May 19, 2014 Memorandum: from Gibson Economics , CollinsWoerman to DPD.

To: Sandy Howard, Seattle Department of Planning and Development

From: John Gibson, Gibson Economics
Steve Moddemeyer, CollinsWoerman

Re: Responses to Comments on the Seattle Unreinforced Masonry Retrofit Policy Benefit-Cost Analysis

Date: May 19, 2014

Overview

The City of Seattle and the Unreinforced Masonry Policy Advisory Committee have received three memoranda addressing issues raised by the URM Retrofit Policy Benefit-Cost Analysis. They cover a variety of topics, ranging from which seismic impact model ought to be used to economic assumptions to technical details concerning underlying building fragility curves.

In this memo we offer responses to the points raised in these memoranda. The three sets of comments are:

A. Kenneth A. Goettel to Sandy Howard et al, March 23, 2014;
B. Kenneth A. Goettel to David Gonzalez (of the URM Retrofit Policy Advisory Committee) and Seth Thomas, April 14, 2014; and
C. Seth Thomas to the Seattle URM Advisory Committee, April 14, 2014

They are addressed in that order, with individual topics covered in the order they were raised in the documents.

We would like to note that we have had an opportunity to discuss the points raised by Mr. Goettel, both with him and with other experts in the fields involved. Many of the issues are familiar and were addressed in the "Sensitivity Analysis" section of our report. Those concern inherently uncertain assumptions and assessment of the impacts of selecting alternative values for those assumptions. We have made minor changes to the baseline where appropriate, but believe the original set of assumptions is reasonable. We do agree that recognition of the wide band of impact uncertainty in both directions is important in considering the results of our report.

A few of the issues raised are much more fundamental, such as calling into question the use of the industry standard HAZUS model. Questions disputing the validity of the assumptions within or results from that model were lodged. In those cases, we are comfortable that the model and its structure represent the best available vehicle for this study.

A. Issues Raised and Response to Ken Goettel's 3/23/14 Memo to Sandy Howard, and Steve Moddemeyer

1. The analysis should use hazard curves and an Excel model, rather than HAZUS.

Response: It is useful to consider a range of earthquakes. It is particularly important that they reflect a range that represents relevant earthquake risks. This study used three, the Nisqually, Cascadia and Seattle "scenarios," which were selected in consultation with local earthquake experts.

The important corollary is that the probabilities associated with the set of earthquakes should be sufficient to capture the aggregate hazard risk. In other words, with three earthquakes the individual probabilities need to be larger than they would be with more earthquake events, since each is representing a wider range of events. This study has consciously sought to achieve this.

The inherent uncertainty in these estimates, however, has also prompted us to conduct a sensitivity analysis in which the probabilities of each of the three representative quakes are assumed to be half and double the baseline probability estimates.

As for the selection of the national HAZUS model as the supporting source for complex impact calculations, this is a very widely used, federally developed model, which incorporates extensive, detailed inputs from many national experts in the field. It is well suited to evaluate individual and cumulative earthquake impacts for a large inventory of buildings such as that involved in this study, and has resident capabilities to take into account individual location information on each building in an input data set.

2. The building damage threshold that requires demolition should be lowered from 50% to 15-25%

Response: This seems to be an individual opinion, which is at odds with the chosen practice of the major HAZUS and FEMA models used for analysis in this field. The damage-to-cost parameters for this study are those used in the FEMA HAZUS model. The FEMA model for BCAs is consistent with HAZUS.

In any case, even if such an assumption were warranted, this change would make much less of a difference than the comment suggests. Looking at rough estimates of the impacts if all buildings with any damage were tear-downs, we found that even that extreme assumption would only increase the building damage savings produced by Bolts+ from HAZUS' estimated 43% of the damage to un-retrofitted URMs to 54% of that damage.

3. Building values:

a. For calculating damage it should be replacement cost, rather than assessed value.

Response: To base the analysis on replacement cost would grossly overstate the actual value and lease rates of the buildings in the city-wide inventory of URMs. Building owners risk losing property of the existing value – not some supposed future value - just as building owners set lease rates

based on the value of the space they provide now, not on rates they could provide with a new building. The purpose of this study is to provide Seattle decision-makers with an unbiased estimate of the benefits and costs, not how much would be spent to create a modern and therefore different replacement.

Our study uses assessed value with a 10% adder to reflect market value of Seattle buildings. This additional value is consistent with the general view of real estate professionals and City staff, and reflects the building investment value that would be lost if the building were destroyed.

Replacement cost would be at a higher level and would be consistent with buildings that are superior in market value to those being replaced. Such higher value replacement buildings would also produce higher building revenues, making them an inaccurate indicator of the damage loss of the current URMs that might be damaged.

b. For historic buildings, "re-creation" cost should be used to calculate damage, rather than assessed value.

Response: This comment applies primarily to individual building assessments, which FEMA often does as part of the grant application/review process. The point is that the cost to repair may be higher than either assessed value or cost of replacement. This may be true in certain individual cases.

It should be pointed out that the URM Retrofit study is designed to evaluate a complete cohort of buildings, rather than an individual building. There are sure to be many buildings for which the benefit-cost analysis results would be better and others for which they would be worse than the overall average.

4. Other Input Values

a. Occupancy rates are not documented, and may be too low.

Response: This document was requested by the city of Seattle to assist policy makers in evaluating URM policy options thus many details are not necessary nor were required to be described in detail in our report. The building occupancy rates used in this study are the HAZUS standard daytime and nighttime values for each building type.

These HAZUS occupancy rates were combined with building use information provided in the DPD data base for each of the buildings in the study, in order to calculate the total number of people exposed in each building, as well as in the aggregate.

The results of the HAZUS runs underlying our report differentiate between the casualty impacts of daytime and nighttime events. These two separate sets of results were included in the report appendices.

b. Current FEMA casualty cost values were developed in 2008, so they are too low.

Response: The initial draft of our report used the currently adopted FEMA set of casualty values. While some may assert that they are too low, raising them to reflect several years' change in the CPI does not affect the general result.

In the second draft of our report these values were adjusted for changes in the CPI from 2008 to 2013, which raised the baseline B:C ratio from 0.072 to 0.076.

c. The study's baseline discount rate is too high.

Response: We disagree. This assumption was considered carefully to match the application to the City-wide set of privately-owned and publicly-owned URMs. The baseline discount rate used for the study is the same as the FEMA standard value of 7% (above inflation). For a large set of primarily private sector buildings, this was deemed to be a representative value.

Sensitivity analyses were performed assuming both 3% and 10%. The sensitivity analyses reflect the range that might be relevant for different cohorts of specific building owners. Public agency owners are likely to use values between 3% and 7% (as Seattle Public Utilities does, for example), and private owners with differing time preference and differing access to capital likely to use values between 7% and 10%. In either case, higher values in those ranges are recognized to be appropriate when the future benefits associated with an investment are more uncertain, a distinction that is emphasized in SPU's applications. That is the case here, where there is considerable uncertainty surrounding the future benefits.

The reviewer notes that using a lower discount rate would increase the benefits. That is certainly true, but our goal was to develop an unbiased estimate of the benefits and costs, not to produce a certain result.

d. The study's baseline time horizon is too low.

Response: The baseline time horizon used for the study is the FEMA standard value of 30 years. We reviewed this assumption and determined that it was appropriate in this context. This assumption is for an economic planning horizon for primarily privately-owned buildings, and is not inconsistent with the fact that buildings last longer than 30 years.

Sensitivity analyses were performed assuming both 20 years and 50 years. The sensitivity analyses recognize that some newer buildings, those in better-than-average condition and public buildings may have longer planning lives, while those that are older, those in private hands and those in worse condition may have shorter planning lives.

The reviewer notes that using a longer horizon for the analysis would increase the benefits. That is certainly true, but once again, our goal was to develop an unbiased estimate of the benefits and costs, not to produce a certain result.

5. **Seismic Fragility curves**

    a. **They are based on typical buildings which understates the extent of damage.**

Response: It is true that fragility curves are based on typical un-retrofitted and typical Bolts-Plus retrofitted URM buildings. Damage impacts would be greater for above-average buildings and less for below-average buildings. Depending on the distribution of building conditions, the average of their individual impacts could be greater than the impacts of an average building, as noted in the report narrative comments on building-to-building impact variability.

Again, for evaluation of individual buildings it would be appropriate to determine whether they are above- or below-average, and thus whether their fragility is greater or less. This is not the focus of the URM Retrofit study.

    b. **The Bolts-Plus fragility curves developed for the study are suspect, because the damage results they produce are too high.**

Response: We disagree. These fragility curves were necessary for the project, and their results have been assessed for reasonableness by local experts.

The purpose of the study was to evaluate the Bolts-Plus standard, specifically. In order to do so with the aid of the HAZUS model, it was necessary to develop building fragility curves consistent with Bolts-Plus seismic retrofits, since those are not part of the standard HAZUS inventory of building type fragility curves.

We sought out the widely recognized structural engineering firm Degenkolb Engineers, with leading expertise in this field, extensive experience and familiarity with HAZUS model requirements and familiarity with the proposed Seattle retrofit standards, to develop these fragility curves for both low-rise and mid-rise URM buildings. Our study relied on those fragility curves.

The Bolts-Plus standard is intended as a life safety standard, and various local structural engineers have expressed no surprise that the HAZUS results based on that standard and its associated fragility curves show a much higher benefit percentage in preventing deaths and injuries while doing less to prevent building damage.

It would be a mistake to scale up the results for individual buildings and apply them to the entire building stock included in this study.

6. **HAZUS Inputs and Results**

    a. **What does "stable soil" mean?**

Response: Location of liquefaction soils used in this study to distinguish buildings on this basis for aggregate impact comparisons are identified in the City of Seattle's GIS database. Soils not listed as liquefaction are considered "stable" for the purposes of these comparisons. The impact results presented for subsets of buildings in Appendices 4.A, 4.B and 4.C identify buildings as in liquefaction zones - or not - based on City mapping of the 929 individual URM buildings in the sample.

It is possible that the City mapping and the HAZUS soil designation used for impact calculations do not align perfectly. That, however, would not affect the overall results, which were generated based on HAZUS soil designations. If there are differences, they might mute to some degree the differences between HAZUS results that are reported for buildings in liquefaction zones versus the remainder. This distinction is unlikely to become relevant to policy options which are based upon a much broader range of considerations.

b. How was liquefaction potential included in the calculations?

The soil types for the entire area of the City are resident in the HAZUS model that was used to estimate earthquake impacts and damages. HAZUS provides specific soil information for any specified locations of buildings within Seattle. The 929 URM building locations were provided in precise longitude and latitude (accurate to within feet) for all buildings in the DPD data set that underlies the study, based on building-by-building mapping.

c. Some HAZUS-based results look puzzling...including:

- **The fraction of URMs with no damage for all three scenarios.**

  Response: Earthquake damages reflect an inventory that spans the entire city, with a variety of soils and distances from earthquake sources. The HAZUS estimates take all this into account and the results presented reflect the aggregate inventory.

- **The absence of any RMs with extensive or complete damage, even for the Seattle Fault scenario.**

  Response: The results behind this question are based on the HAZUS fragility curves for reinforced masonry buildings. Note that the results do not affect the BCA, which compares the impacts for un-retrofitted URMs to the impacts for Bolts+ seismically retrofitted URMs, as noted in the Report.

- **Why is the estimated damaged percentage for the Cascadia scenario only a little higher than the Nisqually scenario?**

  Response: The question addresses the underlying shake map characterization of the two events in the HAZUS runs. These shake maps were input from pre-existing USGS earthquake definition information, as noted in the Report.

- **22% damage for the Seattle Fault scenario seems low for URMs, given the strong ground motions, presumably with a lot of short period ground motion for this nearby crustal event.**

  Response: Again, the results are based on the shake maps and fragility curves in the HAZUS runs. Impacts would be expected to vary more by location within

Seattle for this earthquake, given its proximity, and the overall result cited is an average of impacts estimated by HAZUS for all buildings throughout Seattle.

- **Why is the percentage reduction in damages for Bolts+ substantially lower for Cascadia than for the Nisqually scenario? I would expect a monotonically increasing trend from the small to medium to larger ground motions.**

  Response: A complicating factor in the case of the Cascadia scenario is the longer duration of the earthquake. To the extent this is captured in HAZUS, it may explain why Bolts+ would be proportionally less successful in reducing damages for that scenario than for the other two.

- **Are the Bolts+ cost estimates reasonable?**

  Response: As noted in the report, the Bolts+ costs would vary substantially from one building to the next. The overall average used in the baseline BCA calculations is based on extensive interviews and individual building cost estimates within Seattle in the past year or two. To address the uncertainty of the average, as well as the building-by-building variation, sensitivity analyses were conducted for Bolts+ retrofit costs both higher and lower by 50%.

B. Issues Raised and Response to Ken Goettel's 4/14/14 Memo to David Gonzalez and Seth Thomas

1. **The building value used seems to be very low.**

   Response: See responses to 3.a and 3.b of Mr. Goettel's 3/23/14 memo.

2. **The damage percentages shown for the Seattle Fault are grossly discordant with the USGS Shakemap ground motions and the HAZUS PGA fragility curves for a Pre-Code URM.**

   Response: We reviewed the HAZUS results, and determined that for the Seattle Fault scenario HAZUS runs, the ground motions for individual buildings were in the range, 20% to 64%, which accords with the range expected by Mr. Goettel. As his attached "ShakeMap for Seattle M6.7 Scenario" indicates the buildings at the higher end of that range are indeed those closer to the Pioneer Square-International District area, while buildings north of downtown lie within the 9.2%-18% and 18%-34% ranges.

D. Issues Raised and Response to Issues in Seth Thomas'4/14/14 Memo to the Seattle URM Advisory Committee

1. **<u>Hazard</u>: While the 3 agreed upon scenarios do represent the 3major earthquake source for the Seattle area I don't think the hazard probability is accurately represented:**

   - **Variability in ground motions including epistemic uncertainties are not accounted for when using "shakemap" scenarios**

     Response: This comment suggests using an entirely different approach to the analysis. The HAZUS approach that was chosen, as is documented in the Report, allows for efficient analysis of an extensive inventory of buildings. It is also the commonly used, nationally developed model for these analyses.

   - **It is not clear how soil properties are being accounted for relating to the pga for each scenario**

     Response:See the response to items 6.a and 6.b of Mr. Goettel's 3.23.14 memo.

   - **Not clear how liquefaction is handled**

     Response: See the response to items 6.a and 6.b of Mr. Goettel's 3.23.14 memo.

2. **<u>Fragility Curves</u>: It is not clear how the fragility curves are applied.**

   Response: The fragility curves for Un-retrofitted URMs are those in HAZUS, as explained in the Report. Those for Bolts+ retrofitted URMs are those that were developed by Degenkolb Engineers, again as explained. This study uses the HAZUS model, which produces both structural and non-structural impact information. The BCA Study did not substitute some other sequential analytical approach, but relied on the HAZUS impact information.

3. **<u>Building Inventory</u>: It is not clear what the building inventory used was. It should be included in the appendix.**

   Response: The building inventory is described in the report. DPD has published the initial list of URMs on their web pages.

4. **<u>Building and Retrofit Costs</u>:**
   - **It is not clear how building contents were valued or what % of structural and non-structural value was lost in each scenario.**

     Response: This information is all presented and explained in the report.

   - **Buildings last a lot longer than 30 years.**

Response: See the response to item 4.d of Mr. Goettel's 3.23.14 memo.

- ***A few local engineers in Portland think the retrofit costs are a little off.***

  Response: See the response to the final bulleted point in 6.c of Mr. Goettel's 3/23/14 memo. It notes the review by and recommendation of Seattle engineers to use the assumption in the Seattle BCA.