HL-LHC Project

Evolution of risk assessment
Key concepts and qualitative results

Isabel Bejar Alonso - CERN
HL-LHC Configuration, Quality Risk, & Resources Officer

EDMS 2255174

Frame

- Risk is the effect of uncertainty on the achievement of objectives.
- Taking risks is inherent to all activities and a necessity.
- All members of the HL-LHC Project already take into account the risks in their daily activities and is our duty to demonstrate that they are addressed in a **systematic** and **transparent way**.

What has been done for HL-LHC

Methodology used

- Since 2017 we have used the methodology created in 2012 for CERN
- This methodology was implemented with the support of Deloitte to implement at CERN a Risk management system adapted to our “Special nature”.
- From the more than 50 known methodologies was selected the “Risk intelligence map” with Brainstorming sessions

Steps

- The top management fills the map with risks they think exist for the different categories
- Then they asses the impact and the vulnerability following a pre-agreed matrix
- The results are then fine tuned
- The top risks are then identified and action plans are established
- The risks and the actions are re-evaluated every year

In HL-LHC the same exercise is repeated within the WPs

Risks and Risks

Risk is very subjective. Whatever methodology we use will be subject to the “willingness” to take risks and to the subjective appreciation of the impact of the identified risks

Moving from qualitative to quantitative

The difficulty of quantifying risks

Literature is very rich on risks quantification methodologies. A lot of them address one objective (insurance, liability, contingency definition, ….).

Some of them are based on a list of foreseen adverse events, other in general risk topologies

The difficulty of quantifying risks

Those based on a foreseen adverse events:

- Miss unpredictable events that are beyond what is normally expected
- Tend to minimize the “accumulative” risks
- Concentrate on known “feared” risks more than on known “under control” risks

Those based in general risk topologies

- Miss worst case adverse events
- Do not consider liabilities beyond the intrinsic value
- Do not consider “snow ball” effects

First approach to quantifying risks

- HL-LHC is a project without contingency and as so risk management has been always considered as a tool to increase resilience and to anticipate and minimize the effect of adverse events.
- First approach: to use our present Risk register based on the risk map to obtain a “topological risk”
- In a later stage for each risk with an action to explore its fault tree and quantify if its consequences are covered by the general exercise or if an addition “over cost” has to be considered.

IxV	Risk ID	Risk	Description	Actions	Comments
16	5	Delivery	Several WP3 magnets are delivered as in kind contribution or through collaboration agreements, for a total of **6** collaborations, 3 from member states and **3** from non-member states. Little leverage is available in case of delay. The same is applicable for our own deliverables	**2017** Today there is consolidated schedule managed by the WPL that is updated every three months with the input received by the collaborations and the internal suppliers. The vulnerability is 4 as there is little leverage in case of a delay in one of the collaborations and on our own internal supplies but CERN has always been proactive to anticipate issues and minimize impact on the global schedule. In some cases, CERN already took over specific tasks to reduce the delays and minimize impact on global schedule. **2018** The following action will be implemented from 2019: - Global review of the schedule to anticipate possible bottlenecks. (to eliminate “artificial” bottlenecks)	- The action set in 2017 was effective and continues giving good results. -The Spanish collaboration has some delay but the impact on the deliveries is being reduced by anticipating the call of tenders. -Active discussion with the collaborations to find solutions (e.g. possibility to build the long magnet prototype in CIEMAT…)
12	14	Production	Wrong production speed. Bankruptcy of the company that was awarded the contract. Risk of components that are late and delay the full integration of the cryoassembly.	**2017** We anticipated the orders relative to several components. The most critical ones (Nb3Sn strand) are already completed, even though production is still ongoing and we will be vulnerable until the delivery of the last strand. **2018** The following action will be implemented from 2019:	- The action set in 2017 was effective and continues giving good results. - Most of the components are already ordered and they are finishing the procurement process.

Moving from our qualitative risk to a quantitative risk

- Risks maps cover a full spectrum of risks even those normally neglected
- Impact can be mapped to events like the ones of a traditional risk register
- There is no evaluation of cost of individual events but a general evaluation of what over/under cost can come from a family of risks
- Vulnerability can be mapped to probability with some hypothesis

From qualitative to quantitative: Impact on cost

Impact assessment	Catastrophic Extreme	Major	Moderate	Minor	Negligible
Assessment scale	5	4	3	2	1

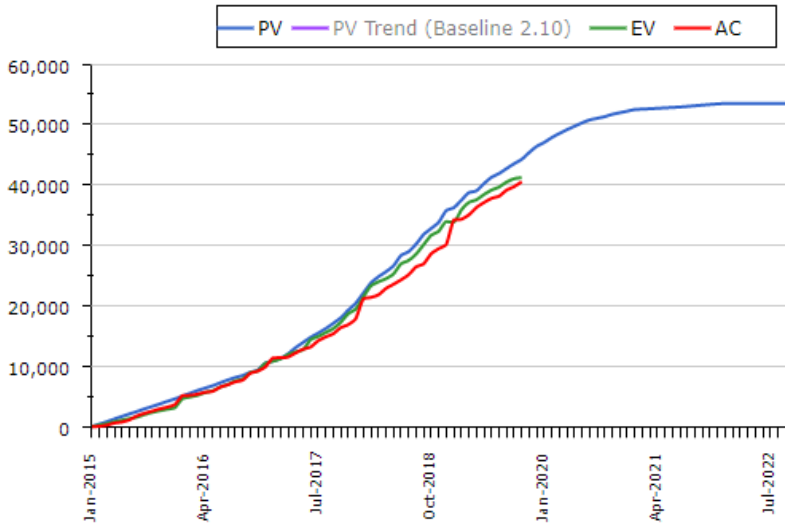
Impact	Minimum	Most likely	Maximum
5	20 %	30 %	40 %
4	10 %	15 %	20 %
3	0 %	5 %	10 %
2	-10 %	**0 %**	10 %
1	-20 %	-10 %	0 %

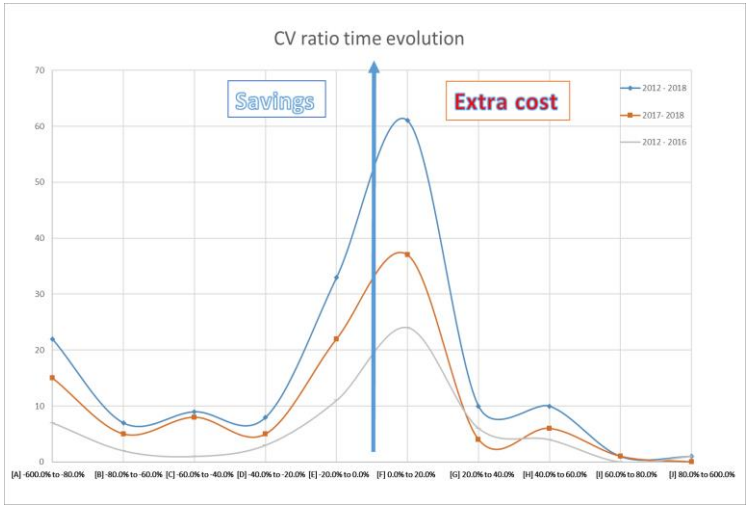
Impact 2

is considered as the “on budget” scenario

Financial loss	Reputation	Legal/ Regulatory	Safety	Environment	Objectives

Values based on experience





Domain	
Civil Engineering and Technical Infrastructures	19%
Collimators and new material resistants to high temperatures	-10%
Cryogenics systems for HL-LHC	-15%
Cryostats and subcomponents for cryogenic equipment*	-15%
Electrical Equipment, electronics and instrumentation for accelerators	-1%
High precission Assembling and manufacturing technologies	-8%
Magnets components and assemblies	-11%
Others	33%
Raw Materials	11%
Ultra high vacuum components and systems	-6%

DR range	Total
[A] 40 KCHF to 100 KCHF	-7%
[B] 100 KCHF to 200 KCHF	17%
[C] 200 KCHF to 500 KCHF	-6%
[D] 500 KCHF to 750 KCHF	-1%
[E] 750 KCHF to 1,500 KCHF	-7%
[F] 1,500 KCHF to 60,000 KCHF	-2%

From qualitative to quantitative: Vulnerability - Probability

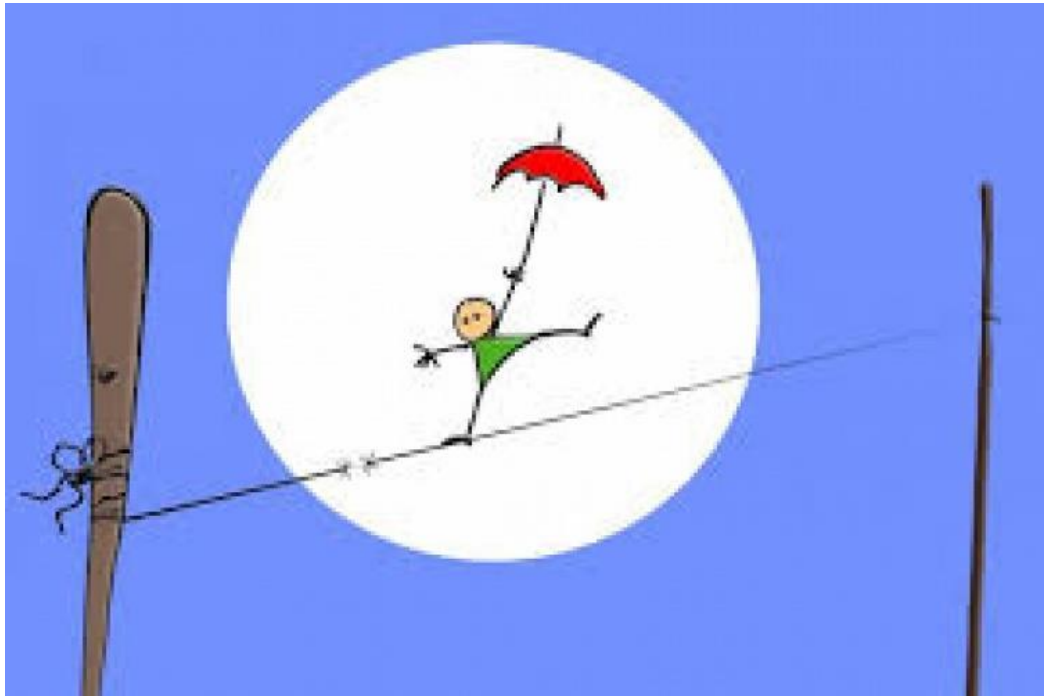
Vulnerability assessment	Severe vulnerability	High vulnerability	Moderate vulnerability	Mild vulnerability	No evidence of vulnerability
Assessment scale	5	4	3	2	1

Vulnerability	Probability
5	100 %
4	50 %
3	30 %
2	20 %
1	10 %

INTERNAL CONTROL	PREVIOUS RISK EXPERIENCE	CAPABILITY	RATE OF CHANGE

Still values are reality dependent of the WPL

IxV	Risk ID	Risk	Description	Actions	Comments
16	5	Delivery	Several WP3 magnets are delivered as in kind contribution or through collaboration agreements, for a total of **6** collaborations, 3 from member states and **3** from non-member states. Little leverage is available in case of delay. The same is applicable for our own deliverables	**2017** Today there is consolidated schedule managed by the WPL that is updated every three months with the input received by the collaborations and the internal suppliers. The vulnerability is 4 as there is little leverage in case of a delay in one of the collaborations and on our own internal supplies but CERN has always been proactive to anticipate issues and minimize impact on the global schedule. In some cases, CERN already took over specific tasks to reduce the delays and minimize impact on global schedule. **2018** The following action will be implemented from 2019: - Global review of the schedule to anticipate possible bottlenecks. (to eliminate "artificial" bottlenecks)	- The action set in 2017 was effective and continues giving good results. -The Spanish collaboration has some delay but the impact on the deliveries is being reduced by anticipating the call of tenders. -Active discussion with the collaborations to find solutions (e.g. possibility to build the long magnet prototype in CIEMAT…)
12	14	Production	Wrong production speed. Bankruptcy of the company that was awarded the contract. Risk of components that are late and delay the full integration of the cryoassembly.	**2017** We anticipated the orders relative to several components. The most critical ones (Nb3Sn strand) are already completed, even though production is still ongoing and we will be vulnerable until the delivery of the last strand. **2018** The following action will be implemented from 2019:	- The action set in 2017 was effective and continues giving good results. - Most of the components are already ordered and they are finishing the procurement process.



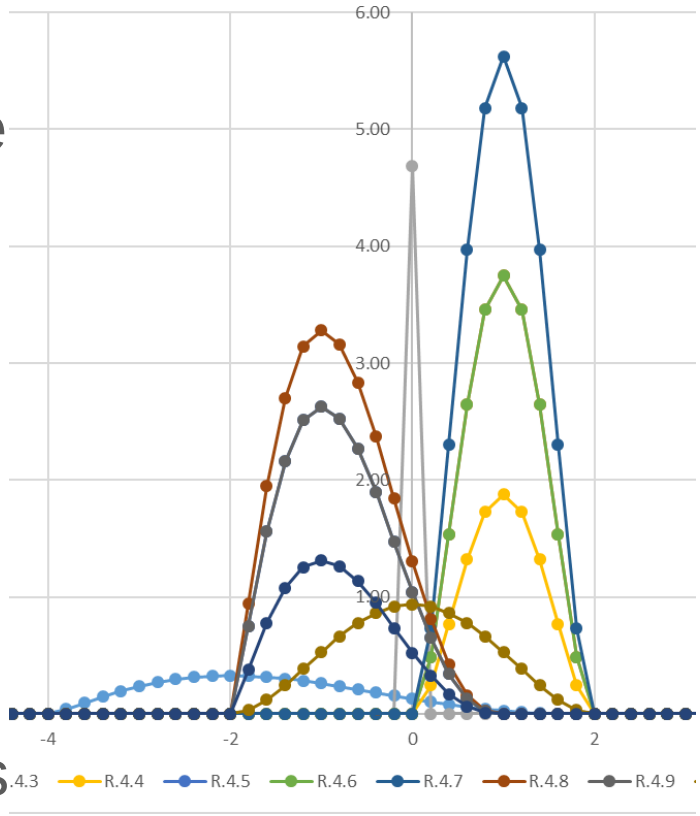
Exploration of several scenarios

Vulnerability	Probability Optimistic	Impact	Minimum	Most likely	Maximum
5	70%	5	10 %	20 %	30 %
4	40%	4	5 %	10 %	15 %
3	20%	3	-5 %	0 %	5 %
2	40%	2	-10 %	0 %	10 %
1	20%	1	-30 %	-15 %	0 %

Vulnerability	Probability Pessimistic	Impact	Minimum	Most likely	Maximum
5	100%	5	30 %	50 %	60 %
4	80%	4	15 %	20 %	40 %
3	50%	3	5 %	15 %	25 %
2	50%	2	0 %	10 %	20 %
1	50%	1	-10 %	0 %	10 %

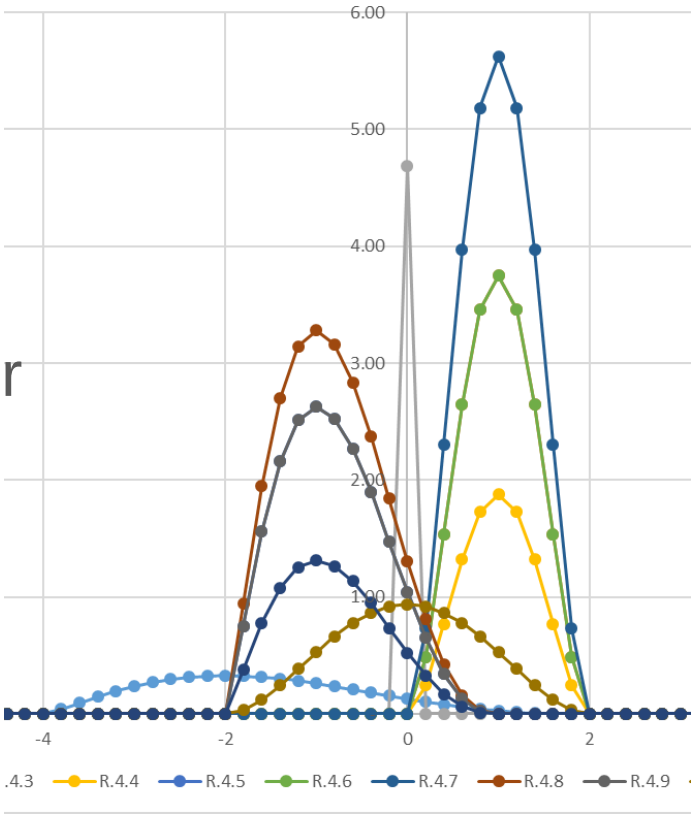
Distribution of the Risk

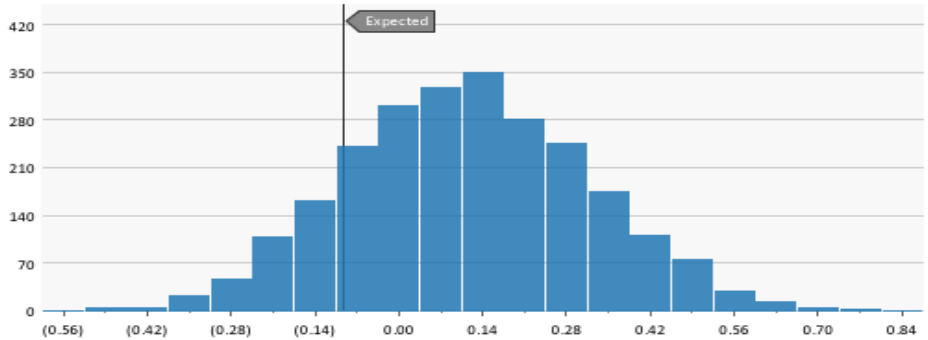
- The risk pattern will take a consideration the impact profile (PERT distribution based on the most likely, minimum and maximum)
- The probability that the event happens based on the vulnerability of the event
- The relative weight of each family of risks (ex. Production risk for WP3 will have 200 times more weight than the risks on lack of scientific publications)



Distribution of the Risk

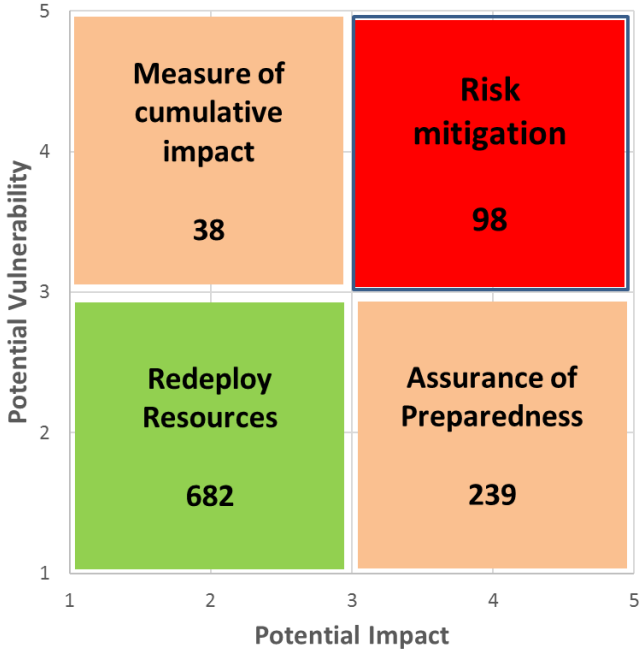
- The all is normalized so that the final value is expressed in percentage of residual value.
- There is a Monte Carlo simulation for each one of the risk and a global computation for all the risks together



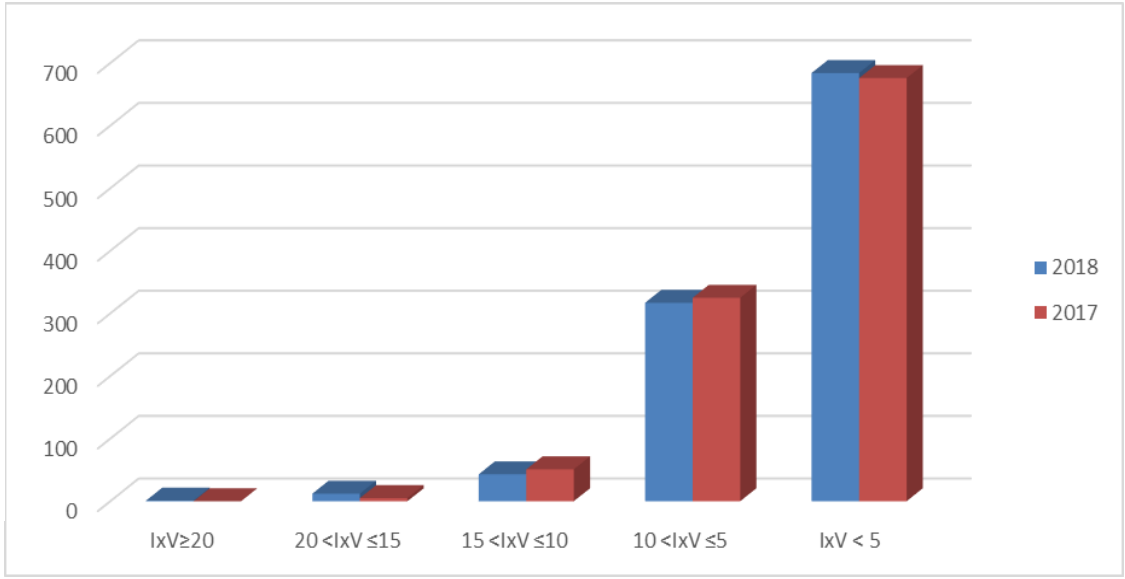


Main conclusions – Risk exercise

- From the qualitative approach we know that the main feeling is that the project is fully under control.
- This is corroborated by the cost figures from 2014 to 2019

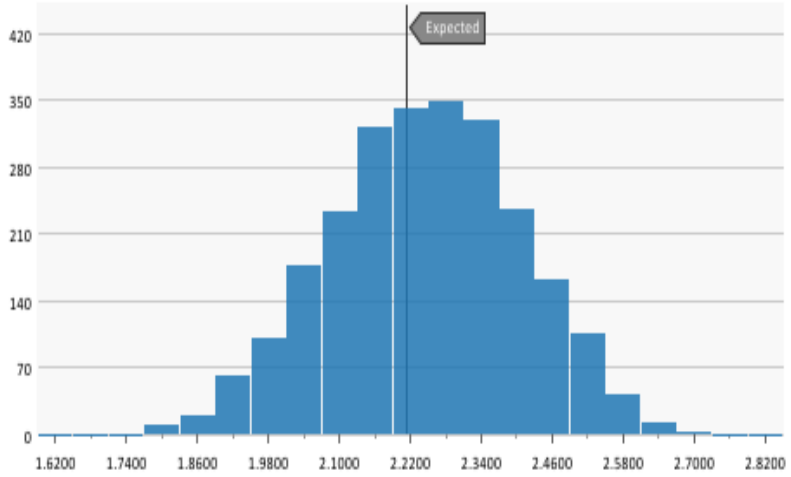


IxV	IxV≥20	20 <IxV ≤15	15 <IxV ≤10	10 <IxV ≤5	IxV < 5
2018	1	12	43	317	684
2017	0	5	51	325	676

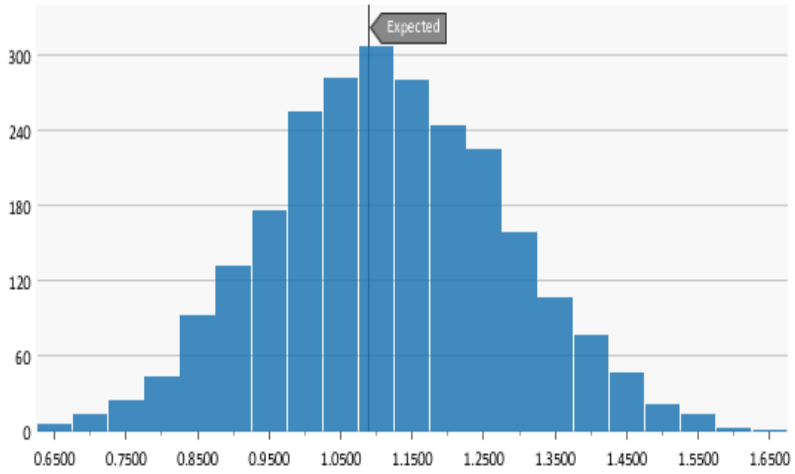


Main conclusions – Risk exercise (Examples)

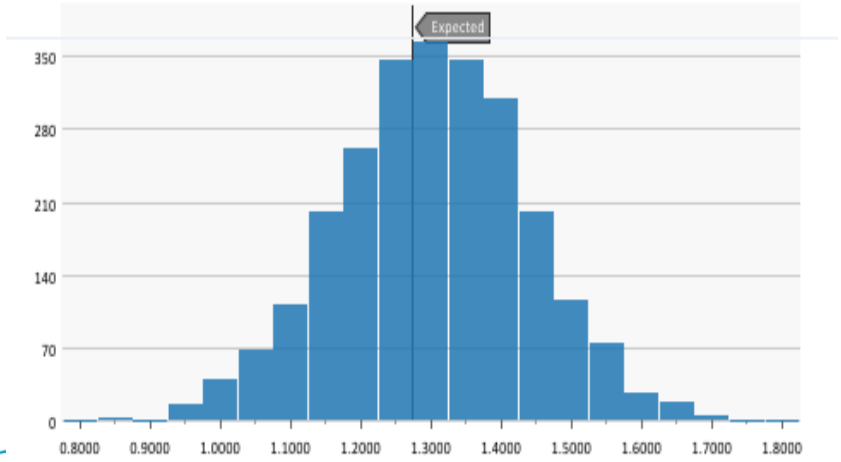
WP3



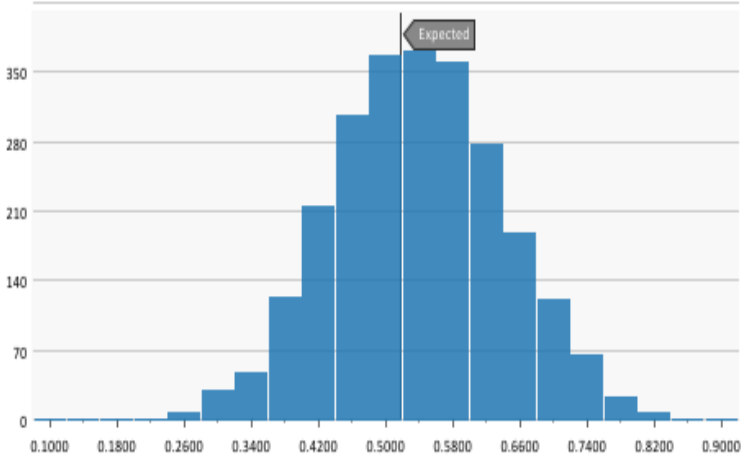
WP4



WP5



WP6A



Main conclusions – Risk exercise

The quantitative approach has as basis this same feeling

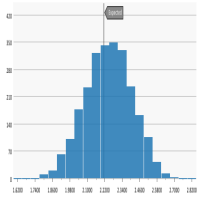
In %	WP2	WP3	WP4	WP5	WP6A	WP6B
Mean	(0.044)	2.20	1.10	1.30	0.52	0.96
Lowest	(0.320)	1.60	0.63	0.82	0.15	0.58
Highest	0.280	2.70	1.60	1.70	0.82	1.40
P50	(0.110) - 0.019	2.10 - 2.30	0.98 - 1.20	1.20 - 1.40	0.45 - 0.59	0.88 - 1.00

In %	WP7	WP8	WP9	WP10	WP11	WP12
Mean	0.57	0.30	(0.28)	(0.71)	1.00	(0.037)
Lowest	0.096	(0.30)	(0.72)	(0.94)	0.52	(0.61)
Highest	0.990	0.88	0.21	(0.46)	1.50	0.54
P50	0.47 - 0.66	0.18 - 0.41	(0.39) - (0.17)	(0.76) - (0.66)	0.92 - 1.1	(0.16) - 0.084

In %	WP13	WP14	WP15	WP16	WP17	WP18
Mean	0.86	(0.64)	1.40	(0.11)	2.20	(0.64)
Lowest	0.23	(0.92)	1.00	(0.47)	1.50	(0.93)
Highest	1.40	(0.30)	1.80	0.26	2.80	(0.32)
P50	0.74 - 0.98	(0.7) - (0.57)	1.30 - 1.40	(0.18) - (0.03)	2.00 - 2.40	(0.70) - (0.57)

Expected Extra cost in % of the remaining non committed budget

Main conclusions – Numerical over cost



In %	WP2	WP3	WP4	WP5	WP6A	WP6B
To be committed	3,176,143	55,481,639	37,035,856	24,306,660	27,522,533	22,606,831
Mean	(1,398)	1,220,596	407,394	315,987	143,117	217,026
Lowest	(10,164)	887,706	233,326	199,315	41,284	131,120
Highest	8,893	1,498,004	592,574	413,213	225,685	316,496

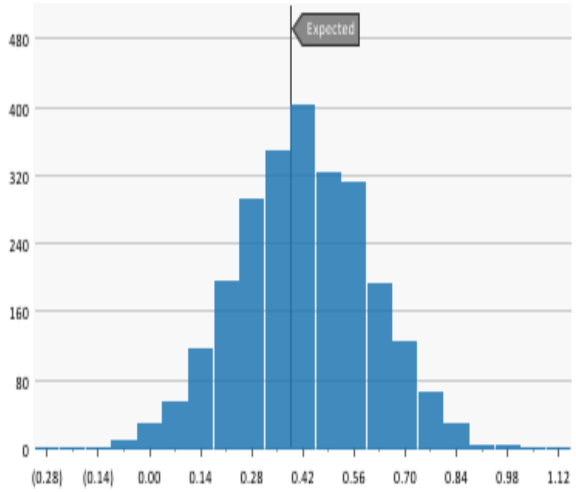
In %	WP7	WP8	WP9	WP10	WP11	WP12
To be committed	19,475,353	4,794,419	81,306,490	1,124,692	1,292,170	28,795,233
Mean	111,010	14,383	(227,658)	(7,985)	12,922	(10,654)
Lowest	18,696	(14,383)	(585,407)	(10,572)	6,719	(175,651)
Highest	192,806	42,191	170,744	(5,174)	19,383	155,494

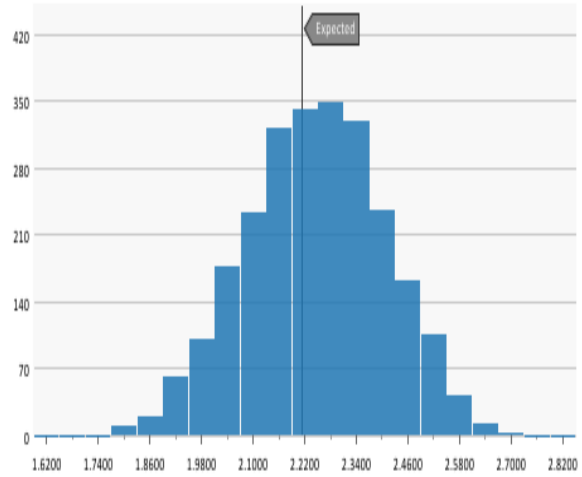
In %	WP13	WP14	WP15	WP16	WP17	WP18
To be committed	10,688,536	1,743,568	32,510,916	6,941,666	97,763,595	2,749,206
Mean	91,921	(11,159)	455,153	(7,636)	2,150,799	(17,595)
Lowest	24,584	(16,041)	325,109	(32,626)	1,466,454	(25,568)
Highest	149,640	(5,231)	585,196	18,048	2,737,381	(8,797)

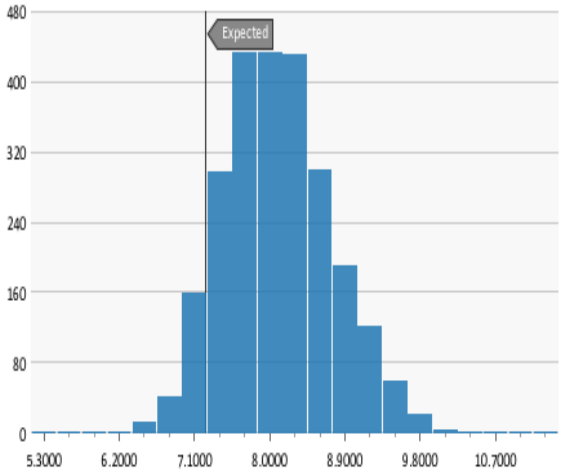
Expected Extra cost around 5 MCHF

Optimistic – Realistic? - Pessimistic

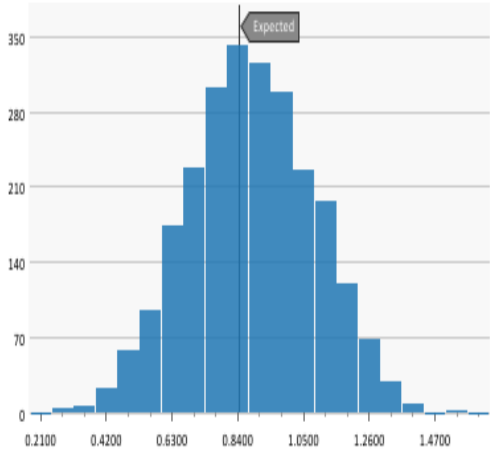
WP3

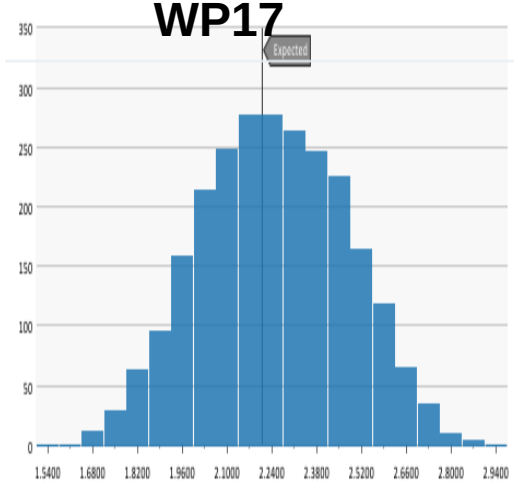


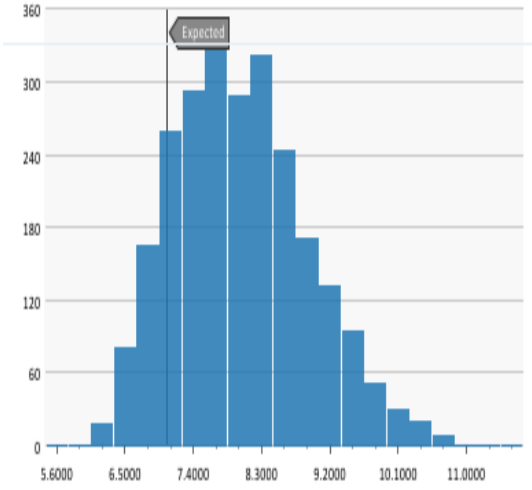




WP17

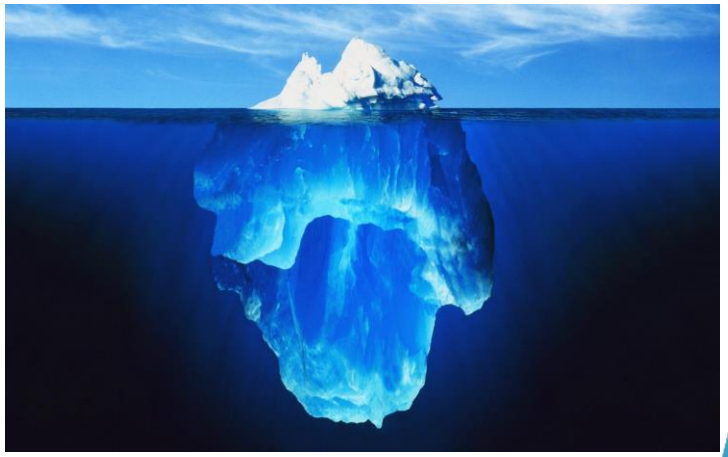






Main conclusions

- Risk is very subjective and the values given by WPLs are linked to their risk appetite
- We have engaged more than 50% of the budget and launched most part of procurement so our risk is every time less linked to the maturity level/pricing and more to production nonconformities, contract/collaboration management and non detected design problems.

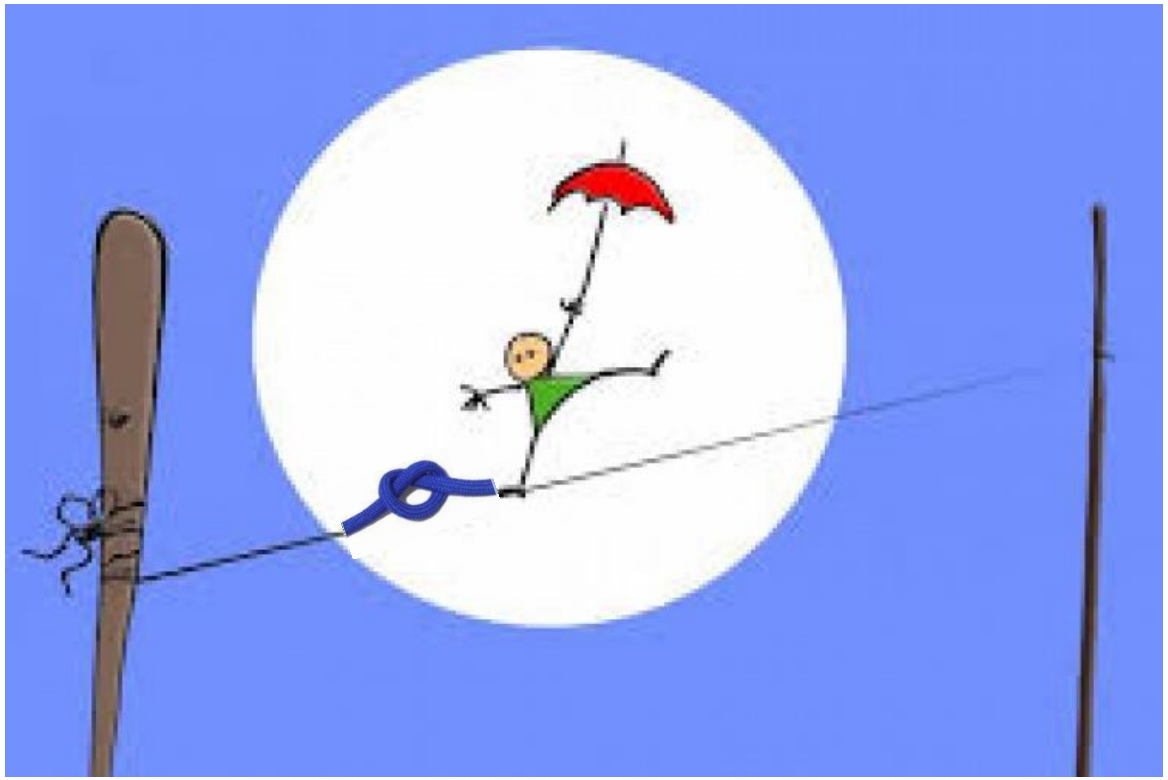


Main conclusions

- This is a first approach.
- There is still WPs such as WP9 and non civil engineering from WP17 where the risk of procurement is potentially under estimated
- If there are time delays those can create extra costs
- We haven’t yet added the result of analysing the impact of the worst adverse events
- The perception of the risk from the collaborations is indirect and while they do not have “direct cost” (full in-kind contributions) impact they can have an strong indirect impact (retake the activities, procurement of components, rework if nonconformities, delay on other activities, transport, storage, …)

Creating a risk-conscious culture within an organization is the first step to protect the organization against the risks consequences

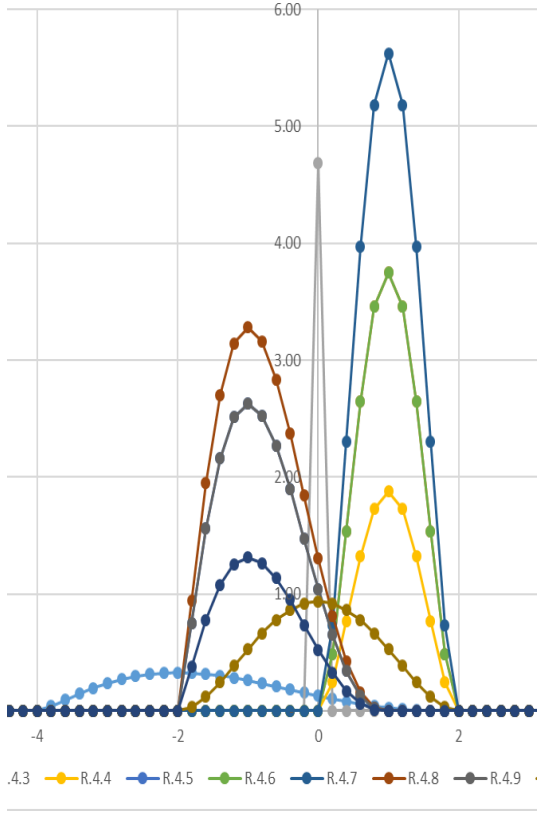
Questions?



Extra information

Normalizing the Risk (example)

- A Risk with impact 4 will have an over/under cost bracket of [10%,15%, 20%]
- If its relative weight is of 1/60th of the total value the impact for the global WP is [0.16%, 0.25%, 0.33%]
- If the vulnerability is 4 we consider that in 50% of the cases we will have an “event” instead of no deviation so the final contribution will be
- [0.08%, 0.12%, 0.17%] the addition of all will plot our over/under cost



What we look at when doing the risk assessment

Risk assessment attempts to answer the following fundamental questions:

- What can happen and why (by risk identification)?
- What are the consequences (by risk analysis)?
- Are we vulnerable, are there any factors that mitigate the consequence of the risk or that reduce the probability of the risk or that can increase our resilience (risk evaluation)?

Why we do risk assessment

The purpose of risk assessment is to provide evidence-based information and analysis to **make informed decisions** on how to treat particular risks and how to select between options. Some of the principal benefits of performing risk assessment include:

- understanding the risk and its potential impact upon objectives;
- providing information for decision makers;
- contributing to the understanding of risks, in order to assist in their treatment options;
- identifying the important contributors to risks;
- comparing of risks in alternative systems, technologies or approaches;
- assisting with establishing priorities;

Risk process

Mitigation Plans

Risk Intelligence map

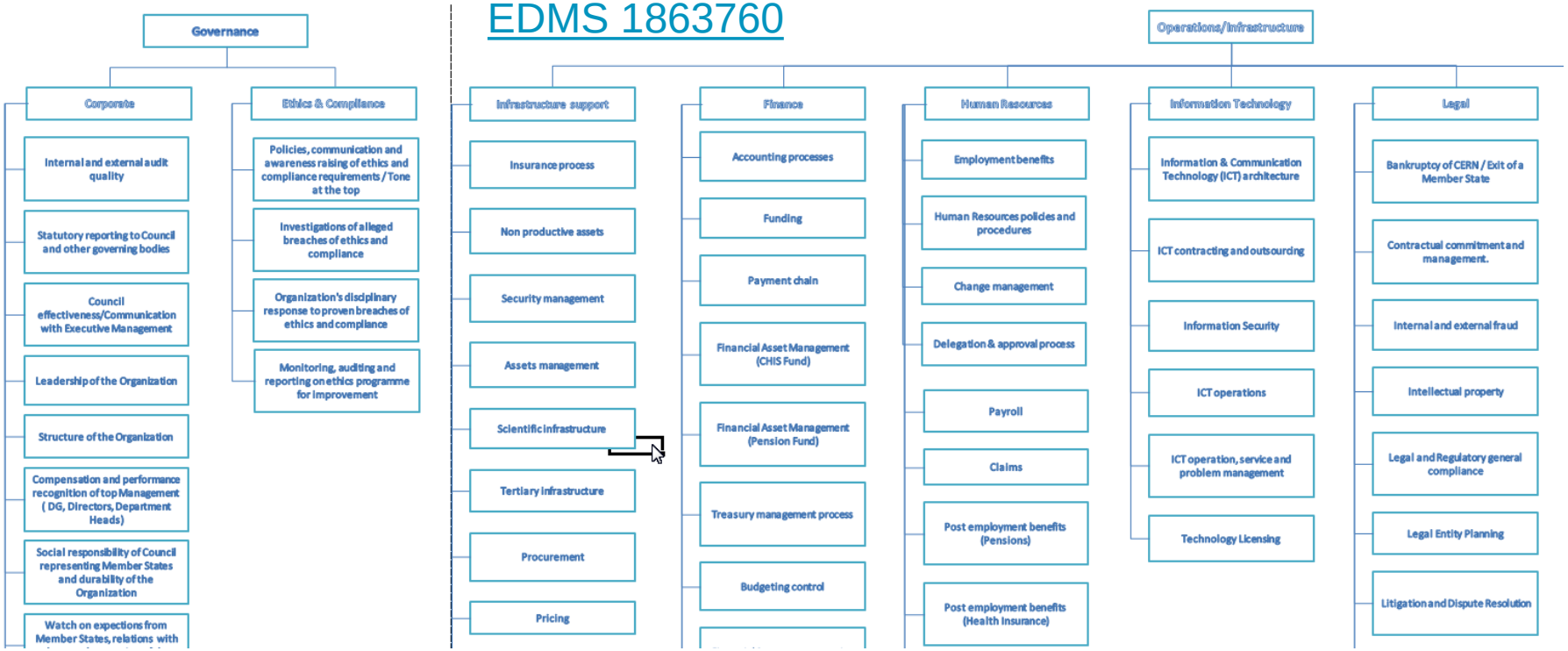
Standardized business catalog to inventory most critical risks

Governance	Corporate
	Ethics & Compliance
Strategy and Planning	Corporate Responsibility & Sustainability
	Strategy
	Planning
	External Factors
Delivering on mission	Hosting of Scientific Collaborations
	Knowledge transfer and training
	Research tools
Operations/Infrastructure	Infrastructure support
	Corporate Image
	Finance
	Human Resources
	Information Technology
	Legal

Risk Intelligence map

- Adapted to CERN and to the HL-LHC Project
- Every area that could create value also carries the potential for risk
- For every area of activity we should understand the threats and the opportunities, where we are weak and where we are strong

EDMS 1863760



Top increase of I*V

First Level	Second level	Risk	#
Delivering on mission	Collaborations	Knowledge transfer	2
		Monitoring of collaborations	2
	HL-LHC	Delivery	3
		Installation	1
		Interface of components	2
		Interface with LHC	1
		Planning	2
		Product Design/ Quality	4
		Production	1
		R&D	1
Governance	Corporate	Structure	3
Operations/ Infrastructure	Corporate Image	Project image and reputation	1
	Finance	Accounting processes	2
		Budgeting control	1
	Human Resources	Recruitment/Talent pipeline	2
	Infrastructure support	Procurement	1
Strategy and Planning	Corporate Responsibility & Sustainability	Short term impact on the environment	1
		Waste reduction and elimination	1
	External Factors	Changes of applicable laws and regulations	1
	Planning	Project management	2
	Strategy	Dependency on external collaborations	2
		Strategy for outsourcing	1
		Suppliers resilience and dependency	1

Assessing the Risk - Impact

- There are several things that can go “wrong”.
- Danger can come from inside (Weakness) or from outside (Threats)
- It can affect directly or indirectly the achievement of our objectives

EDMS 1863763

Impact assessment	Catastrophic Extreme	Major	Moderate	Minor	Negligible
Assessment scale	5	4	3	2	1

Financial loss	Reputation	Legal/ Regulatory	Safety	Environment	Objectives

Assessing the Risk - Vulnerability

- The same adverse event can affect us very differently if we have bust our resilience capacity
- Do we have the right persons, control systems, the experience or drilled this scenario …?

EDMS 1863764

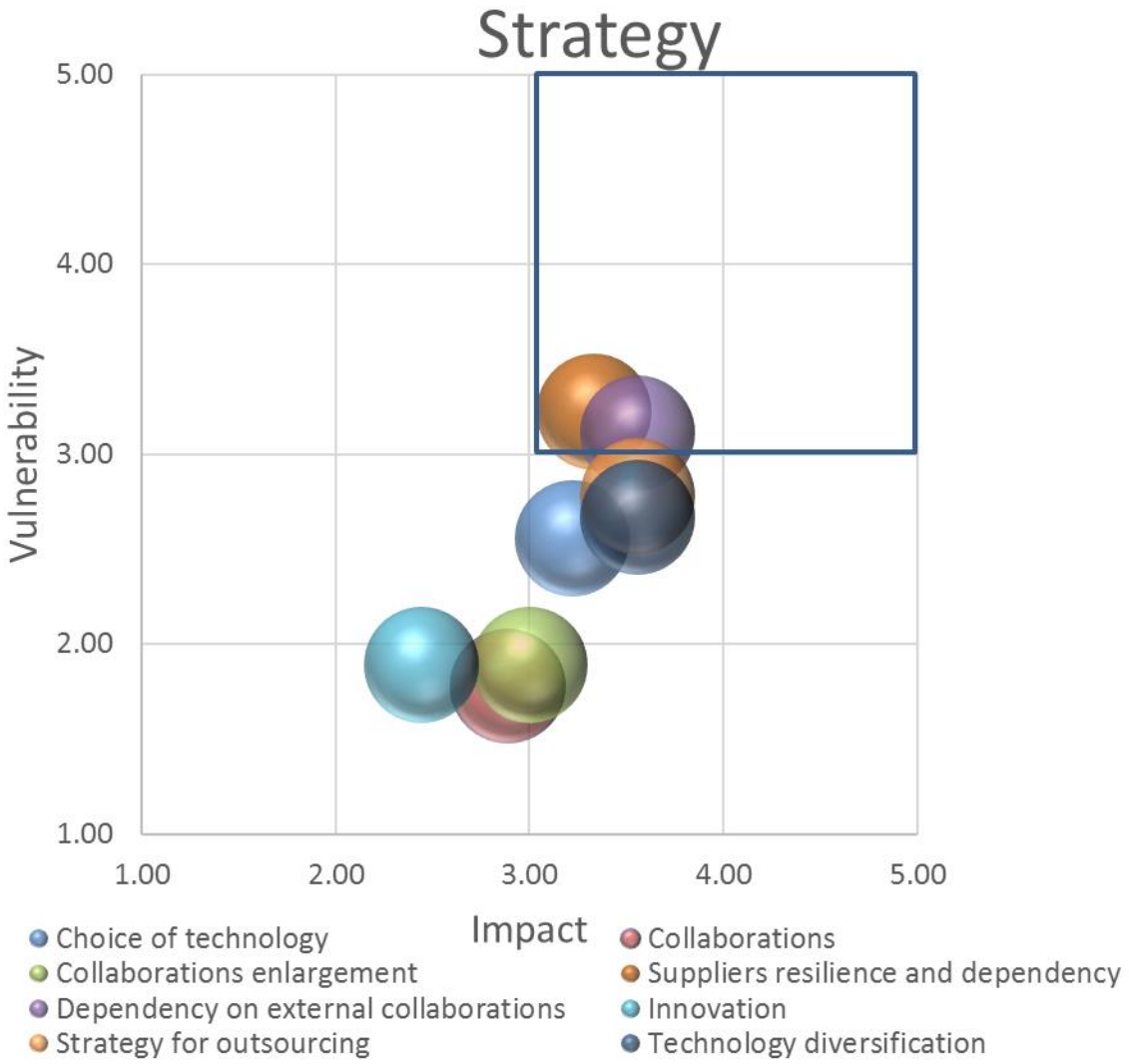
Vulnerability assessment	Severe vulnerability	High vulnerability	Moderate vulnerability	Mild vulnerability	No evidence of vulnerability
Assessment scale	5	4	3	2	1

INTERNAL CONTROL	PREVIOUS RISK EXPERIENCE	CAPABILITY	RATE OF CHANGE

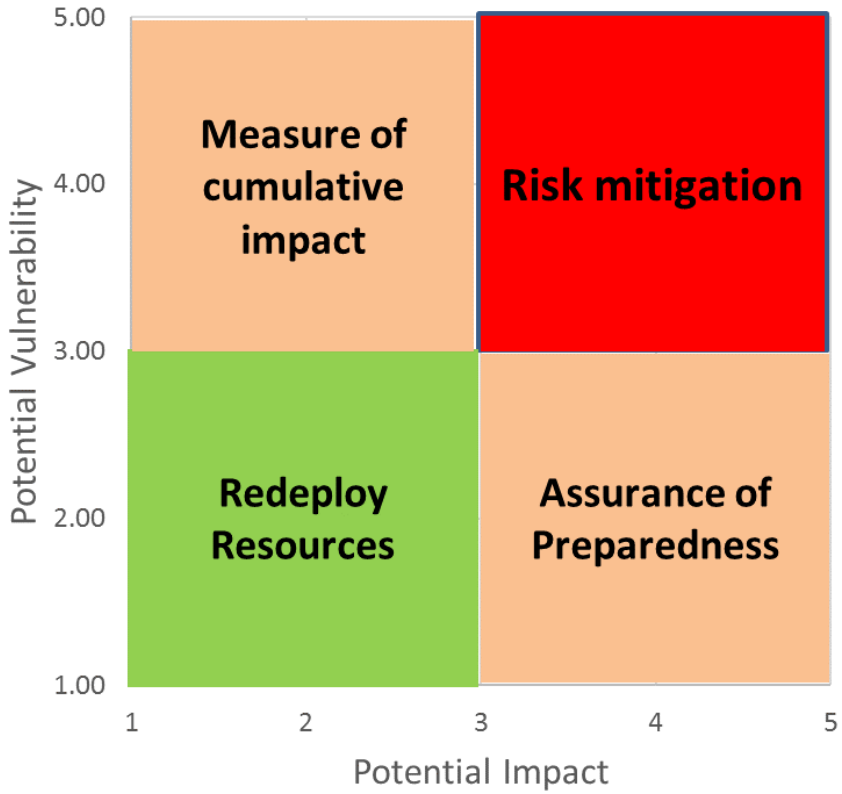
Assessing the Risk

For every area

- How many adverse scenarios you can identify?
- Which would be the impact?
- Are you vulnerable?



Treatment



For which risk I should:

- Mitigate?
- Assure my preparedness?
- Measure the Cumulative Impact
- Redeploy control resources

Treatment – Action plan

- Every action under “Risk mitigation” has an Action Plan.
- Action are monitored during the PSM
- Reports are stored on EDMS

https://edms.cern.ch/project/CERN-0000188683

PIxPV	Risk ID	Risk Category	Risk	Actions	Driver	Deadline
13.2	5	Delivery	Delay on the global HL-LHC Schedule	The following actions have been implemented to formalize and communicate any possible delay likely to jeopardize the global project schedule: - Project Steering Meetings (PSM), 2-3 times per year - EVM reporting, These mechanisms allow the project to systematically identify when a potential action to reduce or eliminate a delay is required. Reporting on the delays is done to the CERN Council every 6 months and every 18 months during the Cost and Schedule review.	P. Office	Continuous Monitoring
11.1	81	Dependency on external collaborations	Risks of over dependency on external collaborations	The following actions have been implemented to monitor the risk of delays due to collaborations: - Formal review of delays during the Collaboration Boards (CB) - Scrutiny of the status of collaborations during the PSM The following actions have been implemented to reduce the risk of losing core technology or information: - For each in-kind contribution providing a new technology, CERN obtains the full description and/or manufactures a prototype or spares. - Documentation and drawings are systematically recovered from all collaborations - Tooling is eventually recovered at CERN to assure maintenance In general,	P. Office	Continuous Monitoring

Monitoring and review

The risk assessment process will highlight context and other factors that might be expected to vary over time and which could change or invalidate the risk assessment. These factors should be specifically identified for on-going monitoring and review, so that the risk assessment can be updated when necessary.

Data to be monitored in order to refine the risk assessment should also be identified and collected.

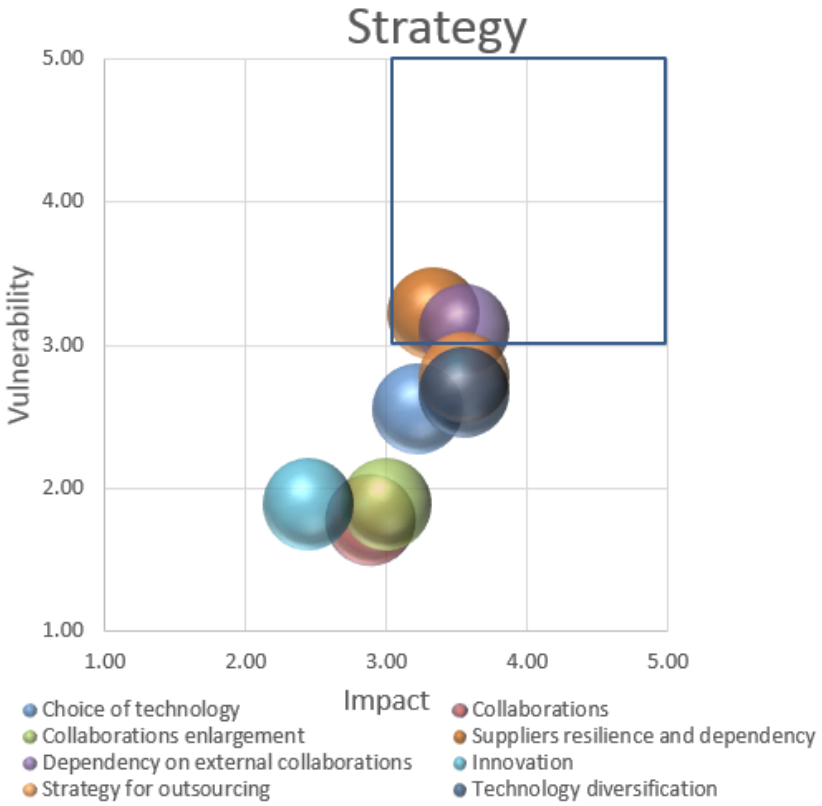
The effectiveness of controls should also be monitored and documented in order to provide data for use in risk analysis. Accountabilities for creation and reviewing the evidence and documentation should be defined.

Example - Action Plan

PIx PV	Risk ID	Risk Category	Risk	Actions
10.0	25	Structure	Bad management of the interface between the WP structure and the groups	The following actions have been implemented to avoid risk linked to the interface of the WPs and the Groups contributions (services): - Involvement of the GLs in the PSM and TCC including endorsement of GLs on actions and resources. The information is also provided to DH and DPOs
9.0	19	Reporting	Non clarity on the reporting line between the project and hierarchy line with conflicts on the reporting given by Project Leader and Department Heads	Clarification in the HL-LHC executive committee, chaired by DATS

Example of risk on MARCI chart

- Dependency on external collaborations
- Suppliers resilience and dependency



	Label of the Chart		
	Strategy		
Domain	Risk	I	V
Strategy	Choice of technology	3.22	2.56
Strategy	Collaborations	2.89	1.78
Strategy	Collaborations enlargement	3.00	1.89
Strategy	**Dependency on external collaborations**	3.56	3.11
Strategy	Innovation	2.44	1.89
Strategy	Strategy for outsourcing	3.56	2.78
Strategy	**Suppliers resilience and dependency**	3.33	3.22
Strategy	Technology diversification	3.56	2.67

Creating a risk-conscious culture within an organization is the first step to protect the organization against the risks consequences

Thanks to the Project Office and Project Leaders