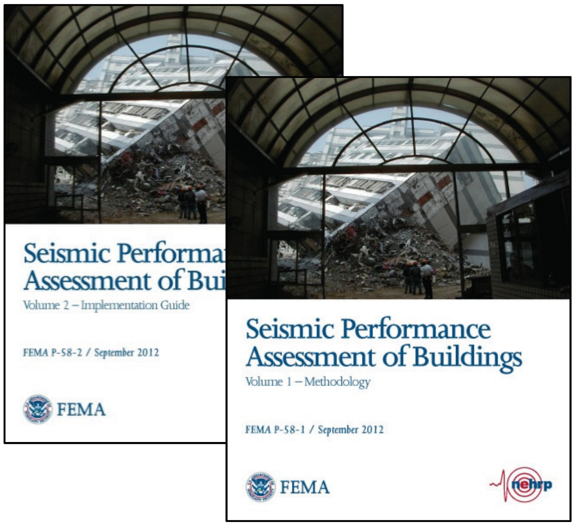

Background Document

FEMA P-58/BD-3.7.8

Casualty Consequence Function and Building Population Model Development

Prepared by

Hope A. Seligson
MMI Engineering
2100 Main Street, Suite 150
Huntington Beach, California 92648

Submitted to

APPLIED TECHNOLOGY COUNCIL
201 Redwood Shores Parkway, Suite 240
Redwood City, California 94065
www.ATCouncil.org

Prepared for

FEDERAL EMERGENCY MANAGEMENT AGENCY
U.S. Department of Homeland Security
500 C Street, SW
Washington, D.C. 20472

September 12, 2008

Background Documentation

FEMA P-58 Background Documents are a series of reports documenting the technical background and source information for key aspects of the FEMA P-58 methodology and its implementation. These reports were developed over the course of the 10-year ATC-58/ATC-58-1 Projects funded under FEMA Contracts EMW-2001-RP-0056 and HSFEHQ-06-D-1105.

Background Documents were developed by consultants, serving at various levels within the project hierarchy, reporting the results of: (1) decisions on technical development protocols; (2) focused studies on the development of key aspects of the methodology; (3) documentation of recommended procedures; and (4) collection of available data for the development of structural and nonstructural fragilities. They were initially intended to serve as a record of the technical state-of-knowledge at the time they were produced, and as resources for the development of the eventual project reports. As such, they represent a snapshot in time, and may, or may not, match the technical content, recommended procedures, or data incorporated into the final methodology and its implementation.

This Background Document is intended for the purpose of providing supplemental knowledge to users of the FEMA P-58 methodology. Information contained herein has not been independently verified for accuracy as a stand-alone document, and may have been superseded in its final implementation within the methodology. Users of information in this document assume all liability arising from such use.

Notice

Cover illustration – Primary resource documents for the FEMA P-58 *Seismic Performance Assessment of Buildings, Methodology and Implementation* series of products: FEMA P-58-1, *Volume 1 – Methodology*, and FEMA P-58-2, *Volume 2 – Implementation Guide*.

Risk Management Products Team
Casualty Consequence Function and Building Population Model Development
Prepared by Hope A. Seligson
September 12, 2008

This memo provides documentation of the recommended casualty consequence functions for use in the ATC-58 Performance Based Earthquake Engineering Design Methodology and PACT software, and the associated building population model required for implementation of building-specific casualty estimation.

Casualty Consequence Function Development

The focus of the current phase of development of the ATC-58 casualty consequence functions has been on fatalities related to building collapse, to demonstrate the implementation of the proposed consequence function form within the ATC-58 and PACT framework. It is anticipated that future development will address non-fatal injuries, as well as casualties caused by building damage other than collapse. It should be noted that modeling of non-fatal injuries is generally more complicated than that for fatalities because historic data on non-fatal injuries if often limited or poorly documented, and the classification of injury types varies widely from event to event.

For the purpose of fatality model development, discussions regarding the expected functional form of collapse fragilities were held by the Risk Management Products (RMP) Team and the Structural Performance Products (SPP) Team. It is expected that within PACT, the probability of collapse will be represented by single collapse fragility, and that a building model may include from one to "n" mutually exclusive collapse modes. For each collapse mode, a collapse consequence function tabulating the fraction of floor area that collapses for each floor level must be specified, along with the relative probability of occurrence of each collapse mode, given that collapse has occurred.

Accordingly, the collapse data required as input to the fatality consequence function consists of the floor-specific estimates of the fraction of floor area suffering collapse. These are expected to vary with collapse mode. For example, if the collapse mode is a complete collapse (e.g., pancake or side-sway collapse), the fraction of floor area expected to collapse is 100% at all floor levels. On the other hand, if just a single story collapses, the collapse fraction for other floors may be less than 100%.

The recommended casualty consequence function functional form is a mean fatality rate, or the expected fraction of exposed in-building population killed, given collapse. Mean fatality rates used by most loss estimation methodologies are typically expert opinion-based, utilizing limited available historic data. These published models often do not vary significantly with structure type. For example, the ATC-13 fatality rate for most buildings in the "Destroyed" damage state is 20%; the exceptions are light steel frame and wood frame which have a 2% fatality rate (ATC, 1985). Similarly, the HAZUS fatality rate for buildings in the "Complete damage state with collapse" is 10%, except for wood light frame (<5000 sq ft), mobile homes and light steel frame structures, which have a 5% fatality rate (DHS/FEMA, 2007).

In recent earthquakes, more attention has been paid to collecting epidemiologically sound casualty data, in conjunction with building damage data. These data, when robust, may be used to develop building-type specific casualty models. For example, following the 1999 Kocaeli Turkey earthquake, a population-based survey was conducted that allowed for the development of fatal and non-fatal injury models for concrete frame buildings with infill walls. In practice, however, statistically viable data sets are rare, as both population exposure data within the damaged or collapsed structure, and specific damage state information are required.

The fatality consequence function for collapse takes the form of an expected fatality rate (%) for all occupants, given collapse. To estimate the number of fatalities for the building, the number of occupants for each floor subject to collapse is multiplied by the collapse fraction and collapse mode occurrence probability, and by the fatality rate. Floor fatalities are then summed over all floors to arrive at a total fatality estimate for the building. For the purpose of modeling fatalities related to collapse within PACT, fatality rates have been associated with PACT's vertical framing systems (as described in Appendix D of the 35% Draft Guidelines document), given in Table 1. A brief description of the selected fatality models is provided in the following sections.

Table 1: ATC-58 Vertical Seismic Framing System Designations

S1 – Steel Moment Frame
S2 – Steel Braced Frame
S3 - Steel Eccentrically Braced Frame
S4 – Steel Light Frame
S5 - Steel Moment Frame with Concrete Infill Walls
S6 - Steel Moment Frame with Unreinforced Masonry Infill Walls
C1 – Concrete Moment Frame
C2 – Concrete Shear Wall
C3 – Concrete Frame with Unreinforced Masonry Infill Walls
RM – Reinforced masonry Bearing Walls
URM – Unreinforced Masonry Bearing Walls
W1 – Light Wood Frame Shear Wall
Light Wood Frame Diagonal Strut Bracing

PEER-funded Non-Ductile Concrete Frame Building Casualty Model

In support of the Pacific Earthquake Engineering Research (PEER) Center's Performance-Based Earthquake Engineering Framework and its Van Nuys Test Bed application, casualty models (both fatality and injury) were developed for non-ductile concrete frame structures using available population survey data from the Kocaeli Earthquake of August 17, 1999 (Shoaf, et al., 2005, Seligson et al., 2006). The population-based survey data for the City of Gölcük, gathered by Dr. Marla Petal of the Bagazici University, Kandilli Observatory and Earthquake Research Institute, includes specific information on sample population demographics, deaths and injuries, building type, building damage, the injured person's location within the building, and action taken at the time of the earthquake. The survey included a random sample of 453 households (1,861 individuals) from Gölcük, and utilized a modified version of a post-earthquake questionnaire designed by the Center for Public Health and Disasters at the University of California, Los Angeles.

The majority of surveyed households (80.1%) reported living in concrete structures, which had an average age of 14.7 years. Most concrete structures (67%) were mid-rise (five to ten stories), and were generally assumed to be frame structures with infill walls. Damage descriptors included in the survey were used to classify the damage state of each respondent's building. The damage state of "Total collapse" was assigned when the respondent identified the structure as "Entire Building Destroyed", along with any other reported damage. "Partial collapse" was assigned when the respondent reported "Ceiling/roof collapsed" and/or "Floors Collapsed". (To address the prevalence of damageable masonry infill walls common in Turkish construction, an assumption was made that "Wall Collapse," in the absence of other collapse damage, did not necessarily indicate partial or total building collapse.) Eighty-three percent of households in concrete buildings reported damage to their residences as a result of the earthquake; 35% of families in concrete buildings reported collapse or partial collapse. Mid-rise buildings were more likely to suffer collapse; 76% of mid-rise buildings had reportedly collapsed, as compared to 47% of low-rise buildings.

To develop casualty rates specifically applicable to damaged non-ductile concrete frame buildings, the analysis sample was restricted to the 1,270 individuals who were living in concrete buildings that were reported damaged in the earthquake. The resulting fatality rates for building suffering "Total Collapse" are summarized in Table 2.

Table 2: Non-Ductile Concrete Frame Building Fatality Rates for "Total Collapse" Developed from Gölcük Population Survey Data

Damage State	Building Height	Occupant Location	Fatal injury rate per 100
"Total Collapse"	Overall	Overall	10.7
"Total Collapse"	4 stories and less	Overall	0.0
"Total Collapse"	5 – 10 stories	Overall	13.1
"Total Collapse"	5 – 10 stories	Ground Floor	6.9
"Total Collapse"	5 – 10 stories	Upper Floors	18.5

As a point of comparison, Sahin and Tari (2000) reported that 5,025 people died in Gölcük during the earthquake. In 1999, there were approximately 80,000 residents living in Gölcük. This translates to a mortality rate of about 6%. In contrast, the population survey produced an overall mortality rate of 2% of individuals. Since households where all of the members died could not be surveyed, models developed from these data can potentially underestimate mortality, and should be considered a lower bound.

<u>Wood Frame Structures</u>

Despite recent U.S. earthquake experience with notable occurrences of fatalities in wood frame buildings (e.g., Northridge meadows), an empirical U.S. wood frame fatality model does not exist. While the collapse of the tuck-under wood frame Northridge Meadows apartment building in the Northridge earthquake was highlighted in most reports of the earthquake, the data required to develop a fatality model were not systematically collected. Sixteen fatalities were reported, but the exact number of collapsed apartment units and the total population of occupants within those collapsed units were not documented.

Some data are available from the 1995 Kobe earthquake. Murakami and Ohta (2004) conducted a population survey in the Higashinada ward of the City of Kobe, where the overall mortality rate was reported to be 0.85%. Data collected include dwelling information and damage levels for the household, as well as data on individual casualty and entrapment. Dwellings in Higashinada were predominantly 2 story (83% of total) and of wood construction (80% of total), 17% of all dwellings (20.9% of wooden dwellings) were reported to suffer “total collapse”. Within dwellings classified as “Total Collapse”, the reported fatality rate was just 0.8%, while injury rates (for both “serious” and “light” injury) totaled 23.4%, leaving 75.8% of occupants uninjured.

Unreinforced Masonry Buildings

Many anecdotal reports of fatalities exist for unreinforced masonry buildings in the U.S. (e.g., as many as nine URM-related fatalities in the 1989 Loma Prieta earthquake, two fatalities in the collapse of a URM building in the 2003 San Simeon earthquake, etc.). In general, these data are inadequate to develop a reliable fatality model.

Data from the 1976 Tangshan, China earthquake have been used to develop collapse and fatality rates which vary with intensity (Shiono, 1995, as reported in Nichols & Beavers, 2003). The official fatality total for the Tangshan earthquake totaled 242,000 deaths, whereas unofficial death tolls put the total significantly higher, at 655,000. The official (lower) value was used in developing the relationship between intensity, collapse and fatality, which peaks at a fatality rate of 30% for 100% building collapse at Intensity >11.

For the purpose of modeling fatalities related to collapse within PACT, available fatality rates have been associated with PACT’s vertical framing systems. Table 3 lists the framing systems, and the recommended default expected fatality rate. Where building type-specific rates are not currently available, recommended default models have been taken from HAZUS (DHS/FEMA, 2007), and are highlighted in italics.

Table 3: Recommended ATC-58 Default Fatality Rates

ATC-58 Vertical Seismic Framing System Designation & Material	Default Fatality Rate (% of Occupants) given Collapse	Fatality Rate Source
S1 – Steel Moment Frame S2 – Steel Braced Frame S3 - Steel Eccentrically Braced Frame	*10%*	*HAZUS default fatality rate for "Complete damage state with collapse"*
S4 – Steel Light Frame	*5%*	*HAZUS default fatality rate for "Complete damage state with collapse" for light steel frame structures*
S5 - Steel Moment Frame with Concrete Infill Walls	*10%*	*HAZUS default fatality rate for "Complete damage state with collapse"*
S6 - Steel Moment Frame with Unreinforced Masonry Infill Walls	19%	1999 Turkey Earthquake, Golcuk (Shoaf et al., 2005; Seligson et al., 2006), rate for upper floors of mid-rise concrete frame structures with masonry infill walls
C1 – Concrete Moment Frame	11%	1999 Turkey Earthquake, Golcuk (Shoaf et al., 2005; Seligson et al., 2006), overall rate for all concrete frame structures
C2 – Concrete Shear Wall	*10%*	*HAZUS default fatality rate for "Complete damage state with collapse"*
C3 – Concrete Frame with Unreinforced Masonry Infill Walls	19%	1999 Turkey Earthquake, Golcuk (Shoaf et al., 2005; Seligson et al., 2006), rate for upper floors of mid-rise concrete frame structures with masonry infill walls
RM – Reinforced Masonry Bearing Walls	*10%*	*HAZUS default fatality rate for "Complete damage state with collapse"*
URM – Unreinforced Masonry Bearing Walls	30%	1964 Tangshan Earthquake (Shiono, 1995 as presented by Nichols & Beavers, 2003)
W1 – Light Wood Frame Shear Wall Light Wood Frame Diagonal Strut Bracing	1%	1995 Kobe Earthquake, Higashinada Ward (Murakami & Ohta, 2004)

Building Population Model

In order to estimate building-specific casualties, the ATC-58 methodology and PACT software will require a building population model that adequately reflects potential building occupancy and its variation over time. It is recommended that the ATC-58 building population model consider the **theoretical worst case or maximum peak population**, as well as a **date/time-specific population** derived from typical daily and monthly occupancy patterns. The methodology can also include a more likely average occupancy, such as the "**equivalent continuous occupancy**" utilized by the University of California at Berkeley (Comerio, 2000).

> The Equivalent Continuous Occupancy (ECO) Calculation is an abstract number used to measure the population at risk in any given building during an earthquake. It represents the number of persons theoretically occupying a building on a continual basis—for 24 hours a day, 365 days a year. The ECO provides a means to account for actual varying use. For example, one person present in a building for 8 hours a day, 52 weeks a year would contribute .33 to the ECO for that building. The following shows the calculation of this ECO.
>
> 56/168 x 52/52 x 1 = .33
> [Hrs per Week/Total hrs per Week] x [Wks per Yr/Total Wks per Yr] x Persons = ECO
>
> Accounting for all building occupants in all spaces of a building, a total ECO for each building can be calculated. This total building ECO is the number of persons who may be occupying a building at any given hour of any given day, distributed on an annual basis. (Comerio, 2000)

For each ground motion estimate or realization within PACT, the three population models may be used to generate three fatality estimates; a "worst case" fatality estimate, as well as a date/time-specific fatality estimate, and an ECO fatality estimate.

The implementation of the recommended building population models within PACT should address the following considerations:

- The population models should be applicable for all the occupancy templates envisioned for PACT. (Table 4 provides the list of expected occupancy templates, including recommended education sub-classes useful for population modeling).

- Within PACT, the population models should be functional with minimal user input (e.g., include default data), but should accommodate significant user-input data, when available.

- PACT should be able to estimate peak population levels, date/time-specific population levels, and equivalent continuous occupancy on a ***floor by floor*** basis, to reflect both changes in use and differences in potential damage/collapse.

- The date/time specific population levels and equivalent continuous occupancy calculations should reflect variation in population levels with:
    - Time of Day
    - Day of Week (weekday/weekend)
    - Month of the year (e.g., reflects potential building closures for regular holidays or extended breaks).

Table 4: ATC-58 Occupancy Classes, with Proposed Education (k-12) Sub-classes

Occupancy Class Number	Occupancy Class Description
1	Commercial office
2a	Education (k-12): Elementary Schools
2b	Education (k-12): Middle Schools
2c	Education (k-12): High Schools
3	Healthcare
4	Hospitality
5	Multi-unit residential
6	Research
7	Retail
8	Warehouse

The basic structure of the proposed building population model has been laid out in an operational spreadsheet provided to PACT developers and the Risk Management Products Team. The spreadsheet (*Building Population Models.xls)* identifies required building input data (e.g., number of stories, typical square footage area by floor, selected occupancy template, etc.) and demonstrates implementation of the default population model for each population parameter described below.

Modeling of the Theoretical Worst Case or Maximum Peak Population

Building-specific peak population can be estimated as the sum of individual floor peak populations, determined from floor square footages and a recommended default peak population model (expressed in terms of number of occupants per 1000 square feet) for each occupancy class. Recommended default peak population models are provided in Table 5. The basic formula for floor peak population is as follows:

Floor Peak Population = [Occupants per 1000 SF|Floor Occupancy Type] x [floor square footage/1000]

Table 5: Recommended Default Peak Population Models

PACT Occupancy Template Number	Occupancy Description	Peak Population Model (Occupants per 1000 SF)	Peak Population Model - Time of Day	Default Population Model Source
1	Commercial office	4.0	Daytime (3 pm)	ATC-13
2a	Education (k-12): Elementary Schools	14.0	Daytime	Sample of Southern California School Data
2b	Education (k-12): Middle Schools	14.0	Daytime	Sample of Southern California School Data
2c	Education (k-12): High Schools	12.0	Daytime	Sample of Southern California School Data
3	Healthcare	5.0	Daytime (3 pm)	ATC-13
4	Hospitality	2.5	Nighttime (3 am)	ATC-13
5	Multi-unit residential	3.1	Nighttime (3 am)	ATC-13
6	Research	3.0	Daytime (3 pm)	ATC-13
7	Retail	6.0	Daytime (5 pm)	HAZUS CA
8	Warehouse	1.0	Daytime (3 pm)	ATC-13

Determination of Date/time-specific Population

Building population is expected to vary with time of day, day of the week, and month of the year. For each occupancy type, recommended default population patterns have been developed. These recommended default population patterns reflect time of day (reflecting hours of operations, and lunch time fluctuations, etc.), day of week (weekdays vs. weekends), and monthly population variations (due to building closures for holidays, extended breaks, etc.), relative to expected peak population. Recommended default time of day (and day of week) variations are provided in Table 6, and plotted graphically in Figure 1a-i, while recommended monthly population variations are given in Table 7. It is also recommended that PACT present the default population patterns to the user (for each floor's occupancy class), and allow for user modification. For example, it might be useful to allow the user to close the building on specific days (e.g., holidays).

Based on the hourly, weekday/weekend, and monthly population profiles developed, an hourly annual population distribution can be developed. For use within PACT, it is recommended that an earthquake occurrence time be simulated (e.g., by generating a random number between 1 and 8760, and selecting the associated time and date), and the associated time-specific building population can be determined by multiplying net percent occupancy by peak population.

Table 6: Recommended Default Time of Day and Day of Week Population Variations (relative to Expected Peak Population) by PACT Occupancy Class.

PACT Occupancy Class	1 - Office		2a - Elementary Schools		2b - Middle Schools		2c - High Schools		3 - Healthcare (Hosp.)	
Time of Day	Week-days	Week-ends	Week-days	Week-ends	Week-days	Week-ends	Week-days	Week-ends	Week-days	Week-ends
12:00 AM	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%
1:00 AM	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%
2:00 AM	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%
3:00 AM	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%
4:00 AM	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%
5:00 AM	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%
6:00 AM	0%	0%	0%	0%	5%	0%	5%	0%	40%	40%
7:00 AM	25%	0%	5%	0%	50%	0%	50%	0%	40%	40%
8:00 AM	50%	5%	100%	2%	100%	2%	100%	2%	40%	40%
9:00 AM	75%	5%	100%	2%	100%	2%	100%	2%	60%	50%
10:00 AM	100%	5%	100%	2%	100%	2%	100%	2%	80%	65%
11:00 AM	100%	5%	100%	2%	100%	2%	100%	2%	100%	80%
12:00 PM	50%	5%	100%	2%	100%	2%	100%	2%	100%	80%
1:00 PM	50%	5%	100%	2%	100%	2%	100%	2%	100%	80%
2:00 PM	100%	5%	100%	2%	100%	2%	100%	2%	100%	80%
3:00 PM	100%	5%	50%	2%	100%	2%	100%	2%	100%	80%
4:00 PM	75%	5%	5%	2%	50%	2%	50%	2%	100%	80%
5:00 PM	50%	5%	5%	2%	25%	2%	25%	2%	100%	80%
6:00 PM	25%	0%	5%	0%	5%	0%	5%	0%	100%	80%
7:00 PM	0%	0%	0%	0%	0%	0%	0%	0%	100%	80%
8:00 PM	0%	0%	0%	0%	0%	0%	0%	0%	80%	65%
9:00 PM	0%	0%	0%	0%	0%	0%	0%	0%	60%	50%
10:00 PM	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%
11:00 PM	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%

Table 6 (cont.): Recommended Default Time of Day Population Variations (relative to Expected Peak Population) by PACT Occupancy Class.

PACT Occupancy Class	4 - Hospitality - Hotel		5 - Multi-Unit Resid.		6 - Research		7 - Retail		8 - Warehouse	
Time of Day	Week-days	Week-ends	Week-days	Week-ends	Week-days	Week-ends	Week-days	Week-ends	Week-days	Week-ends
12:00 AM	100%	100%	100%	100%	10%	10%	0%	0%	0%	0%
1:00 AM	100%	100%	100%	100%	10%	10%	0%	0%	0%	0%
2:00 AM	100%	100%	100%	100%	10%	10%	0%	0%	0%	0%
3:00 AM	100%	100%	100%	100%	10%	10%	0%	0%	0%	0%
4:00 AM	100%	100%	100%	100%	10%	10%	0%	0%	0%	0%
5:00 AM	100%	100%	100%	100%	10%	10%	0%	0%	0%	0%
6:00 AM	100%	100%	80%	100%	25%	25%	0%	0%	0%	0%
7:00 AM	80%	100%	60%	100%	25%	25%	0%	0%	25%	0%
8:00 AM	70%	100%	40%	100%	50%	25%	5%	5%	50%	2%
9:00 AM	50%	75%	20%	75%	75%	25%	10%	10%	100%	2%
10:00 AM	50%	50%	20%	50%	100%	25%	20%	25%	100%	2%
11:00 AM	50%	25%	20%	50%	100%	25%	40%	50%	100%	2%
12:00 PM	50%	25%	20%	50%	50%	25%	60%	75%	100%	2%
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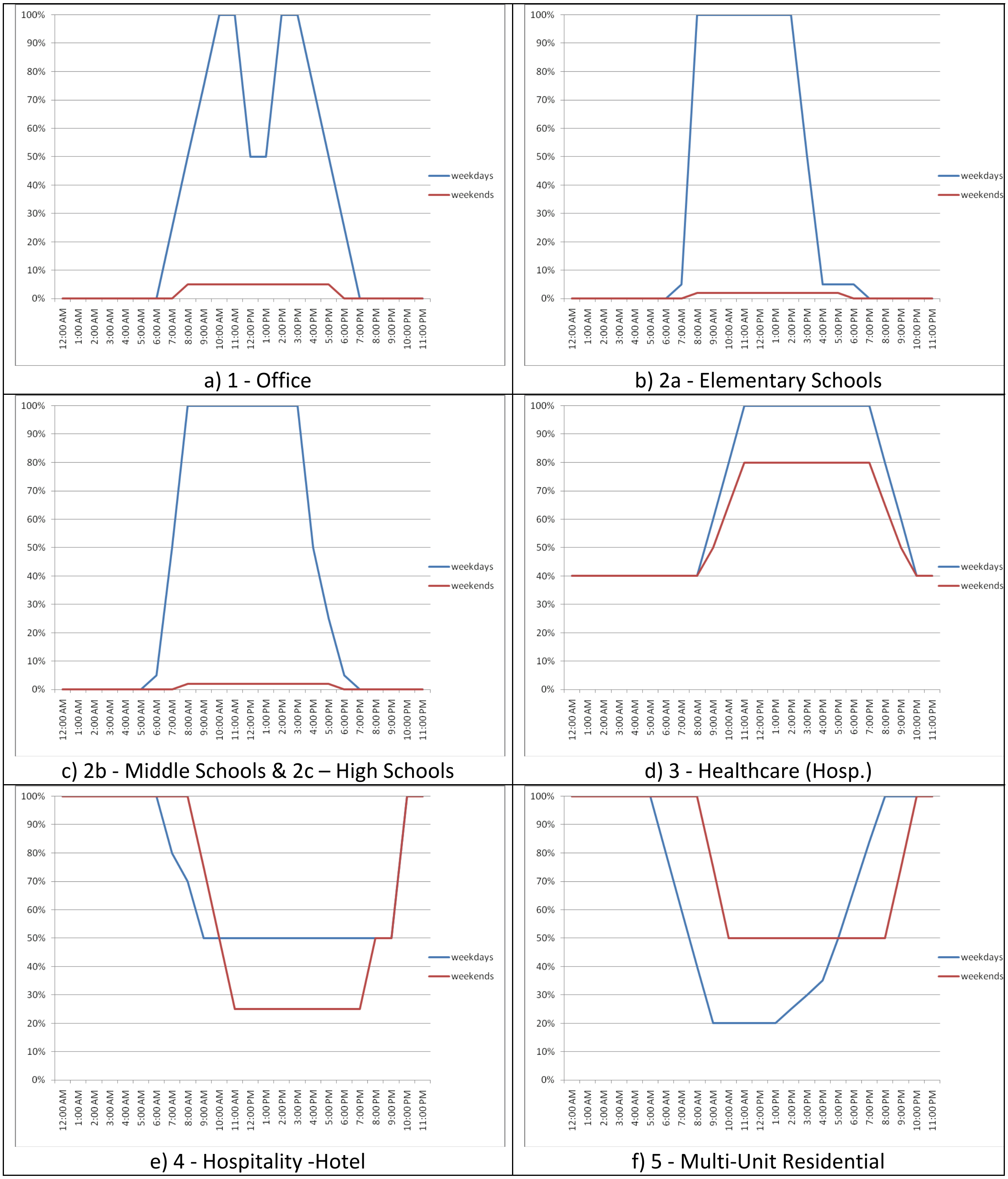
6:00 PM	50%	25%	67%	50%	25%	25%	60%	75%	50%	0%
7:00 PM	50%	25%	84%	50%	25%	25%	60%	50%	25%	0%
8:00 PM	50%	50%	100%	50%	10%	10%	40%	25%	0%	0%
9:00 PM	50%	50%	100%	75%	10%	10%	20%	10%	0%	0%
10:00 PM	100%	100%	100%	100%	10%	10%	5%	5%	0%	0%
11:00 PM	100%	100%	100%	100%	10%	10%	0%	0%	0%	0%



a) 1 - Office

b) 2a - Elementary Schools

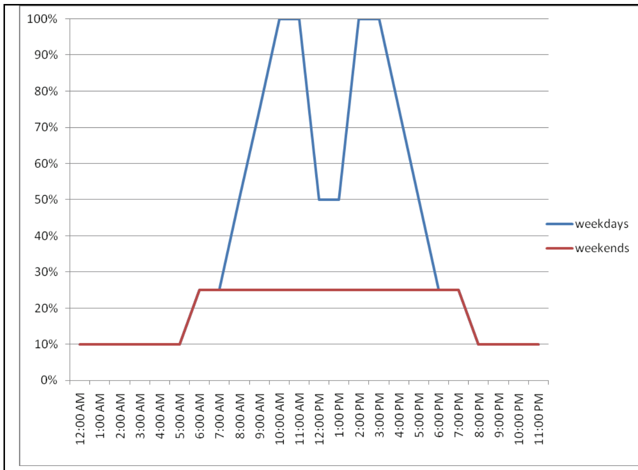
c) 2b - Middle Schools & 2c – High Schools

d) 3 - Healthcare (Hosp.)

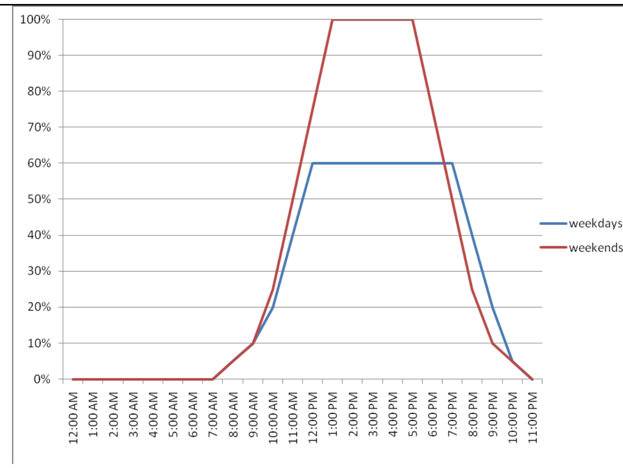
e) 4 - Hospitality -Hotel

f) 5 - Multi-Unit Residential

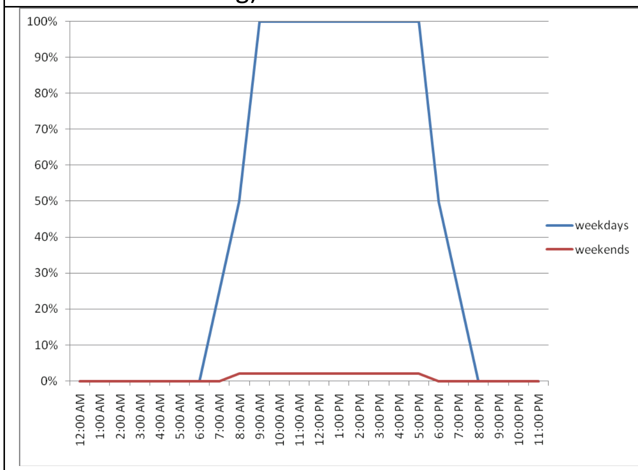
Figure 1: Charts of Recommended Default Time of Day Population Variations (relative to Expected Peak Population) by PACT Occupancy Class.



g) 6 - Research



h) 7 - Retail



i) 8 - Warehouse

Figure 1 (Continued): Charts of Recommended Default Time of Day Population Variations (relative to Expected Peak Population) by PACT Occupancy Class

Table 7: Recommended Monthly Population Variations (Relative to Expected Peak Population) by PACT Occupancy Class

	1 - Office		2a - Elementary Schools		2b - Middle Schools		2c - High Schools		3 - Healthcare (Hosp.)	
Month	**Week-day**	**Week-end**	**Week-day**	**Week-end**	**Week-day**	**Week-end**	**Week-day**	**Week-end**	**Week-day**	**Week-end**
Jan.	91%	100%	73%	100%	73%	100%	73%	100%	100%	100%
Feb.	95%	100%	90%	100%	90%	100%	90%	100%	100%	100%
March	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
April	100%	100%	77%	100%	77%	100%	77%	100%	100%	100%
May	95%	100%	95%	100%	95%	100%	95%	100%	100%	100%
June	100%	100%	77%	100%	77%	100%	77%	100%	100%	100%
July	95%	100%	0%	100%	0%	100%	0%	100%	100%	100%
Aug.	100%	100%	0%	100%	0%	100%	0%	100%	100%	100%
Sept.	95%	100%	95%	100%	95%	100%	95%	100%	100%	100%
Oct.	100%	100%	95%	100%	95%	100%	95%	100%	100%	100%
Nov.	95%	100%	81%	100%	81%	100%	81%	100%	100%	100%
Dec.	95%	100%	64%	100%	64%	100%	64%	100%	100%	100%
	4 - Hospitality - Hotel		**5 - Multi-Unit Resid.**		**6 - Research**		**7 - Retail**		**8 - Warehouse**	
Month	**Week-day**	**Week-end**	**Week-day**	**Week-end**	**Week-day**	**Week-end**	**Week-day**	**Week-end**	**Week-day**	**Week-end**
Jan.	100%	100%	100%	100%	91%	100%	95%	100%	91%	100%
Feb.	100%	100%	100%	100%	95%	100%	100%	100%	95%	100%
March	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
April	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
May	100%	100%	100%	100%	95%	100%	100%	100%	95%	100%
June	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
July	100%	100%	100%	100%	95%	100%	95%	100%	95%	100%
Aug.	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Sept.	100%	100%	100%	100%	95%	100%	100%	100%	95%	100%
Oct.	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Nov.	100%	100%	100%	100%	95%	100%	95%	100%	95%	100%
Dec.	100%	100%	100%	100%	95%	100%	95%	100%	95%	100%

Calculation of Equivalent Continuous Occupancy (ECO)

ECO is estimated from peak population and expected day and month building population levels. The basic ECO formula is as follows:

*Floor ECO = Floor Peak Population * [((PctWeekdayDay *PctWeekdayMonth *6257.143) + (PctWeekendDay *PctWeekendMonth * 2502.857))/ (365*24)]*

Where:

- Total average annual number of weekday hours = 6257.143 weekday hours/year
- Total average annual number of weekend hours = 2502.857 weekend hours/year
- PctWeekdayDay = average of 24 hour weekday occupancy percentages

- PctWeekendDay = average of 24 hour weekend day occupancy percentages
- PctWeekdayMonth = {sum of [(monthly weekday occupancy level in percent) x (average annual number of weekday days per month)] for 12 months}/total annual number of weekday days
- PctWeekendMonth = {sum of [(monthly weekend day occupancy level in percent) x (average annual number of weekend days per month)] for 12 months}/total annual number of weekend days

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