because is more efficient (ref).

Table XX at page XX syntethize the licensing approaches, considering, at the same time, the potential effects that these have on licensing objective (considering both the public and the private perspective) (Ref).

R2-*How can be compared different licensing processes*?

[153] To Take advantage of the “Economies of replication” REF,.

The Licensing process can be understood in different manners: as burocratical proceeding, as documental path, as institutional and technical review, as regulatory risk source and as projects.

Furthermore, as introduced in the previous answer, the licensing process can be differentiated considering different drivers.

The same drivers can be used to compare different licensing system on multi-attribute basis; by contrast, the simple identification of these drivers (that in this thesis work are defined as "licensing parameters" ref) is not sufficient to compare the processs.

What's' further required it's a perspective in considering the different attributes.

This thesis work focus the comparison between different licensing process on project management performances (ref effect on nuclear project performances) and a real example of international comparison is also issued as case study (REF comparison).

To be more complete, the achievement of the private objectives (category that includes the project management performances) needs to be compared with the fulfillment of the public ones, especially in terms of regulatory control, nuclear safety and security and public transparency and involvement.

The model introduced at (ref table) permits to draft quickly the tradeoff between the public and private exigencies on qualitative and multi-attribute basis.

R3- ***How to consider the Project management performances in relation to the licensing process*****?**

The project management performances can be simulated coherently with the licensing proceeding to be evaluated.

Section XX introduces a general simulation that serves to indentify the general variables to consider by both the Regulatory body and operator.

This last analyze only the critical licensing delay and the soft and hard rework (ref).

To be more complete the regulatory constrains also need to be considered.

With respect to the deterministic effect of licensing process (ref) (e.g. licensing fees) the effect on project performances is relatively low (this is true only considering the large project).

The main effects on project performances are determinate by the vast uncertainty and potential negative consequences on project performances, that give raise the regulatory risk.

This risk has deep influence on technology competiveness especially in financial terms (ref chap 2).

For this reason is essential to increase the level of confidentiality with respect the licensing processes.

This thesis work is mostly based on the estimation of the severity of consequences of the project path diversion generated within the licensing process.

The probability side of risk is not deeply analyzed even due to the lack of data and on the complexity of factors affecting such probability distribution.

A further complication is that the acceptance at the various stages have some degree of correlation due to the depth assessment of the same scope (the for example exist conditional probabilities of find an application lack between the various steps considering the various aspect concerning the application).
Due to the complexity of the problem Table XX try to indicate the main source of risk considering only the licensing system.
A more precise evaluation need an expert judgment that associate the probability of fail one or more licensing steps considering the specific license application, reactor design technology, Implementing organization, etc.

R4- *Which measures can be adopted to reduce the regulatory risk*?

To reduce the regulatory risk can be adopted various measures both considering the institutional perspective and the private one.
From the institutional side are proposed the following measures:

- Identify the key performance indicators concerning the project development in a way to consider this during the regulatory activities; in this way is possible balancing these with traditional indicator concerning nuclear safety (Note that some parameters may be synergic and then may increase the effectiveness of the licensing process).
- Put in place measure to increase the confidence on licensing proceeding: for example assign to the Owners' group a team of professions specialized in the licensing process in a way that it can help it (this team need to be considered a supporting staff function rather than inspector). Most RB has available a consultation service for applicants but this is usually expensive and require a period of time for the prenotation. Include, into the licensing fee, a dedicated tem may increase the direct collaboration between the regulatory institution and the Owners' group.
- Introduce several sub steps that gradually assess a portion of the total applications' scope. These sub steps need to be not- critical (in a way that not increase the risk of delay) and shall guarantee to the applicant that when a specific sub-steps is achieved this part is accepted on final RHP.

  Adoption these sub steps, is possible to reduce drastically the risk of rework because the control of the project development is really stringent.

  Furthermore is assumed that the Owner is inactivated to anticipate the sub-assessment in a way that a potential delay and soft rework can be easility recuperated without serious consequences. By contrast is the sub step fail to be approved, the defect is detected in advance and the rework cost is lower that in the original case.

  This measure shall change the perspective usually adopted by Owners' group enhancing a deeper collaboration between these. : And the sub steps can be understood opportunities (to reduce the regulatory risk on rolling wave basis) rather than treats.

-Anticipate as soon as possible all possible source of uncertainty, e.g. public inquiries, institutional decision and assign all responsibilities to the RB.

In this case the public acceptance is enhanced, in parallel with the regulatory control and the licensing risk.

The excessive involvement of politic actors shall be reduced or anticipated as soon as possible because may represent a great source of risk, especially in terms of delays when the institutional passages are several and crossed.

-Consider the existing reactor technologies including the further development and craft the regulatory process on the long term development strategy.

This point is especially critical for Small-Modular reactor: the modern licensing processes are characterized to be long and complex, traditionally crafted for large LWRs.

By contrast the IV generation of nuclear reactors is characterized to introduce novel physics process and totally different sizes.

As result the licensing process may be a problematic bottleneck which deteriorates the potential benefits of small and modular reactors.

Furthermore the deterministic and probabilistic safety assessments are now mostly based on LWR technology.

Some modular reactors have demonstrated higher level of simplicity and safe, by contrast the regulatory an process may be extremely delayed due to the absence of experience and standards on novel and innovative technologies.

For this reason is necessary to select the preferred technology well in advance with respect the application submission.

The measures to put in place, from the Owner group parties, are argued at follow:

- Increase the level of operative flexibility in concomitance with the critical regulatory holding points.

  This can be partially achieved having part of facility scope not constrained by the regulatory decision.

  An alternative could be to leave some infrastructural works unfinished in a way that if a delay takes places, the workforce can be shifted easily.

-Make contractual arrangements to reduce or avoid the period of contract notification (ref) in proximitation of the programmed RHP. This clause can be negotiated during the contract awarding route and serve as protection from the licensing risk.

- In the case of the First of a kind is necessary to don't have harry up and to proceed smoothly and carefully and expenses of time.

This is particularly important because the certification of a reactor improve the design competiveness for the further development.

Some contractors have shown the excessive harry up that lead the main contractor to start the licensing process before the final development of the engineering phase.

This choice is epceially risky

The licensing process is characterized to be crafted to the specific nuclear programme, infrastructure and approach adopted into countries.
The first factors to consider are then the legal and administrative tradition of the specific country to be

First the licensing process rules and procedures are originally drafted by Government at the time of nuclear programme lunch. As result the division of duties, between institutions, and the licensing procedure is usually related to the national administrative tradition.
On the other hand, some norms governing the licensing process may be imported from abroad to rend more fast and effective the development of the nuclear legal infrastructure.
A key concern, under the government decision, is the discrimination between the unfied str