QuakeStar – Rating buildings in New Zealand – Proposed system and processes

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2016 NZSEE Conference

ABSTRACT: Following the Canterbury Earthquakes there have been calls for the development of a reliable rating system for the earthquake performance of existing and new buildings in New Zealand. Support for the idea has come from the property owners, central government, local government, insurance industry, earthquake engineers and the Canterbury Earthquakes Royal Commission.

In 2015 The New Zealand Earthquake Commission (EQC) funded work by the author to develop technical processes suitable for the New Zealand market place. The proposed processes use key results from any appropriate method of structural assessment to determine ratings for safety, damage and repair time. The initial focus is on commercial buildings but it is planned to adapt the processes to enable assessment of small residential properties – which are part-insured by the EQC throughout New Zealand.

The processes developed, in the form of interactive Excel spreadsheets, result in ratings of 1 to 5 stars based on assessed performance in 500-year shaking. Special efforts have been made to make the processes compatible with the %NBS scoring system which has been used extensively since 2004 as a de facto earthquake rating. The QuakeStar process aims to improve significantly on the %NBS approach by limiting grades to five levels and by requiring agreement on the star-rating between an assessing engineer and an independent reviewing engineer.

Outputs of the QuakeStar processes are similar to those currently adopted by the US Resiliency Council and currently being trialled in Los Angeles City.

The overall aim is to embed the rating system into the property market so that, for purchase or rental transactions, questions are always asked about earthquake performance. Such an outcome is seen as a fitting legacy of the Canterbury earthquakes. Main benefits of such a rating system are: a) improved public safety; b) improved resilience of buildings and cities; c) ongoing public / user awareness of the value of good earthquake engineering.

The paper describes the proposed technical processes as well as organisational, administrative and fee structures. Results of some initial pilot studies on a range of existing buildings are presented as examples of application and to indicate possible ratings for a range of buildings.

1 WHY HAVE AN EARTHQUAKE RATING SYSTEM?

The Canterbury earthquakes, particularly the 22 February 2011 event, highlighted the need for greater public understanding of the likely earthquake performance of buildings. Most owners had paid for property solely on the basis of its functionality and décor. Following the Canterbury earthquakes the market value of low earthquake-rated buildings dropped substantially, notably in Wellington. Earthquake performance became highly relevant in the property market and the Canterbury Earthquakes Royal Commission recommended the development of a rating system for buildings [1]. Experiences since the Canterbury earthquakes have caused the property industry to consider the need for an earthquake rating of buildings to sit alongside other ratings such as for accommodation standard and energy / green building ratings.

At present the %NBS ratings resulting from assessments using the NZSEE Guidelines [2] are taken as de facto ratings. The QuakeStar process looks to improve on the %NBS process and provide a broader and more consistent basis for comparing buildings when purchasing or renting. It would be up to the owner to apply for a QuakeStar rating. The property market is seeking to improve its measures of building quality across a range of attributes and sees earthquake ratings as valuable in that context. The main benefits of such a rating system are: a) improved public safety; b) improved resilience of buildings and cities; c) ongoing awareness of the value of good earthquake engineering.

2 PROPOSED RATINGS

The QuakeStar ratings are intended as a first-level guide in property decision-making. They are based on an expert assessment of the earthquake performance characteristics of the building *and the site*. The aim is to provide a reasonable way of comparing buildings while emphasising that *the ratings do not represent a prediction of performance for the subject building.* They are intended to give the best possible indication of the *generally expected performance* given the characteristics identified.

Table 1 shows the proposed *separate* ratings for Safety, Damage and Repair Time.

Table 1. Proposed QuakeStar Ratings for Safety Damage and Repair Time

QuakeStar Rating	Safety		Damage		Repair Time
	Risk of personal harm	Safety Score [1]	Description	% RV	Time to restore function
*****	Extremely low	200+	Minimal	0-10	Days
****	Very low	150-199	Moderate	11-20	Weeks
***	Low	100-149	Significant	21-30	Months
**	Moderate	67-99	Substantial	31-50	> 6 Months
*	High	34-66	Severe	> 50	> 12 Months
EP	Very high	0-33			

1. The QuakeStar Safety Scores are set to align with %NBS for buildings of Importance Level 2.

Each separate rating is based on consideration of the impact on the building of 500-year shaking – as would be used for a new building design at the site. The ratings thus provide a basis for comparison with other buildings around New Zealand which takes account of the varying seismic hazard with location.

The Safety rating is about risk of personal harm in 500-year shaking, the Damage rating is based on assessed mean damage in 500-year shaking, and the Repair Time is based on estimates of time to repair that assessed damage, assuming reasonable access to the building and to design / construction resources.

The system has been devised to align with the recently introduced rating system in Los Angeles City, California by the US Resiliency Council [3]

Safety ratings

Safety assessments are based on a Safety Score and assigned according to the numbers shown in Table 1. Safety Scores are aligned with %NBS (Percent New Building Standard) which has been used as a measure of earthquake performance to date. The %NBS value is a measure of the ground shaking intensity required to attain ultimate limit state (ULS) in a building compared with the ground shaking intensity that would be used for the design of a new building. The %NBS concept provides a comparison with the standard for new buildings *of the same Importance Level (IL)*. For example for an IL4 hospital building, the New Building Standard requires design for 2500-year shaking, while for an IL2 office building the New Building Standard requires design for 500-year shaking. Thus IL4 buildings with any given %NBS rating would be expected to perform better in 500-year shaking than IL2 buildings with the same %NBS rating.

The QuakeStar rating process takes account of this expected better performance by relating assessments for all buildings to performance in 500-year shaking. This is illustrated by the following examples:

- An IL2 building at 100%NBS would have a QuakeStar Safety Score of around 100 = 3 Star
- An IL3 building at 100%NBS would have a QuakeStar Safety Score of around 130 = 4 Star
- An IL4 building at 100%NBS would have a QuakeStar Safety Score of around 180 = 5 Star

Damage ratings

The overall Damage score is equal to the estimated percentage mean damage (cost of reinstatement – including evaluation, re-design and demolition) for the whole building and site compared to their combined replacement value (RV). Star-ratings are assigned according to the values shown in Table 1.

Values used for the divisions are subject to further deliberation, but the divisions proposed seem reasonable. The USRC system limits the five-star category to 5% RV. This seems a very low value and implies a precision in the estimates which seems hard to justify in the aftermath of the 22 February 2011 earthquake and its impact on buildings in the Christchurch CBD. “Undamaged” buildings cost significant amounts to evaluate. At the other end of the scale, many buildings suffered only moderate *physical damage* yet cost much more to repair than was initially apparent. Many were demolished – equivalent to a 100% damage ratio.

Repair Time ratings

The worksheet uses the same split of elements used for the damage worksheet and is located next it to facilitate estimates of repair time. Estimating repair times involves significant challenges, firstly in estimating the time to repair each element and then to work through the sequencing – assuming availability of reasonable resources. The time entered for each element should be the time from start of overall repair work to completion of that element – based on a programmed approach. The star-rating for the building is based on the time to restore functionality.

In response to comments, the worksheet was extended to include the influence of external services on which the building relies. Separate Repair Time ratings are determined for the building alone and for the building *plus* external services. This is intended to provide insights into the criticality of external services in the overall restoration of function to the building.

The initial proposal was to follow the USRC approach and assign ratings for Downtime – i.e. the time between the earthquake and reinstatement of function. This introduces the issue of denial of access and unavailability of resources. The Christchurch CBD experience where access was denied for over a year resulted in the adoption of a Repair Time Rating that assumes access to the site and reasonable availability of resources. This at least gives a basis for like-for-like comparison. It seemed preferable to deal with potential lack of access and availability of resources separately.

3 QUAKESTAR RATING WORKSHEETS

The author developed the processes and worksheets with input and comments from a reference group of technical experts – leading structural designers and researchers. The QuakeStar ratings are based on entry of key performance data into Excel worksheets – one for Safety and one that combines Damage and Repair Time. An additional worksheet records External Factors that are not part of the rating process but which are seen as helpful in describing the overall earthquake risk context of the building.

The ratings worksheets are interactive so that as data is entered the star-rating appears in the relevant cell. This should help users to test the sensitivity of the ratings to changes in performance data.

Table 2. QuakeStar Safety Rating Worksheet

Note: A larger version of Table 2 is included at the end of the paper – for those unable to zoom in on screen

<table>
<tr><td colspan="9">QuakeStar Rating - Safety
Aadvaark Apartments - Tower Block 7/5 Richter Street, Quaketown</td><td>QuakeStar Safety Rating</td><td colspan="3">*</td><td>Notes</td></tr>
<tr><td colspan="9">Note: Rating is based on assessed performance in a 500-year event.</td><td>Safety rating
Overall</td><td>***
120</td><td>*
58</td><td>*
58</td><td>This is the overall rating applying to the building. It is based on the lowest individual scores in the column.</td></tr>
<tr><td rowspan="2">Earthquake Performance Aspect</td><td rowspan="2">Item</td><td rowspan="2">Attribute</td><td rowspan="2">Measure</td><td colspan="3">Score range</td><td colspan="2">User input
Building Scores</td><td rowspan="2">Safety rating
Structure/Site/Building Stability</td><td rowspan="2">E-W
***
120</td><td rowspan="2">N-S
*
58</td><td rowspan="2">Building
*
58</td><td rowspan="2">This shows the overall score without considering the Secondary Structure score. (If some of these items do not have safety implications they can be given a high score - enough so they do not govern.)</td></tr>
<tr><td>Min</td><td>Max</td><td>IL2 NBSmin</td><td>E-W</td><td>N-S</td></tr>
<tr><td rowspan="2">Stability Assessment</td><td>Site</td><td>Overall site stability</td><td>GSIcap/GSI 500</td><td>0</td><td>None</td><td>100</td><td>130</td><td>120</td><td rowspan="2">Safety rating Site/Building Stability</td><td rowspan="2">E-W
***
130</td><td rowspan="2">N-S
***
120</td><td rowspan="2">Building
***
120</td><td rowspan="2">This shows the results of examining the stability of the Site and of the Building. Including this means that these important issues are considered. They may govern in many cases.</td></tr>
<tr><td>Building</td><td>Building overall stability</td><td>GSIcap/GSI 500</td><td>0</td><td>None</td><td>100</td><td>140</td><td>120</td></tr>
<tr><td rowspan="10">Structural Capacity Assessment</td><td rowspan="10">Primary Structure</td><td>Basic Capacity at ULS</td><td>Duls / D500</td><td>0</td><td>None</td><td>100</td><td>100</td><td>100</td><td rowspan="10">Safety rating
Primary Structure ULS</td><td rowspan="10">E-W
***
133</td><td rowspan="10">N-S
*
58</td><td rowspan="10">Building
*
58</td><td rowspan="10">This shows the result of examining the primary structure on its own, including foundations, regardless of stability or floor/stair issues.</td></tr>
<tr><td>Modifying factors</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Integrity (Load paths)</td><td>Below/About/Above Average</td><td>0.9</td><td>1.1</td><td>1.0</td><td>1.1</td><td>0.9</td></tr>
<tr><td>Structure ductility</td><td>>4 / >2 / <2</td><td>0.9</td><td>1.1</td><td>1.0</td><td>1.1</td><td>0.9</td></tr>
<tr><td>Capacity design</td><td>Not applied or effective / Applied and effective</td><td>1.0</td><td>1.1</td><td>1.0</td><td>1.1</td><td>1.0</td></tr>
<tr><td>Consequences of failure</td><td>Major/Significant/Minor</td><td>0.8</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.8</td></tr>
<tr><td>Asymmetry</td><td>Severe</td><td>0.9</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.9</td></tr>
<tr><td>Separation</td><td>Effect on structural capacity</td><td>0.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td></tr>
<tr><td>Combined Attribute Factor, MF</td><td>(Calculated)</td><td></td><td></td><td></td><td>1.33</td><td>0.58</td></tr>
<tr><td>Modified Capacity at ULS</td><td>(Calculated)</td><td></td><td></td><td></td><td>133</td><td>58</td></tr>
<tr><td rowspan="3">Structural Capacity Assessment</td><td rowspan="3">Floors and Stairs</td><td>Diaphragm action</td><td>Duls or Auls / D500 or A500</td><td>None</td><td>0</td><td>100</td><td>120</td><td>120</td><td rowspan="3">Safety rating
Floors and Stairs</td><td rowspan="3">E-W
***
120</td><td rowspan="3">N-S
***
120</td><td rowspan="3">Building
***
120</td><td rowspan="3">This shows the results of examining the safety issues on the Floors and Stairs. It is particularly targetted at precast floors and stairs.</td></tr>
<tr><td>Vertical support</td><td>Duls support / D500 support</td><td>None</td><td>0</td><td>100</td><td>120</td><td>120</td></tr>
<tr><td>Stair support</td><td>Minimum value of (Available seating / ISD500)</td><td>None</td><td>0</td><td>100</td><td>150</td><td>150</td></tr>
<tr><td rowspan="6">Structural Capacity Assessment</td><td>Cladding</td><td rowspan="6">1.2</td><td>Duls / D500 or Auls / A500</td><td>None</td><td>0</td><td>100</td><td>120</td><td>120</td><td rowspan="6">Safety rating
"Non-structural" elements</td><td rowspan="6">E-W
***
120</td><td rowspan="6">N-S
***
120</td><td rowspan="6">Building
***
120</td><td rowspan="6">These results need to be derived according to the scale of safety issues involved. Items that would "fail" which have no significant safety issues should be excluded.</td></tr>
<tr><td>Glazing</td><td>Duls / D500 or Auls / A500</td><td>None</td><td>0</td><td>100</td><td>120</td><td>120</td></tr>
<tr><td>Ceilings</td><td>Duls / D500 or Auls / A500</td><td>None</td><td>0</td><td>100</td><td>120</td><td>120</td></tr>
<tr><td>Partitions</td><td>Duls / D500 or Auls / A500</td><td>None</td><td>0</td><td>100</td><td>120</td><td>120</td></tr>
<tr><td>Building Services</td><td>Duls / D500 or Auls / A500</td><td>None</td><td>0</td><td>100</td><td>140</td><td>150</td></tr>
<tr><td>Appendages</td><td>Duls / D500 or Auls / A500</td><td>None</td><td>0</td><td>100</td><td>120</td><td>130</td></tr>
<tr><td colspan="14">Note 1: A basic score of 100 represents minimum design-level performance for a new building of IL2 Category. With modifying factors an average new building of this type is expected to score about 130.</td></tr>
<tr><td colspan="14">Note 2: Data for both directions is required. If an attribute is clearly not critical in one direction enter a higher score for that direction and add a note.</td></tr>
</table>

The Safety worksheet, Table 2, first requires information on the overall stability of the site and of the building. Data on the structural capacity of the primary structure is then required. A special section on floors and stairs is included followed by a section on "non-structural" elements. For each section a star-rating is determined for each direction (N-S and E-W) based on the data entries. The worksheet allocates an overall building star-rating equal to the lowest rating in any section. The worksheet thus provides an overview of the earthquake characteristics of the building and the site on one page. Critical aspects are clear and can be communicated simply.

Data to be entered in each key performance measure is the ratio of assessed ultimate limit state (ULS) capacity and assessed demand from 500-year shaking. This may be expressed as the ratio of accelerations, velocities or displacements, whichever is appropriate. The worksheet computes a safety score and then uses Look-up tables to convert the score into a star rating.

Many existing reports on earthquake characteristics of buildings are focused on the structure. Consideration of site characteristics is seen as essential for a credible rating – even though this may present considerable challenges.

For the primary structure section some judgement is required to modify the basic ratio of capacity-to-demand to account for critical attributes that either improve or reduce the generally expected earthquake performance. Users are required to choose a modifying factor within a stated range. These critical factors are: Integrity (of load paths), ductility (of critical elements and overall), use of capacity design, consequences of failure (of the assessed critical elements that limit primary structure performance), asymmetry (beyond that taken account in analyses), and (lack of) separation (influence of pounding or building-to-building impact). The worksheet modifies the basic capacity/demand score according to modifying values entered and determines the star-rating from that score.

The "non-structural" elements section requires capacity / demand ratios as for other sections. However, data is required only for those elements whose failure have safety implications.

Table 3. QuakeStar Damage / Repair Time Worksheet

QuakeStar Rating - Damage / Repair Time		**Damage Rating**				**Repair Time Rating**		
Vulnerability Assessment Method		QuakeStar		*		Building only		**
		Damage score		55		Building + external services		*
Note: Rating is based on assessed damage in 500-year event.		*Vulnerability Assessment Method - H M L*						
		User input		Look-up value	Calculation		User input	Look-up value
Item	**Sub-item**	**Proportion of whole**	**Damage Vulnerability**	**Damage ratio DR500 (%)**	**Damage %Bldg RV**	**Sub-item**	**Time Code**	**Repair Time**
Site	Part of site supporting building	5	M	40%	2.0	Site	4	> 6 months
Foundations	Piles, pads, retaining walls, anchors	5	P	10%	0.5	Foundations	3	Months
Structure	Primary structure: columns, walls, beams	10	M	40%	4.0	Primary structure	3	Months
	Floors	10	H	80%	8.0	Floors	3	Months
	Stairs	2	H	80%	1.6	Stairs	2	Weeks
	Roof	3	H	80%	2.4	Roof	2	Weeks
Non-structural elements	Cladding / walls	15	M	40%	6.0	Cladding / walls	3	Months
	Glazing	15	M	40%	6.0	Glazing	4	> 6 months
	Ceilings	5	H	80%	4.0	Ceilings	3	Months
	Partitions	5	M	40%	2.0	Partitions	3	Months
Building Services	Lifts, plant, distribution networks	25	H	80%	20.0	Building services	4	> 6 months
Other *(Describe)*	Add description(s) as needed	0	P	10%	0.0	Other	0	#N/A
		100 *Check = 100*		**Total**	**55**	**Building only**	**4**	**> 6 months**
						External services	**5**	**> 1 year**
						Power	3	Months
						Water	3	Months
						Telecoms / Internet	3	Months
						Sewerage	3	Months
						Access roads	5	> 1 year

Vulnerability to MDR Look-up Table	
Vulnerability	Mean DR
H	80%
M	40%
P	10%

Could have different look-up tables for each item based on research

Repair Time Code Key	
1	*Days*
2	*Weeks*
3	*Months*
4	*> 6 months*
5	*> 1 year*

Table 4. External Factor Worksheet

External Factor Assessment - Effects on building *from beyond its site boundary*

Enter Score and then comment on evidence / lack of evidence of any issues beyond the subject site that could have significant influence on Safety, Damage or Repair / Down time. Qualitiative comment only needed - enough to alert owner / prospective purchaser of potential concern.

External Factor	Score	Safety / Damage / Repair Time
Earthquake Fault Movement	0	Site remote from known faults. No issues.
Landslip / Boulder Roll	0	Site not shown to be subject to risk on Council maps. No issues.
Liquefaction / Lateral spreading	1	Potential for minor liquefaction / lateral spreading movement on adjacent sites. Unlikely to be a safety or damage concern but repair time could be affected.
Adjacent buildings / sites	1	Building to North is URM. Collapse of parts could well occur in 500-year shaking and pose a safety risk, cause damage and increase repair time.
Utilities	1	No evidence of special measures to protect incoming utilities from expected differential movement. No safety or damage issues but repair / reinstatement of operations could be delayed.
Site access	1	Liquefaction potential and landslip risk to major roads essential to building function. Could affect time to reinstate function but no safety or damage issues.
Tsunami / Flooding	0	Site not shown to be subject to risk on Council maps. No issues.
Total Score	**4**	**Multiple issues of potential concern identified**

Scoring system (for each heading): Evidence of effective protection measures **or** evidence that risk is not present or that effects are insignificant, Score = 0; Otherwise, Score =1.

Overall rating from score: 0 = No issues; 1 = Single issue of potential concern identified; 2 = Two issues of potential concern identified; 3 or more = Multiple issues of potential concern identified

Two alternative methods of determining the Damage rating are proposed. Both require the user to enter values (or accept a pre-entered set of values) estimating the percentage of the total replacement value of the building that each building element group represents. In the Vulnerability Assessment Method, shown in Table 3, the user is required simply to classify each element as of high (H), moderate (M) or low (P) vulnerability to earthquake actions in the context of the building. The Mean Damage Ratio method allows the user to enter particular mean damage ratios determined from any recognised method.

The External Factor Worksheet does not form part of the star-rating process but is included to record external factors which could affect the risk of personal harm, extent of damage or repair time for the assessed building and site.

4 QUAKESTAR ORGANISATION AND OPERATION

Figure 1 provides an overview of the proposed organisation and operation of the QuakeStar ratings system which is designed to provide sustained consistency and credibility.

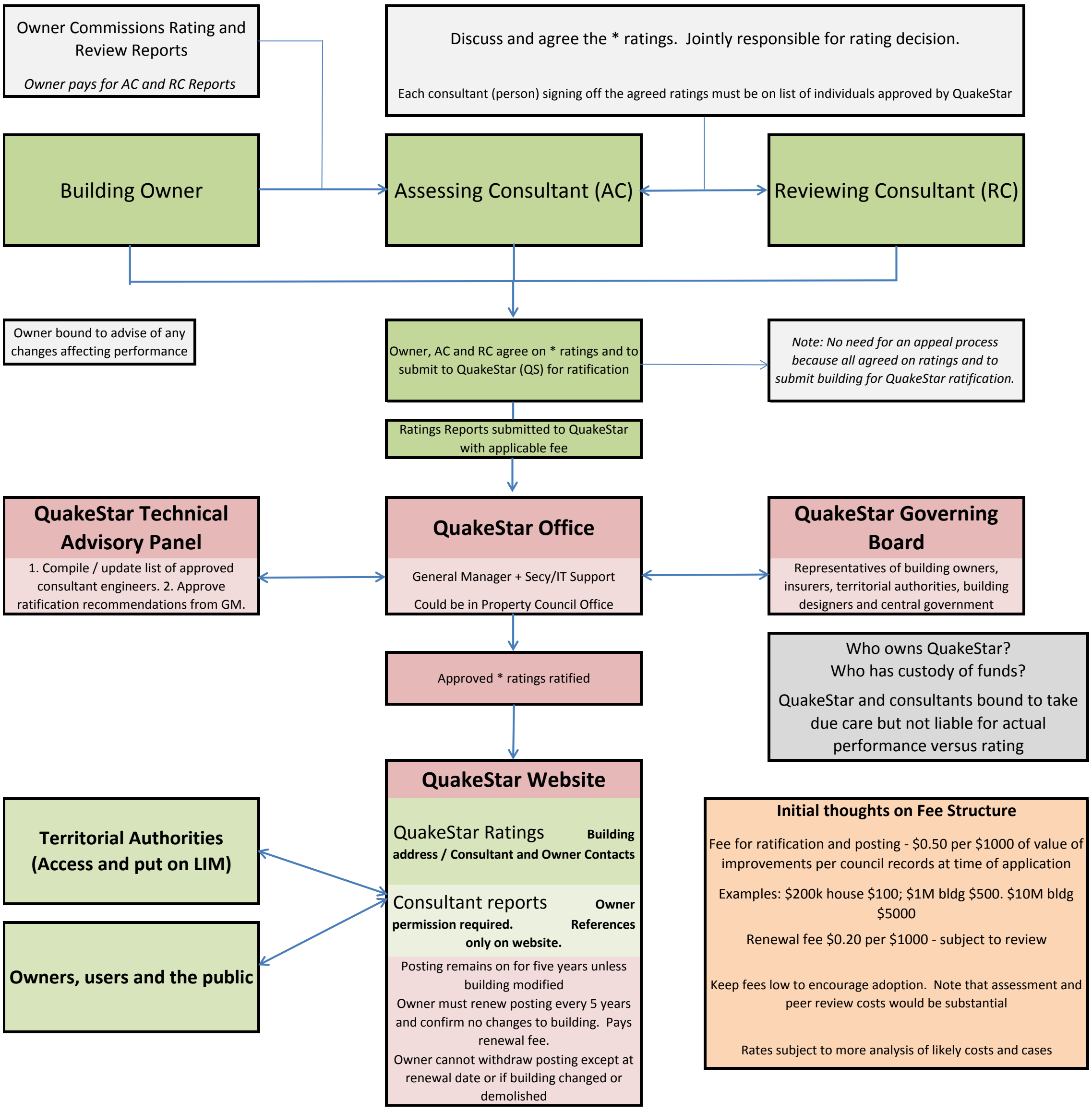

Figure 1 - Proposed QuakeStar organisation and operation

5 PILOT STUDY EXAMPLES

The above processes represent the current status of proposals which have received general endorsement from the technical expert group. It is proposed to hold a Pilot Study Workshop to allow members of that group to apply the processes to real buildings for which they or their firms have made structural / earthquake assessment reports. Experience at this workshop will be used to fine-tune the worksheet processes.

The author carried out a very preliminary 'pilot study' by applying the worksheets to a selection of New Zealand office buildings for which recent engineer reports were available. Table 5 shows the results for indicative purposes. Although completion of the worksheets required considerable imagination and assumptions, the overall outcome in terms of ratings seemed reasonable. They are all office buildings of Importance Level 2 for which a new building should rate 3-star for safety. Notional examples of buildings of different types and importance are included to indicate how the best and worst might rate. Table 6 shows indicative ratings for notional buildings showing likely star ratings for a range of building types.

Table 5. Indicative ratings of office buildings in Auckland and Wellington

QuakeStar Preliminary Assessments Summary - Office Buildings								
Building	Design	%NBS	QuakeStar Score	QuakeStar Ratings			External Factors	Comment
				Safety	Damage	Repair		
1	1950s	60	62	*	**	*	3	Robust MWD design but dated
2	1987	100	121	***	***	**	4	Stair details not checked.
3	1988	100	133	***	**	**	4	Assumes no issues with floor support
4	Late 70s	75	100	**	**	*	5	Limited by façade detailing. *** otherwise.
5	1996	65	71	**	**	*	4	Damage issues with floors and reclaimed site
6	1973	90	88	**	**	**	5	Issues with separation, stairs
7	1973/2004	80	97	**	**	*	3	Close to *** on Safety
8	1986	65	54	*	**	*	2	Separation, column capacities
9	1986	90	73	*	**	*	2	Stair issues. Otherwise **.
10	1979/2004	100	100	**	*	*	4	Safety *** with no issues on stairs / floors
11	2009	**100**	107	***	**	*	6	
12	2002	**133**	161	***	****	**	4	133%NBS means low impact at 500yr shaking
13	1989	120	145	***	***	**	4	
14	1986	110	96	**	**	**	3	Issues with diaphragms / blockwall separation
15	Late 70s	110	80	**	**	*	3	Issues with floor supports and column detailing
16	70s /2007	100	110	***	***	**	3	

Table 6. Indicative ratings of notional buildings

Building	Design	%NBS	QuakeStar Score	QuakeStar Ratings			External Factors	Comment
				Safety	Damage	Repair		
URM40	1930	40	30	EP	*	*	na	URM with 40%NBS
URM 50	1930	50	40	*	*	*	na	URM with 50%NBS
Pre 65 RC	1960	50	45	*	*	*	na	Pre 1965 Reinforced Concrete with 50%NBS
2015 IL2	2015	100	130	***	**	*	na	New IL2 Design - conventional
2015 IL2 - BI	2015	100	130	***	****	**	na	New IL2 Design - with Base Isolation
2015 IL3	2015	100	170	****	***	**	na	New IL3 Design - conventional
2015 IL3 - BI	2015	100	170	****	*****	***	na	New IL3 Design - with Base Isolation
2015 IL4	2015	100	230	*****	***	***	na	New IL4 Design - conventional
2015 BI IL4	2015	100	230	*****	*****	****	na	New IL4 Design - with Base Isolation

6 IMPLEMENTATION

The development of the proposals for QuakeStar organisation, operation and rating processes has now reached a stage where further work is needed to gauge the property market response, test and refine the technical processes (including development of owner and user manuals), establish a suitable organisational structure, and determine viable means of funding this not-for-profit enterprise.

Initial reaction from Property Council has been encouraging. The simplicity and relevance of presentation is appealing. More importantly, the Property Council is currently updating its methods of assessing buildings for other attributes. It sees the inclusion of some sort of earthquake rating as essential. It is proposed to work with the Property Council and its members to see how the QuakeStar approach can meet this need.

The property market including owners, funders and insurers have responded favourably to the idea of a ratings system for earthquake. But this has been without seeing the implications of what this might mean in terms of ratings for typical buildings. It is proposed to present the QuakeStar system and examples to a range of property market representatives and work through issues raised so that the system, when implemented, will meet the needs of the industry.

The existence and use of the %NBS approach should be an advantage. At present it is the de facto rating scheme for New Zealand and is serving a purpose in the market place. The QuakeStar processes are compatible with %NBS and use a similar scoring approach. It should be possible to introduce QuakeStar into the market as providing a broader and more consistent basis for comparison.

Further developments include writing a user manual to a) more closely define the requirements for assessment and rating and b) improve consistency of operation and outcomes.

Rating of buildings for earthquake performance is a challenging task for assessing and reviewing engineers. Every effort will be made to limit liability to the obligation to follow due and recognised practices. At the same time, credibility of the ratings will have to be established and maintained. This will require consultation with legal advisers and development of legal frameworks for QuakeStar. It is intended to draw on the experience of similar organisations such as the NZ Green Building Council.

The organisational and operational model shown in Figure 1 shows the essence of what is needed. Further work will be required to define the structure and operation, and to define responsibilities for all aspects, notably those of the general manager, Technical Advisory Panel and the Governing Board.

A particular challenge is the fee structure and funding overall. Given a reasonable volume of buildings it should be possible to keep fees modest, but there is little doubt that start-up funding will be needed to position QuakeStar in the marketplace.

7 ACKNOWLEDGEMENTS

The financial assistance of EQC and the encouragement of Richard Smith, Manager Research and Education, is gratefully acknowledged, as is the input from members of the technical group. The QuakeStar concept has grown from initial work by Don Holden and Bob Burnett who coined the name. Dr Ron Mayes, a New Zealand-trained engineer, who has led the introduction of the USRC rating system in California, provided valuable information, comment, insights and inspiration.

REFERENCES

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QuakeStar Rating - Safety

Aadvaark Apartments - Tower Block 7/5 Richter Street, Quaketown

	QuakeStar Safety Rating	*			Notes
Note: Rating is based on assessed performance in a 500-year event.	Safety rating **Overall**	***	*	*	This is the overall rating applying to the building. It is based on the lowest individual scores in the column.
		120	58	58	

Earthquake Performance Aspect	Item	Attribute	Measure	Score range			*User input* Building Scores						Notes
				Min	Max	IL2 NBSmin	E-W	N-S	Safety rating **Structure/Site/Building Stability**	*E-W*	*N-S*	*Building*	This shows the overall score without considering the Secondary Structure score. (If some of these items do not have safety implications they can be given a high score - enough so they do not govern.)
										***	*	*	
										120	*58*	*58*	
Stability Assessment	**Site**	Overall site stability	GSIcap/GSI 500	0	None	100	130	120	Safety rating **Site/Building Stability**	*E-W*	*N-S*	*Building*	This shows the results of examining the stability of the Site and of the Building. Including this means that these important issues are considered. They may govern in many cases.
										***	***	***	
	Building	Building overall stability	GSIcap/GSI 500	0	None	100	140	120		*130*	*120*	*120*	
Structural Capacity Assessment	**Primary Structure**	**Basic Capacity at ULS**	**Duls / D500**	**0**	**None**	**100**	100	100	Safety rating **Primary Structure ULS**	*E-W*	*N-S*	*Building*	This shows the result of examining the primary structure on its own, including foundations, regardless of stability or floor/stair issues.
		Modifying factors								***	*	*	
		Integrity (Load paths)	Below/About/Above Average	0.9	1.1	1.0	1.1	0.9		*133*	*58*	*58*	
		Structure ductility	>4 / >2 / <2	0.9	1.1	1.0	1.1	0.9					
		Capacity design	Not applied or effective /	1.0	1.1	1.0	1.1	1.0					
		Consequences of failure	Major/Significant/Minor	0.8	1.0	1.0	1.0	0.8					
		Asymmetry	Severe	0.9	1.0	1.0	1.0	0.9					
		Separation	Effect on structural capacity	0.0	1.0	1.0	1.0	1.0					
		Combined Attribute Factor, MF	***(Calculated)***				1.33	0.58					
		Modified Capacity at ULS	***(Calculated)***				133	58					
Structural Capacity Assessment	**Floors and Stairs**	Diaphragm action	Duls or Auls / D500 or A500	None	0	100	120	120	Safety rating **Floors and Stairs**	*E-W*	*N-S*	*Building*	This shows the results of examining the safety issues on the Floors and Stairs. It is particularly targetted at precast floors and stairs.
		Vertical support	Duls support / D500 support	None	0	100	120	120		***	***	***	
		Stair support	Minimum value of (Available seating / ISD500)	None	0	100	150	150		*120*	*120*	*120*	
Structural Capacity Assessment	**Cladding**	1.2	Duls / D500 or Auls / A500	None	0	100	120	120	Safety rating **"Non-structural" elements**	*E-W*	*N-S*	*Building*	These results need to be derived according to the scale of safety issues involved. Items that would "fail" which have no significant safety issues should be excluded.
	Glazing		Duls / D500 or Auls / A500	None	0	100	120	120		***	***	***	
	Ceilings		Duls / D500 or Auls / A500	None	0	100	120	120					
	Partitions		Duls / D500 or Auls / A500	None	0	100	120	120					
	Building Services		Duls / D500 or Auls / A500	None	0	100	140	150		*120*	*120*	*120*	
	Appendages		Duls / D500 or Auls / A500	None	0	100	120	130					

Note 1: A basic score of 100 represents *minimum* design-level performance for a new building of IL2 Category. With modifying factors an *average* new building of this type is expected to score about 130.

Note 2: Data for both directions is required. If an attribute is clearly not critical in one direction enter a higher score for that direction and add a note.