DEVELOPMENT OF A RISK ASSESSMENT CALCULATOR BASED ON A SIMPLIFIED FORM OF THE IEC 62305-2 STANDARD ON LIGHTNING PROTECTION

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Abstract: IEC Technical Committee 81 is currently creating the new IEC 62305 series of standards on Lightning Protection. Working Group 9 is responsible for Part 2 of this series, which deals with the assessment and management of risk its CDV (Committee Draft for Voting) stage and has been circulated to National Committees for comment.

The paper details the development of the Simplified IEC Risk Assessment Calculator software tool as described in Informative Annex J of IEC62305-2 Ed.1/CDV 2. This tool is intended as a simplified implementation of the more rigorous treatment of risk management found in the written document. It is designed to be relatively intuitive for users who wish to obtain an initial assessment of risk sensitivity, but should not be considered a substitute to a full understanding of the methods provided in the standard when dealing with more complicated structures or those where greater risks to personal or system operation are involved.

Keywords: Risk, Risk Management, Risk Assessment, Lightning Risk, Lightning Protection.

1. INTRODUCTION

The simplified IEC Risk Assessment Calculator is intended to function as a companion, and not alternative, to the written standard. Its intended purpose (and limitations) may be summarised as follows:

- To promote the risk management methods detailed in the standard in a simplified and user-friendly format, thereby gaining wider adoption within the lightning protection community by lightning protection installers and general contractors.
- To enable more general users of the IEC 62305-2 standard to conduct calculations on typical structures without requiring that they first have an in-depth knowledge of the details and methodologies covered in the body of the standard.
- The software does not implement the full functionality of the written standard – such an implementation would have added unintended complexity to the tool. Users are encouraged to use the written standard for a more detailed treatment of risk when assessing complicated structures or special circumstances.
- The tool is intended to provide an assessment of the risk components pertaining to relatively uncomplicated structures. As such, certain parameters found in the written standard are defaulted to fixed values within the software and the user restricted to a subset of choices.
- The tool is designed to give conservative outcome. That is to say that it tends to give more protection rather than less protection required by the IEC standard.
- It is not intended to handle the calculation of risk exposure to services[5].

2. SOFTWARE INTERFACE

The user interface of the IEC Risk Assessment Calculator has been designed to fit on a single screen for ease of use - Figure 1. The user starts by making selections from drop-down selection boxes. After each selection, a complete recalculation of the background algorithms is automatically performed and the results displayed in the “Calculated Risks” frame.

As with the written standard, the software tool calculates the risk components of the four areas of risk:

$\mathbf{R_1}$: The risk of loss of Human Life
$\mathbf{R_2}$: The risk of loss of Essential Services
$\mathbf{R_3}$: The risk of loss of Cultural Heritage value, and
$\mathbf{R_4}$: The risk of Economic loss

It further subdivides these risk components into the contributions from a direct lightning discharge and the contribution from an indirect discharge. These calculated risk components are then compared to “Tolerable Risk values” as provided in the standard. Where the calculated risk is lower than the tolerable risk, it is highlighted in Green. Likewise, where the calculated risk exceeds the tolerable risk, it is highlighted in Red, thereby indicating to the user that risk management measures must be taken to lower the risk exposure.

The software tool is unable to provide direction as to how this should be achieved; rather, it is the responsibility of the user in conjunction with an understanding of the standard and the interaction of risk components, to make these adjustments. The tool does however provide the user with a quick and interactive means of assessing which parameters effect the particular risk component needing reduction and also of the relative sensitive of these parameters in making this adjustment.

For the more experienced user, a report of the individual components associated with the four loss categories can be viewed by clicking the “Calculations” button – figure 2. This information can be printed and used in conjunction with the written standard to better analyse the risk results and determine measures to improve these where necessary.

Parameters used in the algorithms to calculate the risk components, are divided into three categories:

- Those where the user can make choices as per the options provided in the written standard.
- Those where the user’s choices are restricted to a subset of the options provided in the written standard.
- Those where the values are fixed as constants and inaccessible to be altered.

This data can be viewed in Table 1 to 8.

The software provides standard windows based features including: the ability to print results, store and retrieve project files, use of interactive tooltips which provide guidance to the user as to the purpose of each drop-down control, multiple language support and an online upgrade facility.

This last feature is intended to allow the TC81 Working Group to update the database upon which the software relies, with new options and parameters as these become available. It is intended that updates of the software will be limited to releases that coincide with amendments to the written standard. No working group, or IEC central office, support of the software is envisaged. The tool is provided on an “as is” basis and is informative, not normative, to the standard.

3. SUMMARY

The Risk Assessment Software Calculator is a new approach being adopted by the IEC, to promote the wider use of their standards by providing easy to use software tools. This concept is in its infancy, and as such, the authors are encouraging the lightning community to thoroughly test and evaluate the software and provide feedback to TC81 WG9 via their national committees. A full paper providing detailed algorithms has been provided by the authors on the IEC TC81 ftp server and can be made available upon request.

As stated at the outset, this software is intended as a “simplified” tool, and by no means exhausts all the possibilities which software implementation opens up. It can be expected that more comprehensive, commercial packages will become available in the future which will enable lightning protection experts to conduct more detailed risk assessment studies.

A more comprehensive 22-page paper dealing with this software tool and providing relevant algorithms, is available upon request from the authors, and will in due course be made available as a download from the IEC TC81 FTP server.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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IEC 62305-2, Ed. 1: Protection against lightning - Part 2: Risk management (CDV stage).

IEC 62305-3, Ed. 1: Protection against lightning - Part 3: Physical damage to structures and life hazard (CDV stage).

IEC 62305-4, Ed. 1: Protection against lightning - Part 4: Electrical and electronic systems within structures (CDV stage).

IEC 62305-5, Ed. 1: Protection against lightning - Part 5: Services (NP stage).

6. DATA ENTRY TABLES

STRUCTURAL DIMENSIONS		
L, W, H	Structure length, width, height in metres	▪ **User entered**
H_p	Height of highest roof protrusion metres	▪ **User entered**

Table 1- Structure undergoing risk assessment

STRUCTURAL ATTRIBUTES		
r_f	Probability that a dangerous discharge will initiate a fire, explosion, mechanical destruction or chemical release.	High risk of mechanical and thermal effects. High or significant risk of fire or mechanical damage, roof of combustible material e.g. thatched roof - 10^{-1}

	IEC 61662 Ed 2, Page 28, Table B.7.	Ordinary risk of mechanical and thermal effects. Significant use of combustible building material, e.g. timber frame; or risk of mechanical damage, e.g. significant masonry dislodged - 10^{-2} Low risk of mechanical and thermal effects (e.g. modern reinforced concrete building) - 10^{-3} None - No risk of mechanical and thermal effects (all metal structure) - 0
Ks1	Screening effectiveness of external structure. *Annex B, based on Equation B3.*	Poor - Brick, masonry, flammable material, timber or non conducting material, unprotected roof installations with electrical lines to inside, e.g. antennae - 1.0 Average - Continuous reinforced concrete or steel columns or down conductors (maximum spacing 20m) - 0.2 Good - All metal construction - 10^{-4}
Ks2	Screening effectiveness of zones internal to the structure. *Assume no internal spatial screening of zones inside building.*	▪ **Fixed** factor - 1.0
P_A	Probability that lightning will cause a shock to animals or human beings inside and up to 3m outside of the structure due to dangerous step and touch potentials. *Annex B, Table B1.*	▪ **Fixed** factor - 1.0 (i.e. No protection measures adopted)
D_m	Distance from structure that a lightning strike to ground creates a magnetic field sufficient to induce an over-voltage exceeding the impulse level of equipment internal to the structure. *Annex A, Section A.3*	▪ **Fixed** factor - 250m

Table 2 - Structure undergoing risk assessment

ENVIRONMENTAL INFLUENCES		
C_d	Height factor for surrounding object height. (Direct strikes to structure). *Annex A, Table A1, Location factor. Name changed to more descriptive term Height factor. Value of 0.25 for same height has been added.* *Note: The software assumes there is no out building/s.*	▪ Structure in large area of structures or trees of the same height or greater height. e.g. typical building in CBD, or shed in an industrial area – 0.25 ▪ Structure surrounded by smaller structures e.g. tall building in urban area – 0.5 ▪ Isolated structure with no other structures or objects within a distance of 3 x height from the structure e.g. structure in a rural area – 1.0 ▪ Isolated structure on hilltop or knoll e.g. communications site – 2.0
C_e	Service Line Density -density factor relating to service drops. *Annex A, Table A4, Environment Factor. Name changed to more descriptive term of Service Line Density.*	▪ **Rural** (i.e. Sparse e.g. farms) - 1 ▪ **Suburban** (e.g. Large housing development or suburb) - 0.5 ▪ **Urban** (i.e. Dense e.g. town or city) - 0
T_d	Number of thunder days per year	▪ **User entered**
N_g	Equivalent annual flash density	▪ **Computed**

Table 3 - Location of structure relative to its environment.

BUILDING WIRING		
K_{s3}	Screening effectiveness of internal wiring type. *Annex B, Table B5. Reduced number of choices.*	▪ **Unscreened** wiring - 1.0 ▪ **Screened** (continuously) wiring - 0.1

Table 4 - Building wiring within the structure.

EQUIPMENT		
Ks4	Correction factor for impulse level of equipment.	Fixed factor - 1.0 [illegible]

		(applies to impulse withstand level of 1.5 kV)

Table 5 - Electrical / electronic equipment located within the structure.

CONDUCTIVE SERVICE LINES *There are 3 types of service lines – power (can be either underground or overhead), other overhead, and other underground. Any number of service lines can be selected. Note: they must be in different routes. Also the worst-case service line attributes must be entered. The service line lengths have been set based on the different land use in the "service line density" input field.*		
Power Lines:		
pl	Power line type.	▪ **Aerial** - 1.0 ▪ **Buried** - 2.0 ▪ **None** – 0
P_{LD0}	Probability of failure of electrical/electronic equipment due to direct or indirect strike to power service line **based on external wiring type**. *Annex B, Table B6. Reduced number of choices.*	▪ **Unscreened** wiring - 1.0 ▪ **Screened** cable with screen earthed or wiring in continuous metal conduit that is earthed - 0.4
C_{t0}	Correction factor for the presence of a distribution transformer. *Note: A transformer is only possible for the power line. Annex A, Table A3*	▪ LV line **without** a transformer - 1.0 ▪ MV line **with** a HV/LV transformer or isolation transformer - 0.2
Other Overhead Service Lines:		
n_{oh}	Overhead Service Line	▪ **User entered** - number of overhead service lines in separate routes.
P_{LD1}	Probability of failure of electrical/electronic equipment due to direct or indirect strike to other overhead service line **based on external wiring type.** *Annex B, Table B6. Reduced number of choices.*	▪ **Unscreened** wiring – 1 ▪ **Screened** cable with screen earthed, or wiring in continuous metal conduit that is earthed - 0.4
H_{cl}	Height of conductors above ground.	▪ **Fixed** value - 6m
D_{L1}	Lateral distance away from the overhead line at which the effects of indirect strikes need to be considered. *Annex A, Table A.2.*	▪ **Fixed** value - 500m
C_{t1}	Correction factor for transformer.	▪ **Fixed** factor - 1 (i.e. no isolation transformer)
l_{a1}, w_{a1}, h_{a1}	Dimensions of adjacent structure *Simplification made - assume there is no adjacent structure*	▪ **Fixed** value - 0m
Conductive Underground Services - Electrical Services e.g. Communication Lines:		
n_{ug}	Number of underground service lines in separate routes.	▪ **User entered** - number of underground service lines in separate routes.
P_{LD2}	Probability of failure of electrical/electronic equipment due to direct or indirect strike to other underground service line **based on external wiring type**. *Annex B, Table B6. Reduced number of choices.*	▪ **Unscreened** wiring - 1 ▪ **Screened** cable with screen earthed or wiring in continuous metal conduit that is earthed - 0.4
P_2	Soil resistivity.	▪ **Fixed** factor - 100 ohm metres.
C_{t2}	Correction factor for transformer.	▪ **Fixed** factor – 1 (i.e. no isolation transformer)
l_{a2}, w_{a2}, h_{a2}	Dimensions of adjacent structure *Simplification made - assume there is no adjacent structure.*	▪ **Fixed** value – 0m

Table 6 - Assumes one or no power line(s) and that this is either overhead or underground and that they are in separate routes. The length of service lines is determined from the selection of C_e as: "rural", "suburban" or "urban".

ACCEPTABLE RISK & LOSS CATEGORIES

Loss Category 1 - Loss of Human Life:		
h_1	Special hazards: Increasing factor applied to damage factor for fire and overvoltage when risk of loss of human life is aggravated by special hazards. *Annex C, Table C.5.*	▪ No special hazard – 1 ▪ Low level of panic (building with less than three floors and less than 100 people) – 2 ▪ Difficulty of evacuation, immobilised people – 5 ▪ Average level of panic (sport or cultural structure with between 100 and 1000 people) – 5 ▪ High level of panic (theatres, concert halls, cultural & sport events with more than 1000 people) – 10 ▪ Hazards for surroundings or environment – 20 ▪ Contamination of surroundings or environment – 50
L_{f1}	Loss factor for fire: *Annex C, Table C.1.*	▪ Hospitals, Hotels, Public buildings - 0.1 ▪ Industrial properties, Properties for commercial activities, Schools, Offices - 0.05 ▪ Public entertainment buildings, Churches, Museums, Temporary structure - 0.02 ▪ Other structures - 0.01
L_{o1}	Loss factor for overvoltages: *Annex C, Table C.1* *(option "0" added).*	▪ Properties with risk of explosion - 0.1 ▪ Hospitals - 0.001 ▪ Structures with safety critical systems e.g. high rise with elevator - 0.00001 ▪ Structures with no safety critical systems e.g. house - 0
R_{T1}	Tolerable risk: Probability of loss of human life per year. *Section 5.3, Table 5.*	▪ **Fixed** value for loss of human life 10^{-5}
L_{t1}	Loss factor for step and touch potentials: Unacceptable loss of human life due to step and touch potentials inside, and up to 3m outside. *Annex C, Table C.1.*	▪ **Fixed** value - 10^{-4}
R_a	Reduction factor in loss of human life based on floor/ground contact resistance for step and touch potential inside and up to 3m outside. *Annex C, Table C.2* *(worst case assumed).*	▪ **Fixed** value - 10^{-2}
Loss Category 2 - Loss of Essential Service to the Public:		
L_{f2}	Damage factor for fire: Unacceptable loss of service to the public due to fire. *Annex C, Table C.6.*	▪ Gas supply, Water supply - 0.1 ▪ Radio, TV, Telecommunications, Power supply, Railway - 0.01 ▪ No essential service function associated with the structure - 0
L_{o2}	Loss factor due to overvoltages: Unacceptable loss of service to the public due to overvoltages. *Annex C, Table C.6.*	▪ Gas supply, Water supply - 0.01 ▪ Radio, TV, Telecommunications, Power supply, Railway - 0.001 ▪ No essential service function associated with the structure - 0.0
R_{T2}	Tolerable risk: Probability of loss of essential service to the public per year. *Section 5.3, Table 5.*	▪ **Fixed** value for loss of human life - 10^{-3}
Loss Category 3 - Loss of Cultural Heritage: (It is assumed that there are no electronic devices inside)		
L_{f3}	Damage factor for fire: Unacceptable loss of irreplaceable cultural heritage due to fire. *Annex C, Table C.4.*	▪ Typical value - 0.1 ▪ No cultural heritage value - 0.0
R_{T3}	Tolerable risk: Probability of loss of cultural heritage per year.	▪ **Fixed** value for loss of cultural heritage - 10^{-3}

	Section 5.3, Table 5.	
Loss Category 4 - Economic Loss: (Economic loss is expressed as a probability. ie. 1 in 10 years means a probability of total loss of the structure once in 10 years)		
h_4	Increasing factor applied to situation where environmental hazards exist. *Annex C, Table C.5, reduced number of options.*	▪ No special hazard – 1 ▪ Hazards for surroundings or environment – 20 ▪ Contamination of surroundings or environment – 50
L_{f4}	Loss factor for fire: Unacceptable economic loss due to fire (average value of possible loss / total value of structure, contents & activities). *Annex C, Section C.5.* *(estimated values for different structures).*	Typical values of economic loss: ▪ Hospitals, Industrial properties, Museum, Agricultural properties - 0.5 ▪ Properties for public use, Hotels, Offices, Schools, Commercial activities, Public entertainment, Prisons, Churches - 0.2 ▪ Others - 0.1
L_{o4}	Loss factor due to overvoltages: Unacceptable economic loss due to overvoltages (average value of possible loss / total value structure, contents & activities). *Annex C, Section C.5.* *(estimated values for different structures).*	▪ Risk of explosion - 0.1 ▪ Hospitals, Hotels, Industrial properties, Offices, Commercial activities - 0.01 ▪ Museum, Properties for public use, Agricultural properties, Schools, Public entertainment, Prisons, Churches - 0.001 ▪ Others - 0.0001
L_{t4}	Loss factor for step and touch potentials: Unacceptable economic loss due to step and touch potential inside, and up to 3m outside, the structure. *Annex C, Section C.5.*	▪ Agricultural properties with animals inside or outside the structure - 0.01 ▪ Agricultural properties with no animal shock risk – 0
R_{T4}	Tolerable risk: Probability of economic loss per year.	▪ Depends on the structure owner's requirement. Range available is 0.1, 0.01, 0.001, 0.0001, 0.00001. ▪ Suggested default value if unknown - 0.001 (i.e. 1 in 1000 year probability of economic loss).

Table 7 - Tolerable risk and loss factors

PROTECTION MEASURES IMPLEMENTED		
E	Efficiency of lightning protection system on the structure: Takes into account interception and sizing efficiencies. Assumes surge protection is applied to either all OR none of the internal equipment within the structure.	▪ Level I - 98% ▪ Level II - 95% ▪ Level III - 90% ▪ Level IV - 80% ▪ No protection - 0.
r	Reduction factor for fire protection measures: *Annex C, Table C.3.*	▪ No protection measures - 1.0 ▪ Extinguishers, hydrants, manual alarm installations, fixed manually operated extinguishing installations - 0.5 ▪ Protected escape routes, fire proof compartments, automatic alarms protected from overvoltage, automatically operated extinguishers, operating time of escape routes less than 10 minutes - 0.2.
SP	Surge protection. Note: The user's selection of surge protection applies to all services and the entire structure being protected.	▪ No surge protection – 0 ▪ Equipotential bonding SPDs at the entry points of service lines – 1.0 ▪ Full Surge Protection "*SPD Set*" as detailed in IEC 62305-4: - 2.0

Table 8 - Measures adopted on the structure to reduce damage due to lightning

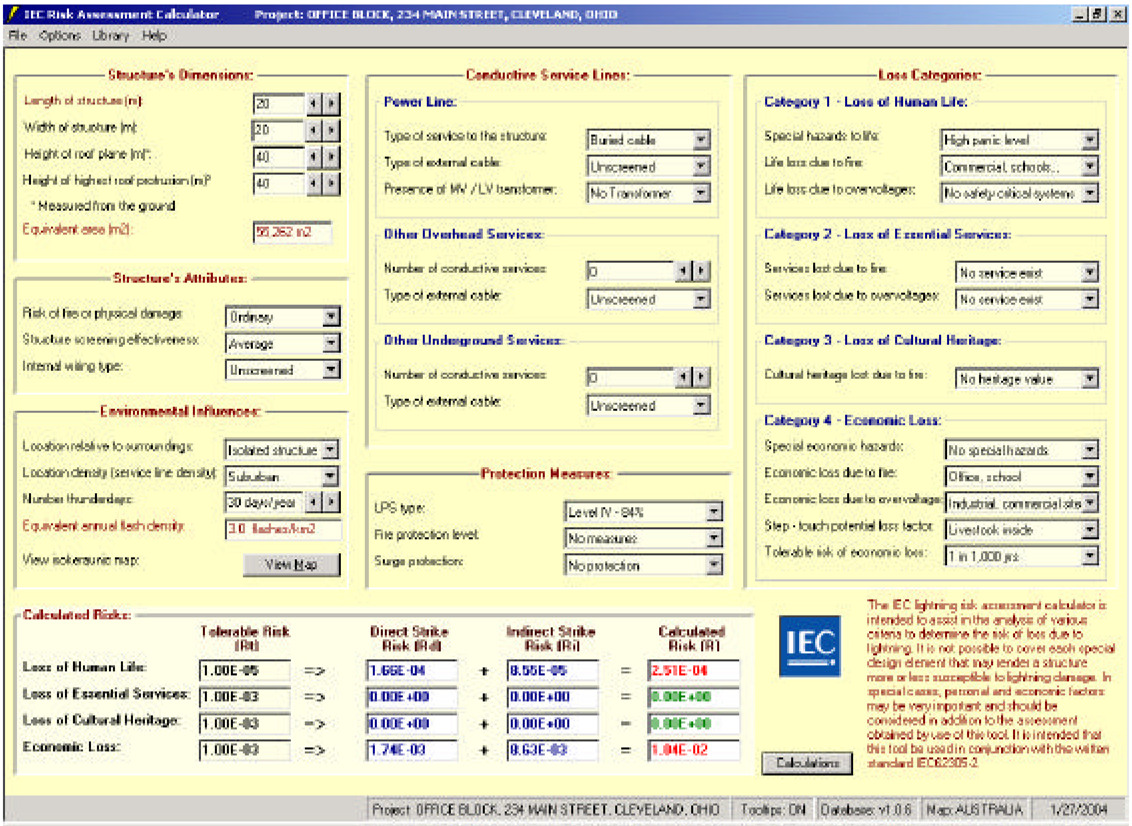

Figure 1- Main User Interface showing user-entered input parameters and menu structure.

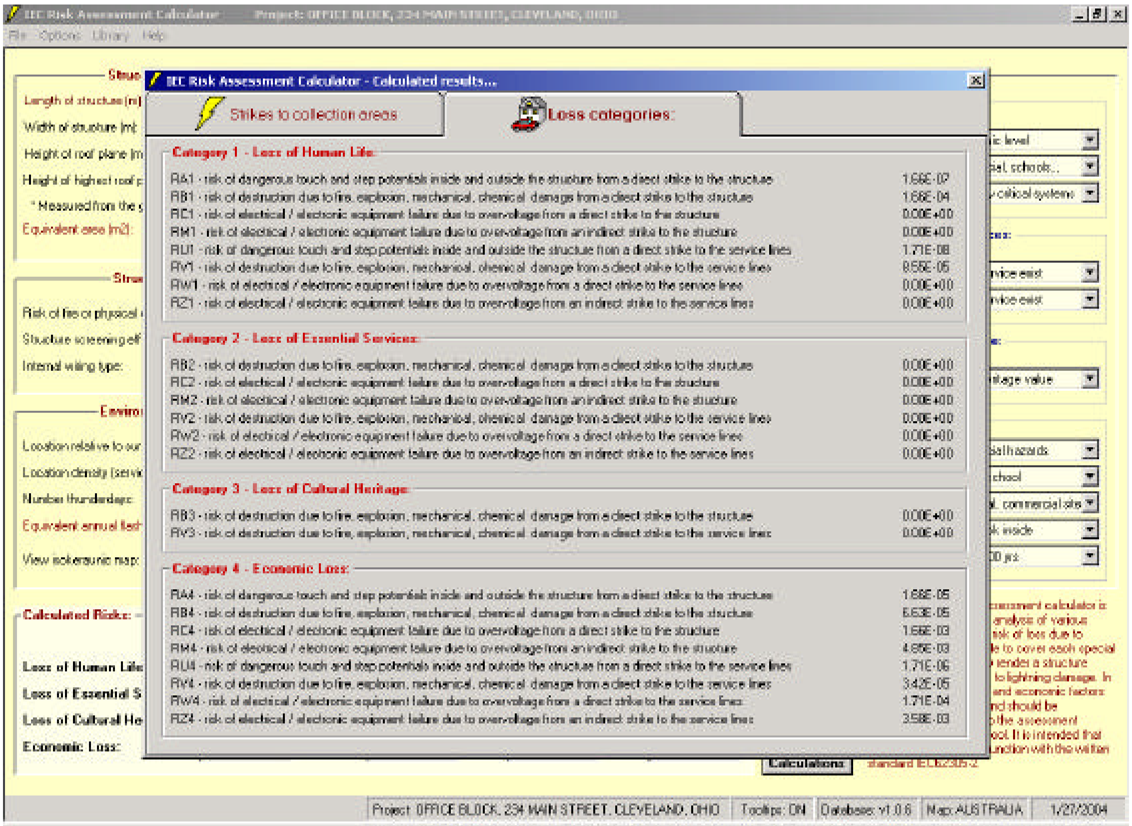

Figure 2- The calculations at each stage can be viewed when needing to evaluate the output in conjunction with the written standard.