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Improvements to the Probabilistic Risk Assessment Tool for Radiological Dispersal

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Defence R&D Canada – Ottawa

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Improvements to the Probabilistic Risk Assessment Tool for Radiological Dispersal Devices

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Abstract

Following the recommendations from DRDC Ottawa TM 2009-274 *An evaluation of the Probabilistic Risk Assessment Tool for radiological dispersal devices*[1], some identified problems were investigated and fixed in the Probabilistic Risk Assessment (PRA) Tool for Radiological Dispersal Devices (RDDs). This includes issues related to the calculation of feasibility and consequence variables, but also coding problems which affected the behaviour of the software. Prior to these improvements, the code of the PRA Tool was overhauled in order to allow the software to work properly with currently available dependencies and also to increase its speed and accuracy.

Résumé

À la suite des recommandations contenues dans le document *An evaluation of the Probabilistic Risk Assessment Tool for radiological dispersal devices*[1], DRDC Ottawa TM 2009-274, certains des problèmes identifiés pour l'outil d'Évaluation Probabiliste des Risques (PRA Tool) associés aux Dispositifs de Dispersion Radiologique (DDR) ont été examinés et résolus. Ces problèmes incluent certains éléments reliés aux calculs de faisabilité et de conséquences, mais également des erreurs de programmation affectant l'utilisation du logiciel. Précédant ces modifications, le code du PRA Tool a fait l'objet d'une mise à jour importante afin de permettre au logiciel de fonctionner correctement lorsque utilisé avec les versions les plus récentes des logiciels et librairies dépendantes et aussi de sorte à améliorer sa vitesse d'exécution et sa précision.

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Executive summary

Improvements to the Probabilistic Risk Assessment Tool for Radiological Dispersal Devices

Pierre-Luc Drouin; DRDC Ottawa CR 2011-028; Defence R&D Canada – Ottawa; June 2011.

Introduction and Background: The PRA Tool (project CRTI-02-0024RD) is a computer software that was developed to assess the probabilistic risks for radiological dispersal devices. The tool currently supports over 1.3 million different types of RDD events. Risks are computed using the product between the feasibility of a specific event and the consequences resulting from a successful attempt.

Feasibilities: In the PRA Tool, feasibilities are defined as the probability of success for a RDD, given the existence of the intent for a specific attack. Following the results from the analysis presented in DRDC Ottawa TM 2009-274, different reported problems related to the calculation of these feasibilities were fixed in the software. These include a significant change in the calculation of the joint feasibility for the different groups of radiological materials and a modification of the feasibilities for solid practices.

Consequences: The consequences that are evaluated by the PRA Tool consist in the dose to the population, the disruption of the economic activity and the decontamination costs. After the identification of some issues in the evaluation of the disruption costs for outdoor energetic RDDs, an improved model has been implemented for such scenarios, after performing multiple simulations. Scenario-dependent minimum number of disrupted people have also been added to the calculations. Finally, disruption consequences resulting from worried well individuals have been incorporated.

Software Improvements: In order to allow the usage of the PRA Tool with up-to-date dependencies, the software has been updated to use a new, freely available back end. The accuracy of risk and consequence calculations has been improved significantly, going from three digits to double precision. The histogramming code has been replaced, allowing to compute risks over an order of magnitude faster.

Future Plans: It is acknowledged that the PRA Tool would benefit from being able to handle uncertainties and correlations and to propagate them through the risk calculations. Work is thus underway to give to the tool the flexibility required to allow the integration of such parameters. These modifications are also recommended to expand the usage of the PRA Tool for other types of events.

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Improvements to the Probabilistic Risk Assessment Tool for Radiological Dispersal Devices

Pierre-Luc Drouin ; DRDC Ottawa CR 2011-028 ; R & D pour la défense Canada – Ottawa ; juin 2011.

Introduction et mise en contexte : Le PRA Tool (projet CRTI-02-0024RD) est un logiciel qui a été développé afin d'évaluer les risques probabilistes associés aux dispositifs de dispersion radiologiques. Présentement, ce logiciel supporte plus de 1.3 million d'événements DDR de types différents. Les risques y sont calculés à l'aide du produit entre la faisabilité d'un événement spécifique et les conséquences résultant d'une tentative réussie.

Faisabilités : Dans le PRA Tool, les faisabilités sont définies comme étant la probabilité de succès pour un DDR, conditionellement à l'existence d'une intention pour une attaque spécifique. À la suite des résultats contenus dans le document DRDC Ottawa TM 2009-274, différents problèmes reliés au calcul de ces faisabilités ont été résolus. Ces changements incluent une modification du calcul de la faisabilité conjointe pour les différents groupes de matériels radiologiques ainsi qu'une correction des valeurs de faisabilité pour les pratiques solides.

Conséquences : Les conséquences considérées par le PRA Tool incluent les doses reçues par la population, la perturbation de l'activité économique et les coûts de décontamination. Après avoir identifié certains problèmes dans l'évaluation des coûts de perturbation pour les DDR qui sont à la fois énergétiques et à l'extérieur, un modèle amélioré a été implémenté pour ces scénarios. Des valeurs minimales et dépendant sur les scénarios pour le nombre de personnes perturbées ont aussi été incorporées. Finalement, des conséquences pour les perturbations résultant des individus inquiets sans fondement ont aussi été ajoutées.

Améliorations du logiciel : Le PRA Tool a été mis à jour afin d'utiliser un nouveau système dorsal de traitement. La précision des calculs de risque et de conséquences a été aussi améliorée significativement, passant de trois chiffres à la double précision. Le code de génération d'histogrammes a été remplacé, permettant de calculer les risks plus de dix fois plus rapidement.

Plans futurs : Le PRA Tool bénéficierait de supporter des incertitudes et des corrélations et de pouvoir propager celles-ci à travers les calculs de risque. Du travail est présentement en cours afin de donner au logiciel la flexibilité nécessaire pour permettre d'intégrer ces paramètres. Ces modifications sont aussi recommandées afin d'étendre l'utilisation du PRA Tool pour d'autres types d'événements.

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1 Modification of Feasibility Calculations

The PRA Tool estimates risks by first evaluating feasibilities and consequences and then by computing their product. Event feasibilities differ from event probabilities by the fact that the former assume that the intent is already fixed, while the latter include an evaluation of this intent. The probability of an event $P(\text{event})$ is thus given by

$$P(\text{event}) = P(\text{intent})P(\text{event}|\text{intent}), \tag{1}$$

where $P(\text{event}|\text{intent})$ is the feasibility, that is, the probability of an event conditional to the intent. In the PRA Tool, feasibilities are defined differently however, as no attempt is made to determine their absolute scale. These feasibilities are only significant when values from different options are considered, since all options from a given "basic event" share the same scale. In [1], different problems in the PRA Tool related to feasibility calculations were identified. This section presents the modifications that were made to fix some of them.

1.1 Practice Feasibility Calculation

In the tool, a "practice" represents a group of RAdiological Materials (RAMs). Each one of these practices is characterised by a type of legitimate application. A total of 44 practices were defined, including 35 solid, 5 powder, 3 liquid and 1 gas practices.

1.1.1 Joint Feasibility Calculation

The feasibility associated to a practice is evaluated using three parameters: "availability" (A), "ease-of-handling" (E) and "security" (S)[2]. Originally, the joint feasibility (F) for a given practice was computed using

$$F = 10^{\sqrt{(\log A)^2 + (\log E)^2 + (\log S)^2}}. \tag{2}$$

The reasoning behind the usage of the addition in quadrature and the logarithms was to reduce the overall spread in the results[1], which would otherwise spans over 4 orders of magnitudes.

However, it is not clear if a reduced range is appropriate. From a probabilistic point of view, the joint feasibility for a practice i, that is to say the probability of success in acquiring RAM from the practice group i given the intent, is given by

$$P(\text{acquire } i|\text{intent}) = P(\text{find } i \cap \text{take } i \cap \text{handle i}|\text{intent}), \tag{3}$$

where $\cap$ is the intersection operator, and where "find", "take", and "handle" represent the steps necessary to acquire the RAM and which are associated to the parameters A, E and S

respectively. Using the definition of conditional probability then gives

$$\begin{aligned}
&P(\text{acquire } i|\text{intent}) \\
&\qquad = P(\text{find } i|\text{intent})P(\text{take } i \cap \text{handle i}|\text{intent} \cap \text{find } i) \\
&\qquad = P(\text{find } i|\text{intent})P(\text{take } i|\text{intent} \cap \text{find } i)P(\text{handle i}|\text{intent} \cap \text{find } i \cap \text{take } i). \quad (4)
\end{aligned}$$

In the above expression, $P(\text{find } i|\text{intent})$ is the feasibility for finding the radioactive material, while $P(\text{take } i|\text{intent} \cap \text{find } i)$ is the feasibility for taking it once it was found and $P(\text{handle i}|\text{intent} \cap \text{find } i \cap \text{take } i)$ is the feasibility for handling the material once it was found and taken. These three feasibilities should be directly proportional to the parameters A, E and S respectively. It is thus asserted that the joint feasibility should be computed from the product of the parameters A, E and S. The code of the PRA Tool has been modified to reflect this change. Table 1 shows the updated feasibility values along with the previous ones for the different practices.

1.1.2 Correlated Practice Feasibility Variables

In [1], it is mentioned that the original method to compute the joint feasibilities, (2), was partially motivated by a desire to avoid overcompensating for the correlations between the parameters A, E and S, since they all depend strongly on the source strength. However, the method of computing a joint feasibility, as described in the previous section, considers the correlations between the different feasibilities and gives the most probable joint feasibility for a given practice, assuming that the parameters were evaluated as defined above by the subject matter experts. The correlations between the parameters A, E and S are thus not relevant to compute the most probable joint feasibility. They would be important however in the calculation of the uncertainty on the joint feasibility if the uncertainties on the individual parameters were considered by the PRA Tool.

1.1.3 Feasibility for Unconverted Practices

It was noticed in [1] that the scale for the physical form conversion feasibilities was not appropriate for the solid practices, because the “Choose No Conversion” option for these practices had a value different than one, the implicit value used for powder, liquid and gas practices. All the physical form conversion feasibility values for the solid practices have thus been scaled up by a factor of $1/0.29$ to fix this problem. Table 2 shows the old and the new feasibility values for the different conversion options.

1.2 PRA Tool Feasibility Correlations

As identified in [1], a number of correlations are currently not considered in the fault tree diagram of the PRA Tool. To take such correlations into account, non-trivial design and

Table 1: *Updated feasibilities associated to the different practices, along with the previous values.*

Practice	Old Feasibility	New Feasibility
Group G03: Solid Practice		
Bulk Radioisotopes (solid)	0.0047	$6.93401976073982\times10^{-4}$
Calibration Facilities	0.0015	$1.37637685476339\times10^{-4}$
Consumer Products	0.1036	$1.81025996259916\times10^{-1}$
Fixed Industrial Gauges	0.0052	$1.28322811812789\times10^{-3}$
Fresh Fuel (enriched)	0.0023	$1.38810733932104\times10^{-4}$
Fresh Fuel (natural)	0.0048	$4.39893170911596\times10^{-4}$
High-Medium Dose Rate Brachytherapy	0.0049	$9.00206074201311\times10^{-4}$
High Level Waste	0.0003	$7.24103985039664\times10^{-6}$
Industrial Chemicals	0.1036	$1.81025996259916\times10^{-1}$
Industrial Radiography	0.0435	$4.07699507736733\times10^{-2}$
Instrument Check Sources (Medical)	0.0311	$1.85080978576138\times10^{-2}$
Irradiators (Industrial)	0.0006	$2.23024027392217\times10^{-5}$
Irradiators (Portable)	0.0014	$1.03807547295286\times10^{-4}$
Irradiators (Self-shielded & blood)	0.0016	$1.28600867743044\times10^{-4}$
Laboratory Equipment	0.0549	$6.02686228828213\times10^{-2}$
Large Calibration Sources	0.0044	$8.55485412085261\times10^{-4}$
Lightning Preventors	0.0290	$7.92749042821424\times10^{-3}$
Long-lived Isotopes	0.0153	$1.15856637606346\times10^{-3}$
Low-intermediate level waste	0.0090	$2.50250337229708\times10^{-3}$
Low-dose rate brachytherapy (except below)	0.0280	$1.33669595638322\times10^{-2}$
Low-dose rate (eye plaques & permanent implants)	0.0280	$1.33669595638322\times10^{-2}$
Medical Radioisotope Generators	0.0124	$3.83717183752219\times10^{-3}$
Miscellaneous Solid Sources	0.0093	$1.14046377643747\times10^{-3}$
NORM	0.0280	$1.15856637606346\times10^{-2}$
Neutron Sources	0.0249	$9.97091187399618\times10^{-3}$
Ore & Ore Concentrates	0.0020	$2.11322506993976\times10^{-4}$
Portable Gauges	0.0435	$4.07699507736733\times10^{-2}$
Radioisotopic Generators	0.0060	$7.29896816919982\times10^{-4}$
Small Calibration Sources	0.0922	$1.30338717307140\times10^{-1}$
Static Eliminators	0.0435	$4.07699507736733\times10^{-2}$
Teletherapy Machines	0.0027	$4.11522776777742\times10^{-4}$
Thickness & Fill Gauges	0.0435	$4.07699507736733\times10^{-2}$
UF6 (enriched)	0.0015	$1.37637685476339\times10^{-4}$
UF6 (natural)	0.0011	$9.46259087649833\times10^{-5}$
Well Logging Gauges	0.0383	$2.94449644476529\times10^{-2}$

Practice	Old Feasibility	New Feasibility
Group G04: Liquid Practice		
Bulk Radioisotopes (liquid)	0.0047	$6.93401976073982\times10^{-4}$
Medical Radioisotopes (unit dose)	0.0715	$8.86303277688549\times10^{-2}$
Research Sources	0.0549	$6.02686228828213\times10^{-2}$
Group G05: Gas Practices		
Miscellaneous Noble Gases	0.0020	$2.11322506993976\times10^{-4}$
Group G06: Powder Practices		
Tritium	0.0300	$1.40657199093955\times10^{-2}$
UO2 (enriched)	0.0027	$3.05383614650628\times10^{-4}$
UO2 (natural)	0.0027	$3.05383614650628\times10^{-4}$
UO3	0.0019	$2.06456528214509\times10^{-4}$
Yellowcake	0.0034	$4.68871812392883\times10^{-4}$

Table 2: *Feasibilities associated to the conversion of solid practices into some other physical forms.*

Conversion Option	Old Feasibility	New Feasibility
Choose no conversion	0.29	1.00
Chemical conversion to liquid	0.18	0.60
Thermal conversion to gas	0.04	0.14
Chemical conversion to gas	0.09	0.30
Mechanical conversion to powder	0.17	0.61
Chemical conversion to powder	0.14	0.48
Thermal conversion to powder	0.09	0.33

coding work is necessary and also significant inputs will be required from subject matter experts. Regarding the development of the tool, the current structure of the relational database (or even a database using fixed table schemas) is not really appropriate to handle correlation tables or conditional probabilities and would need extensive redesign to allow it. The current database performance is also a limiting factor for the amount of extra information that can be stored. Finally, the actual tool's code strongly depends on the database structure, such that important changes of this code would be also necessary to handle correlations in addition to the modifications associated to the calculation of feasibilities. Considering these different elements, it seems that it would be more productive to replace the data management system of the PRA Tool prior to investing important efforts to include such correlations. The tool would greatly benefit from such changes at other levels. Important gains in performance would be expected combined with a significantly increased flexibility which would allow to expand the tool's functionalities much more easily in the future.

2 Modification of Consequences Calculations

To compute the consequences of RDD events, the PRA Tool evaluates the effects of the following elements:

– The dose to the population.
– The costs associated to the disruption of the economy.
– The decontamination and/or rebuilding costs.

The total consequences are then obtained by adding the individual contributions together, using a conversion factor of 250 000 $\$/(\text{person Sv})$ between doses and costs.

2.1 Disruption Time for Non-Explosive Energetic RDDs

In the PRA Tool, disruption costs are computed using the disruption time, the number of disrupted people, their average salary per working day and an “economic impact factor” which relates salaries to economic activity. In [1], it was discovered that the disruption time for non-explosive energetic RDDs was mistakingly set to one day instead of 30 days. This is fixed in the current version of the tool.

2.2 Number of Disrupted People

2.2.1 Reevaluation of the Number of Disrupted People for Outdoor Energetic RDDs

For outdoor energetic RDD scenarios, the PRA Tool evaluates the number of disrupted people using a function depending on source activity (A) and dispersability (d) and which was determined from HPAC studies, as documented in [3]. In this document, the number of disrupted people as a function of the contamination threshold is plotted and a piecewise function is fitted for three ranges of contamination. However, it has been found recently that the function used by the PRA Tool was greatly overestimating the number of disrupted people. The software uses the function

$$N_d = 8.25 \times 10^{-6} (Ad)^{0.72481}, \tag{5}$$

which is based on the high contamination ($> 748.4178\ \text{Bq}/\text{cm}^2$) region of the fitted piecewise function, although the calculation for the number of disrupted people should be based on a committed effective dose equivalent (CEDE) threshold of only about 1 mSv in a day.

To remedy this problem, a series of HPAC simulations were performed using the same configuration as the original studies, but this time using different ^{137}Cs source activities,

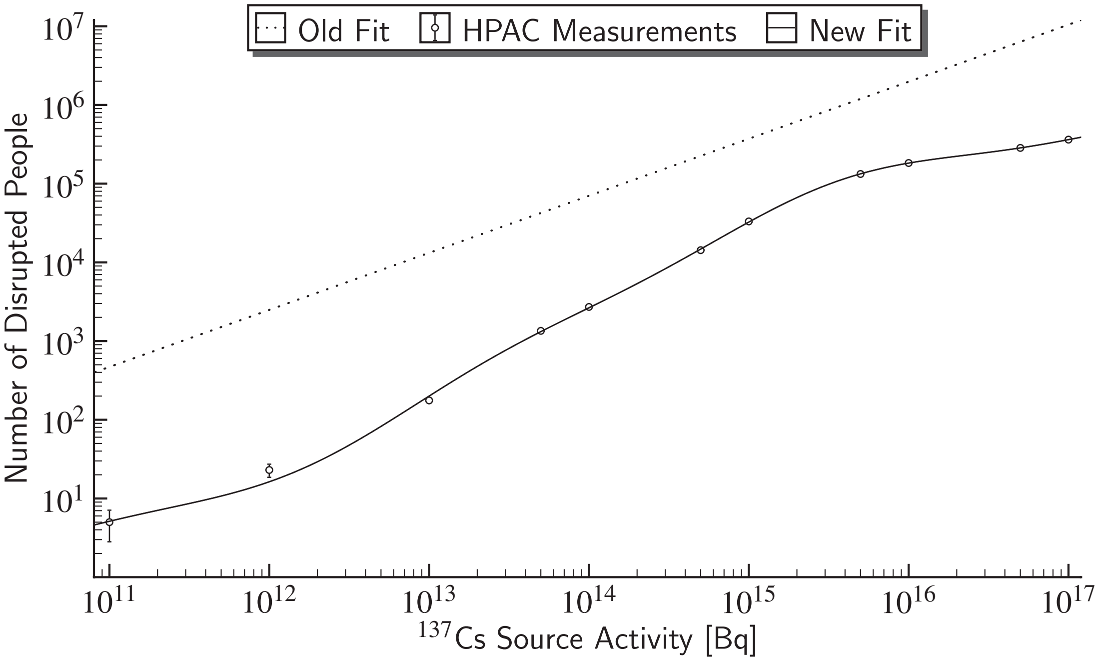

Figure 1: *Number of disrupted people (defined as the number of people affected by a committed effective dose equivalent of 1 mSv or greater for a period of 24 hours) obtained with the mentioned HPAC simulations as a function of the source activity. Also shown is the fit of an analytical function to the data points and the old function. Error bars used for the fit are simple Poisson statistical uncertainties.*

ranging from 10^{11} to 10^{17} Bq. The number of people exposed to a CEDE above 1 mSv in a day was then computed for each simulation. Figure 1 shows the results from these simulations, along with the function (5) when using a dispersability value of 0.5, as prescribed in [3]. Also shown is a fit of an analytical function to the new HPAC simulation results, using the same dispersability value. The new analytical function has the form

$$N_d = a_0(Ad)^{a_1} 10^{a_2 \sin[a_3 \log_{10}(Ad)+a_4]+a_5 \sin[a_6 \log_{10}(Ad)+a_7]}, \tag{6}$$

where the sine functions are measured in radians and where the parameter values are shown in Table 3. In the fit, simple Poisson statistical uncertainties were assumed for the HPAC measurements, although the actual uncertainties are expected to be much larger (but they are not provided by HPAC).

2.2.2 Number of Disrupted People for Low Activity and/or Dispersability RDDs in Outdoor Energetic Scenarios

As noted in [1], the disruption costs associated to outdoor energetic events with low activity sources seem to be underestimated by the PRA Tool. In order to provide more realistic

Table 3: *Values for the parameters of the new analytical function* (6) *used to evaluate the number of disrupted people for outdoor energetic RDD events.*

Parameter	Value
a_0	$6.085885892448474\times10^{-7}$
a_1	$6.916875055465214\times10^{-1}$
a_2	$6.301523569235662\times10^{-1}$
a_3	$8.037163323633574\times10^{-1}$
a_4	1.851441350588543
a_5	$6.722397988418964\times10^{-2}$
a_6	2.817983842071209
a_7	$-2.886926907276951\times10^{1}$

results, scenario-dependent numbers of disrupted people N_s are now added to Equation (6). These numbers were determined using the following method:

- It was first assumed that any outdoor dispersal would at least disrupt people within the area of a city block (which has an approximative area of 100 m × 100 m = 0.01 km^2).
- For scenarios in urban areas, it was assumed that people from four office buildings would be disrupted, each building representing 1000 people.
- For scenarios where the release occurs near a specific type of building, the number of disrupted people was calculated using the number of people affected by the corresponding indoor scenario for this building. If this building was likely to be located in an urban area, 3000 people were assumed to be disrupted in (three) other buildings in the same city block.
- Otherwise for scenarios involving a release at a generic location in a suburban area, N_s was computed using the population density in Montreal suburbs using results from the 2006 census[4][5], giving 1.2 person per block. Finally, N_s is set to 0 for rural areas.

The scenario-dependent numbers of disrupted people for outdoor energetic events, as used in the updated version of the PRA Tool, are shown in Table 4.

2.2.3 Estimation of the Number of Worried Well People for Outdoor Scenarios

If an outdoor RDD event occurred, there would be important economic consequences associated to people disrupted by the radiation, as it was estimated in Section 2.2.1. However, case studies show that an even larger number of people are expected to be disrupted by such an event, without having any exposure to the material. It is estimated that there would be about three of these "worried well" people for each genuinely affected person[6].

To take into account additional disruption costs associated to the worried well people, the updated version of the PRA Tool first computes this number of people using the number of genuinely affected people and a "worried well to genuine" ratio, $r_{w\rightarrow g}$. The number

Table 4: *Scenario-dependent minimum numbers of disrupted people for outdoor energetic events, as implemented in the updated version of the PRA Tool.*

Scenario	Number of Disrupted People
Urban	4000
Near government building	5000
Suburban	1.2
Near critical infrastructure	10000
Near hospital	3400
Near prison	60
Near school	2150
Rural	0
Tourist Attraction	2000

of genuinely affected people here excludes the scenario-dependent number N_s for outdoor energetic scenarios, since these people are considered to be already disrupted whether or not they are exposed. The disruption associated to worried well people, in "person day", is thus computed using this number of worried well people and the disruption time for each individual. This parameter should represent the time required for diagnosis and treatment of the worries and is currently set to two days.

2.2.4 Summary of Disruption for Outdoor Scenarios

For outdoor scenarios, disruption, in "person day", is now computed using

$$D = N_s t_s + N_d (t_s + r_{w\to g} t_w), \tag{7}$$

where N_s is the scenario-dependent number of disrupted people for energetic releases, where N_d is the number of genuinely affected people (which depends on the source activity for energetic releases), where $r_{w\to g}$ is the worried well to genuine ratio, currently set to three, where t_s is the scenario-dependent disruption time for genuinely affected people and where t_w is the disruption time for worried well people (currently two days).

3 Other Updates

The code of the PRA Tool having not been updated for a few years, a number of changes were required to allow the software to work correctly with the current version of its dependencies. Some problems were also identified regarding the usage of its graphical interface. This section addresses the modifications of the PRA Tool related to these aspects.

3.1 Replacement of the Borland JDataStore^{TM} Database

Originally, the PRA Tool was using a Borland JDataStore^{TM} database to store the basic event, practice, scenario, histogram and system constant information for the different user profiles. This database product was a closed-source commercial software which no longer exists. It was necessary to replace this database to ensure correct functioning with the current and future versions of Java^{TM}.

Java defines the JDBC^{TM} API that allows database operations through an almost database-independent interface. A number of JDBC drivers have been written, including a SQLite driver from the Xerial project[7]. This driver is open-source, Apache Licensed (version 2.0) and actively maintained, which makes it favourable for the PRA Tool. The code of the PRA Tool has thus been modified to use the JDBC interface instead of the JDataStore API. A conversion tool was written and the old database was converted into a SQLite database.

3.2 Increase of Calculation Accuracy

In the previous version of the PRA Tool, the accuracy of the feasibility and consequence calculations was limited to only three significant digits. This constraint has been removed, but it rendered risk calculation processing very slow, going from two minutes to over 16 minutes. Profiling of the software revealed that the histogramming code, not the risk calculations *per se*, was the source of the inefficiencies. The feasibility, consequence and risk values were binned twice while generating the histograms and this was performed using linear algorithms.

3.3 Replacement of the Existing Histogramming Code

To remedy this problem, the histogramming code of the PRA Tool has been completely replaced with a logarithmic algorithm that uses a binary search to find bins. Using this new code, risk calculation time using the improved numerical accuracy went down from 16 minutes, as mentioned above, to only 1.5 minute. The processing time is now mostly limited by database operations.

3.4 Replacement of the Graphical Object Layout Manager

While working with the PRA Tool, it has been noticed that some of the graphical objects were not scaling properly when resizing the window of the software and that some of the lists in the “Assess” panel were missing scroll bars (the latter problem might be a consequence of using a newer version of Java). To fix these issues, and also to get rid of the dependency on the class `VerticalFlowLayout` from Borland, the code has been modified to use `MiGLayout`[8], an open-source, BSD licensed layout manager.

3.5 Rewriting of the Export/Import Functionalities

Along with the JDataStore database SQL operations, the Borland package used by the previous version of the PRA Tool included a class `TextDataFile` that was used for the import and export functionalities of the PRA Tool. As a substitute, a new class was created which allows to load the legacy files and also to export profiles suited for the updated version of the tool.

Along with the other changes described above, the PRA Tool is now completely independent from the discontinued Borland JDataStore package. While it was still available, JDataStore required the purchase of licenses for the users of the library. It is no longer necessary, since all the dependencies were replaced by open-source solutions.

4 Conclusions

Important changes to the feasibility calculations in the PRA Tool have been performed. These include mainly the joint feasibility calculations for the different practices and the feasibilities for the solid practices relatively to the powder, liquid and gas practices.

Significant changes have also been made regarding the calculation of the number of disrupted people for outdoor scenarios, including the activity-dependent and an added scenario-dependent numbers of disrupted people for energetic scenarios. The number of worried well people are now also considered.

Regarding software-related modifications, the old back end has been replaced by a newer, maintained database solution. Calculation accuracy has been greatly improved and computation efficiency was increased. Finally, the management of the graphical objects has been upgraded.

The current plan for future development is to give the tool the flexibility that is necessary to incorporate uncertainty and correlation propagation along with the possibility to integrate additional components of risk assessment more easily.

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Following the recommendations from DRDC Ottawa TM 2009-274 *An evaluation of the Probabilistic Risk Assessment Tool for radiological dispersal devices*[1], some identified problems were investigated and fixed in the Probabilistic Risk Assessment (PRA) Tool for Radiological Dispersal Devices (RDDs). This includes issues related to the calculation of feasibility and consequence variables, but also coding problems which affected the behaviour of the software. Prior to these improvements, the code of the PRA Tool was overhauled in order to allow the software to work properly with currently available dependencies and also to increase its speed and accuracy.

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