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Determination of Relative Importance of Nonproliferation Factors

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DETERMINATION OF RELATIVE IMPORTANCE OF NONPROLIFERATION FACTORS

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ABSTRACT

Methodologies to determine the proliferation resistance (PR) of nuclear facilities often rely on either expert elicitation, a resource-intensive approach without easily reproducible results, or numeric evaluations, which can fail to take into account the institutional knowledge and expert experience of the nonproliferation community. In an attempt to bridge the gap and bring the institutional knowledge into numeric evaluations of PR, a survey was conducted of 33 individuals to find the relative importance of a set of 62 nonproliferation factors, subsectioned into groups under the headings of Diversion, Transportation, Transformation, and Weaponization. One third of the respondents were self-described nonproliferation professionals, and the remaining two thirds were from secondary professions related to nonproliferation, such as industrial engineers or policy analysts. The factors were taken from previous work which used multi-attribute utility analysis with uniform weighting of attributes and did not include institutional knowledge. In both expert and non-expert groups, all four headings and the majority of factors had different relative importance at a confidence of 95% (p=0.05). This analysis and survey demonstrates that institutional knowledge can be brought into numeric evaluations of PR, if there is a sufficient investment of resources made prior to the evaluation.

INTRODUCTION

Nuclear nonproliferation is a field that was born the moment the first nuclear weapon was detonated. As long as nuclear facilities exist, the threat of the proliferation of weapons-usable material will continue to be a significant concern. A comparison of the proliferation resistance (PR) of fuel cycles has been in discussion for over thirty years.[1] Major US initiatives in nuclear power in the past five years have included clauses related to nuclear nonproliferation: the Global Nuclear Energy Partnership (GNEP) program discusses new reactors with higher PR[2] while the Advanced Fuel Cycle Initiative (AFCI) is based on creating technology that has more PR.[3]

The ability to evaluate PR is a required component of any thorough analysis of various cycles. Failing to evaluate the PR of a cycle objectively and clearly leads to misunderstandings, over and underestimates of risk, and misallocation of limited resources. Several methods of evaluating the PR of a facility or cycle have been determined, including IAEA's INPRO (INternational PROject on innovative nuclear reactors and fuel cycle)[4], GEN IV International Forum experts' group (PRPP - Proliferation Resistance and Physical Protection)[5], AFCI (Advanced Fuel Cycle Initiatives) multi-attribute utility analysis (MAUA) methodology[6], JAEA's FS Project (Feasibility Studies on commercialized fast reactor cycle system)[7], TOPS (Technological Opportunities to increase the Proliferation resistance of global civilian nuclear power Systems methodology)[8], BNL (Brookhaven National Lab methodology)[9], SNL RIPA (Sandia National Laboratory Risk Informed Probabilistic Analysis)[10], SAPRA (Simplified Approach for PR Assessment of nuclear systems)[11] and Giannangeli's Method.[12]

Each of these methodologies has their advantages and disadvantages. Proliferation resistance analysis tools must meet competing values: clarity, simplicity, transparency, accuracy, repeatability, ease-of-use, speed, and updatability. No analysis methodology has been found yet that can meet all of these criteria effectively, and subsequently several simplifying assumptions have been offered in the major methodologies. It is clear that to approach PR from a scientific viewpoint, two of those values are the most crucial: repeatability and accuracy. Methodologies which are accurate and rely heavily on expert elicitation are often not repeatable However, methodologies which are numeric (repeatable), often do not include the institutional knowledge which should form the basis of estimate (accuracy). This research was undertaken to include the institutional knowledge present in a set of stakeholders into numeric analyses to allow for repeatable and accurate analyses.

DESCRIPTION OF PREVIOUS NUMERIC PROLIFERATION RESISTANCE ANALYSES

There are two major proliferation resistance analyses which are numeric, recent, and have the ability to include institutional knowledge: SAPRA and Giannangeli's Method. It is clear that regardless of assumptions, the most important factor is accuracy. Unfortunately, the existing methodologies do not include the expert institutional knowledge when aggregating information, and as such their results are questionable. Each of these analyses is explained briefly below.[1]

The Simplified Approach for Proliferation Resistance Assessment of Nuclear Systems (SAPRA)

The Simplified Approach for Proliferation Resistance Assessment of Nuclear Systems (SAPRA) is a simplified analysis of the JAEA PR methodology, which itself is based on the Technological Opportunities for Increased Proliferation Resistance of Global Civilian Nuclear Power Systems (TOPS). SAPRA has been completed recently and has published at least one comprehensive analysis of a fuel cycle.[13] SAPRA assumes that there are four stages to acquisition to a nuclear weapon by diversion: diversion of nuclear material, transportation of the nuclear material to a second site, transformation of the material into a weapons-usable form, and weaponization of the material by adding a physics package. During each of these stages of proliferation, there are barriers which inhibit the progress of the proliferator to obtain a successful weapon. These barriers are often left generic, such as "Material" or "Institutional" to encompass all possible barriers. A specific point during a fuel cycle is chosen for evaluation. Each of the potential barriers to proliferation is then rated by a panel of experts on a scale from zero to four with zero being no barrier at all and four being an extremely resistant barrier. The scores for each barrier are then summed and normalized to one to give an average value of the resistance for each barrier. The average value of all of the barriers to proliferation is then assigned the PR of that stage (e.g. diversion). In the study of Ref. 13, the overall PR was defined as the average of the PR for each of the stages. There are several reasons this final PR value may be questionable:

1. Some barriers to proliferation are more important than others because some barriers may have multiple impeding-factors folded into a single barrier. For example, a "Radiation" barrier may have "damage to electronics by neutrons" and "Potentially lethal dose" together. Furthermore, adding too many potential factors can dilute the influence of any given barrier.

2. The scale of values is not the same for each attribute. There are very different considerations for how a proliferator could overcome the barrier of "Material handling" compared to "Being detected by Safeguards" The definitions for low, medium, high, and very high resistance are not numeric.

3. The system is founded fundamentally on a panel of experts. PR is a measurement of a quality that is difficult to quantify; a very large panel would be required to ensure that the values reported are close to the true, relative PR between fuel systems. Current panels likely will not provide repeatable results.

4. The SAPRA method has assumed independent attributes and uses a direct averaging scheme rather than take any assumption regarding the enemy intent aspect of the risk equation. As a result, the SAPRA method more accurately portrays the vulnerability of a facility, rather than the risk.

The SAPRA method does have some excellent qualities, despite these flaws. The division of the proliferation into four, clearly required stages helps show a second layer of information that is valuable to evaluators. The idea of finding independent attributes to test and considering these as an aggregate is a great step forward. Finally, the analysis of the once-through and MOX recycle fuel cycles proved that no system has perfect PR, international safeguards can have significant impact, and most material has some intrinsic barriers to proliferation.

Giannageli's Method (TAMU MAUA)

Giannangeli improved on SAPRA and was a revision of the Texas A&M University's Multi-Attribute Utility Analysis (MAUA) method by adding extra layers of information, changing the aggregation scheme, and seeking a more objective analysis by avoiding the use of expert panels. These additions created a system which serves as an excellent foundation for future tools.

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[1] Some of these methodologies are based on previous methodologies, which are not explained here. This paper seeks to present only the most recent numeric methodologies for brevity.

The Giannageli method is designed exclusively to handle diversion, similar to the SAPRA method. It is based on MAUA using a two tier analysis of very detailed information feeding into the higher stages of diversion, transportation, transformation, and weaponization. This detailed information was a set of 53 attributes that represented barriers to proliferation in the four stages to a weapon taken from a draft of a comprehensive report on PR attributes.[14]

Rather than having a panel evaluate the relative PR values for each case for each barrier, the attributes chosen were to be quantifiable. For example, the idea of the barrier for "material bulk" became the mass per significant quantity (SQ) and volume per SQ of material. The mass per significant quantity of material is not directly correlated to the PR. As a result, utility functions were created. Utility functions turn inputs for attributes into a normalized PR value for a given attribute, which can be input into an overarching methodology.

Giannangeli's method addressed a few of the above concerns about SAPRA. The expert elicitation was replaced with a more objective utility analysis, which allowed for repeatable results and less bias. However, there is room for significant improvement on the Giannangeli method:

1. The choice of uniform weights still does not address the issue that some barriers are more valuable than others. In Giannangeli's method, the sonic load from a transmutation facility was as important as radioactive releases.

2. Because the method was only two-tiered, the second tier attributes such as "Material handling during weaponization" were three times as important as "Knowledge and Skills needed to design and fabricate a weapon."

3. Giannangeli's method was based on an earlier draft of the attribute list, which was missing attributes and furthermore had several duplicated entries, leading to an overemphasis on certain attributes and underemphasis of others.

CREATION OF AN INSTITUTIONAL KNOWLEDGE DRIVEN WEIGHT SET FROM SURVEY OF STAKEHOLDERS

It is clear from the previous work that institutional knowledge needs to be included in the PR analysis. SAPRA's pure average is an adaptation of the MAUA methodology used by Giannangeli, and so the weights for each attribute (institutional knowledge) should be determined in the most general case. The choice of weights is crucial to MAUA analysis. A survey of stakeholders was taken to determine the appropriate weighting structure. The survey methodology is presented by first explaining the attributes considered for evaluation and then the participants involved. The actual method in which the survey was performed is presented third, including a brief explanation of the observed survey fatigue. Finally, the outliers which were removed from the sample set are explained and the final weights and their associated uncertainty are tabled.

Description of Attributes Chosen

The SAPRA and Giannageli methodologies both use an outline of Diversion, Transportation, Transformation, and Weaponization. Giannangeli's method used a draft version of the Ref 14, the most comprehensive list of PR attributes at this time. As a result, the survey attributes chosen follow the finalized copy of Ref 14 (also listed in the results of the Mixed Group, below). This multi-tier approach is enumerated below and shown in Fig. 1:

1. The first tier are specific data associated with a facility or process. Examples include "IAEA imagery analysis rate" or "neutrons per second per gram of material."

2. The second tier utility values are a combination of lower tier utility values with a chosen weight structure. Second tier utility values include "material handling during diversion" and "knowledge and skills needed to fabricate a weapon."

3. The third tier, or overview, combines the utility values from the second tier and their respective weights. It consists of only four utility values: Diversion, Transportation, Transformation, and Weaponization. These four stages are combined into a single metric for comparison of systems in both SAPRA and Giannangeli's Method.

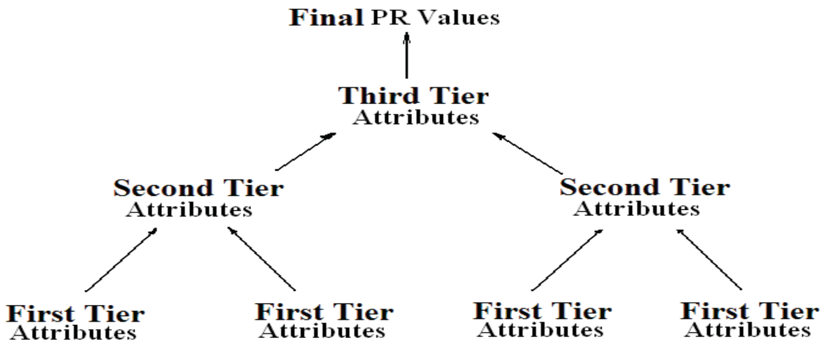

Figure 1. Attribute Structure of Ref 12.

Description of Participants

The choice of participants can have a large impact on the weighting scheme determined. For this weight search, two sets of opinions were elicited. The first are "experts" which represent a group of specialists who are actively engaged in nonproliferation research. Experts included nonproliferation specialists from the International Atomic Energy Agency (IAEA), Nuclear Security Science and Policy Institute (NSSPI), Oak Ridge National Laboratory (ORNL), Savannah River National Lab (SRS), Pacific Northwest National Laboratory (PNNL), and Los Alamos National Lab (LANL). The second are "nonexperts" who are intelligent participants on the periphery of nonproliferation research without having direct training or experience in the field. Nonexperts included reactor physicists, former weapon scientists, industrial engineers, transport theory specialists, health physicists, particle physicists, chemical engineers, and policy specialists of the Monterrey Institute of International Studies and the Bush School of Government and Public Service.

Complete random sampling could not be achieved because of the limited access to the communities in question. However, equal solicitation was made of available participants. A total of 33 interviews were performed from January 2008 to April 2008.

Description of Method and Survey

The surveys were presented in a top down manner: the participant would assign weights to the four stages of diversion (third tier), and then to the problems associated with each stage in order of the four stages (second tier), and then each of the attributes within each of the problems in order of the stages (first tier). Each participant weighted an attribute from 0-10, with 0 being "absolutely not important at all" and 10 being "This is likely the most important attribute." The survey participants were informed they were assigning weight not based on how difficult they found the stages, but how much emphasis or importance should be put on an attribute when it is considered in the analysis. If this was unclear to a participant, the participant was asked to consider the following: "If you could choose to put money into increasing the difficulty (with a linear increase based on money) of any of these attributes, where would you choose to put your money" and "Or, consider these attributes in that if you would rather the proliferator have a harder time with X than Y, then you want to rate X relatively higher than Y." In each of the presented categories, participants were informed the weights they assigned would be renormalized to sum to 1.0. The surveys to determine the weights of these various attributes were given in person by the same researcher, with standardized language. In some cases, multiple surveys were given at the same time by written response. Surveys from March 2008 and April 2008 had the option to stop the survey after the second tier stage because of an observation of survey fatigue.

Four participants of the survey, all non-experts, actively stated they were suffering from survey fatigue, with two respondents unwilling to continue after a certain period of time. Survey fatigue is an increasing decrease in the responsiveness of a survey participant.[15] This can be characterized by refusal to continue, rapid and uniform response, or patterns in response based on question. The majority of survey fatigue studies have concluded that longer surveys and lower salience tended to increase survey fatigue.[16] This lower salience for non-experts may have resulted in faster survey fatigue, which would tend to obscure the results.

RESULTS OF SURVEY

The final weights, their standard deviations, and results from the two-sided student-t test are shown in the following sections: Expert, Non-expert, and Mixed Group. In each section, only results at a confidence of 95% (p=0.95) and higher are explicitly mentioned. The full results for the Expert and Non-expert groups are reported in full in Ref 17.[17]

Expert Group

The expert group showed the highest amount of correlation in their responses, and many of their response differed from the uniform weights case. The diversion stage is regarded as 33.0% more important than the original weight assigned in the uniform case at a confidence of p=0.999. Transportation is 25.6% less important at confidence of p=0.999. Transformation is 10.7% more important at a confidence of p=0.98 while weaponization is 10.8% less important at the same confidence. These results follows traditional nonproliferation teaching that diversion is the most important aspect to consider in PR analyses, smuggling networks make transportation easy, transformation has significant technical challenges, and the weaponization must be assumed whenever performing an analysis.

Second tier utilities still had significant differences from the uniform assumption. The materials control and accountability system was 19.1% more important at a confidence of p=0.999. The difficulty in making facility modifications was 6.0% less important at p=0.95, and the process monitoring systems were 23.0% less important at a confidence of p=0.98. Second tier uniform weighting is prevalent until the handling difficulties during the weaponization stage is seen as 17.5% less important but the knowledge and skills needed to fabricate the device is 19.0% more important, both at confidence p=0.99.

Several individual attribute differences are significant. The material form is 35.7% less important at p=0.98, while the radiation dose is 48.9% more important at p=0.99. Chemical reactivity is 57.2% less important at p=0.98. Export equipment was 14.4% more important at p=0.999, and skilled workers are 9.2% more important at the same confidence. The heating rate was 31.6% less important at p=0.99. Radiotoxicity was also 7.8% less important at p=0.98. Many of the attributes showed changes at confidence of p=0.90, indicating a need for a larger sample. Because the expert group was very small (n=11), few outlier removals could be justified leading to a decrease in resolution of the data.

Non-Expert Group

The non-expert group showed less correlation than the expert group. The diversion stage is not resolved differently at the p=0.95 confidence, though does show a 17.6% increase at the p=0.90 confidence level. Transportation is 19.1% less important than uniform weights at p=0.99. Transformation cannot be resolved at any reasonable confidence. Weaponization can be resolved at the p=0.90 confidence level to be 14.3% less important than uniform weights.

The second tier had few resolved differences from uniform. Material handling during transportation is 13.8% less important and evading detection during transport is 10.8% more important (both at p=0.98). The equipment needed during the transformation process is 17.0% more important at p=0.98 while the workforce is 13.3% less important.

The individual attributes showed few differences, especially when compared to the expert group. Temperature of the source process is 28.7% less important at p=0.99. Expected vs actual material unaccounted for is 14.5% less important at p=0.98. Immediate chemical toxicity is 19.1% more important at p=0.97. At the same confidence, shield thickness is 15.4% more important. At p=0.99, Unskilled labor is 51.0% less important, skilled labor is 38.0% less important, but technical expert work is 73.7% more important. Isotopic signatures released from the transformation process are 25.0% more important at p=0.97. The heat and sonic loads are 17.3% and 31.2% less important respectively at p=0.97.

Differences Between Expert and Nonexperts

The differences between the expert and non-expert groups can be significant. They range from 0.2% for knowledge and skills needed to design and fabricate a weapon to 88.62% regarding chemical reactivity. The diversion stage is regarded as more important to experts than non-experts, which corroborates with the traditional training that diversion is the most important step. Experts favored mass, volume, and radiation dose heavily (25% or more over non-experts) through the entire survey, and tended to ignore heat load, chemistry, non-nuclear signatures, and newer technologies such as process monitoring. Experts also had a much higher regard for material unaccounted for, which may indicate that the phrasing of that attribute needs to be reworked because non-experts do not recognize the connotation associated with that phrase. Many attributes which require special training to understand their significance are regarded more highly by experts than non-experts. For example, phases in the phase diagram, which affects the reliability of weapons, was rated low by non-experts but very high by non-experts. In the following table, each of the three tiers are shown, their final weight according to the survey weights, the sample deviation, and the probability that there is a difference between the uniform weight value, the true value as believed by the respondent group, and the percent difference between what experts believed was the true value and what nonexperts believed was the true value.

Table 1: Weight Results for Experts and Non-Experts Combined

	INPUT	Final Weight	Sample Deviation	Probability of Difference	Percent Difference Experts vs Nonexperts
1.	Diversion Stage	0.318	0.080	1.000	9.2%
1.1.	Material handling difficulty during diversion	0.177	0.052	0.651	-1.9%
1.1.1.	Mass/SQ of nuclear material	0.133	0.047	0.445	35.3%
1.1.2.	Volume/SQ of nuclear material	0.141	0.032	0.940	21.8%
1.1.3.	Number of items/SQ	0.130	0.057	0.234	26.3%
1.1.4.	Material Form	0.137	0.055	0.583	-59.0%
1.1.5.	Radiation level in terms of dose	0.143	0.059	0.732	31.6%
1.1.6.	Chemical reactivity	0.119	0.045	0.378	-50.0%
1.1.7.	Temperature of Source Process	0.096	0.031	0.999	-9.1%
1.1.8.	Heat load of material	0.101	0.047	0.937	-58.0%
1.2.	Difficulty of evading detection by the accounting system	0.174	0.040	0.603	-0.7%
1.2.1.	Uncertainty in accountancy measurements	0.270	0.042	0.922	4.7%
1.2.2.	Expected vs. Actual MUF	0.228	0.047	0.905	25.2%

1.2.3.	Frequency of measurement	0.239	0.038	0.695	-19.0%
1.2.4	Amount of Material Available	0.262	0.066	0.506	-13.2%
1.3.	Difficulty of evading detection by the material control system	0.192	0.036	0.994	6.1%
1.3.1.	Probability of detection	1.000	0.000		0.0%
1.4	Difficulty of covertly making facility modifications	0.164	0.040	0.350	-7.3%
1.4.1	Is there enough physical space to make modifications	0.149	0.031	0.347	17.2%
1.4.2	Number of People for Modifications	0.158	0.054	0.685	10.7%
1.4.3	Remote handling tools required?	0.133	0.050	0.618	-6.4%
1.4.4	Specialized tools required?	0.128	0.029	0.920	-2.2%
1.4.5	Requirement for the process to be halted for modifications	0.170	0.045	0.913	-27.2%
1.4.6	Risk of Modification (safety)	0.109	0.052	0.945	16.7%
1.4.7	Risk of penetrating containment	0.152	0.032	0.733	-7.2%
1.5	Difficulty of evading IAEA with covert facility modifications	0.155	0.051	0.690	19.4%
1.5.1	Probability of being caught	1.000	0.000		0.0%
1.6	Difficulty in evading Off Normal Detection System	0.140	0.046	0.978	-15.2%
1.6.1	Prob of getting caught	1.000	0.000		0.0%
2.	Transportation Stage	0.199	0.063	1.000	-12.1%
2.1.	Material handling difficulty during transportation	0.469	0.108	0.942	14.8%

2.1.1.	Mass/SQ of nuclear material	0.118	0.064	0.299	57.9%
2.1.2.	Volume/SQ of nuclear material	0.145	0.046	0.875	27.8%
2.1.3.	Material Form	0.145	0.052	0.834	-17.9%
2.1.4.	Radiation level in terms of dose	0.130	0.068	0.216	56.1%
2.1.5.	Heat load of material	0.113	0.039	0.728	-21.0%
2.1.6.	Chemical reactivity	0.125	0.045	0.032	-88.6%
2.1.7.	Immediate Chemical toxicity	0.141	0.053	0.734	-75.4%
2.1.8.	Time Average Chemical toxicity	0.095	0.056	0.946	-23.0%
2.2.	Difficulty of evading detection during transport	0.531	0.108	0.942	-13.4%
2.2.1.	Mass of material and transportation container	0.131	0.043	0.664	43.7%
2.2.2.	Volume of material and transportation container	0.148	0.040	0.329	2.7%
2.2.3.	Heat load of material	0.129	0.039	0.818	-24.7%
2.2.4.	Shield thickness to reduce radiation to 10 mR/hr	0.159	0.046	0.792	-47.7%
2.2.5.	Host country size	0.142	0.073	0.028	14.4%
2.2.6.	Number of declared nuclear facilities	0.136	0.039	0.476	12.5%
2.2.7.	IAEA imagery analysis rate	0.156	0.089	0.395	-11.1%
3.	Transformation Stage	0.272	0.047	0.991	3.2%
3.1.	Facilities and equipment needed to process diverted materials	0.372	0.097	0.965	-16.3%
3.1.1.	Number of process steps to metallic form	0.386	0.079	0.919	-14.6%
3.1.2.	Number of export controlled/equipment/materials	0.331	0.058	0.266	15.7%

3.1.3.	Minimum electrical requirement	0.283	0.074	0.905	-0.4%
3.2.	Workforce required for transformation	0.317	0.115	0.576	20.3%
3.3.1.	Number of unskilled workers required (e.g. construction)	0.123	0.089	1.000	2.4%
3.3.2.	Number of skilled workers required (e.g. electrician)	0.173	0.100	0.999	55.2%
3.3.3.	Number of advanced degree work (e.g. Grad Student Work)	0.291	0.098	0.893	6.4%
3.3.4.	Number of Technical Experts (e.g. Physicists on chromodynamics)	0.413	0.155	1.000	-38.5%
3.3.	Difficulty of evading detection of transformation activities	0.320	0.081	0.178	-10.5%
3.4.1.	Additional Protocol in force?	0.109	0.051	0.639	33.1%
3.4.2.	Environmental sampling rate	0.115	0.027	0.927	3.4%
3.4.3.	Sensitivity of IAEA equipment	0.104	0.045	0.111	48.5%
3.4.4.	Isotopic signatures	0.129	0.034	0.988	18.0%
3.4.5.	Facility size	0.103	0.032	0.597	33.4%
3.4.6.	Heat load of transformation process	0.079	0.028	0.985	-29.4%
3.4.7.	Sonic load	0.067	0.032	1.000	-20.9%
3.4.8.	Radiation load	0.092	0.035	0.529	-66.6%
3.4.9.	Volume of non-naturally occurring gases emitted	0.100	0.037	0.186	-44.2%
3.4.10.	Undiluted volume liquid emissions	0.101	0.032	0.274	-55.2%
4.	Weapons Fabrication Stage	0.221	0.062	0.987	1.9%
4.1.	Difficulty associated with design	0.331	0.084	0.111	12.5%
4.1.1.	Spont. fission n prod. Rate	0.201	0.054	0.034	-2.7%

4.1.2.	Radiation exposure at one meter	0.186	0.071	0.569	-21.5%
4.1.3.	Heating rate of weapons material	0.187	0.053	0.698	-41.1%
4.1.4.	Can use ballistic assembly methods?	0.199	0.065	0.034	-0.2%
4.1.5.	Number of phases in the phase diagram	0.227	0.100	0.732	45.9%
4.2.	Handling difficulties	0.299	0.099	0.942	-17.2%
4.2.1.	Radiation level in terms of dose	0.317	0.099	0.409	8.8%
4.2.2.	Chemical reactivity	0.358	0.071	0.892	0.5%
4.2.3.	Radiotoxicity	0.325	0.064	0.235	-9.4%
4.3.	Knowledge and skills needed to design and fabricate	0.392	0.082	1.000	0.2%
4.3.1.	Knowledge and skill level for material/weapon type alternatives	1.000	0.000		0.0%

CONCLUSION AND FUTURE WORK

Several of the attributes were determined to be significantly different from the uniform case analysis, showing that not only are uniform case analyses inappropriate, but that it is possible to successfully define the institutional knowledge in a way to be useful to numeric analysis. This inclusion of institutional knowledge should lead to more accurate analyses when conducted by primarily numeric PR analyses such as SAPRA, Giannangeli's Method, and the upcoming method for which this survey was undertaken, the Proliferation Resistance Analysis and Evaluation Tool for Observed Risk (PRAETOR). Future analyses which are executed should not only deviate from uniform assumptions but also consider the stakeholder to which the analysis is directed.

Experts tended towards "tried-and-true" physical measurements, while nonexperts were more open to chemical, calorimetric, and other attributes less associated with current materials control and accountability practices. If an analysis is able to compare the relative effectiveness in many of these attributes, further research opens in the comparison of true effectiveness against perceived effectiveness to determine if a false bias exists in the nonproliferation community.

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