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Prevention and preparedness projects in civil protection and marine pollution. Prevention Priorities

KnowRISK

Know your city, Reduce seISmic risK through non-structural elements

Prevention and preparedness projects in civil protection and marine pollution. Prevention Priorities

Deliverable Report

Deliverable C1 – Review of non-structural damage from past earthquakes

Task C – Non-structural seismic risk reduction

Deliverable/Task Leader: EERC

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PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
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Preface

This report is a deliverable for the C1 task within the EU Project KnowRISK, **Know** your city reduce your seismic **risk** through non-structural elements. Task C1 focuses on classification systems for non-structural components in relation to different facilities and stakeholder perspective, for the purpose of developing disaster risk management procedures.

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Abstract

Damage to non-structural components constitutes a large portion of loss due to earthquakes, and the loss can be up to 85% of total construction cost of commercial buildings (Sankaranarayanan, 2007). Recent earthquake losses from damage to non-structural components in countries having codified seismic design provisions have far exceeded losses from structural damage (Filiatrault and Sullivan, 2014). Understanding damages to non-structural components, sources of non-structural earthquake damage, and how damages affect the functionality of facilities are all critical aspects for developing general recommendations concerning disaster risk management. Information about specific facilities and specific stakeholders allows for more detailed recommendations. The main contribution of this work is a method for developing stakeholder- and facility-specific disaster risk management procedures for non-structural damages. The method is based on nine steps, five provide information or guidance to the process, and four are individual processes within the method. An application of the method is demonstrated through a desktop study that uses information found in existing literature to be used as a basis for the discussion. Existing literature is used to provide information and guidance regarding the five following steps: i) a general non-structural component classification system; ii) definitions of four stakeholder objectives (societal and governmental, owner and facility managers, finance managers, and designers and academics); iii) non-structural components in hospitals, schools, and homes; iv) generalized damage states for non-structural components; and v) basic procedures for disaster risk management. The results are presented in four templates for four stakeholder types. Furthermore, Performance-Based Earthquake Engineering is discussed as an ideal engineering approach for systemizing engineer-stakeholder dialogue for disaster risk management. It is suggested to add mitigation and preparedness procedures from a stakeholder perspective to PBEE to create a full-scale disaster risk management methodology.

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1 Introduction

The purpose of Task C1 described herein is to develop disaster risk management (DRM) procedures to guide stakeholders in managing their risk from non-structural components (NSC). NSC are architectural, mechanical, electrical components and building content. Even though structural performance during an earthquake may be sufficient to allow continued use of a building, non-structural damage may significantly affect the usability of the facility. The seismic risk of NSC damage should therefore also be specially addressed during the design phase. Effective DRM procedures can be developed from the understanding of the relationship between NSC damages and stakeholder priorities. By including details of NSC for individual facilities it is possible to develop even more useful DRM procedures.

The main contribution of this work is the development of a method on how to develop DRM procedures for seismic risk of NSC damage that takes both the stakeholder and the facility perspective into account. The method involves nine steps. The schema in Figure 1.1 shows these steps and the relationship between the steps. The white boxes represent information provided into the method and the grey boxes represent steps that involve a process within the method. The first two steps are input steps: 1. a classification system for NSC and 2. a stakeholder perspective. Research on these topics can lead to the most appropriate way to address these two steps. Combining these two leads to a stakeholder specific NSC classification system (step 3). The next step is to define NSC damage states (step 4). Merging general damage states with stakeholder specific NSC classification will lead to damage state criteria for stakeholder specific NSC (Step 5). Step 6 is to define general disaster risk management procedures. Step 7 uses the details of step 5 to customize the general disaster risk management procedures identified in step 6 towards a stakeholder perspective. Step 8, provides details about the facility in question. Finally, inserting these details of step 8 into step 7 brings the facility perspective into the stakeholder-related disaster risk management procedures (step 9).

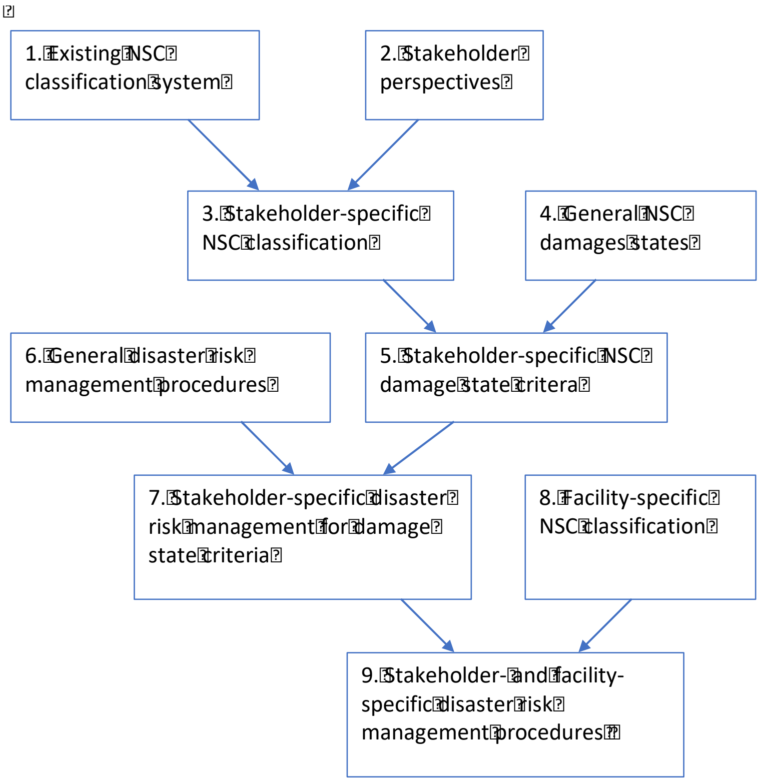

Figure 1-1 Method for developing stakeholder- and facility-specific risk management procedures

An application of the method is demonstrated through a desktop study that addresses four stakeholders (societal and governmental, owner and facility managers, finance managers, and designers and academics), and three facility types (hospitals, schools, and homes).

Section 2 of this report describes the information taken from the literature identified during the desktop study for steps 1, 2, 4, 6, and 8 of the method. Step 1 is a study on existing NSC classification systems. A NSC classification system is the grouping of NSCs that are estimated to have similar seismic performance, i.e. similar levels of damageability for a given hazard level. Step 2 looked for ways in defining stakeholder perspective for various building related stakeholders, and in particular to demonstrate the differences between them. Step 4 defines general NSCs damage states. Damage states are a grouping of damage levels from no damage to being destroyed. Damages can also be presented as average values, but from a DRM perspective damage states are useful as they allow the stakeholder to make decisions for different levels of damage. Damage states are the basis for fragility curves, which relate probability of damage and hazard levels (or probability of exceeding a certain damage state for a given hazard level). Step 6 presents general DRM procedures. The last part of the desktop study is step 8, which uses chosen documents to create a list of facility-specific NSCs to characterize facilities. The desktop study led to references on Performance-based Earthquake Engineering (PBEE). Section 2 concludes with a fairly thorough description of PBEE due to its importance to the subject matter herein.

Section 3 presents the four analytical steps, 3, 5, 7 and 9. The analytical steps all involve a merging of two previously defined steps. The first, step 3, is viewing the existing NSC classification system from the perspective of the chosen stakeholders. The next analytical step, step 5, is to develop criteria for stakeholder-specific damage states. From these criteria step 7 specifies stakeholder-specific disaster risk management procedures. Finally, step 9 produces templates of procedures for a given stakeholder and facility ready to be further developed by stakeholders during an application

Section 4 discusses the outcome of the work, including a comparison of the templates in section 3, and the importance of engineer-stakeholder dialogue. Section 5 presents key conclusions that can be drawn from this work and future work. In addition to the section on References, the references are also presented in the Annexes grouped according to the desktop study.

2 Desktop Study

2.1 Step 1: Existing Classification Taxonomies

The desktop study identified fifteen references that included or discussed a NSC classification system. These references are listed in Annex A, based on authors, year, and title. Thirteen references are for buildings in general and residential buildings, one is for hospitals, and one is for schools. The review of these documents led to one reference being chosen as the basis of the C1 task by K.A. Porter (2005) titled A Taxonomy of Building Components for Performance-Based Earthquake Engineering. Porter´s classification system (taxonomy) includes both structural and NSC, and is presented in Annex B.

Porter outlines a review of literature work where he studied taxonomies designed for use in earthquake engineering, general building component taxonomies, laboratory testing and surveys to quantify component damageability, and post-earthquake reconnaissance reports. The scope of Porter´s taxonomy for NSC is for commercial and engineered buildings, in particular components that typically contribute significantly to post-earthquake repair costs, causalities and downtime. Non-fixed contents are considered to a limit amount because contents matter to casualties and downtime.

Porter used the following 10 objectives to build his taxonomy:

1. Clear definitions
2. Common fragility curves
3. Distinguishes differences in seismic performance
4. Testable
5. Amenable to assessment of consequences
6. Flexible
7. Collectively exhaustive
8. Simple
9. Collapsible
10. Familiar to construction contractors and engineering practitioners

From the perspective of Task C1, of the 10 objectives listed, objectives #2, #3, and #5 are key objectives. All of them relate to damages. Objective #2 states the need for common fragility curves. Common fragility curves mean three things: (1) All members of the taxonomic group share a common set of damage states relevant to the facility´s seismic performance; (2) All members are sensitive to the same type of excitation (force, deformation, acceleration, etc.); and (3) The excitation at which members enter a particular damage state is identically distributed. The cumulative distribution functions of these capacities are the fragility functions (or fragility curves). Objective #3 states that the taxonomy should allow an analyst to choose a new group for a building component that has been retrofitted. This requires that the grouping is expandable, or in other words, collapsible (objective #9). Porter (2005) presents five collapsible levels. Objective #5 highlights the need to be able to assess consequences of damages, acknowledging that damages are not just the initial impact damages, but also a chain of damages and affects. This is of particular importance when defining a stakeholder perspective to understand what consequences are important to the stakeholder.

Porter´s approach is based on Performance-Based Earthquake Engineering (PBEE). The premise of PBEE is to take stakeholder perspective into account during the design phase. Due to its relevance to the subject matter herein, PBEE is explained in the last subsection of Section 2.

2.2 Step 2: Stakeholder Perspective

2.2.1 Defining Stakeholder Perspective

A stakeholder is a person or group with an interest or concern in a particular matter. A stakeholder perspective is governed by a stakeholder´s objectives, including their ability to control their surroundings. To further understand stakeholder perspective, it is necessary to understand what is of value to the stakeholder. The Sustainable Livelihood Framework divides all things of value (assets) into five categories, Physical, Human, Environmental, Economic and Social. These categories can also be used to define damages and consequences, for example:

- Physical impact: loss of function, rubble, unsafe placarding, repair cost
- Human impact: Injuries, deaths
- Environmental: Pollution, hazards material accidents
- Economic: Downtime, cascading, economic loss, business interruption, output loss, loss of wages
- Social: Societal break down, e.g., lost social contact due to loss of communication; emotional impact, services, e.g. loss of medical assistance or welfare, loss of home

Building related stakeholders come into play at different times of the building life cycle. Some are important before the design work begins, like lenders and insurers, others can affect the design process like owners, and users, e.g., hospital staff may make decisions about the layout and NSC although they do not own the hospital. Yet others make decisions that affect the response of NSC after the building is built, e.g., the occupants.

This part of the desktop study led to twelve references, covering building owners (2), occupants (1), facility managers (5), local building and safety staff members (1), and post-earthquake damage inspectors (3), and one reference from a workshop that covered a variety of building related stakeholders (ATC-58, 2002). These references are listed in Annex C. These references provide a general idea of the normal day-today goals and objectives of each stakeholder.

2.2.2 Chosen Stakeholder Perspectives

After reviewing these references, it was decided to use the stakeholder perspective definitions outlined in FEMA 445 (FEMA 2006) Next-generation performance-based earthquake engineering design criteria for buildings. Stakeholder perspectives are presented here for five chosen stakeholders. Paragraphs marked “FEMA 445:” are taken directly from FEMA 445.

2.2.2.1 Owners and Managers

FEMA 445: Owners and managers are responsible for commissioning building design and construction, acquiring, maintaining and/or operating buildings and facilities. They make decisions about catastrophic risks that lead to action (or inaction) on a relatively narrow scale. Motivations generally spring from the best interests of the specific business or institution. Within the owner/manager category, three perspectives have been identified as important for interaction: investors, institutions and industry. This distinction between these categories reflects the assumption that different stakeholder groups characteristically have different motivations and criteria for decisions relative to catastrophic hazard mitigation. It is important to capture these distinctions (e.g., investment risk, operational risks, and market risks).

The desktop study revealed that with advances in the technology and design of building services and fabric, the complexity of modern buildings demands ever-increasing awareness of how they operate in order to achieve the optimum benefits and cost savings available. The technical detail is available to the professional and technical staff involved with the operation and maintenance of the building through operation and maintenance manuals.

2.2.2.2 Societal and Governmental Interests

FEMA 445: This stakeholder category includes those who represent broader societal and governmental interests. These individuals view catastrophic risk in a different context than do owners/managers. Their focus is on public safety and the impact of catastrophes on local/regional/national economies. Their decisions relate primarily to public policy, legislation and administration. The societal/governmental category is separated into three perspectives for focus groups: policy-makers, regulators, and special interest and advocacy groups. This reflects the different levels of sophistication, scope of decision-making and problem-solving ability, and types of criteria used by the three groups:

- Policy-makers are making broadly applicable decisions for the community.
- Regulators are considered more as "enforcers," focused on the problem one building at a time.
- Special interest and advocacy groups "speak" for the interested and affected public).

2.2.2.3 Financial Managers

FEMA 445: The third stakeholder category is primarily financial in nature. The owner/manager and the societal/governmental stakeholder categories have a direct stake in decisions about risks associated with buildings (e.g., protect the assets and protect the community interest). Financial stakeholders, however, have an indirect interest in building performance decisions made by others. Their decisions relate primarily to whether or not to assume risk associated with buildings and at what compensation level. The financial category might be represented by three focus groups: lenders, insurers, and securities packagers. Financial stakeholders differ from the previous two categories in that the stake is indirect: the concern is the financial risk associated with the decision to finance or assume risk, rather than in protection of people or owned assets. The three groups (lenders, insurers, and securities packagers) represent different views with respect to when and how the financial decisions are made, which in turn may impact how they characterize the risk and performance issues. Financial stakeholders tend to use very complex statistical and mathematical tools for decision-making.

2.2.2.4 Design Professionals, Consultants, and Researchers

FEMA 445: The fourth category of stakeholders are design professionals, consultants, and researchers. The design and consulting communities are the conduits through which design will be implemented.

This group of stakeholders is key to the success of disk risk management procedures being understood and implemented by owners, managers, and other previously mentioned stakeholders. They provide the information that allows others to assess options and decide what measures to take. However, designers, consultants, and researchers do not have a building related perspective that relates to a facility; they need to understand everybody else´s perspective for design purposes, and are therefore not used as a stakeholder group in the development of the method.

2.2.2.5 Homeowners

The fifth category of stakeholders chosen for task C1 are homeowners. This perspective is developed by listing individual rooms likely to be in a home, and NSC that are likely to be found in these rooms.

2.3 Step 4: NSC Damage Characterization

2.3.1 General NSC Damage States

As stated before, all members of a taxonomic group share a set of damage states relevant to the facility´s seismic performance. A set of damage states describe the various levels of damage a component can sustain due to an earthquake or other damaging processes, from no damage to destroyed. The number of damage states used to describe this range depends on the interest of those who develop them and the information available to develop them. Pantoli et al. (2016) define general minor, moderate, or severe damage states for NSC in the following manner:

- **Minor**: Primarily aesthetic or easily *repairable* damage that would not pose a *hazard to occupants*. Examples of this damage include easily repairable cracks in partition walls, facades or drywall ceilings and small movement of equipment or contents that do not affect their functionality.

- **Moderate**: Requires *repair* to ensure optimal *functionality* of the component, but it does not require *evacuation* of the building nor pose a *life safety hazard*. Examples include damage to the connections that require their replacement and damage to access doors that prohibit their smooth or complete opening.

- **Severe**: Poses a significant *life-safety hazard* directly or indirectly (i.e., threatens safe evacuation). Examples include complete detachment of gypsum boards from partition walls, excessive loss of ceiling tiles, toppling of equipment or contents, *complete failure* of the opening mechanism of doors, or failure of critical elements of an egress that would render it unusable.

These general descriptions are based on three criteria: repair level, functionality, and life-safety. The examples provided with each damage state give insight into the type of damage that can occur. Lumping together large varieties of NSC, such as tile finish, interior partitions, electrical equipment, will produce large uncertainty in component damageability, and therefore large uncertainty when assessing facility-level performance.

Descriptions of damage within each damage state help stakeholders to gain an understanding of what to expect during earthquakes and use for decision making.

2.3.2 NSC Fragility Curves

Designers of new construction or retrofitting need access to fragility curves in order to estimate damages. Due to the large number of diverse NSC many fragility curves are needed. The desktop study identified the following fragility curves for NSC provided by FEMA (2012):

- Exterior wall construction
- Exterior glazing systems
- Roof tiles, masonry chimneys, and parapets
- Interior partitions
- Ceilings
- Stairs
- Elevators
- Mechanical equipment and distribution systems (e.g., chillers, cooling towers, air handling units, piping, and ducting)
- Electrical equipment and distribution systems (e.g., transformers, switchgear, distribution panels, battery racks, recessed lighting, and pendant lighting)
- Access floors, workstations, bookcases, filing cabinets, and storage racks

2.3.3 Stakeholder priority damage aspects

In 2002, the Applied Technical Council held an invitational workshop in Chicago, Illinois on communicating earthquake risk, and asked stakeholders questions to help identify what aspects of damage were important to them (ATC 2002). Participants were an expanded group of stakeholders including commercial real estate investors, insurers, lenders, attorneys, and architects. Their collective opinions were used to select concepts for expressing and measuring consequences. The priority aspects of damage were:

- Primary issues
    - Life losses
    - Direct and indirect economic losses
- Amount of time that an individual facility would be out of service (downtime)
- Low probability but potentially significant consequences of earthquakes
- Uncertainties associated with prediction of the effects of earthquakes and the performance of individual affected structures

Regarding financial losses, some of the participants:

- Acknowledged that they would implement rigorous cost-benefit type analyses to assist in the risk-selection decision making.
- Indicated that there was no unique time window over which such economic outcomes would be considered and that each investment or development opportunity would be evaluated using the time frame most appropriate to that individual decisions. Generally, however, time frames that stretched to perhaps a few tens of years were better received than time frames that ran to hundreds or thousands of years.

2.3.4 Injuries associated with NSC

As stated above, the ATC 2002 workshop identified life-safety as the most important aspect of risk. The desktop study uncovered literature on economic equivalent value of deaths and injuries, where the economic value of non-fatal injuries is noted to be of great importance and severely ignored during risk studies (Porter et al., 2006).

Porter et al. (2006) provided the following information: FEMA-356 (ASCE 2000), which defines whole-building performance levels in its performance-based earthquake engineering methodology, explicitly mentions, and accepts, the potential for injuries under its life-safety structural and nonstructural performance levels, but makes no mention of nonfatal injuries under the immediate occupancy, damage-control, or operational performance levels, at which levels the vast majority of injuries probably occur. The 1994 Northridge earthquake injured approximately 246,000 people. Of the injury cost, 96% is associated with nonfatal injuries and less than 1% is associated with structural damage. The majority of the injury cost is associated with nonstructural damage. Causes of injuries during the 1994 Northridge earthquake include:

- Majority of injuries were minor (cuts, bruises, and sprains), caused by nonstructural objects (55% of injuries, resulting from falling objects, pictures, lights, broken glass, etc.)
- Falls (22%)
- Behavior such as jumping out of a window or catching a falling television (15%).

2.4 Step 6: Disaster Risk Management Procedures

The disaster-risk management methodology used in this study is based on Disaster-Function Management approach (Thorvaldsdóttir 2016), which provides an overall goal for disaster-related activities, specific disaster-related objectives, and offers a list of basis activities associated with each objective. It is based on the principle of Management by Objectives from Classical Management Theory.

2.4.1 Disaster and Disaster-Related Goal

Before discussing how to deal with a disaster it is necessary to have a clear definition of what a disaster is. There are many definitions of a disaster. The definition used herein is as follows (UNISDR, 2009):

> A disaster is a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

This definition includes both the societal problems due to different types and of impacts, and the ability to cope with such impacts and losses, indicating not only the problem but also a solution.

An important aspect of this definition is that a disaster is the serious disruption, not the cause of the disruption, there is a subtle but significant difference. That means that the disaster (i.e., the disruption) is also on going throughout recovery, and eventually dies out as the recovery is complete. This is highlighted here to avoid the misunderstanding that recovery is a post-disaster activity. Systematic learning to improve the DRM system is the only post-disaster activity.

The goal of a disaster-related management system outlines *what* the system does; *what it produces*. The overall goal of a disaster-related management system is obtained by rephrasing the definition of a disaster as follows:

> The goal of a disaster-related management system is to guide organizational members on what to do in order to minimize the risk of serious disruptions to the functioning of the organization involving widespread human, material, economic or environmental losses and impacts is low, and to cope with such events using one's own resources if they occur.

If this goal is not met, a secondary goal of the system is to cope with serious disruption with the assistance of others.

2.4.2 Theoretical Disaster Phases

There are two fundamental disasters phases: on-going disaster and non-disasters. However, it is convenient to use three theoretical phase: before a disaster (risk), during a disaster (operations), and after a disaster (learning). These phases are only for theoretical purposes. The purpose of defining phases is not to lock people into separating their activities into different phases of activity, but to help clarify the objectives needed to define DRM activities. The fundamental aim of DRM is therefore to address the DRM objectives (described next section) at any time that an objective is relevant. Once people get used to working with objectives, the notion of phases will become obsolete.

2.4.3 DRM Objectives and Disaster Functions

There are eight DRM objectives (Thorvaldsdóttir and Sigbjörnsson, 2014), listed in the table 2.1. The first three are pre-disaster objectives, the next four are objectives for disaster operations, and last objective focusing on learning from experience.

Table 2-1 Disaster-related objectives (Thorvaldsdóttir and Sigbjörnsson, 2014)

#	Disaster-related objectives
1.	To understand disaster risk, its components and context
2.	To measurably reduce known disaster risk
3.	To prepare for dealing with future disasters
4.	To gain control over actual damaging processes
5.	To perform lifesaving operations
6.	To provide temporary assistance (relief) to those affected
7.	To implement non-temporary measures in order to return a community to normalcy
8.	To systematically learn from recent events and implement changes

A disaster function (DF) is defined as a set of coordinated activities that are collectively managed to meet one the disaster-related goals. Disaster Functions (DF) are management functions. Management functions group and manage actors that work on similar activities. A disaster function therefore groups and manages activities needed to meet one of the eight disaster-related objectives listed in the table 2.2, (Thorvaldsdóttir and Sigbjörnsson, 2014). Terminology for the disaster functions associated with each of objectives is presented in the table below.

Table 2-2 Disaster Functions (Thorvaldsdóttir and Sigbjörnsson, 2014),

DF#	Disaster Function
DF1	Disaster Risk Analysis
DF2	Disaster Risk Mitigation
DF3	Operations Preparedness
DF4	Impact Operations
DF5	Rescue Operations
DF6	Relief Operations
DF7	Recovery Operations
DF8	Systematic Learning

Basic procedures associated with each DRM objective are listed in the tables below (Thorvaldsdóttir, 2016). These lists are not exhaustive, meaning more activities can be added to the lists as needed, but they are crucial, meaning that they all need to be included. The procedures in table 2.3 are those to be followed *prior* to a disaster.

Table 2-3 Pre-disaster procedures (Thorvaldsdóttir, 2016),

DF#1	Disaster Risk Analysis Basic Activities
DF1.1	Develop natural process parameters, such as peak values, temporal changes, geographical variations and probabilities of occurrence (hazard analysis).
DF1.2	Classify, characterize and inventory objects exposed to a hazard, such as structures, people and services.
DF1.3	Develop damage models and determine vulnerability factors.
DF1.4	Develop probabilistic or deterministic scenarios, consisting of direct damages, losses and human impact, and cascading damages and consequences, such as loss of function and service disruptions, from a human, material, economic or environmental perspective.

DF#2	Mitigation Basic Activities
DF2.1	Identify opportunities for reducing risk through land-use planning, building codes, construction inspection, public education in making homes and work places safer, financial insurance, service backup systems, and other measures.
DF2.2	Analyse each option, based on cost, estimated time of completion, resources required, effectiveness as in level of risk reduced, benefits per beneficiary, and other relevant aspects.
DF2.3	Compare benefits of different options and different combinations of options, and select an option or a combination.
DF2.4	Implement and monitor actual reduced risk and re-evaluate choice against anticipated reduction.

DF#3	Operations Preparedness Basic Activities
DF3.1	Develop standard procedures for assessment and coordination for impact, rescue, relief and recovery operations.
DF3.2	Establish facilities and communications networks and procure equipment.
DF3.3	Write contingency plans based on DF1.4 scenario.
DF3.4	Train personnel and test plans.

The operations preparedness (DF#3) produces need to be developed for each of the four types of disasters operations, i.e., for DF#4, #5, #6, and #7 *during* disasters. The procedures for the four types of operations are listed in Table 2.4

Table 2-4 Disaster operations procedures (Thorvaldsdóttir, 2016)

DF#4	Impact Operations Basic Activities
DF4.1	Monitor natural processes and damaging processes, diagnose current situation and forecast possible turn of events and convert existing impact contingency plan to an operations plan.
DF4.2	Protect population to avoid the need for rescue operations through warnings, directives, closing off areas, and evacuations, to the extent possible.
DF4.3	Protect property by redirecting natural processes, such as sandbagging, digging diversion trenches, cooling lava and control of reservoir spillways.
DF4.4	Halt or reduce on-going damaging process by intervening, such as stopping leaking gas lines, putting out fires, avoiding potential explosions, and shoring damaged structures.

DF#5	Rescue Operations Basic Activities
DF5.1	Perform reconnaissance missions to gain overview and convert rescue contingency plan to an operations plan.
DF5.2	Search for, locate, access, medically assist people and ensure their safety.
DF5.3	Transport victims, and hand them and information about them over to medical facilities or other parties.
DF5.4	Perform support operations, such as crowd control and closing off of hazardous areas.

DF#6	Relief Operations Basic Activities
DF6.1	Perform needs assessments to get an overview and convert relief contingency plan to an operations plan.
DF6.2	Sustain life and provide temporary relief through providing for basic needs, such as shelter, water, food, cooking facilities, heat, clothing, fuel, physical and mental health, and financial assistance.
DF6.3	Make temporary repairs to homes, roads and bridges, etc.
DF6.4	Make temporary repairs for temporary renewals of services, such as intermittent power supply.
DF6.5	Perform support operations, such as crowd control and closing off of hazardous areas.

DF#7	Recovery Operations Basic Activities
DF7.1	Perform a situation assessment to get an overview and convert contingency plan to an operations plan.
DF7.2	Restoration processes: remove rubble and clean up the affected area, reunite family members and bury the deceased, fully restore services and reconstruct the physical environment.
DF7.3	Reform processes: renew urban planning and revise building codes.
DF7.4	Re-establish livelihoods, and support the physical and mental rehabilitation of people, their hope and eagerness for the future.

2.5 Step 8: Defining Facility-Specific NSC

References from the desktop study were chosen to help identify NSCs for hospitals and schools. These NSCs are presented in the subsections below. They are not meant to be exhaustive, but representative, in order to show the differences between facility perspectives. The third facility type, residential buildings (homes), is created from author´s experience.

2.5.1 Hospitals

Achour et a. (2011):

- Healthcare key factors are often classified into two categories
    - Physical (structural and non-structural)

- Social (staff and administrative parts, e.g., partnerships with other organizations)

- Structural and architectural, (ii) equipment, and (iii) utilities
- Structural and architectural damage tended to be different and specific to the situation, while utility supplies and equipment damage were similar in most cases with some common trends.
- Experience shows that all medical departments must be able to provide diagnosis and treatment to injury.
- A hospital is a hotel (lobby with check in and check out, kitchen, laundry, beds, bathrooms), an office building, a laboratory, and a warehouse.
- A typical healthcare facility depends on the following components:
    - The state of its buildings
    - Continuity of its utility supplies
        - Electrical
        - Water
        - Telecommunications
    - Availability and sufficiency of staff
    - Diagnose and treatment equipment and medical supply
    - Easy accessibility for its daily operation
- Interdependency of systems: power generations needed to be switched off due to loss of water used for its cooling system. Can switch to air cooling systems. But need to understand the characteristics of damages and interdependency.
- Unstable equipment damages other equipment and utilities

McIntosh et al. (2012):

- Windows, suspended ceilings, partition walls, floor coverings, medical equipment, and building content.
- Ceilings: The repair takes hours to days, but the repairs have been going on for months. Led to a pre-cautionary evacuation.
- Walls: did not lead to loss of function, but the areas damaged had to be shut down for repair.
- Egress: staircases damaged and propped up to remain functional during the emergency phase. The stairs were taken out of service one at a time and repaired. Emergency lights failed due to lack of power. Elevators where either damaged or automatically shut down. Staff members were injured during the evacuation.
- Pumps and chillers in rooftop plant rooms jumped off their mounts
- Internal and external roof coverings and roof top water tanks, that lead to ingress of water into the floors below, leading to evacuation (with no elevators and damaged staircases).
- Loss of internal and external services and damages to back-up systems
    - Waste-water. Broken sewage pipes had to be replaced
    - Water. Main water was out for day, and full pressure did not come back for a week. The lack of water impaired other systems. The hospital had a backup water system, but that did not prove sufficient.
    - Power
    - Hospital suction. The ventilation system is important in maintaining an appropriate pressure gradient in different areas of hospitals. Infection-controlled areas, malfunction could create a risk of infection to patients and staff.
    - Hospital backup power systems failed (e.g. oil pressure gauge broke, clogged filters due to sediments in tanks that had been disturbed by the ground shaking, difficulty in priming pumps, shortages to the main low-voltage

switchboard caused small fires, damaging main electrical panel and further complicating power restoration efforts)

Pantoli et al. (2016):

- EGRESS
  - Steel Stairs
  - Passenger Elevator
- ARCHITECTURAL FAÇADES
  - Levels 1–3: Cold-Formed Steel (CFS) Balloon Framing Overlaid with Synthetic Stucco
  - Levels 4-5: Precast Concrete Cladding Panels
- INTERIOR ARCHITECTURAL COMPONENTS
  - Ceilings
  - Partition Walls
  - Level 1: Access Doors
- SERVICES
  - Heating, Ventilation, and Air Conditioning (HVAC):
  - Electrical Distribution System:
  - Fire Sprinkler System:
  - Gas piping:
- EQUIPMENT
  - Level 2: Residential and Laboratory
  - Level 3: Computer Servers
  - Levels 4–5: Medical
    - Patient care beds and stretchers:
    - Carts and shelves:
    - Ultrasound imagers:
    - Intensive care unit breakout door
    - Headwall
  - Roof: Penthouse, Air Handling Unit, Cooling Tower

2.5.2 Schools

FEMA_395 (2005):

Unsafe buildings expose school administrators to the following risks:

- Death and injury of students, teachers, and staff
- Damage to or collapse of buildings
- Damage and loss of furnishings, equipment, and building contents
- Disruption of educational programs and school operations

Initiate housekeeping or maintenance measures to reduce or eliminate risks from earthquake damage to equipment, furnishings, and unsecured objects in buildings. Work may include such tasks as:

- Fastening desktop equipment
- Anchoring bookcases, storage shelves, etc.
- Restraining objects on shelves
- Securing the storage of hazardous materials such as chemicals

Check that:

- All classroom doors, doors of high-occupancy rooms, and doors to outside open outwards;

- Exit pathways are kept clear; make sure that all building occupants can safely exit in case building evacuation is necessary
- Non-structural building elements are securely fastened to the buildings
- Fire suppression equipment is located appropriately and maintained in good working condition;
- Flammable and combustible materials are limited, isolated, eliminated, and separated, away from dangerous interactions and heat sources;
- Electrical systems are maintained and are not overloaded;
- Classrooms have two exits wherever possible. (Sometimes the second exit is a window.)

Perform:
- Move heavy items below head level;
- Tightly secure tall and heavy furniture and appliance to walls, floors and ceilings. (e.g., use L-brackets to walls or spring-loaded adjustable tension rods to ceiling or wedges under bottom front, or strip barrier fastened to tabletop, as appropriate);
- Fasten cabinet doors and drawers with latches that will hold shut during shaking;
- Secure heaters and cooling systems suspended inside or outside of building;
- Fasten liquid propane gas tanks, fire extinguishers and other gas cylinders to the wall;
- Protect from glass that may break into large shards (e.g., rearrange furniture, use window film, curtains, or install strengthened glass.);
- Secure heavy and important electronic items to table top or floor using straps and clips, buckles or Velcro;
- Secure lighting fixtures to ceiling;
- Fasten pictures on closed hooks;
- Limit, isolate, eliminate or secure hazardous (poison, flammable) materials.

Standard emergency response procedures are built around six basic emergency procedures detailed below:
- Building evacuation;
- Shelter-in-place;
- Assemble and shelter outside;
- Evacuate to safe haven;
- Emergency student release/family reunification.

Seismic performance improvements for schools are presented in figure 2.1

2.5.3 Residential Buildings

By going over the functionality of each room that is in a typical residential building, a home will provide a person with the following facilities:
- Kitchen: food, drinks, place to cook, cooking utensils, cookers
- Bedroom: sleep, rest, clothes
- Bathroom: toilet, cleaning, cleaning utensils (toothbrush, towels)
- Laundry-room: washing clothes, drying clothes
- Living room: social life, connection to media (TV)
- Home office: source of income
- Garage: car, car-keys may be somewhere else.
- Communication (less dependent if have mobile phone), routers
- All your worldly possessions are usually kept in your home
- Biggest financial investments are usually in your home
- Emotional values: memorabilia
- Refuge, safety behind locked doors, protected by law.

Rank *	Level of Seismicity			Definitions and Purpose		
	L	M	H	Seismic Performance Improvement	Description	Purpose
1	✓	✓	✓	Bracing of Parapets, Gables, Ornamentation & Appendages	Construct parapet bracing on the roof side of the parapet. Gables are braced in the attic space. Other elements are anchored in a positive manner.	Prevents parapets, gables and ornamentation from falling outward
2	✓	✓	✓	Anchorage of Canopies at Exits	Canopies or roofs over exits	Prevents collapse of canopies which would block exits and possibly injure persons
3		✓	✓	Bracing or Removal of Chimneys	Chimneys should be braced to the structure	Chimneys may topple onto yards or through roofs
4	✓	✓	✓	Bracing or Reinforcing Masonry Walls at Interior Stairs	Interior exit stairs may have unreinforced masonry enclosure walls that could collapse	Prevents collapse of walls blocking stairways
5		✓	✓	Suspension and Bracing of Lights	Lights may swing or otherwise fall in an earthquake	Falling lights could injure occupants. Lights should not be supported by a suspended ceiling in a high and moderate seismic zone. Pendent lights should have their sway limited.
6	✓	✓	✓	Anchorage and Bracing of Emergency Lighting	Positive attachment of emergency lights	Battery packs are heavy and could fall
7		✓	✓	Fastening and Bracing of Ceilings	Diagonal bracing of ceiling	Suspended ceilings should be braced against sidesway to reduce the chance of elements falling
8		✓	✓	Restraint of Hazardous Materials Containers	Chemical labs, shops, etc may have materials that could, when combined, create a fire or chemical hazard	Reduces danger of breakage and mixing of chemical
9		✓	✓	Bracing and Detailing of Sprinkler and Piping	Sprinkler pipes should be braced in each direction	Sprinkler lines could break and flood the building
10		✓	✓	Anchorage and Detailing of Rooftop Equipment	Equipment should be properly attached, and restrained if isolation-mounted	Equipment could slide or fall off platforms
11		✓	✓	Fastening and Bracing of Equipment – Mechanical and Electrical	Equipment above ceilings	Fans and other equipment could sway and fall on occupants
12	✓	✓	✓	Cladding Anchorage	Heavy cladding (concrete) must be connected to the structure	Prevents cladding from falling. Careful design is required so the cladding does not limit the structures type of lateral movement.
13		✓	✓	Anchorage of Masonry Veneer	Veneer over exterior wood or masonry walls or over other materials in steel or concrete structure. Materials may be brick, terra cotta, stone or similar materials	Inadequately anchored veneer could fall outward
14		✓	✓	Anchorage of Exterior Wythe in Cavity Walls	A masonry wall separated from the veneer by a hollow space	Veneer could fall outward. Existing anchorage should be checked for rust damage and loss of strength.
15	✓	✓	✓	Glazing Selection and Detailing	Glass above a walking surface	Prevents it from falling onto the walking surface and injuring persons
16		✓	✓	Bracing of Interior Partitions – Masonry & Wood	Bracing may be vertical or diagonal braces	Interior partitions must be braced to prevent falling/collapse
17		✓	✓	Anchorage of Steel Stud Backup	Steel studs behind veneer or other cladding	Steel studs are used as a backup to support veneer or other cladding and could become detached and fall
18		✓	✓	Attachment and Bracing of Cabinets and Furnishings	Anchorage to structural walls or other elements	Cabinets and other furnishings could topple. Cabinets have moved caused damage. Fallen file cabinets may block exit doors.
19		✓	✓	Attachment and Bracing of Large Ductwork	Large ducts	Ducts could fall on occupants
20		✓	✓	Shut-Off Valves	Installation of a shut-off device	Gas and water lines could break and should have a means of turning them off
21		✓	✓	Support and Detailing of Elevators	Elevator guides have become dislodged in earthquakes. Applies to cable lift elevators	Keeps elevators functioning
22		✓	✓	Underfloor Bracing of Computer Access Floor	Raised floors for cabling	Floors could collapse damaging equipment

* Rank in terms of 'life safety effectiveness'

Figure 2-1 NSC Seismic Performance Improvements (Figure page C-21 in FEMA 2005)

2.6 Performance Based Earthquake Engineering

Due to the significance of Performance Based Earthquake Engineering (PBEE) and Performance Based Seismic Design (PBSD) to Task C1, the basic concepts are outlined herein. PBSD is a design process of new buildings, or seismic upgrade of existing buildings, which includes a specific intent to achieve pre-defined seismic performance objectives in future earthquakes (FEMA 2012). Performance assessment is the process used to determine the performance capability of a given building design. In performance assessment, engineers conduct structural analyses to predict building response to earthquake hazards, assess the likely amount of damage, and determine the probable consequences of that damage. As stated in FEMA (2012), this approach is best utilized for critical facilities or other structures where increased performance, can be justified, there will always be a need for typical prescriptive–based building codes for buildings that require a typical level of engineering involvement.

Moehle and Deierlein (2004) FEMA P-58-1 (2012), Porter (2003), and other references, describe the methodology and application. The following description of PBEE objectives and methodology, and all figures are from these references.

2.6.1 Performance Objectives

The PBEE objectives are expressions of performance in the form of probable damage and resulting consequences associated with earthquake shaking. Each performance objective is a statement of the acceptable risk of incurring damage or loss for identified earthquake hazards.

The following performance objectives, i.e., measurable objectives, are used in PBEE:

1. **Casualties.** Loss of life, or serious injury requiring hospitalization, occurring within the building envelope.
2. **Repair cost.** The cost, in present dollars, necessary to restore a building to its pre-earthquake condition, or in the case of total loss, to replace the building with a new structure of similar construction.
3. **Repair time.** The time, in weeks, necessary to repair a damaged building to its pre-earthquake condition.
4. **Unsafe placarding.** A post-earthquake inspection rating that deems a building, or portion of a building, damaged to the point that entry, use, or occupancy poses immediate risk to safety.

Design professionals, owners, and other stakeholders jointly identify the desired building performance characteristics, and determine levels. The effects of these decisions are evaluated to verify that the final building design is capable of achieving the desired performance, followed by a performance assessment, where engineers compare the predicted performance capability with the desired performance objectives. If the assessed performance is equal to or better than the stated performance objectives, the design is adequate. If the assessed performance does not meet the performance levels, the design is revised or the performance levels altered, in an iterative process, until the assessed performance and the desired objectives match. The iterative design process is presented the flowchart in figure 2.2.

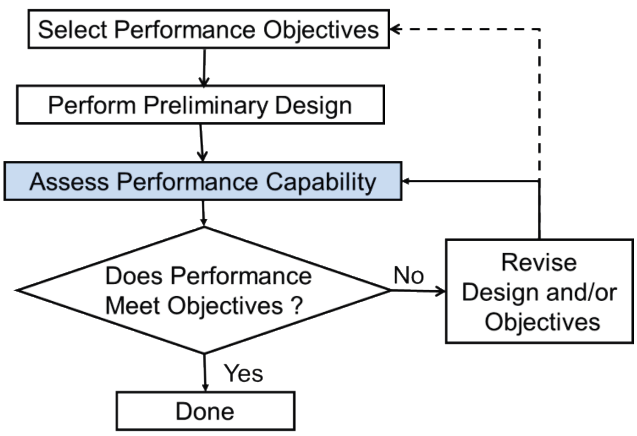

Figure 2-2 PBEE iterative process (Figure 1.1 in FEMA 2012)

For new buildings, preliminary design information must be developed to a sufficient level of detail to allow determination of performance capability. In the case of existing buildings, basic building design information is already defined, but preliminary retrofit measures must be developed (if necessary).

Once performance objectives are selected, designs must be developed and the performance capability determined. As a minimum, basic building design information includes:

(1) Location and characteristics of the site;
(2) Building size, configuration, and occupancy;
(3) Structural system type, configuration, strength, and stiffness; and
(4) Type, location, and character of finishes and nonstructural systems.

2.6.2 Methodology

The first generation of PBEE conceptualized the problem as shown in the figure 2.3. Here, the building is visualized as being loaded by earthquake-induced lateral forces that result in four performance-oriented descriptions: Immediate Occupancy, Life Safety, Collapse Prevention, and Collapse. Various shortcomings were identified on the approach to determining engineering demand, component performance, and structural performance, which resulted in a second generation, the PEER methodology.

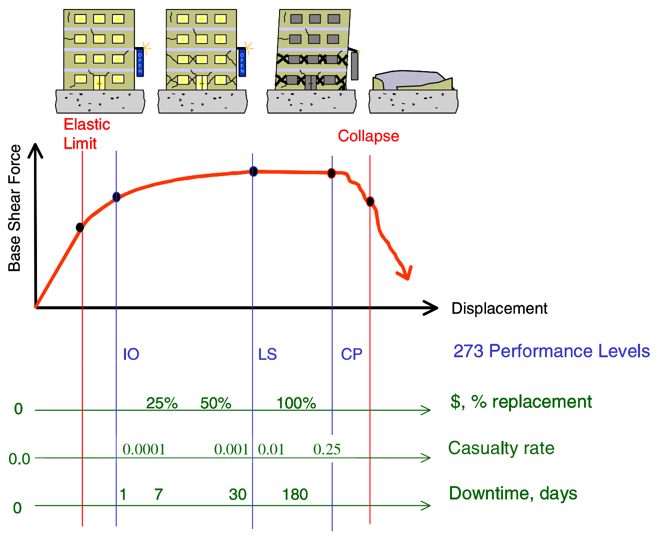

Figure 2-3 First generation PBEE methodology (Figure 1 in Moehle and Deierlein, 2004)

The current PBEE methodology has four stages of analysis: hazard analysis, structural analysis, damage analysis, and loss analysis, presented in the figure 2.4. Nonstructural components are important in the third and fourth analytical stages.

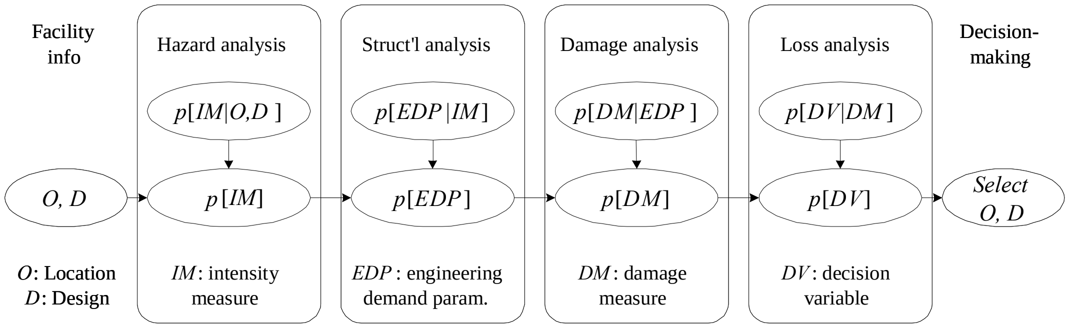

Figure 2-4 Four analysis stages of PBEE (Figure 2 in Moehle and Deierlein, 2004)

The outcome of each step is mathematically characterized by a generalized variable:

1. **Intensity Measure (IM)**, ground motion parameter, which defines in a probabilistic sense the salient features of the ground motion hazard that affect structural response.
2. **Engineering Demand Parameters (EDP)**, which describe structural response in terms of deformations, accelerations, or other response quantities calculated by simulation of the building to the input ground motions.
3. **Damage Measures (DM),** which describe the condition of the structure and its components.
4. **Decision Variables (DV)**, which translate the damage into quantities that enter into risk management decisions. Consistent with current understanding of the needs of decision-makers, the decision variables have been defined in terms of quantities such as repair costs, downtime, and casualty rates

Due to inherent uncertainties, the four variables are expressed in a probabilistic sense as conditional probabilities of exceedance, i.e., p[A|B]. The approach is based on the assumption that each stage can be treated separately, where the conditional probabilities between parameters are independent.

2.6.3 Damage Analysis and Damage Measures

A damage analysis relates earthquake demand parameters (EDPs), such as interstory drift, deformation, and associated forces, to damage measures (DMs). The DMs include quantitative descriptions of damage to structural elements, nonstructural elements, and contents.

To be useful within the probabilistic context of the PBEE framework, the DMs are defined in terms of fragility relations. Fragility functions (or curves) model the probability of physical damage (conditioned on structural response, design, and location outlined in first two stages). Damage is commonly described as the ratio of repair cost to replacement cost. Figure 2.5 shows fragility relations for nonstructural partition walls, identifying probability of being in a given Damage State as a function of the interstory drift ratio for three damage states. The damage states in this case describe the damage and the repairs needed:

1. Least damage: Small cracks only (paste, tape, repaste and paint).
2. Moderate damage: Wide cracks in gypsum boards (replace gypsum boards)
3. Most damage: Sever damage to gypsum boards and distortion of metal frame (replace partition)

Implementation of the procedures requires data on structural and non-structural fragility, and estimates of potential casualties, repair cost, and repair times, associated with this damage.

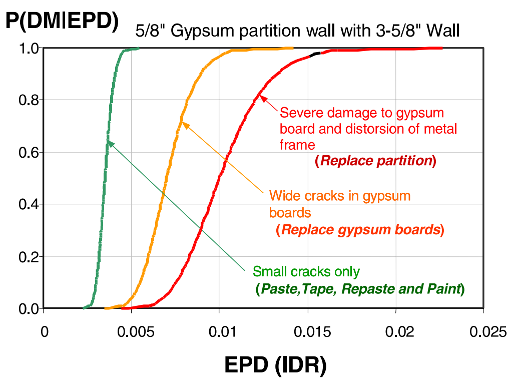

Figure 2-5 Example fragility curves (Figure 8 in Moehle and Deierlein, 2004)

2.6.4 Loss Analysis and Decision Variables

Losses are presented as repair costs, operability, and repair duration, and the potential for casualties. These measures of performance (i.e., performance metrics) are referred to as Decision Variables (DV), since they are used to inform stakeholder decisions about future performance.

When addressing decisions, it is important to understand how DVs relate to different stakeholders. For example, the loss of 90 percent of the air conditioning in a facility may represent a fixed cost of replacement for a range of occupancies, but the impact on functionality will vary greatly depending on the occupancy (a hospital would be completely nonfunctional while an office building may be able to continue operations).

2.6.5 Example of Damage States

The figure presents an PBEE application of a bridge. Unlike buildings where collapse hazard to occupants, repair costs, and loss of functionality are all significant considerations, overriding performance metric for the bridge the reduced capacity of a bridge coupled with the required time to restore the bridge to full functionality. PBEE is applied to create fragility relationships, such as shown in figure 2.6, which relate the ground motion IM to the probability of the bridge being in a specified functional state. The damages states are: 1 lane closed (75% traffic capacity), only emergency lane open (50% traffic capacity), and all lanes closed (0% traffic capacity).

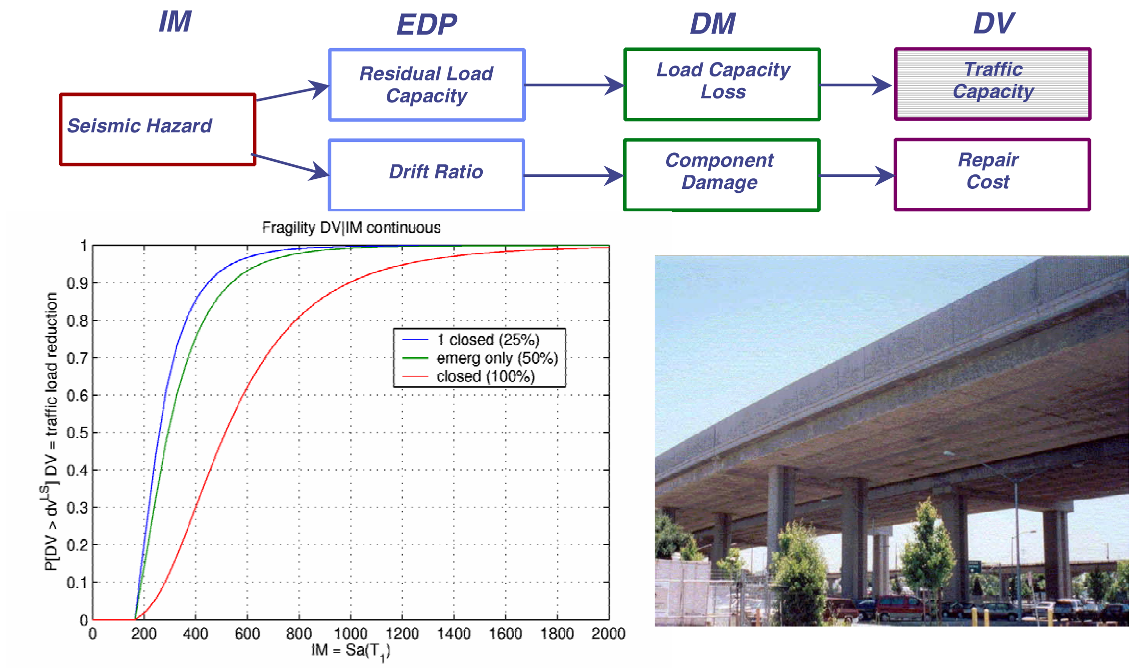

Figure 2-6 PBEE applied to a road (Figure 11 in Moehle and Deierlein, 2004)

2.6.6 The 3rd Generation Methodology

The 2012 PBSD methodology presented in FEMA (2012) is the result of an update PBSD, i.e., the 3rd generation. It was developed to improve the ability to predict response, the acceptance criteria, the application to the design of new buildings, and ways of communicating performance to stakeholders that is meaningful and useful for decision-making purposes. Two of the five objectives relate directly to stakeholders:

- Develop a **framework for performance assessment** that properly accounts for, and adequately communicates to stakeholders, limitations in our ability to accurately predict response, and uncertainty in the level of earthquake hazard.

- Revise the **discrete performance levels** defined in present-generation procedures to create new performance measures that better relate to the decision-making needs of stakeholders.

Implementation of the methodology requires basic data on structural and nonstructural component vulnerability. FEMA (2012) provides fragility and consequence data on structural systems and components the systems listed in figure 2.7. Figure 2.8 lists the building occupancies for which nonstructural component data and population models are provided.

Material	System	Comments
Concrete	Beam-column frames	Conventionally reinforced, with or without modern seismic-resistant detailing
	Shear walls	Shear or flexurally controlled, with or without seismic-resistant detailing
	Slab-column systems	Post-tensioned or conventionally reinforced, with or without slab shear reinforcement
Masonry	Walls	Special or ordinary reinforced masonry walls, controlled by shear or flexure
Steel	Moment frames	Fully restrained, pre- or post-Northridge, Special, Intermediate, and Ordinary detailing
	Concentrically braced frames	"X"-braced, chevron-braced, single diagonals, special, ordinary, or nonconforming detailing
	Eccentrically braced frames	Flexure or shear links at mid-span of link beam
	Light-framed walls	Structural panel sheathing, steel panel sheathing or diagonal strap bracing
	Conventional floor framing	Concrete-filled metal deck, untopped steel deck, or wood sheathing
Timber	Light-framed walls	Structural panel sheathing, gypsum board sheathing, cement plaster sheathing, let-in bracing, and with or without hold downs

Figure 2-7 Structural systems and components for which fragility and consequence data have been provided (Table 1.1 in FEMA 2012)

Table 1-2 Building Occupancies for which Nonstructural Component Data and Population Models have been Provided

Occupancy	Comment
Commercial Office	None
Education (K-12)	Typical elementary, middle school, high school classrooms
Healthcare	General in-patient hospitals, medical equipment excluded
Hospitality	Hotels and motels
Multi-Unit Residential	Apartments; also applicable to single-family detached housing
Research Laboratories	Special purpose laboratory equipment excluded
Retail	Shopping malls and department stores
Warehouse	Inventory excluded

Figure 2-8 Building occupancies for which NSC data and population models been provided (Table 1.2 in FEMA 2012)

2.6.7 Stakeholder perspective in PBSD

The stakeholder perspective is ensured in the performance-based design process through collaboration between the designer and owner. Each performance objective is a statement of the acceptable risk of incurring damage or loss for identified earthquake hazards. Design professionals, owners, and other stakeholders jointly identify the desired building performance characteristics at the outset of a project. As design decisions are made, the effects of these decisions are evaluated to verify that the final building design is capable of achieving the desired performance. The collaboration is an iterative process, where various design or retrofit variations can be tested to see the performance outcomes.

3 Results

3.1 Step 3: Stakeholder-Specific NSC Classification

Step 3 is viewing the existing NSC classification system from the perspective of the chosen stakeholders. Stakeholder specific NSC classification is composed of the following steps

1. The NSC (and structural) classification system defined by Porter (2005) is presented as the basic NSC classification system. Table 3.1 shows the first three levels. The fourth and fifth levels are in Annex B

Table 3-1 First 3 levels of Porter´s (2005) NSC classification system

A. Substructure	A.1 Foundations	Standard Foundations
		Special Foundations
		Slab on grade
	A.2 Basement construction	Basement excavation
		Basement walls
B. Shell	B.1 Superstructure	Floor construction
		Roof construction
		Structural Steel Elements
		R/C structural Elements
	B.2 External Enclosure	External Walls
		External Windows
		External Doors
	B.3 Roofing	Roof Cover
		Roof openings
	B.4 External Finishing	Wall Finishes
C. Interior	C.1 Interior Construction	Partitions
		Interior Doors
		Fittings
	C.2 Stairs	Stairs
		Stairs Finish
	C.3 Interior Finishes	Wall Finish
		Floor Finish
		Ceiling Finish
D. Services	D.1 Conveying	Elevator Lift
		Escalator, Moving Walk
		Other Conveying
	D.2 Plumbing	Plumbing Fixtures
		Domestic Water Distribution
		Sanitary Waste
		Rain Water Drainage
		Other Plumbing
	D.3 HVAC	Energy Supply
		Heat Generation System
		Cooling Generation System
		Distribution System
		Terminal, Package Unit
		Control, Instrumentation
		Testing and Balancing
		Other HVAC
	D.4 Fire Protection	Sprinklers
		Standpipe
		Fire Protection Specialities
		Other Fire Protection
	D.5 Electrical	Electrical Service and Distribution
		Lighting, Branch Wiring
		Communication and Security
		Other Electrical
E. Equipment and Furnishings	E.1 Equipment	Commercial Equipment
		Institutional Equipment
		Vehicular Equipment
		Other Equipment
	E.2 Furnishings	Fixed
		Mobile

2. List stakeholder type (table 3.2, column 1)
3. Create stakeholder perspectives for the chosen stakeholders (table 3.2, column 2)
4. Assess the relevance of the NSCs in Porter´s classification system based on the stakeholder perspective (table 3.2, column 3)

Table 3.2 shows that the owners and facility managers are involved in more detailed information of NSC than the other stakeholders, and that the financial managers deal with the most simplified aspects of NSC, the financial one. However, financial information is based on the more detailed information.

Table 3-2 Stakeholder Specific NSC Classification System

Stakeholder type	Stakeholder Perspective	NSC
1. Owners and facility managers *Can have input on design during design phase*	• Commission building design and construction, • Acquiring, maintaining and/or operating buildings and facilities. Decisions about catastrophic risks that lead to action (or inaction) on a relatively narrow scale. • Perspective on specific business or institution. 1. Investors/ investment risk 2. Institutions/ operational risks 3. Industry/ market risks	B.2 External Enclosure B.3 Roofing B.4 External Finishing C.1 Interior Construction C.2 Stairs C.3 Interior Finishes D.1 Conveying D.2 Plumbing D.3 HVAC D.4 Fire Protection D.5 Electrical E.1 Equipment E.2 Furnishings
2. Occupants of residential buildings *Make decisions on content after design phase and after the building has been built*	The homeowner perspective is those who live in the home, regardless of whether the individual is the owner of the building, renting, etc.	E.1 Equipment E.2 Furnishings All building content
3. Societal and governmental interests *Make decisions prior to design phase on pre-requisites to the design*	• Public safety • Local/regional/national economies. • Public policy, legislation and administration. • Perspective 1. Policy-makers; decisions for the community 2. Regulators; "enforcers," focused on the problem one building at a time 3. Special interest and advocacy groups; "speak" for the interested and affected public	The main channel for this stakeholder perspective for controlling design is through building codes. Relevant NSC are therefore those addressed in building codes. This will vary between countries. Note: Societal and governmental interests also focus on preparedness aspects, such as the functioning of government owned facilities during disasters, which is the owner perspective.
4. Financial managers *Lenders make decisions prior to design phase on whether a building will be built* *Insurers decide whether the owners will be able to buy earthquake insurance*	• Financial risk associated with the decision to finance or assume risk, rather than in protection of people or owned assets. • Represent different views with respect to when and how the financial decisions are made, which in turn may impact how they characterize the risk and performance issues. • Financial stakeholders tend to use very complex statistical and mathematical tools for decision-making. • Perspective 1. Lenders 2. Insurers 3. Securities packagers	Lenders will want their money back want the facilities to be functional so have money to pay back loans. Insures want to not have to pay out. Meaning that buildings sustain less damage than deductible. The NSC of interest to insurers will depend on what is insured. In some cases, mechanical, electrical, and mechanical equipment are insured with the structural components, and the building content is insured separately.

3.2 Step 5: Stakeholder-Specific NSC Damage State Criteria

The next analytical step, step 5, is to develop criteria for stakeholder-specific damage states as outlined in Table 3.3. The first column lists the stakeholder and the second highlights the aspects that are important to the stakeholder in regards to damage states. The last column in table 3.3 is an adaption of general damage state criteria (listed below) for each stakeholder type.

Human impact
1. Life-safety
2. Non-fatal injuries

Loss of function
3. Building level: To be able to continue operations
4. Building level: To be able to get income and pay loans
5. Building level: To have a home

Repair cost/Capital loss (financial/economical)
6. Building level
7. Societal level

Table 3-3 Step 5: Stakeholder Specific NSC General Damage State Criteria

Stakeholder type	Damage State Aspects	General Damage State Criteria
1. Owners and facility managers *Investment* *Operations* *Market*	Keeping the operations going so that 1. investments are not lost, 2. for the sake of continued operations, 3. that the placement of the facility within the market is not decreased. The fundamental aspect is keeping the facility functioning	For groups B to E in Porter´s list: • Deaths that lead to loss of function • Non-fatal injuries that leads to loss of function • Damages leading to loss of function • Capital loss due to damages and repair on a micro level (building level) • Economical loss due to value of facility in market
2. Home owners	In regards to the physical aspects, the main aspects are to be able to continue to use your home and that the event does not lead to financial difficulties. In regards human impact, life-safety and non-fatal injuries are the main aspects, from an economical level (loss of breadwinner), emotional loss, and loss of caretaker (small children losing parent).	For group E in Porter´s list and for all building content: • Life-Safety • Non-fatal injuries • Functionality • Repair cost
3. Societal and governmental interests *Public safety* *Economy*	If building codes fail to protect society there will be economic losses in society due loss due to loss of life and non-fatal injury (reduced work force), and reduced economies from the overall damages	For any NSC in the building code: • Deaths that lead to economic losses • Non-fatal injuries that lead to economic losses • Repair cost on a macro level (community, national level)
4. Financial managers *To assume financial risk*	Financial risk due to deaths of people with life insurance Financial risk due to injuries among people with health insurance Insured building value and replacement/repair value	For insured NSC: • Deaths to those with life insurance • Non-fatal injuries to those with health insurance • Ability of facility to function in order to pay loans • Repair cost of insured NSC that are damaged to a level in relation to the deductible level.

These general damage state criteria address mainly physical, human, and economic aspects. During an implementation where specific context is given all asset groups (physical, human, economic, environmental, and social) should be considered when defining damage state criteria.

The general damage state criteria developed for table 3.5 can be used to add detail to the general damage states presented by Pantoli et al., as shown below, however, stakeholder perspectives are lost.

- **D1 Minor**: Primarily aesthetic or easily **repairable** damage that would not pose a hazard to **occupants**. Examples of this damage include easily repairable cracks in partition walls, facades or drywall ceilings and small movement of equipment or contents that do not affect their functionality.
    1. No deaths
    2. Non-fatal injuries do not require hospital visits
    3. Able to continue operations with interruption
    4. Can pay loans
    5. Has a home
    6. Repair cost under deductible
    7. Societal economy not affected

- **D2 Moderate**: Requires **repair** to ensure optimal functionality of the component, but it does not require **evacuation** of the building nor pose a life safety hazard. Examples include damage to the connections that require their replacement and damage to access doors that prohibit their smooth or complete opening.
    1. No deaths
    2. Non-fatal injuries do require outpatient hospital visits
    3. Operations are interrupted, but remain on location
    4. Can pay loans if they can be adjusted due to reduced income
    5. Has a home, but needs to make adjustments in living arrangements
    6. Repair cost over deductible, but under reinsurance value
    7. Societal economy is moderately affected

- **D3 Severe**: Poses a significant **life-safety hazard** directly or indirectly (i.e., threatens safe evacuation). Examples include complete detachment of gypsum boards from partition walls, excessive loss of ceiling tiles, toppling of equipment or contents, complete failure of the opening mechanism of doors, or failure of critical elements of an **egress** that would render it unusable.
    1. Deaths
    2. Non-fatal injuries do require hospitalization
    3. Operations are interrupted, and need to be relocated
    4. Cannot pay loans.
    5. Needs a temporary new location.
    6. Repair cost over deductible, but over reinsurance value
    7. Societal economy is severely affected

Since the stakeholder perspective is lost, these expanded versions of Pantoli's et al. states will not be pursued further herein.

The general damage states used as a basis herein were minor, moderate, and severe. Step 5 is a two-part process. The second part is to create minor, moderate, and major damage state criteria from the general damage state criteria in table 3.3 (last column), for each stakeholder. These are presented in the table 3.4. The damage state criteria are not totally different for all stakeholders, but sufficiently different to demonstrate that consideration needs to be taken for individual stakeholders.

Table 3-4 Step 5: Stakeholder Specific NSC Criteria for three Damage States

Stakeholder type	Minor Damage State	Moderate Damage State	Severe Damage State
1. Owners and facility managers, for groups B to E in Porter´s list:	• No deaths • Non-fatal injuries that do not require hospital visits • No loss of function • Minor capital loss • No economic losses, clients are not aware of damages	• No deaths • Non-fatal injuries that require outpatient visits to hospitals Repairable loss of function • Moderate capital loss • Some loss of clients due to interrupted operations	• Deaths • Non-fatal injuries that require hospitalization • Operations need to relocate while waiting for repairs or new facilities • Severe capital loss • Loss of clients due to interrupted operations.
2. Home owners, for group E in Porter´s list and for all building content:	• No deaths • Non-fatal injuries that do not require hospital visits • Continued functionality • Repair cost within deductible level	• No deaths • Non-fatal injuries that require outpatient visits to hospitals • Continued functionality, but living arrangements need to be made • Repair cost above deductible level	• Deaths • Non-fatal injuries that require hospitalization • Need to move out while repairs are made or find new location • Repair cost above deductible level
3. Societal and governmental interests, for any NSC in the building code	• No deaths • Non-fatal injuries are so limited that they do not affect the economy • Repair cost does not impact societal economy	• No deaths • Non-fatal injuries that require outpatient hospital visits to the extent that it affects the economy • Repair cost moderately impacts societal economy	• Deaths to the extent that it affects the economy • Non-fatal injuries that require hospitalization to the level that it affects the economy • Repair cost severely impacts societal economy
4. Financial managers, for insured NSC	• No deaths • No non-fatal injuries that are insured • Are able to function and pay loans • Repair cost of damaged insured NSC are above the deductible.	• No deaths • Non-fatal injuries to those with health insurance, outpatients only • Adjustment to loan payments are requested. • Repair cost of damaged insured NSC are above deductible level and below reinsurance level.	• Deaths to those with life insurance • Non-fatal injuries to those with health insurance, including hospitalization • Are not able to pay loans • Repair cost of damaged insured NSC are above deductible level and above reinsurance level.

3.3 Step 7: Stakeholder specific DRM Procedures for NSC Damage States

Step 7 specifies stakeholder-specific disaster risk management procedures, based on step 5 and 6. Step 5 produced criteria for minor, moderate, and severe damage states. Step 6 provides the general DRM procedures, which can be simplified into the following:

1. Risk analysis
   a. Hazard analysis: The probability of occurrence of an earthquake is not included in this project
   b. Exposure: the stakeholder specific NSC for facility in question
   c. Vulnerability models: Models are assumed, by stating clearly distinct increased damages, repair cost, injury, and decreased functionality with increased hazard level
   d. Disaster scenario: The descriptions in the minor, moderate, and, severe damage states

2. Mitigation
   a. Identify mitigation options
   b. Analyse options
   c. Compare and choose
   d. Implement

3. Preparedness for impact, rescue, relief, and recovery operations
   a. Procedures for assessing the situation
   b. Facilities for communication, and equipment
   c. Contingency plans
   d. Training and testing plans

A combination of step 5 and 6 leads to a table in the format presented in table 3.5. For the sake of reducing the amount of information repeated in this report, the table is presented in a completed form in step 9.

Table 3-5 Format for Step 7

	Minor Damage State	Moderate Damage State	Severe Damage State
Disaster scenario			
Mitigation			
Preparedness			

3.4 Step 9: Stakeholder- and Facility-Specific DRM Procedures for NSC

Finally, step 9 produces tables of procedures for a given stakeholder and facility as templates ready to be further developed by stakeholders. Stakeholder and facility specific DRM procedures for NSC for the chosen stakeholders are outlined in the following tables

3.4.1 Owners and Facility Managers/ Hospital

Table 3-6 DRM template for hospital owners/managers

<table>
<tr><td>stakeholder perspective</td><td colspan="3">Owners and managers are responsible for commissioning building design and construction, acquiring, maintaining and/or operating buildings and facilities. They make decisions about catastrophic risks that lead to action (or inaction) on a relatively narrow scale.

Perspective on specific business or institution:
• Institutions/ operational risks</td></tr>
<tr><td>Exposure (examples)</td><td colspan="2">• Hospital suction
• Water pipes
• sewage pipes
• Telecommunications
• Windows
• Suspended ceilings
• Partition walls
• Floor coverings
• Medical equipment
• Staircases
• Elevators
• Rooftop pumps and chillers
• Internal and external roof coverings
• Roof top water tanks
• Hospitals, see Section 2.5.1 for more detail</td><td>Exposure groups B to E in Porter´s list:

B.1 Superstructure
B.2 External Enclosure
B.3 Roofing
B.4 External Finishing
C.1 Interior Construction
C.2 Stairs
C.3 Interior Finishes
D.1 Conveying
D.2 Plumbing
D.3 HVAC
D.4 Fire Protection
D.5 Electrical</td></tr>
<tr><td>DS</td><td>1. Minor DS</td><td>2. Moderate DS</td><td>3. Severe DS</td></tr>
<tr><td>Disaster scenario</td><td>Describe minor damages to the exposure, and the consequences, from a hospital perspective, based on the following:
• No deaths
• Non-fatal injuries are limited
• No loss of function
• Minor capital loss
• No economic losses, patients are not aware of damages, or vaguely so</td><td>Describe moderate damages to the exposure, and the consequences, from a hospital perspective, based on the following:
• No deaths
• Non-fatal injuries affect the ability of the medical and administrative staff to work. Some patients suffer earthquake injuries.
• Repairable loss of function
• Moderate capital loss
• Need to restrict the number of patients received</td><td>Describe severe damages to the exposure, and the consequences, from a hospital perspective, based on the following:
• Deaths among hospital staff and patients.
• Non-fatal injured staff become part of the hospital patients
• Patient care needs to be relocated while waiting for repairs or new facilities
• Severe capital loss
• Most of the hospital service is shut down.</td></tr>
<tr><td>Mitigation</td><td>Implement the following based on the disaster scenario for minor damage states
a. Identify mitigation options
b. Analyse options
c. Compare and choose
d. Implement</td><td>Implement the following based on the disaster scenario for moderate damage states
a. Identify mitigation options
b. Analyse options
c. Compare and choose
d. Implement</td><td>Implement the following based on the disaster scenario for severe damage states
a. Identify mitigation options
b. Analyse options
c. Compare and choose
d. Implement</td></tr>
<tr><td>Preparedness</td><td>Implement the following based on the disaster scenario for minor damage states, and hospital perspective, taking into consideration any mitigation measures that are to be implemented:
a. Procedures for assessing the situation
a. Facilities for communication, and equipment
b. Contingency plans
c. Training and testing plans</td><td>Implement the following based on the disaster scenario for moderate damage states, and hospital perspective, taking into consideration any mitigation measures that are to be implemented:
a. Procedures for assessing the situation
b. Facilities for communication, and equipment
c. Contingency plans
d. Training and testing plans</td><td>Implement the following based on the disaster scenario for severe damage states, and hospital perspective, taking into consideration any mitigation measures that are to be implemented:
a. Procedures for assessing the situation
b. Facilities for communication, and equipment
c. Contingency plans
d. Training and testing plans</td></tr>
</table>

3.4.2 Owners and Facility Managers/ Schools

Table 3-7 DRM template for school owners/managers

Stakeholder perspective	Owners and managers are responsible for commissioning building design and construction, acquiring, maintaining and/or operating buildings and facilities. They make decisions about catastrophic risks that lead to action (or inaction) on a relatively narrow scale. Perspective on specific business or institution: • Institutions/ operational risks		
Exposure (examples)	Content: • Desktop equipment • Bookcases, storage shelves, etc. • Objects on shelves • Hazardous materials such as chemicals Mechanical, electrical and architectural: • Bracing of Parapets, Gables, Ornamentation & Appendages • Anchorage of Canopies at Exits • Bracing or Removal of Chimneys • Suspension and Bracing of Lights • Anchorage and Bracing of Emergency Lighting • Fastening and Bracing of Ceilings • Restraint of Hazardous Materials Containers • Bracing and Detailing of Sprinkler and Piping • Anchorage and Detailing of Rooftop Equipment • Fastening and Bracing of Equipment – Mechanical and Electrical • Cladding Anchorage • Anchorage of Veneer • Glazing Selection and Detailing • Bracing of Interior • Attachment and Bracing of Cabinets and Furnishings • Attachment and Bracing of Large Ductwork • Large ducts • Shut-Off • Support and Detailing of Elevators • Underfloor Bracing of Computer Access Floor Schools, see Section 2.5.2 for more detail	Exposure groups B to E in Porter´s list: B.1 Superstructure B.2 External Enclosure B.3 Roofing B.4 External Finishing C.1 Interior Construction C.2 Stairs C.3 Interior Finishes D.1 Conveying D.2 Plumbing D.3 HVAC D.4 Fire Protection D.5 Electrical	
DS	1. Minor DS	2. Moderate DS	3. Severe DS
Disaster scenario	Describe minor damages to the exposure, and the consequences, from a school perspective, based on the following: • No deaths • Non-fatal injuries can be dealt with by school staff • No loss of function • Minor capital loss • No economic losses, pupils are not aware of damages, or vaguely so	Describe moderate damages to the exposure, and the consequences, from a school perspective, based on the following: • No deaths • Pupils, teachers, and administration staff need to go to hospital to tend to injuries as outpatients • Repairable loss of function • Moderate capital loss • Need to restrict the number of pupils attending	Describe severe damages to the exposure, and the consequences, from a school perspective, based on the following: • Deaths to pupils, teachers, and administration staff • Pupils, teachers, and administration staff need to be hospitalized • School activities need to relocated while waiting for repairs or new facilities are found • Severe capital loss • Some pupils may be sent to other schools
Mitigation	Implement the following based on the disaster scenario for minor damage states a. Identify mitigation options b. Analyse options c. Compare and choose d. Implement	Implement the following based on the disaster scenario for moderate damage states a. Identify mitigation options b. Analyse options c. Compare and choose d. Implement	Implement the following based on the disaster scenario for severe damage states a. Identify mitigation options b. Analyse options c. Compare and choose d. Implement
Preparedness	Implement the following based on the disaster scenario for minor damage states, and school perspective, taking into consideration any mitigation measures that are to be implemented: a. Procedures for assessing the situation d. Facilities for communication, and equipment e. Contingency plans f. Training and testing plans	Implement the following based on the disaster scenario for moderate damage states, and school perspective, taking into consideration any mitigation measures that are to be implemented: a. Procedures for assessing the situation b. Facilities for communication, and equipment c. Contingency plans d. Training and testing plans	Implement the following based on the disaster scenario for severe damage states, and school perspective, taking into consideration any mitigation measures that are to be implemented: a. Procedures for assessing the situation b. Facilities for communication, and equipment c. Contingency plans d. Training and testing plans

3.4.3 Home Owners/Homes

Table 3-8 DRM template for homeowners

<table>
<tr><td>Stakeholder perspective</td><td colspan="3">1. Kitchen
2. Bedroom
3. Bathroom
4. Laundry-room
5. Living room
6. Home office
7. Garage
8. Communication
9. Emotional values
10. The home is a refuge</td></tr>
<tr><td>Exposure (examples)</td><td colspan="2">• Food, drinks, place to cook, cooking utensils, cookers
• Bed clothes
• Toilet, bath/shower, cleaning utensils (toothbrush, towels)
• Washing machine, dryer
• Furniture, TV, radios
• Office supplies, work documents not backed up
• Car, car-keys may be somewhere else.
• Routers
• Memorabilia
• Walls, locks on doors/windows</td><td>Exposure groups E in Porter´s list:

E.1 Equipment
E.2 Furnishings</td></tr>
<tr><td>DS</td><td>1. Minor DS</td><td>2. Moderate DS</td><td>3. Severe DS</td></tr>
<tr><td>Disaster scenario</td><td>Describe minor damages to the exposure, and the consequences, from a home perspective, based on the following:
• No deaths
• Non-fatal injuries that do not require hospital visits
• Continued functionality
• Repair cost within deductible level</td><td>Describe damages to the exposure, and the consequences, from a home perspective, based on the following:
• No deaths
• Non-fatal injuries that require outpatient visits to hospitals
• Continued functionality, but living arrangements need to be made
• Repair cost above deductible level</td><td>Describe damages to the exposure, and the consequences, from a home perspective, based on the following:
• Deaths
• Non-fatal injuries that require hospitalization
• Need to move out while repairs are made or find new location
• Repair cost above deductible level</td></tr>
<tr><td>Mitigation</td><td>Implement the following based on the disaster scenario for minor damage states
a. Identify mitigation options
b. Analyse options
c. Compare and choose
d. Implement</td><td>Implement the following based on the disaster scenario for moderate damage states
a. Identify mitigation options
b. Analyse options
c. Compare and choose
d. Implement</td><td>Implement the following based on the disaster scenario for severe damage states
a. Identify mitigation options
b. Analyse options
c. Compare and choose
d. Implement</td></tr>
<tr><td>Preparedness</td><td>Implement the following based on the disaster scenario for minor damage states, and home perspective, taking into consideration any mitigation measures that are to be implemented:
a. Procedures for assessing the situation
g. Facilities, communication, and equipment
h. Contingency plans
i. Training and testing plans</td><td>Implement the following based on the disaster scenario for moderate damage states, and home perspective, taking into consideration any mitigation measures that are to be implemented:
a. Procedures for assessing the situation
e. Facilities, communication, and equipment
f. Contingency plans
g. Training and testing plans</td><td>Implement the following based on the disaster scenario for severe damage states, and home perspective, taking into consideration any mitigation measures that are to be implemented:
a. Procedures for assessing the situation
b. Facilities, communication, and equipment
c. Contingency plans
d. Training and testing plans</td></tr>
</table>

3.4.4 Society and Government Interests/All facilities

Table 3-9 DRM template for social and government interest groups, all facilities

<table>
<tr><td>Stakeholder perspective</td><td colspan="3">Focus is on public safety and the impact of catastrophes on local/regional/national economies. Decisions relate primarily to public policy, legislation and administration. The category is separated into three perspectives for focus groups: policy-makers, regulators, and special interest and advocacy groups, reflecting different levels of sophistication, scope of decision-making and problem-solving ability, and types of criteria used by the three groups:
• Policy-makers: broadly applicable decisions for the community.
• Regulators: “enforcers,” focused on the problem one building at a time.
• Special interest and advocacy groups: “speak” for the interested and affected public.

An example of how these three could interact:
• Policy makers set a new law on building construction, to ensure safety
• Regulators monitor the enforcement of building codes, to ensure safety
• Construction industry as a special interest group may contest content in the new law and code, for example if a change in the code increases the construction cost.</td></tr>
<tr><td>Exposure</td><td colspan="3">Exposure taken into consideration will depend on the facility,</td></tr>
<tr><td>DS</td><td>1. Minor DS</td><td>2. Moderate DS</td><td>3. Severe DS</td></tr>
<tr><td>Disaster scenario</td><td>Describe minor damages to the exposure, and the consequences, from a home perspective, based on the following:
• No deaths
• Non-fatal injuries are so limited that they do not affect the economy
• Repair cost does not impact societal economy</td><td>Describe damages to the exposure, and the consequences, from a home perspective, based on the following:
• No deaths
• Non-fatal injuries that require outpatient hospital visits to the extent that it affects the economy
• Repair cost moderately impacts societal economy</td><td>Describe damages to the exposure, and the consequences, from a home perspective, based on the following:
• Deaths to the extent that it affects the economy
• Non-fatal injuries that require hospitalization to the level that it affects the economy
• Repair cost severely impacts societal economy</td></tr>
<tr><td>Mitigation</td><td>Ensure that building codes addresses design of NSC to maximize public safety and minimize effect on national and local economy when communities are threatened by minor hazard levels.</td><td>Ensure that building codes addresses design of NSC to maximize public safety and minimize effect on national and local economy when communities are threatened by moderate hazard levels.</td><td>Ensure that building codes addresses design of NSC to maximize public safety and minimize effect on national and local economy when communities are threatened by severe hazard levels.</td></tr>
<tr><td>Preparedness</td><td>The following is only relevant for government level disaster response: Implement the following based on the disaster scenario for minor damage states, and home perspective, taking into consideration any mitigation measures that are to be implemented:
a. Procedures for assessing the situation
b. Facilities for communication, and equipment
c. Contingency plans
d. Training and testing plans</td><td>The following is only relevant for government level disaster response: Implement the following based on the disaster scenario for moderate damage states, and home perspective, taking into consideration any mitigation measures that are to be implemented:
a. Procedures for assessing the situation
b. Facilities for communication, and equipment
c. Contingency plans
d. Training and testing plans</td><td>The following is only relevant for government level disaster response: Implement the following based on the disaster scenario for severe damage states, and home perspective, taking into consideration any mitigation measures that are to be implemented:
a. Procedures for assessing the situation
b. Facilities for communication, and equipment
c. Contingency plans
d. Training and testing plans</td></tr>
</table>

3.4.5 Financial managers/all facilities

Table 3-10 DRM template for financial managers, all facilities

Stakeholder perspective	Financial stakeholders have an indirect interest in building performance decisions made by others. Decisions relate primarily to whether or not to assume risk associated with buildings and at what compensation level. The financial category might be represented by three focus groups: lenders, insurers, and securities packagers. Financial stakeholders differ from the previous two categories in that the stake is indirect: the concern is the financial risk associated with the decision to finance or assume risk, rather than in protection of people or owned assets. The three groups (lenders, insurers, and securities packagers) represent different views with respect to when and how the financial decisions are made, which in turn may impact how they characterize the risk and performance issues.		
Exposure	Details depend on facility and such things as whether people have taken life and/or health insurance, or disaster risk insurance.		
DS	1. Minor DS	2. Moderate DS	3. Severe DS
Disaster scenario	Describe financial losses due to minor damages to the exposure, and any relevant consequences, based on the following: • No deaths • No non-fatal injuries that are insured • Are able to function and pay loans • Repair cost of damaged insured NSC are above the deductible.	Describe financial losses due to moderate damages to the exposure, and any relevant consequences, based on the following: • No deaths • Non-fatal injuries to those with health insurance, outpatients only • Adjustment to loan payments are requested. • Repair cost of damaged insured NSC are above deductible level and below reinsurance level.	Describe financial losses due to severe damages to the exposure, and any relevant consequences, based on the following: • Deaths to those with life insurance • Non-fatal injuries to those with health insurance, including hospitalization • Are not able to pay loans • Repair cost of damaged insured NSC are above deductible level and above reinsurance level.
Mitigation	Insurers mitigate their risk of minor financial losses through own financial resources	Insurers mitigate their risk of moderate financial losses through reinsurance.	Insurers mitigate their risk of severe financial losses through reinsurance.
Preparedness	Insures need to have plan on how to deal with an increased number of requests for insurance	Insures need to have plan on how to deal with an increased number of requests for insurance that calls for an increase in damage investigators	Insures need to have plan on how to deal with an increased number of requests for insurance that calls for an increase in damage investigators and staff to processes the requests.

4 Discussions

Section 3.4 outlines the key aspects important for developing DRM produces for four types of stakeholders: owners/managers, homeowners, societal and government groups, and financial managers. The information is set up in templates for stakeholders to use a guide. During an application, the text in the templates will be replaced with information relevant to the context of the application and the stakeholders involved. The templates are dialogue frameworks, as they are intended to guide discussions between engineers and stakeholders. Other specialists are likely to be called to the table as well, such as specialists in disaster operations, to discuss operations options.

While the templates are useful guides, the main value of the work presented herein is the method of how the templates were developed, shown in figure 1.1, There are 9 building blocks, five of which require data/information collection and 4 that require processing of the data/information collected. A desktop study was used to collect information for the five information blocks, i.e., steps 1, 2, 4, 6, and 8, and the results were presented as a demonstration. While the demonstration led to templates that can be useful guides for stakeholders, other stakeholders may have data/information that they believe is more relevant to their setting than those chosen in the study. Therefore, a stakeholder may wish to follow the steps of the method, rather than use the final templates in section 3.4.

While all chosen stakeholders in the demonstration were building related, the stakeholder perspectives were different enough to demonstrate the effect of stakeholder perspective on the damages and eventually disaster risk management procedures. Some stakeholders were interested in the direct consequences of damage in regards to remaining functionality of a NSC, while others were only interested in indirect consequences, such as financial losses and human impact. This is reflected in the templates. A comparison of the templates highlights the difference of stakeholder perspective and how that affects others aspects, such as exposure. An owner/manager is interested in the details of exposure, and requires a sophisticated NSC category system. The homeowner needs a less detailed category system based on the assumption that the house/home is already built and the homeowner deals with the interior aspects. The remaining stakeholder groups are interested in exposure to a decreasing level; societal and government groups have a broader interest in exposure at is relates to safety and cost, and finance managers are only interested in exposure from a financial perspective. The different level of detail towards exposure will influence the level of detail in processes for mitigation and preparedness, as demonstrated in the templates in section 3.4. Furthermore, the importance of identifying a specific facility also depends on the stakeholder perspective. Owners and managers of hospitals and schools are going to be more interested in the details of the facilities than, for example financial managers.

The work began by identifying Porter´s NSC grouping as good representation of a general NSC classification system, which has five levels of detail. The first level, applies to most, if not all geographical locations. However, as the level of detail increases, the information becomes more and more specific to its country of origin, USA. Even so, Porter´s NSC grouping can be used for other countries as a guide to help them develop their own: one can follow Porter´s grouping until the details do not apply any more, and then switch them for correct details for the given context.

Further development of the templates, as well as an application of templates, requires the participation of relevant stakeholders so that the stakeholder perspective can be developed in consultation with the them. Stakeholders must provide detailed information about use of the NSCs in the facility. They also need to provide information on how damages to NSC will impact the operation of the facility, and what types of consequences are likely to occur that could affect the operation as this will be different for different stakeholders. For example, evacuation from a school is different from an evacuation from a hospital where the latter requires the transport of bedridden individuals, calling for wider doors. The latter may also be expected to still try to function even though it has been damaged, while a school will be abandoned if its structural integrity has been comprised.

The underlying theme throughout the process of the application is a stakeholder-engineer dialogue. Engineering design ensures that all NSC are designed according to code for components that have design requirements. The Performance-based Earthquake Engineering methodology is specifically developed to include stakeholder perspective and using stakeholders to assist in identifying performance perspectives. By separating the phases of the design into hazard, structural, damage, and loss analysis, it is easy for stakeholders to come into projects at relevant phases, and also allows engineers with different specialties to address different parts of the process. As long as the engineers each understand the output and input of different phases, cooperation is straightforward. The example of the bridge provided in Section 2.6.4 is a good demonstration on the important role of stakeholder and facility perspective. PBEE is a methodology for risk analysis. However, stakeholders are interested in different damages and consequences that could occur despite design precautions. The steps missing in PBEE to create a methodology for full scale disaster risk management are mitigation and preparedness procedures, as presented herein.

The issue of risk communication is therefore not only about the engineer explaining to the stakeholder the type and level of risk the stakeholder faces, but rather risk communication is a dialogue about options and ideas on how to manage risk. Perry et al. (2009) state that risk reduction includes stakeholder education, information sharing and guideline: education about nonstructural hazards and successful nonstructural restraint systems for building owners and managers and also for design professionals, equipment vendors, installers, and building inspectors is needed; owners, insurers, and financiers need more information about the potential legal and financial risks of nonstructural failures and the benefits of improving their existing facilities; and design professionals and installers, need more detailed guidelines and examples of cost effective restraint systems that have been used successfully. Perry et al. go on to address the systemization of risk reduction and that unless the scopes and responsibilities are clearly defined, the work is unlikely to get done.

The weakness in this approach is that damage states for each NSC group, and corresponding fragility curves do not exist, and it will take an extensive amount of work to develop them, and even more time is needed to develop stakeholder specific damage states. The desktop study revealed fragility functions for structural and non-structural components within PBEE. Scientific literature holds more information, but it is likely that future projects will identify the need for research and development.

5 Conclusion

General NSC classification systems, and their associated damage states are the basis for making disaster risk management decisions due to damages from NSC. Including stakeholder perspective and facility specificity into the disaster risk management procedures will lead to improved risk management decision making. By using a structured format of the key aspects required for such DRM procedures, and the relationships between them, it is possible to develop a method for building templates that guide applications for developing stakeholder and facility specific DRM procedures. Stakeholder perspective and facility specificity can be generalized from scientific and grey literature, but actual applications require detailed discussions with relevant stakeholders. Engineer-stakeholder dialogue is thus a necessary component of full scale disaster risk management.

Task C1 looked at the diversity of stakeholders and facilities. The outcome showed that the interest in the details of NSC varies greatly between stakeholders, and therefore, the need for specialist NSC classification systems varies as well. Due to the diversity of interest among stakeholders towards details of NSC, their potential damages and consequences, it is not important to develop a standard NSC classification system that attempts to incorporate all perspectives; it is more valuable to have a general classification system (such as presented by Porter, 2005) and then develop formats that are appropriate for each stakeholder.

Future research should focus on how to systemize engineer-stakeholder dialogue. Performance-based Earthquake Engineering is designed to foster engineer-stakeholder dialogue, and can therefore be used a building block for further development of an engineer-stakeholder dialogue. More research and development work is needed to create country specific NSC classification systems, and associated damage states and facility curves. Future work should also include applications of specific context to investigate whether there are more similarities that can be drawn between stakeholders or facilities to further develop the general templates.

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Annexes

Annex A References for NSC Classification Systems

Buildings in general and housing (15)

Author(s)	**Year**	**Title**
Porter KA	2005	A Taxonomy of Building Components for Performance-Based Earthquake Engineering
FEMA E-74	2011	Reducing the Risks of Nonstructural Earthquake Damage – A Practical Guide
Kao A et al	1999	Nonstructural Damage Database
FEMA P-749	2010	*NEHRP Recommended Seismic Provisions* EARTHQUAKE-RESISTANT DESIGN CONCEPTS, Chapter 4 BUILDINGS, STRUCTURES, AND NONSTRUCTURAL COMPONENTS Understanding the Provisions as a basis for seismic-related codes and standards is important to many others outside the technical community. To support this transfer of knowledge, the BSSC has developed Earthquake-Resistant Design Concepts, FEMA P-749 for use by builders, elected officials, industry representatives, decision–makers in the insurance and finance communities, individual business owners, other members of the building community and the public. The document provides a nontechnical explanation of the concepts of the earthquake-resistant design and requirements of the Provisions. From the BSSC.
Shinozuka et al	1999	Development of Fragility Information for Structures and Nonstructural Components in Shinozuka, M., Grigoriu, M., Ingraffea, A. R., Billington, S. L., Feenstra, P., Soong, T. T., … & Maragakis, E. (2000). Development of fragility information for structures and 43non-structural components. *MCEER Research Progress and Accomplishments*, *1999*, 15-32.
FEMA-445	2006	Next-Generation Performance-Based Seismic Design Guidelines, Program Plan for New and Existing Buildings
Aslani and Miranda, from Aslani´s PhD	2005 PhD	PROBABILISTIC EARTHQUAKE LOSS ESTIMATION AND LOSS DISAGGREGATION IN BUILDINGS, Department of Civil and Environmental Engineering Stanford University
FAROKHNIA	2005 PhD	NONSTRUCTURAL VULNERABILITY FUNCTIONS FOR BUILDING CATEGORIES
Sankaranarayanan,	2007 PhD	SEISMIC RESPONSE OF ACCELERATION- SENSITIVE NONSTRUCTURAL COMPONENTS MOUNTED ON MOMENT-RESISTING FRAME STRUCTURE
Chen	2016 Testing	Full-Scale Structural and Nonstructural Building System Performance during Earthquakes: Part I – Specimen Description, Test Protocol, and Structural Response
Pantoli et al.	2016 Testing	Full-Scale Structural and Nonstructural Building System Performance during Earthquakes: Part II – NCS Damage States
Matsuoka	2008 Testing	NON-STRUCTURAL COMPONENT PERFORMANCE IN 4-STORY FRAME TESTED TO COLLAPSE
Villaverde	1997	Seismic DESIGN OF SECONDARY STRUCTURES: STATE OF THE ART
Filiatrault and Sullivan	2014	Performance-based seismic design of nonstructural building components: The next frontier of earthquake engineering
Hamburger et al.	2006	THE ATC-58 PROJECT: DEVELOPMENT OF NEXT- GENERATION PERFORMANCE-BASED EARTHQUAKE ENGINEERING DESIGN CRITERIA FOR BUILDINGS

Hospitals (1)

Author(s)	Year	Title
Cimellaro et al.	2010	Seismic resilience of a hospital system

Schools (1)

Author(s)	Year	Title
Bay Area Regional Earthquake Preparedness Project	1990	Identification and Reduction of Non-Structural Earthquake Hazards in California Schools

Annex B Porter´s Taxonomy

The first three levels of Porter´s NSC taxonomy

A. Substructure	A.1 Foundations	Standard Foundations
		Special Foundations
		Slab on grade
	A.2 Basement construction	Basement excavation
		Basement walls
B. Shell	B.1 Superstructure	Floor construction
		Roof construction
		Structural Steel Elements
		R/C structural Elements
	B.2 External Enclosure	External Walls
		External Windows
		External Doors
	B.3 Roofing	Roof Cover
		Roof openings
	B.4 External Finishing	Wall Finishes
C. Interior	C.1 Interior Construction	Partitions
		Interior Doors
		Fittings
	C.2 Stairs	Stairs
		Stairs Finish
	C.3 Interior Finishes	Wall Finish
		Floor Finish
		Ceiling Finish
D. Services	D.1 Conveying	Elevator Lift
		Escalator, Moving Walk
		Other Conveying
	D.2 Plumbing	Plumbing Fixtures
		Domestic Water Distribution
		Sanitary Waste
		Rain Water Drainage
		Other Plumbing
	D.3 HVAC	Energy Supply
		Heat Generation System
		Cooling Generation System
		Distribution System
		Terminal, Package Unit
		Control, Instrumentation
		Testing and Balancing
		Other HVAC
	D.4 Fire Protection	Sprinklers
		Standpipe
		Fire Protection Specialities
		Other Fire Protection
	D.5 Electrical	Electrical Service and Distribution
		Lighting, Branch Wiring
		Communication and Security
		Other Electrical
E. Equipment and Furnishings	E.1 Equipment	Commercial Equipment
		Institutional Equipment
		Vehicular Equipment
		Other Equipment
	E.2 Furnishings	Fixed
		Mobile

The remainder of Annex B presents all four levels of Porter´s taxonomy

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
A Substructure	A10 Foundations	A1010 Standard Foundations	A1011 Wall Foundations	A1011.000 Wall Foundations, all
			A1012 Column Foundations, Pile Caps	A1012.000 Column Foundations & Pile Caps, all
			A1013 Perimeter Drainage, Insulation	A1013.000 Perimeter Drainage & Insulation, all
		A1020 Special Foundations	A1021 Pile Foundations	A1021.000 Pile Foundations, all
			A1022 Grade Beams	A1022.000 Grade Beams, all
			A1023 Caissons	A1023.000 Caissons, all
			A1024 Underprinting	A1024.000 Underprinting, all
			A1025 Dewatering	A1025.000 Dewatering, all
			A1026 Raft Foundations	A1026.000 Raft Foundations, all
			A1027 Pressure Injected Grouting	A1027.000 Pressure Injected Grouting, all
			A1029 Other Special Conditions	A1029.000 Other Special Conditions, all
		A1030 Slab on Grade	A1031 Standard Slab on Grade	A1031.000 Standard Slab on Grade, all
			A1032 Structural Slab on Grade	A1032.000 Structural Slab on Grade, all
			A1033 Inclined Slab on Grade	A1033.000 Inclined Slab on Grade, all
			A1034 Trenches, Pits & Bases	A1034.000 Trenches, Pits & Bases, all
			A1035 Under-Slab Drainage & Insulation	A1035.000 Under-Slab Drainage & Insulation, all
	A20 Basement Constr.	A2010 Basement Excavation	A2011 Excavation for Basements	A2011.000 Excavation for Basements, all
			A2012 Structure Back Fill & Compaction	A2012.000 Structure Back Fill & Compaction, all
			A2013 Shoring	A2013.000 Shoring, all
		A2020 Basement Walls	A2021 Basement Wall Construction	A2021.000 Basement Wall Construction, all
			A2022 Moisture Protection	A2022.000 Moisture Protection, all
			A2023 Basement Wall Insulation	A2023.000 Basement Wall Insulation, all
			A2024 Interior Skin	A2024.000 Interior Skin, all
B Shell	B10 Super Structure	B1010 Floor Construction	B1011 Susp. Basement Floor Constr.	B1011.000 Suspended Basement Floors Construction, all
			B1012 Upper Floors Construction	B1012.000 Upper Floors Construction, all
			B1013 Balcony Floors Construction	B1013.000 Balcony Floors Construction, all
			B1014 Ramps	B1014.000 Ramps, all
			B1015 Exterior Stairs and Fire Escapes	B1015.000 Exterior Stairs and Fire Escapes, all
			B1016 Floor Raceway Systems	B1016.000 Floor Raceway Systems, all
			B1019 Other Floor Construction	B1019.000 Other Floor Construction, all
		B1020 Roof Construction	B1021 Flat Roof Construction	B1021.000 Flat Roof Construction, all
			B1022 Pitched Roof Construction	B1022.000 Pitched Roof Construction, all
			B1023 Canopies	B1023.000 Canopies, all
			B1029 Other Roof Systems	B1029.000 Other Roof Systems, all
		B1030 Struct. Steel Elements	B1031 Steel Columns	B1031.000 Steel Columns, all
			B1032 Steel Beams	B1032.000 Steel Beams, all
			B1033 Steel Braces	B1033.000 Steel Braces, all
			B1034 Steel Shearwalls	B1034.000 Steel Shearwalls, all
			B1035 Steel Connections	B1035.000 Steel Connections, all
				B1035.001 Pre-Northridge welded-steel moment-frame conn.
		B1040 R/C Struct. Elements	B1041 RC or Composite Columns	B1041.000 Reinf. Concr. or Composite Columns, all
				B1041.001 Nonductile CIP RC column
			B1042 RC or Composite Beams	B1042.000 Reinf. Concr. or Composite Beams, all
				B1042.001 Nonductile CIP RC beam
			B1043 RC or Composite Braces	B1043.000 Reinf. Concr. or Composite Braces, all
			B1044 RC or Composite Shearwall	B1044.000 Reinf. Concr. or Composite Shearwalls, all
	B20 Ext. Enclosure	B2010 Ext. Walls	B2011 Exterior Wall Construction	B2011.000 Exterior Wall Construction, all
				B2011.001 Exterior shearwall, 3/8 C-D ply, 2x4, 16" OC, 7/8" stucco ext, no int finish
				B2011.002 Exterior shearwall, 15/32 C-D ply, 2x4, 16" OC, 7/8" stucco ext, no int finish
				B2011.003 Exterior shearwall, 7/16 OSB, 2x4, 16" OC, 7/8" stucco ext, no int finish
				B2011.004 Exterior wall, no structural sheathing, 2x4, 16" OC, 7/8" stucco ext, no int finish
				B2011.005 Stucco finish, 7/8", 3-5/8" mtl stud, 16"OC
			B2012 Parapets	B2012.000 Parapets, all
			B2013 Exterior Louvers, Screens, Fencing	B2013.000 Exterior Louvers, Screens, and Fencing, all
				B2013.001 Non-engineered concrete block freestanding walls
				B2013.002 Engineered concrete block freestanding walls
			B2014 Exterior Sun Control Devices	B2014.000 Exterior Sun Control Devices, all
			B2015 Balcony Walls & Handrails	B2015.000 Balcony Walls & Handrails, all
			B2016 Exterior Soffits	B2016.000 Exterior Soffits, all
		B2020 Ext. Windows	B2021 Windows	B2021.000 Windows, all
				B2021.001 Window, Al frame, sliding, std glass, 1-25 sf pane
				B2021.002 Window, Al frame, fixed, std glass, 80"x80" pane
				B2021.003 Windows, wood, double hung, standard glass, 3'-1.5"x4'

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
				B2021.004 Window, AL frame, sliding, heavy sheet glass, 4'-0x2'-6"x3/16"
			B2022 Curtain Walls	B2022.000 Curtain Walls, all
				B2022.001 Highrise curtain-wall systems with annealed glass
				B2022.002 Highrise curtain-wall systems with tempered, wired, or laminated glass, or glass with shatter-resistant film
			B2023 Storefronts	B2023.000 Storefronts, all
				B2023.001 Lowrise storefront windows with annealed glass
				B2023.002 Lowrise storefront windows with tempered, wired, or laminated glass, or glass with shatter-resistant film
		B2030 Ext. Doors	B2031 Glazed Doors & Entrances	B2031.000 Glazed Doors & Entrances, all
				B2031.001 Doors, sliding, patio, aluminum, std, 6'-0"x6'-8", wood frame, insulated glass
			B2032 Solid Exterior Doors	B2032.000 Solid Exterior Doors, all
			B2033 Revolving Doors	B2033.000 Revolving Doors, all
			B2034 Overhead Doors	B2034.000 Overhead Doors, all
			B2039 Other Doors & Entrances	B2039.000 Other Doors & Entrances, all
	B30 Roofing	B3010 Roof Cover	B3011 Roof Finishes	B3011.000 Roof Finishes, all
				B3011.001 Concrete, clay, and slate roofing tiles that are not individually fastened to the roof sheathing
				B3011.002 Concrete, clay, and slate roofing tiles that are individually fastened to the roof sheathing
				B3011.003 Lightweight roofing
			B3012 Traffic Toppings, Paving Membr.	B3012.000 Traffic Toppings & Paving Membranes, all
			B3013 Roof Insulation & Fill	B3013.000 Roof Insulation & Fill, all
			B3014 Flashings & Trim	B3014.000 Flashings & Trim, all
			B3015 Roof Eaves and Soffits	B3015.000 Roof Eaves and Soffits, all
			B3016 Gutters and Downspouts	B3016.000 Gutters and Downspouts, all
		B3020 Roof Openings	B3021 Glazed Roof Openings	B3021.000 Glazed Roof Openings, all
			B3022 Roof Hatches	B3022.000 Roof Hatches, all
			B3023 Gravity Roof Ventilators	B3023.000 Gravity Roof Ventilators, all
	B40 Ext. Finishes	B4010 Ext. Finish	B4041 Wall Finishes to Exterior	B4041.000 Wall Finishes to Exterior, all
				B4041.001 Paint on exterior stucco or concrete
				B4041.002 Brick masonry veneer w/o ties to the supporting wall
				B4041.003 Brick masonry veneer tied to supporting wall

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
				B4041.004 Stone veneer attached with mortar spots
				B4041.005 Stone veneer tied to supporting wall
C Interiors	C10 Int. Construction	C1010 Partitions	C1011 Fixed Partitions	C1011.000 Fixed Partitions, all
				C1011.001 GWB partition, no structural sheathing, 1/2" GWB one side, 2x4, 16" OC
				C1011.002 GWB finish, 1/2", one side, on 2x4, 16"OC
				C1011.003 Interior shearwall, 3/8 C-D ply, 2x4, 16" OC, 1/2" GWB finish one side
				C1011.004 Interior shearwall, 15/32 C-D ply, 2x4, 16" OC, 1/2" GWB finish one side
				C1011.005 Interior sheathing, 3/8 C-D ply, 1/2" GWB finish one side, on 2x4 16" OC
				C1011.006 Interior sheathing, 15/32 C-D ply, 1/2" GWB finish one side, on 2x4, 16" OC
				C1011.007 Interior shearwall, 7/16 OSB, 2x4, 16" OC, 1/2" GWB finish one side
				C1011.008 Interior sheathing, 7/16 OSB, 1/2" GWB finish one side, on 2x4 16" OC
				C1011.009 Drywall finish, 5/8-in., 1 side, on 3-5/8-in metal stud, screws
				C1011.010 Drywall partition, 5/8-in., 1 side, with 3-5/8-in metal stud, screws
			C1012 Demountable Partitions	C1012.000 Demountable Partitions, all
			C1013 Retractable Partitions	C1013.000 Retractable Partitions, all
			C1014 Site Built Toilet Partitions	C1014.000 Site Built Toilet Partitions, all
			C1015 Site Built Compartments Cubicles	C1015.000 Site Built Compartments Cubicles, all
			C1016 Interior Balustrades and Screens	C1016.000 Interior Balustrades and Screens, all
			C1017 Interior Windows & Storefronts	C1017.000 Interior Windows & Storefronts, all
		C1020 Int. Doors	C1021 Interior Doors	C1021.000 Interior Doors, all
			C1022 Interior Door Frames	C1022.000 Interior Door Frames, all
			C1023 Interior Door Hardware	C1023.000 Interior Door Hardware, all
			C1024 Interior Door Wall Opening Elem	C1024.000 Interior Door Wall Opening Elements, all
			C1025 Interior Door Sidelights , Transoms	C1025.000 Interior Door Sidelights & Transoms, all
			C1026 Interior Hatches & Access Doors	C1026.000 Interior Hatches & Access Doors, all
			C1027 Door Painting & Decoration	C1027.000 Door Painting & Decoration, all
		C1030 Fittings	C1031 Fabricated Toilet Partitions	C1031.000 Fabricated Toilet Partitions, all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
			C1032 Fabricated Compartment , Cubicle	C1032.000 Fabricated Compartments & Cubicles, all
			C1033 Storage Shelving and Lockers	C1033.000 Storage Shelving and Lockers, all
			C1034 Ornamental Metals and Handrails	C1034.000 Ornamental Metals and Handrails, all
			C1035 Identifying Devices	C1035.000 Identifying Devices, all
			C1036 Closet Specialties	C1036.000 Closet Specialties, all
			C1037 General Fittings & Misc. Metals	C1037.000 General Fittings & Misc. Metals, all
	C20 Stairs	C2010 Stairs	C2011 Regular Stairs	C2011.000 Regular Stairs, all
			C2012 Curved Stairs	C2012.000 Curved Stairs, all
			C2013 Spiral Stairs	C2013.000 Spiral Stairs, all
			C2014 Stair Handrails and Balustrades	C2014.000 Stair Handrails and Balustrades, all
		C2020 Stair Finish	C2021 Stair, Tread, and Landing Finishes	C2021.000 Stair, Tread, and Landing Finishes, all
			C2022 Stair Soffit Finishes	C2022.000 Stair Soffit Finishes, all
			C2023 Stair Handrail & Balustrade Finish	C2023.000 Stair Handrail & Balustrade Finishes, all
	C30 Int. Finishes	C3010 Wall Finish	C3011 Wall Finishes to Inside Exterior	C3011.000 Wall Finishes to Inside Exterior, all
				C3011.001 Paint on interior of exterior walls
				C3011.002 Ceramic tile veneer over int. of ext. walls
				C3011.003 Wallpaper on interior of exterior walls
				C3011.004 Vinyl wall coverings on int. of ext. walls
			C3012 Wall Finishes to Interior Walls	C3012.000 Wall Finishes to Interior Walls, all
				C3012.001 Paint on interior concrete, drywall or plaster
				C3012.002 Paint on interior partitions
				C3012.003 Ceramic tile veneer over interior partitions
				C3012.004 Wallpaper on interior partitions
				C3012.005 Vinyl wall coverings on interior partitions
			C3013 Column Finishes	C3013.000 Column Finishes, all
		C3020 Floor Finish	C3021 Floor Toppings	C3021.000 Floor Toppings, all
			C3022 Traffic Membranes	C3022.000 Traffic Membranes, all
			C3023 Hardeners and Sealers	C3023.000 Hardeners and Sealers, all
			C3024 Flooring	C3024.000 Flooring, all
			C3025 Carpeting	C3025.000 Carpeting, all
			C3026 Bases, Curbs and Trim	C3026.000 Bases, Curbs and Trim, all
			C3027 Access Pedestal Flooring	C3027.000 Access Pedestal Flooring, all
		C3030 Ceiling Fin.	C3031 Ceiling Finishes	C3031.000 Ceiling Finishes, all
			C3032 Suspended Ceilings	C3032.000 Suspended Ceilings, all
Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
				C3032.001 Lightweight acoustical ceiling 4'-x-2' Al tee-bar grid
				C3032.002 Suspended ceilings w/o diagonal braces, compression struts or both
				C3032.003 Suspended ceilings w/braces, compr. Struts
			C3033 Other Ceilings	C3033.000 Other Ceilings, all
D Services	D10 Conveying	D1010 Elevator, Lift	D1011 Passenger Elevators	D1011.000 Passenger Elevators, all
				D1011.001 Traction passenger elevators
				D1011.002 Hydraulic passenger elevators
				D1011.003 Traction passenger elevators meeting seismic reqts UBC 1994
				D1011.004 Traction passenger elevators exceeding UBC 1994
			D1012 Freight Elevators	D1012.000 Freight Elevators, all
				D1012.001 Traction freight elevators
				D1012.002 Hydraulic freight elevators
				D1012.003 Traction freight elevators meeting seismic reqts UBC 1994
				D1012.003 Traction freight elevators exceeding seismic reqts UBC 1994
			D1013 Lifts	D1013.000 Lifts, all
		D1020 Escalator, Moving Walk	D1021 Escalators	D1021.000 Escalators, all
			D1022 Moving Walks	D1022.000 Moving Walks, all
		D1090 Other Conveying	D1091 Dumbwaiters	D1091.000 Dumbwaiters, all
			D1092 Pneumatic Tube Systems	D1092.000 Pneumatic Tube Systems, all
			D1093 Hoists & Cranes	D1093.000 Hoists & Cranes, all
			D1094 Conveyors	D1094.000 Conveyors, all
			D1095 Chutes	D1095.000 Chutes, all
			D1096 Turntables	D1096.000 Turntables, all
			D1097 Baggage Handling & Loading	D1097.000 Baggage Handling & Loading Systems, all
			D1098 Transportation Systems	D1098.000 Transportation Systems, all
	D20 Plumbing	D2010 Plumbing Fixtures	D2011 Water Closets	D2011.000 Water Closets, all
			D2012 Urinals	D2012.000 Urinals, all
			D2013 Lavatories	D2013.000 Lavatories, all
			D2014 Sinks	D2014.000 Sinks, all
			D2015 Bathtubs	D2015.000 Bathtubs, all
			D2016 Wash Fountains	D2016.000 Wash Fountains, all
			D2017 Showers	D2017.000 Showers, all
			D2018 Drinking Fountains and Coolers	D2018.000 Drinking Fountains and Coolers, all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
			D2019 Bidets, Other Plumbing Fixtures	D2019.000 Bidets and Other Plumbing Fixtures, all
		D2020 Domest.	D2021 Cold Water Service	D2021.000 Cold Water Service, all
		Water Distribution	D2022 Hot Water Service	D2022.000 Hot Water Service, all
			D2023 Domestic Water Supply Eqpt	D2023.000 Domestic Water Supply Equipment, all
		D2030 Sanitary	D2031 Waste Piping	D2031.000 Waste Piping, all
		Waste	D2032 Vent Piping	D2032.000 Vent Piping, all
			D2033 Floor Drains	D2033.000 Floor Drains, all
			D2034 Sanitary Waste Equipment	D2034.000 Sanitary Waste Equipment, all
			D2035 Pipe Insulation	D2035.000 Pipe Insulation, all
		D2040 Rain Water	D2041 Pipe & Fittings	D2041.000 Pipe & Fittings, all
		Drainage	D2042 Roof Drains	D2042.000 Roof Drains, all
			D2043 Rainwater Drainage Equipment	D2043.000 Rainwater Drainage Equipment, all
			D2044 Pipe Insulation	D2044.000 Pipe Insulation, all
		D2090 Other	D2091 Gas Distribution	D2091.000 Gas Distribution, all
		Plumbing	D2092 Acid Waste Systems	D2092.000 Acid Waste Systems, all
			D2093 Interceptors	D2093.000 Interceptors, all
			D2094 Pool Piping and Equipment	D2094.000 Pool Piping and Equipment, all
			D2095 Decorative Fountain Piping Device	D2095.000 Decorative Fountain Piping Devices, all
			D2099 Other Piping Systems	D2099.000 Other Piping Systems, all
	D30 HVAC	D3010 Energy	D3011 Oil Supply System	D3011.000 Oil Supply System, all
		Supply	D3012 Gas Supply System	D3012.000 Gas Supply System, all
			D3013 Coal Supply System	D3013.000 Coal Supply System, all
			D3014 Steam Supply System	D3014.000 Steam Supply System, all
			D3015 Hot Water Supply System	D3015.000 Hot Water Supply System, all
				D3015.001 Electric water heater, resid., 50 gal
			D3016 Solar Energy System	D3016.000 Solar Energy System, all
			D3017 Wind Energy System	D3017.000 Wind Energy System, all
		D3020 Heat Gen.	D3021 Boilers	D3021.000 Boilers, all
		Syst.	D3022 Boiler Room Piping, Specialties	D3022.000 Boiler Room Piping & Specialties, all
			D3023 Auxiliary Equipment	D3023.000 Auxiliary Equipment, all
			D3024 Insulation	D3024.000 Insulation, all
		D3030 Cooling Gen.	D3031 Chilled Water Systems	D3031.000 Chilled Water Systems, all
		Syst.	D3032 Direct Expansion Systems	D3032.000 Direct Expansion Systems, all
		D3040 Distribution	D3041 Air Distribution Systems	D3041.000 Air Distribution Systems, all
		Syst.		D3041.001 Fan, braced
				D3041.002 HVAC ductwork rod hung
				D3041.003 HVAC ductwork with sway braces
			D3042 Exhaust Ventilation Systems	D3042.000 Exhaust Ventilation Systems, all
				D3042.001 Unreinforced brick chimneys
				D3042.002 Reinforced masonry and precast RC chimneys
				D3042.003 Insulated metal-lined flue in wood chimneys
			D3043 Steam Distribution Systems	D3043.000 Steam Distribution Systems, all
			D3044 Hot Water Distribution	D3044.000 Hot Water Distribution, all
			D3045 Chilled Water Distribution	D3045.000 Chilled Water Distribution, all
			D3046 Change-over Distribution System	D3046.000 Change-over Distribution System, all
			D3047 Glycol Distribution Systems	D3047.000 Glycol Distribution Systems, all
		D3050 Terminal,	D3051 Terminal Self-Contained Units	D3051.000 Terminal Self-Contained Units, all
		Package Unit	D3052 Package Units	D3052.000 Package Units, all
		D3060 Control,.	D3061 Heating Generating Systems	D3061.000 Heating Generating Systems, all
		Instrumentation	D3062 Cooling Generating Systems	D3062.000 Cooling Generating Systems, all
			D3063 Heating/Cooling Air Handling Units	D3063.000 Heating/Cooling Air Handling Units, all
			D3064 Exhaust & Ventilating Systems	D3064.000 Exhaust & Ventilating Systems, all
			D3065 Hoods and Exhaust Systems	D3065.000 Hoods and Exhaust Systems, all
			D3066 Terminal Devices	D3066.000 Terminal Devices, all
			D3067 Energy Monitoring & Control	D3067.000 Energy Monitoring & Control, all
			D3068 Building Automation Systems	D3068.000 Building Automation Systems, all
			D3069 Other Controls & Instrumentation	D3069.000 Other Controls & Instrumentation, all
		D3070 Testing &	D3071 Piping System Testing & Balancing	D3071.000 Piping System Testing & Balancing, all
		Balancing	D3072 Air Systems Testing & Balancing	D3072.000 Air Systems Testing & Balancing, all
			D3073 HVAC Commissioning	D3073.000 HVAC Commissioning, all
			D3079 Other Systems Testing, Balancing	D3079.000 Other Systems Testing and Balancing, all
		D3090 Other	D3091 Special Cooling Systems , Devices	D3091.000 Special Cooling Systems & Devices, all
		HVAC	D3092 Special Humidity Control	D3092.000 Special Humidity Control, all
			D3093 Dust & Fume Collectors	D3093.000 Dust & Fume Collectors, all
			D3094 Air Curtains	D3094.000 Air Curtains, all
			D3095 Air Purifiers	D3095.000 Air Purifiers, all
			D3096 Paint Spray Booth Ventilation	D3096.000 Paint Spray Booth Ventilation, all
			D3097 General HVAC Items	D3097.000 General Construction Items (HVAC), all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
	D40 Fire Prot.	D4010 Sprinklers	D4011 Sprinkler Water Supply	D4011.000 Sprinkler Water Supply, all
				D4011.001 Unbraced automatic sprinklers
				D4011.002 Braced automatic sprinklers
				D4011.003 Automatic sprinklers noncompliant with NFPA-13
				D4011.004 Automatic sprinklers compliant with NFPA-13
				D4011.005 Pre-action or deluge sprinklers
				D4011.006 Non-water-based fire-suppression systems
			D4012 Sprinkler Pumping Equipment	D4012.000 Sprinkler Pumping Equipment, all
			D4013 Dry Sprinkler System	D4013.000 Dry Sprinkler System, all
		D4020 Standpipe	D4021 Standpipe Water Supply	D4021.000 Standpipe Water Supply, all
			D4022 Pumping Equipment	D4022.000 Pumping Equipment, all
			D4023 Standpipe Equipment	D4023.000 Standpipe Equipment, all
			D4024 Fire Hose Equipment	D4024.000 Fire Hose Equipment, all
		D4030 Fire Prot. Specialties	D4031 Fire Extinguishers	D4031.000 Fire Extinguishers, all
			D4032 Fire Extinguisher Cabinets	D4032.000 Fire Extinguisher Cabinets, all
		D4090 Other Fire Protection	D4091 Carbon Dioxide Systems	D4091.000 Carbon Dioxide Systems, all
			D4092 Foam Generating Equipment	D4092.000 Foam Generating Equipment, all
			D4093 Clean Agent Systems	D4093.000 Clean Agent Systems, all
			D4094 Dry Chemical System	D4094.000 Dry Chemical System, all
			D4095 Hood & Duct Fire Protection	D4095.000 Hood & Duct Fire Protection, all
	D50 Electrical	D5010 Elect Svc & Distribution	D5011 High Tension Service & Dist.	D5011.000 High Tension Service & Dist., all
				D5011.001 Transformer
				D5011.002 Med voltage switchgear
			D5012 Low Tension Service & Dist.	D5012.000 Low Tension Service & Dist., all
				D5012.001 Unanchored electrical cabinet
				D5012.002 Low voltage switchgear
				D5012.003 Electrical cabinet well anchored
				D5012.004 Electrical cabinet nominally anchored
				D5012.005 Electrical cabinet unanchored
		D5020 Lighting, Branch Wiring	D5021 Branch Wiring Devices	D5021.000 Branch Wiring Devices, all
			D5022 Lighting Equipment	D5022.000 Lighting Equipment, all
				D5022.001 Lay-in fluorescent lighting fixtures w/o 2+ slack safety wires
				D5022.002 Lay-in fluorescent lighting fixtures w/ 2+ slack safety wires

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
				D5022.003 Stem-hung pendant fluorescent fixtures w/o safety wires in stem
				D5022.004 Stem-hung pendant fluorescent fixtures w/ safety wires in stem
				D5022.005 High-intensity-discharge gas vapor lights
		D5030 Commun. & Security	D5031 Public Address & Music Systems	D5031.000 Public Address & Music Systems, all
			D5032 Intercommunication & Paging	D5032.000 Intercommunication & Paging Syst., all
			D5033 Telephone Systems	D5033.000 Telephone Systems, all
			D5034 Call Systems	D5034.000 Call Systems, all
			D5035 Television Systems	D5035.000 Television Systems, all
			D5036 Clock and Program Systems	D5036.000 Clock and Program Systems, all
			D5037 Fire Alarm Systems	D5037.000 Fire Alarm Systems, all
			D5038 Security and Detection Systems	D5038.000 Security and Detection Systems, all
			D5039 Local Area Networks	D5039.000 Local Area Networks, all
		D5090 Other Elect	D5091 Grounding Systems	D5091.000 Grounding Systems, all
			D5092 Emergency Light & Power	D5092.000 Emergency Light & Power Systems, all
				D5092.001 Diesel generator
			D5093 Floor Raceway Systems	D5093.000 Floor Raceway Systems, all
			D5094 Other Special Systems & Devices	D5094.000 Other Special Systems & Devices, all
				D5094.001 Motor control center
				D5094.002 Unbraced motor installation
			D5095 General Construction Items (Elect.)	D5095.000 General Construction Items (Elect.), all
				D5095.002 Electrical distribution panel
				D5095.003 Inverter
E Eqpt. & Furn.	E10 Equipment	E1010 Commercial Equipment	E1011 Security & Vault Equipment	E1011.000 Security & Vault Equipment, all
			E1012 Teller and Service Equipment	E1012.000 Teller and Service Equipment, all
			E1013 Registration Equipment	E1013.000 Registration Equipment, all
			E1014 Checkroom Equipment	E1014.000 Checkroom Equipment, all
			E1015 Mercantile Equipment	E1015.000 Mercantile Equipment, all
			E1016 Laundry & Dry Cleaning Eqpt	E1016.000 Laundry & Dry Cleaning Equipment, all
			E1017 Vending Equipment	E1017.000 Vending Equipment, all
			E1018 Office Equipment	E1018.000 Office Equipment, all
		E1020 Institutional Equipment	E1021 Ecclesiastical Equipment	E1021.000 Ecclesiastical Equipment, all
			E1022 Library Equipment	E1022.000 Library Equipment, all
			E1023 Theater & Stage Equipment	E1023.000 Theater & Stage Equipment, all

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
			E1024 Instrumental Equipment	E1024.000 Instrumental Equipment, all
			E1025 Audio-visual Equipment	E1025.000 Audio-visual Equipment, all
			E1026 Detention Equipment	E1026.000 Detention Equipment, all
			E1027 Laboratory Equipment	E1027.000 Laboratory Equipment, all
			E1028 Medical Equipment	E1028.000 Medical Equipment, all
			E1029 Other Institutional Equipment	E1029.000 Other Institutional Equipment, all
		E1030 Vehicular Equipment	E1031 Vehicular Service Equipment	E1031.000 Vehicular Service Equipment, all
			E1032 Parking Control Equipment	E1032.000 Parking Control Equipment, all
			E1033 Loading Dock Equipment	E1033.000 Loading Dock Equipment, all
			E1039 Other Vehicular Equipment	E1039.000 Other Vehicular Equipment, all
		E1090 Other Equipment	E1091 Maintenance Equipment	E1091.000 Maintenance Equipment, all
			E1092 Solid Waste Handling Equipment	E1092.000 Solid Waste Handling Equipment, all
			E1093 Food Service Equipment	E1093.000 Food Service Equipment, all
			E1094 Residential Equipment	E1094.000 Residential Equipment, all
			E1095 Unit Kitchens	E1095.000 Unit Kitchens, all
			E1097 Window Washing Equipment	E1097.000 Window Washing Equipment, all
			E1099 Other Equipment	E1099.000 Other Equipment, all
	E20 Furnishings	E2010 Fixed Furnishings	E2011 Fixed Artwork	E2011.000 Fixed Artwork, all
			E2012 Fixed Casework	E2012.000 Fixed Casework, all
			E2013 Blinds and Other Window Treatmt	E2013.000 Blinds and Other Window Treatment, all
			E2014 Fixed Floor Grilles and Mats	E2014.000 Fixed Floor Grilles and Mats, all
			E2015 Fixed Multiple Seating	E2015.000 Fixed Multiple Seating, all
			E2016 Fixed Interior Landscaping	E2016.000 Fixed Interior Landscaping, all
		E2020 Movable Furnishings	E2021 Movable Artwork	E2021.000 Movable Artwork, all
			E2022 Furniture & Accessories	E2022.000 Furniture & Accessories, all
				E2022.001 Large freestanding storage furniture subject to overturning
				E2022.002 Large freestanding household electrical appliances
				E2022.003 Small countertop household electrical appliances
				E2022.004 Household entertainment equipment
				E2022.005 Floor-standing furniture subject to crushing
				E2022.006 Heaters and A/C eqpt subject to crushing or overturning
				E2022.007 Indoor accessories, e.g., curtains, sporting goods, bags
				E2022.008 Tableware
				E2022.009 Small home entertainment items subject to falling
				E2022.010 Clothing etc. subject to contam. by glass, other foreign matter
				E2022.011 Desktop computer system unit and CRT monitor
				E2022.012 Countertop contents, frict. coeff ≤ 0.50, ≤ 20 lb
				E2022.013 Countertop contents, frict. coeff ≤ 0.50, 20-400 lb
				E2022.014 Countertop contents, frict. coeff ≤ 0.50, ≤ 20 lb
				E2022.015 Countertop contents, frict. coeff ≤ 0.50, 20-400 lb
				E2022.016 Shelved contents, frict. coeff ≤ 0.50, ≤ 20 lb, ≤ 4 ft AFF
				E2022.017 Shelved contents, frict. coeff ≤ 0.50, ≤ 20 lb, > 4 ft AFF
				E2022.018 Shelved contents, frict. coeff ≤ 0.50, 20-400 lb, ≤ 4 ft AFF
				E2022.019 Shelved contents, frict. coeff ≤ 0.50, 20-400 lb, > 4 ft AFF
				E2022.020 Shelved contents, frict. coeff > 0.50, ≤ 20 lb, ≤ 4 ft AFF
				E2022.021 Shelved contents, frict. coeff > 0.50, ≤ 20 lb, > 4 ft AFF
				E2022.022 Shelved contents, frict. coeff > 0.50, 20-400 lb, ≤ 4 ft AFF
				E2022.023 Shelved contents, frict. coeff > 0.50, 20-400 lb, > 4 ft AFF
				E2022.024 Library shelving not braced to the building frame
				E2022.025 Library shelving that is braced to the building frame
				E2022.026 Contents in cabinets w/o mechanical or strong magnetic catch
				E2022.027 Contents in cabinets w/ mechanical or strong magnetic catch
				E2022.028 Mechanically restrained light contents, light contents on shelves w/bungy-cord or spring-mounted wire restraint
			E2023 Movable Rugs and Mats	E2023.000 Movable Rugs and Mats, all
			E2024 Movable Interior Landscaping	E2024.000 Movable Interior Landscaping, all
F Special Constr., Demo	F10 Special Constr.	F1010 Special Structures	F1011 Air Supported Structures	F1011.000 Air Supported Structures, all
			F1012 Pre-engineered Structures	F1012.000 Pre-engineered Structures, all
			F1013 Other Special Structures	F1013.000 Other Special Structures, all
		F1020 Integrated Construction	F1021 Integrated Assemblies	F1021.000 Integrated Assemblies, all
			F1022 Special Purpose Rooms	F1022.000 Special Purpose Rooms, all
			F1023 Other Integrated Construction	F1023.000 Other Integrated Construction, all
		F1030 Special Construction	F1031 Sound, Vibration & Seismic Const.	F1031.000 Sound, Vibration & Seismic Const., all
			F1032 Radiation Protection	F1032.000 Radiation Protection, all
			F1033 Special Security Systems	F1033.000 Special Security Systems, all
			F1034 Vaults	F1034.000 Vaults, all
			F1039 Other Special Construction Syst.	F1039.000 Other Special Construction Systems, all
		F1040 Special Facilities	F1041 Aquatic Facilities	F1041.000 Aquatic Facilities, all
			F1042 Ice Rinks	F1042.000 Ice Rinks, all
			F1043 Site Constructed Incinerators	F1043.000 Site Constructed Incinerators, all
			F1044 Kennels & Animal Shelters	F1044.000 Kennels & Animal Shelters, all
			F1045 Liquid & Gas Storage Tanks	F1045.000 Liquid & Gas Storage Tanks, all
				F1045.001 Liquid oxygen tank, light anchors
				F1045.002 Liquid oxygen tank, well anchored
			F1049 Other Special Facilities	F1049.000 Other Special Facilities, all
		F1050 Special Control, Instr.	F1051 Recording Instrumentation	F1051.000 Recording Instrumentation, all
			F1052 Building Automation System	F1052.000 Building Automation System, all
			F1059 Other Special Control, Instruments	F1059.000 Other Special Controls & Instrumentation, all
	F20 Selective Demolition	F2010 Building Element Demo.	F2011 Building Interior Demolition	F2011.000 Building Interior Demolition, all
			F2012 Building Exterior Demolition	F2012.000 Building Exterior Demolition, all
		F2020 Hazard Abatement	F2021 Removal of Hazardous Comp.	F2021.000 Removal of Hazardous Components, all
			F2022 Encapsulate Hazardous Comp.	F2022.000 Encapsulation of Hazardous Components, all

Annex C References for Stakeholder Perspectives

Building owners (2)

Author(s)	Year	Title/description
FEMA	2011	Earthquake-induced structural and non-structural damage in hospitals. FEMA E-74
Perry et al.	2009	Reducing the Risks of Nonstructural Earthquake Damage Better education about nonstructural hazards and successful nonstructural restraint systems for building owners and managers and improved tools for defining responsibilities and tracking progress for nonstructural restraint design and installation are needed.

Occupants (1)

Author(s)	Year	Title/description
Perry et al.	2009	Reducing the Risks of Nonstructural Earthquake Damage Better education about nonstructural hazards and successful nonstructural restraint systems for building owners and managers and improved tools for defining responsibilities and tracking progress for nonstructural restraint design and installation are needed.

Facility managers (5)

Author(s)	Year	Title/description
FEMA E-74	2011	Earthquake-induced structural and non-structural damage in hospitals.
FEMA	2007	for hospital managers
Perry et al.	2009	Reducing the Risks of Nonstructural Earthquake Damage Better education about nonstructural hazards and successful nonstructural restraint systems for building owners and managers and improved tools for defining responsibilities and tracking progress for nonstructural restraint design and installation are needed.
Student work	2011	MS factory My city is getting ready projects
Bsria*	2011	Building manuals and building user guides and Building manual template, https://www.bsria.co.uk. Retrieved Oct 2016

*BSRIA is a test, instruments, research and consultancy organisation in construction and building services providing specialist support services for design, construction, facilities management, product testing and market intelligence. As a non-profit distributing member-based Association, Bsria publish best practice guides, hold an extensive library and run training and events.

Local building and safety staff members (1)

Building and Safety Department		
DeKalb Development Services Department of Planning and Sustainability DeKalb County Government	2014	PEER REVIEW CHECKLIST FOR NON-STRUCTURAL PLAN REVIEW
		PEER REVIEW CHECKLIST FOR STRUCTURAL PLAN REVIEW
		Expedited Commercial Plan Review Program Peer Review Policy Manual

Interviews with local building safety managers are planned

Post-earthquake damage inspectors (3)

Insurance and inspectors		
King	2014	Insurance: Its Role in Recovery from the 2010–2011 Canterbury Earthquake Sequence
Indridason	2006	EVALUATION OF BUILDING DAMAGE IN THE JUNE 2000 EARTHQUAKES IN SOUTH ICELAND
Owners and users		
Perry et al.	2009	Reducing the Risks of Nonstructural Earthquake Damage Use Perry et al. (2009). to discuss better education about nonstructural hazards and successful nonstructural restraint systems for building owners and managers and improved tools for defining responsibilities and tracking progress for nonstructural restraint design and installation are needed.

Annex D References for NSC Damage and Design

General or housing related (13)

Author	**Year Country**	**Title/description**
EERI	2015 Nepal	www.eeri.org EERI Earthquake Reconnaissance Team Report: M7.8 Gorkha, Nepal Earthquake on April 25, 2015 and its Aftershocks
Miranda et al.	2012 Chile	Performance of Nonstructural Components during the 27 February 2010 Chile Earthquake
Braga et al.	2011 Italy	Performance of non-structural elements in RC buildings during the L'Aquila, 2009 earthquake
Ricci et al.	2011 Italy	6th April 2009 L'Aquila earthquake, Italy: reinforced concrete building performance
Dhakal	2010 NZ	DAMAGE TO NON-STRUCTURAL COMPONENTS AND CONTENTS IN 2010 DARFIELD EARTHQUAKE
Kam et al.	2010 NZ	SEISMIC PERFORMANCE OF REINFORCED CONCRETE BUILDINGS IN THE SEPTEMBER 2010 DARFIELD (CANTERBURY) EARTHQUAKE
EERI	2016 Nepal	Gorkha, Nepal Earthquake on April 25, 2015 and its Aftershocks
Dhakal, R. P.	2010 NZ	Gorkha, Nepal Earthquake on April 25, 2015 and its Aftershocks
Galloway and Ingham	2015 NZ	NON-STRUCTURAL COMPONENTS, RESIDENTIAL BUILDINGS AND BUSINESS INTERRUPTION
EERC	2008 Iceland	Data from 40 farms during the 2008 earthquake
Villaverde	1997	Outlines the state of the art in 1997 of seismic design for NSC
Filiatrault and Sullivan	2014	Discusses performance-based seismic design of non-structural building components as the next frontier of earthquake engineering.
Matsuoka et al.	2008	NSC seismic testing

Hospitals (10+1)

Author	Year Country	Title/description
Achour et al	2011	Earthquake-induced structural and non-structural damage in hospitals.
Kirsch et al.	2010 Chili	Impact on Hospital functions following the 2010 Chilean Earthquake, Disaster Medicine and Public Health Preparedness
Mitrani-Reiser et al.	2010 Chili	A Functional Loss Assessment of a Hospital System in the Bío-Bío Province
Achour et al.	2011 Italy/China	Earthquake Induced Structural and Non- structural Damage in Hospitals
FEMA 577	2007 USA	Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds
Cimellaro et al.	2010	Seismic resilience of a hospital system
Nuti et al.	2004 Italy	Damage, Vulnerability and Retrofitting Strategies for the Molise Hospital System Following the 2002 Molise, Italy, Earthquake
McIntosh et al.	2012 NZ	The Impact of the 22nd February 2011 Earthquake on Christchurch Hospital
FEMA	2011 USA	Earthquake-induced structural and non-structural damage in hospitals. FEMA E-74
McIntosh et al	2012 NZ	Impact of the 22nd February 2011 earthquake on Christchurch Hospital.

Schools (8)

Author	Year Country	Title/description
Augenti et al.	2002 Italy	Performance of School Buildings during the 2002 Molise, Italy, Earthquake
Grant et al.	2007 Italy	A Prioritization Scheme for Seismic Intervention in School Buildings in Italy
Shaw	2001	Role of Schools in Creating Earthquake-Safer Environment
Kaplan	2004	May 1, 2003 Turkey Bing61 earthquake: damage in reinforced concrete structures
Roces et al.	1992	Risk factors for injuries due to the 1990 earthquake in Luzon, Philippines*
IFC		Disaster and Emergency Preparedness: Guidance for Schools
India	2004	School safety, http://nidm.gov.in/PDF/safety/school/link1.pdf
FEMA 395	2003	Incremental seismic rehabilitation of school building (K-12)

Fragility curves for NSC (7)

Author	Year	Title/description
Shinozuka et al.	2000	Information about fragility curves
Farokhnia	2013	Non-structural Vulnerability Functions for Building Categories (a PhD dissertation, was guided by Porter)
Aslani and Miranda	2005	A summary of Fragility Functions for Non-structural Components use
Mahdi and Mahdi	2013	Fragility curves
Mahdi and Mahdi	2012	Fragility curves
FEMA.	2007	For hospitals (at least a discussion about non-structural issues)
Pujols and Ryan	2016	Development of Generalized Fragility Functions for Seismically Induced Content Disruption