A review of stochastic live load models for code calibration

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ABSTRACT: Reliability-based calibration of partial safety factors of structural design codes requires suitable stochastic models for, among others, live loads. These models need to be compatible with the design values and exceedance probabilities stated in the same codes. This paper presents a critical review of the literature on stochastic models for live loads. These models consist of a sum of sustained and extraordinary loads, modelled as Poisson rectangular wave and spike processes, respectively. The models and their input parameters are reviewed by comparison to design values of EN 1991-1-1 and ASCE/SEI 7 codes. The main conclusion is that JCSS Probabilistic Model Code parameters are often too conservative and unrealistic. An overview of some live load statistics used in code calibration is also presented, and new statistics derived using Monte Carlo simulation are proposed. This study should be relevant for the development of Eurocodes, as its exceedance probabilities for design live loads are not clear.

1. INTRODUCTION

The principles of three different approaches for design and assessment decisions with varying levels of detail regarding the consideration of uncertainties are outlined in ISO 2394 (ISO, 2015), namely: risk-informed decision-making, reliability-based design, and semi-probabilistic design.

The semi-probabilistic approach is considered appropriate for structures for which the consequences of failure and damage are well understood and the failure modes can be categorized and modelled in a standardized manner. It is the method of choice for most international structural design codes, such as the so-called Load and Resistance Factor Design (LRFD) format employed in the North American design standards (ASCE, ANSI, AISC, ACI), or the (slightly different) format employed in the Eurocodes (CEN, 2002a).

Risk- and reliability-based approaches, on the other hand, are applied in the calibration of semi-probabilistic approaches and may be employed to support the design of special structures with severe failure consequences or structures that are not covered by semi-probabilistic design codes.

To perform the reliability-based calibration of the partial safety factors employed in semi-probabilistic design codes, such as the one reported in Ellingwood et al. (1980), suitable stochastic models for both loads and resistances parameters need to be provided. While the characteristics of the variable loads acting on a structure and their effects are arguably the most important input parameters to a reliability-based calibration, they are also the parameters for which we usually know the least.

One such load of particular importance for buildings is the live load. In this paper, a stochastic model for live loads is presented and reviewed, by comparing model results against the design loads prescribed in EN 1991-1-1 (CEN, 2002b) and ASCE/SEI 7 (ASCE, 2016) and live load statistics commonly used in reliability analyses.

2. LIVE LOADS IN BUILDINGS

Live loads consist, according to ASCE/SEI 7 (ASCE, 2016), of all loads produced by the use and occupancy of the building that does not include construction or environmental loads (such as wind, snow, rain, earthquakes) or dead load. These loads are of a stochastic nature, with variability in both space and time. As such, there is uncertainty not only about their maximum intensities within a certain reference period but also about the position and time at which these intensities occur.

The hierarchical stochastic model for live load in buildings considered in this study was originally proposed by Peir (1971) and widely applied thereafter (Peir and Cornell, 1973; McGuire and Cornell, 1974; Ellingwood and Culver, 1977; Chalk and Corotis, 1980; Harris et al., 1981). It is also described in CIB Report 116 (CIB, 1989) and the JCSS Probabilistic Model Code, or PMC (JCSS, 2001).

The fundamental idea of this model consists of representing the live load as a sum of sustained and extraordinary (also called transient or intermittent) stochastic processes. The sustained load corresponds to the weight of all furniture and its contents, movable partitions, and working/living personnel regularly present in the building. It stays "on" for the majority of the building's lifetime, and its intensity at a given point-in-time can be directly measured in a load survey. The extraordinary load, on the other hand, corresponds to localized crowding of people or furniture stacking. It is usually of higher intensity than the sustained load and acts momentarily, staying "on" for relatively short periods, in the order of a few minutes to a few days.

In the stochastic model discussed herein, the sustained load $Q(t)$ and the extraordinary load $P(t)$ are represented as a Poisson rectangular wave process (Figure 1a) and a Poisson spike process (Figure 1b), respectively. The total live load, denoted by $L(t)$, is given by the sum of both processes (Figure 1c). A brief description of the stochastic models for sustained and extraordinary loads is given in the sequence. For more details, the reader is referred to Peir (1971).

2.1. Sustained load model

The arbitrary point-in-time load intensity $w_{ij}(x,y)$ on an infinitesimal area ΔA at a particular location (x,y) on the jth floor of the ith building can be expressed as (Peir, 1971):

$$W_{ij}(x,y) = m + V_{ij} + U_{ij}(x,y), \tag{1}$$

where m is a deterministic overall mean intensity for the whole population of buildings within the same use category; V_{ij} is a zero-mean random variable; and $U_{ij}(x,y)$ is a zero-mean stochastic field. The random variable V can be thought of as a sum of two other independent zero-mean random variables

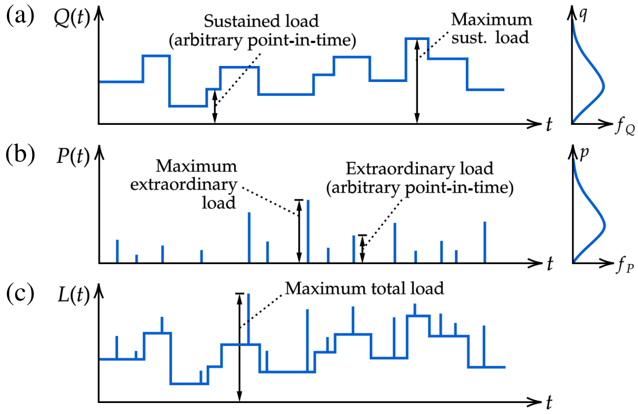


Figure 1: Schematic time histories of the (a) sustained, (b) extraordinary, and (c) total live load in buildings

$V_{ij} = V_{bld(i)} + V_{flr(j)}$, the former representing the building-wide spatial average of building i from m and the latter representing the deviation of the floor-wide spatial average of floor j from $m + V_{bld(i)}$. The stochastic field $U_{ij}(x,y)$ accounts for the local spatial variation within floor j. From this point onwards, the subscripts i and j will be omitted for the sake of simplifying the notation.

While the point load intensities are of little practical interest by themselves, Equation 1 can be used to deduce the characteristics of more relevant quantities, such as load effects. Let S be the load effect caused by the stochastic field $W(x,y)$. Assuming linear elastic behaviour, S can be written as:

$$S = \iint_A W(x,y) I(x,y)\, dy\, dx, \tag{2}$$

where $I(x,\ y)$ is the influence surface for the considered effect; and A is its influence area[1].

Furthermore, we can define the uniform load intensity that would produce the same load effect S as the original stochastic field $W(x,y)$ when applied over the influence area A. This equivalent uniformly distributed load (or EUDL for short) is given by:

$$Q = \frac{\iint_A W(x,y) I(x,y)\, dy\, dx}{\iint_A I(x,y)\, dy\, dx}. \tag{3}$$

It can be shown that $\mathrm{E}[Q] = m$. The variance of the EUDL, however, will depend on the autocovariance

[1] Not to be confused with *tributary area*. The influence area is "that floor area over which the influence surface for structural effects is significantly different from zero" (ASCE, 2016), and it is usually two times the tributary area for beams and four times the tributary area for columns.

of the stochastic field $W(x,y)$. It is reasonable to assume that, if the load intensity at a particular location is higher than the floor average, it is likely that the load intensity at a nearby point would also be high – or, in other words, that the field $W(x,y)$ has a generally positive correlation that tends to vanish as the distance separating the points increases.

Three different autocorrelation functions were examined by Hauser (1971). However, fitting one such exponentially decaying correlation function to load survey data shows that the distance over which the correlation is significantly different from zero is usually small (Peir and Cornell, 1973; Choi, 1990). This indicates that $W(x,y)$ can usually be regarded as an uncorrelated field (white noise). This assumption, which is a reasonable simplification as long as the influence area A is not too small, leads to the following upper bound on the variance of the EUDL:

$$\mathrm{Var}[Q] = \sigma_V^2 + \sigma_U^2 \min\left[\frac{A_0}{A}, 1\right]\kappa, \tag{4}$$

where σ_V^2 is the variance of the random variable V; σ_U is the variance of the stochastic field $U(x,y)$; A_0 is a reference area; and κ is a peak factor that depends solely on the shape of the influence surface. The ratio A_0/A accounts for the fact that the variance of the load intensity is smaller for larger areas. Note that the term $\min[A_0/A, 1]$ in Equation 4 is added to avoid the variance going to infinity as the influence area becomes increasingly smaller. The peak factor κ is given by:

$$\kappa = A\frac{\iint_A I^2(x,y)\,dy\,dx}{\left[\iint_A I(x,y)\,dy\,dx\right]^2}. \tag{5}$$

Usual values of κ range between 1 and 3. The PMC (JCSS, 2001) presents some influence surfaces with values $\kappa = 2.0$ and $\kappa = 2.4$ but does not explain to which effects they correspond. McGuire and Cornell (1974) give the following values for κ: 2.20 for column loads, 2.76 for beam midspan moments, and 2.04 for beam end moments.

Observed data from load surveys show that the arbitrary point-in-time average load (i.e., the integration of $W(x,y)$ over an area A divided by A) shows a distinct skewness where most of the observed values sit left of the mean and is well fitted by a gamma distribution (Peir and Cornell, 1973; Corotis and Doshi, 1977). Since the average load and the EUDL differ from each other only by a weighting function $I(x,y)$, it is reasonable to assume that the EUDL will also be gamma distributed.

As for the temporal variability, it is assumed that the EUDL remains constant for long periods until an abrupt change occurs, when it jumps to a different value (Figure 1a). In reality, the sustained load exhibits short-term fluctuations due to the working/living personnel coming in and out of the building, but these usually have a much lower magnitude than the overall loading intensity, so the constant value assumption is justified[2]. The occupancy changes can be due to a change of tenant or a reorganization of the occupied space by the same tenant and are assumed to be Poisson-arriving with rate λ. It follows that the occupancy duration is exponentially distributed with a mean value of $1/\lambda$.

Model parameters m, σ_U, and σ_V are calibrated from load survey data, under the assumption that the stochastic process is ergodic. The CIB Report 116 (CIB, 1989) presents an overview of many such surveys dating from 1893 to 1976 and collected in six different countries, referring to a review by Sentler (1976), a paper by Chalk and Corotis (1980), and some early JCSS work. The parameters currently given by the PMC (JCSS, 2001), presented in Table 1, seem to be mostly based on this report.

2.2. *Extraordinary load model*

The extraordinary load can be represented as a concentrated load, but for design purposes, a similar approach as the one used for the sustained load is employed, where an equivalently uniformly distributed load is determined.

While the stochastic model for sustained live load in buildings is seemingly well established, the same cannot be said about the extraordinary load. The PMC (JCSS, 2001) states that the statistical properties of the extraordinary EUDL can be evaluated in the same manner as the sustained EUDL. However, only the input parameters m and σ_U are given by the PMC for extraordinary loads, suggesting that the EUDL variance should be computed as:

$$\mathrm{Var}[P] = \sigma_{U,p}^2 \min\left[\frac{A_0}{A}, 1\right]\kappa, \tag{6}$$

[2]While this is true for most usual buildings, it may not be the case for buildings used for storage purposes such as warehouses, where there may be a definite trend of increasing load over time due to the addition of new goods. For more details on warehouse load models, the reader is referred to Lenner and Sýkora (2017).

where the subscript p is used to differentiate from the sustained load parameters (which will from now on be denoted by the subscript q).

Furthermore, the PMC states that "the standard deviation normally gets values in the same magnitude as the mean value" for the arbitrary point-in-time extraordinary load, so it is therefore assumed to be exponentially distributed. This, however, contradicts the parameters given by the PMC, since an exponential distribution should have the same values for the average and standard deviation, and the PMC gives different parameters for m_q and $\sigma_{U,p}$, as shown in Table 1. Honfi (2014) used the PMC model in his study but adopted the (more common) hypothesis that P is gamma distributed.

This inconsistency seems to have been addressed in a current draft of the *JRC Technical Report: Reliability Background of Eurocodes*[3], by CEN/TC 250/SC 10. In this report, a single parameter m_p is given, and it is stated that $P \sim \text{Exponential}(\mu_p = \sigma_p = m_p)$. Still, the choice for an exponential distribution seems rather strange, since the maximum extraordinary load intensity will not become smaller as the influence area increases, contrary to the live load reduction that is practised in most structural design codes.

A different extraordinary load model was proposed by Peir (1971). It stems from the distinct characteristic that people tend to gather in small groups. Therefore, the extraordinary load is represented by a random number M of groups (or load cells) in random positions, each group containing a random number R of people which may vary from cell to cell, and each person having a random weight Q. Assuming that $M \sim \text{Poisson}(\lambda_M)$, it is possible to show that:

$$\text{E}[P] = \frac{\mu_Q \mu_R}{A} \lambda_M, \tag{7}$$

$$\text{Var}[P] = \frac{\mu_Q^2 \mu_R^2 + \mu_R \sigma_Q^2 + \mu_Q^2 \sigma_R^2}{A} \lambda_M \kappa, \tag{8}$$

in which λ_M is the mean number of load cells; A is the influence area; and κ is the peak factor defined in Equation 5.

Different expressions have been proposed for the mean number of load cells λ_A (McGuire and Cornell, 1974; Ellingwood and Culver, 1977; Choi, 1991). In the present study, the expression given in Harris et al. (1981) is used, which is itself a slight modification of the formula given in Ellingwood and Culver (1977):

$$\lambda(A) = \sqrt{\frac{A - 164}{9}}; \quad A \geq 400\text{ft}^2. \tag{9}$$

For areas smaller than 400 ft^2, linear interpolation is employed from $\lambda_M = 6.24$ at $A = 400\text{ft}^2$ to $\lambda_M = 4.90$ at $A = 300\text{ft}^2$ to $\lambda_M = 3.44$ at $A = 200\text{ft}^2$.

Even though this model was conceived with the behaviour of groups of people in mind, it can also be used for situations other than crowds (e.g., extraordinary load due to a remodelling or repair work, in which the weight of a cell may represent a particularly heavy item or a cluster of items). Harris et al. (1981) employ Equations (7) and (8) independently for three different types of extraordinary load – furniture stacking, usual crowding and emergency crowding – each one with its own set of parameters.

The distribution of this arbitrary point-in-time EUDL can be assumed to be gamma (Peir, 1971). As for the temporal variability, much like the sustained load, the extraordinary load process (Figure 1b) is also assumed to be Poisson-arriving with rate λ_p, so that the interval between occurrences is exponentially distributed with an expected value equal to $1/\lambda_p$. The duration d_p of each pulse is considered deterministic, but may also be represented by an exponential distribution.

Owing to its exceptional and transient nature, it is difficult to collect data about extraordinary loads. Input parameters for this type of load are, therefore, mostly estimated based on questionnaires submitted to building occupants, or simply empirically chosen based on engineering judgement and experience. Suggested parameters given by the PMC (JCSS, 2001) are presented in Table 1, and parameters for the multiple extraordinary load model of Harris et al. (1981) are given in Table 2.

2.3. *Total live load*

The maximum sustained or extraordinary load in a reference period T can be analytically computed using well-known expressions for Poisson processes (Melchers and Beck, 2018). The behaviour of the total live load stochastic process $L(t) = Q(t) + P(t)$ (Figure 1c), on the other hand, is much more involved, since its maximum may not coincide with the maxima for each process. Still, the overall maximum can

[3] Unpublished, kindly provided to us by M. Sýkora.

be estimated using an analytical model presented in Chalk and Corotis (1980), which combines three possible load cases that could lead to this maximum, each weighted by its respective likelihood of occurrence. Complete analytical probability distributions for the total time spent above a fixed barrier level, the number of barrier upcrossings and the duration of a single upcrossing are also derived in great detail in Corotis and Tsay (1983). In this paper, however, all live load statistics are obtained using Monte Carlo simulation (MCS).

3. RESULTS

To demonstrate the use of the stochastic model, statistics for the 1-year and 50-year extreme value distributions (L_1 and L_{50}) of the total live load EUDL are derived via Monte Carlo simulation (MCS) using 10^4 samples. Both the PMC (JCSS, 2001) (using Equation 8 and assuming a gamma distribution) and Harris et al.'s (1981) multiple extraordinary loads model were considered for the extraordinary part of the load. The peak factor was adopted as $\kappa = 2.0$, and influence areas up to 500 m^2 were considered. The 50-year extremes are well-fitted by a Gumbel distribution. For more details on the simulation procedure, the reader is referred to Costa et al. (2023).

The model results are then compared with the design values of two major international design codes: ASCE/SEI 7 (ASCE, 2016) and EN 1991-1-1 (CEN, 2002b). The design loads of ASCE/SEI 7 were selected by a panel of 25 experienced engineers using the Delphi method (Corotis et al., 1981). However, it is stated that the minimum uniformly live load values prescribed by this standard are generally similar to the mean of the maximum load in a reference period T, usually $T = 50$ years (ASCE, 2016). As for the Eurocodes, it doesn't make it clear to which exceedance probability their design load corresponds. Some background documents relate the characteristic value to a 5 % probability of exceedance in 50 years (CEN, 1996), which seems rather low compared with the 43 % exceedance of the mean value of ASCE/SEI 7 (if a Gumbel distribution were to be assumed). Some studies refer to the 98 % fractile of annual maximum loads (Honfi, 2014), corresponding to a 50-year return period, similar to what the Eurocodes adopt for the characteristic value of climatic actions.

Another controversy that should be pointed out is

Table 1: Live load parameters for some major occupancies given in the Probabilistic Model Code (JCSS, 2001)

		Sustained load (q)				Extraordinary load (p)			
Occupancy	A_0 [m^2]	m_q [kN/m^2]	$\sigma_{V,q}$ [kN/m^2]	$\sigma_{U,q}$ [kN/m^2]	$1/\lambda_q$ [years]	m_p [kN/m^2]	$\sigma_{U,p}$ [kN/m^2]	d_p [days]	$1/\lambda_p$ [years]
Office	20	0.50	0.30	0.60	5	0.20	0.40	0.3	1–3
Residential	20	0.30	0.15	0.30	7	0.30	0.40	1.0	1–3
Hotel room	20	0.30	0.05	0.10	10	0.20	0.40	0.1	1–3
Patient room	20	0.40	0.30	0.60	5–10	0.20	0.40	1.0	1–3
Classroom	100	0.60	0.15	0.40	10	0.50	1.40	0.3	1–5
Retail	100	0.90	0.60	1.60	1–5	0.40	1.10	1.0	1–14

Table 2: Multiple extraordinary load model parameters given by Harris et al. (1981)

	Furniture stacking (P_1)			Usual crowding (P_2)			Emergency crowding (P_3)		
Occupancy	(μ_R,σ_R) [–]	(μ_Q,σ_Q) [lbf]	λ_p [per yr.]	(μ_R,σ_R) [–]	(μ_Q,σ_Q) [lbf]	λ_p [per yr.]	(μ_R,σ_R) [–]	(μ_Q,σ_Q) [lbf]	λ_p [per yr.]
Office	(1,1)	(500,150)	0.25	(4,2)	(150,25)	0.4	(10,5)	(150,25)	0.02
Residential	(2,1)	(142,25)	0.1	(3,2)	(150,25)	1.0	(10,5)	(150,25)	0.005
Hotel room	(2,1)	(81,25)	0.5	(3,1)	(150,25)	10.0	(10,5)	(150,25)	0.1
Classroom	(4,2)	(222,25)	0.5	(4,2)	(150,25)	1.0	(10,5)	(150,25)	0.1
Retail (first floor)	(8,4)	(175,25)	0.2	(6,3)	(150,25)	4.0	(10,5)	(150,25)	0.1
Retail (upper floors)	(5,2)	(150,25)	0.2	(4,2)	(150,25)	4.0	(10,5)	(150,25)	0.1

NOTE 1: Recommended values for the duration d_p are 2 weeks for P_1, 6 hours for P_2, and 15 minutes for P_3.
NOTE 2: 1lbf $\approx$ 4.45N

the live load reduction (LLR) allowed in both codes. ASCE/SEI 7 (ASCE, 2016) allows only for influence area-based reduction for beams and columns alike, which is more consistent with the stochastic model. EN 1991-1-1 (CEN, 2002b), on the other hand, allows for storey-based and area-based live load reduction (but not both simultaneously). Strangely, for the most common occupancy types, the recommended formulas allow for a reduction of up to 50 % in area-based LLR (typically used for beams) but only 30 % for storey-based LLR. This seems counter-intuitive since the allowed reduction should be larger for columns, since they support larger areas. Nevertheless, it should be noted that there is no explicit rule that precludes the use of area-based LLR for columns as well.

In addition to that, EN 1991-1-1 (CEN, 2002b) doesn't make it clear if the area to be considered in area-based LLR is the tributary or influence area[4]. Both hypotheses are assumed in this study. This leads to there being two different curves for beams and columns when the tributary area is used, since it usually differs from the influence area by a factor of two for beams and four for columns.

Design code prescriptions are compared to the 98 % fractile of annual maxima and the mode, mean value and 95 % fractile of 50-year extreme live load in Figure 2 for office buildings. It is clear that the 5 % exceedance values are way higher than the design load given in EN 1991-1-1 (CEN, 2002b). The Eurocode design loads seem to be closer to the mean 50-year extreme live load.

It is also interesting to note that the mode of L_{50} is not equal to the 98 % fractile of L_1. This occurs because, contrary to what is assumed for climatic actions, the annual maxima for live loads are not fully independent because the average time between occupancy changes of the sustained load is usually greater than one year (e.g., $1/\lambda = 5$ years for office buildings). Thus, we find it to be preferable to define the characteristic value in terms of L_{50} instead of L_1, since unlike annual maxima the 50-year extremes can reasonably be assumed to be independent.

Comparing the results obtained from both models and with literature results, it would seem that the JCSS model is somewhat conservative. Though the results couldn't be included due to space constraints, a similar behaviour was observed for the other occupancy types listed in Table 1 (these results can be seen in Costa et al. (2023)). Based on this, it is found that the JCSS parameters are often unreasonably conservative and unrealistic.

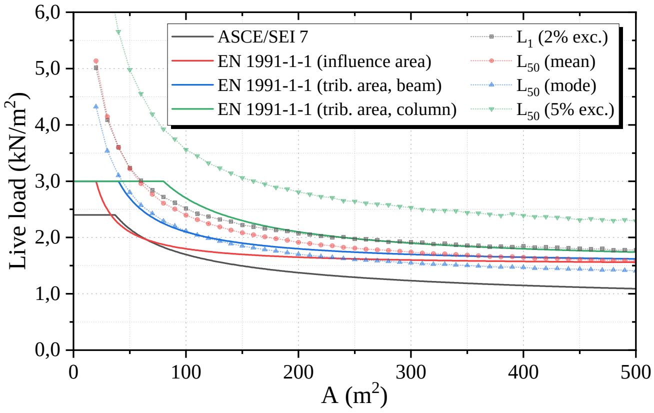
This is especially true for occupancy types for which there are very few suitable load surveys, such as schools and retail areas (Honfi, 2014; Costa et al., 2023), and for the extraordinary load parameters. Even for the more extensively surveyed categories, such as office use, the majority of the data was gathered more than four decades ago. This points to the need to carry out new load surveys in a standardized manner to further support the stochastic model with more recent data. While some individual effort using more modern technologies instead of direct weighing has been made in this sense (Chen and Li, 2022; Zhou and Chen, 2022), the research regarding live load surveys is still very limited.

While both extraordinary load models considered in this study have some degree of subjectivity in the selection of their parameters due to the lack of data, we believe the model proposed by Peir (1971) (Equations 7 and 8) to be more suitable because it physically represents the localized crowding of people more appropriately. Furthermore, the empirical selection of input parameters is facilitated since they have more familiar meanings (average weight of a person/furniture, average amount of people in a group, etc).

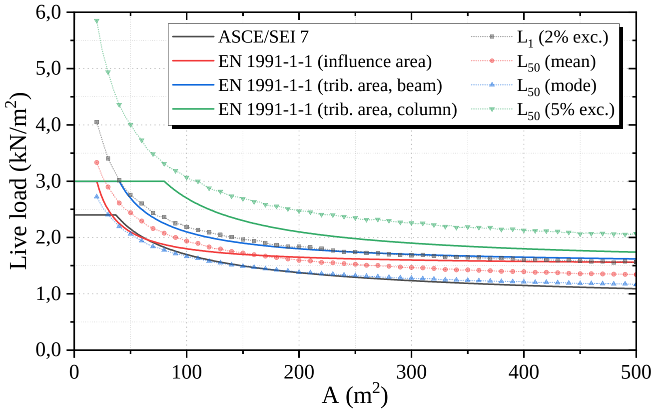
Table 3 shows a review of live load statistics used in reliability analysis such as code calibration. The L_{50} statistic by Holický and Sýkora (2011) in particular has been frequently used in ongoing Eurocode calibration, and while it is in agreement with the 5 % exceedance probability mentioned in background documents, it is specific for office use, considers only the sustained load part, and was derived using approximate analytical expressions. The authors also present a statistic for 5-year maxima (L_5), where the 5-year reference period corresponds to the expected time between sustained load renewals for office use (Table 1) and may not hold for other uses with different characteristics.

We believe the MCS approach considering both sustained and extraordinary loads employed herein to be more suitable to derive extreme live load statistics. Using Harris et al.'s (1981) multiple extraordinary load model and appropriately selecting the influence areas A to be $100\,\mathrm{m}^2$ for classrooms and retail and

[4] Instead, it refers to *loaded area* or *supported area*.



(a) JCSS PMC model (JCSS, 2001)



(b) Harris et al. (1981) model

Figure 2: Live load for office buildings using different stochastic models, simulation vs. code values

Table 3: Live load statistics for average point-in-time (L_{apt}), 5-year (L_5) and 50-year (L_{50}) extreme distributions

Reference	Random variable	Distribution	Bias μ_L/L_k	c.o.v. σ_L/μ_L	Exc. probability $1-F_L(L_k)$
Ellingwood and Galambos (1982)	L_{50} (50 years)	Gumbel	1.00	0.25	0.43
Szerszen and Nowak (2003)	L_{50} (50 years)	Gumbel	0.93	0.18	0.28
Holický and Sýkora (2011)	L_{50} (50 years)	Gumbel	0.60	0.35	0.05
Costa et al. (2023)	L_{50} (50 years)	Gumbel	0.92	0.25	0.30
JRC Technical Report*	L_{50} (50 years)	Gumbel	0.74	0.26	0.094
Present study	L_{50} (50 years)	Gumbel	1.00	0.29	0.43
Holický and Sýkora (2011)	L_5 (5 years)	Gumbel	0.20	1.10	0.005
Ellingwood and Galambos (1982)	L_{apt} (instant.)	Gamma	0.25	0.55	0.0003
Costa et al. (2023)	L_{apt} (instant.)	Gamma	0.21	0.76	0.0015
Present study	L_{apt} (instant.)	Gamma	0.20	0.95	0.005

* JRC Technical Report: Reliability Background of Eurocodes (unpublished).

50 m^2 for all other occupancies, we get mean 50-year extreme loads that are consistent with the characteristic loads L_k given in EN 1991-1-1 (CEN, 2002b). The L_{50} and L_{apt} statistics referred to as "present study" in Table 3 were obtained in this manner, and correspond to the average of occupancy types listed in Table 2.

As for the arbitrary point-in-time live load (L_{apt}) statistics, its mean and variance are practically equal to those of the sustained EUDL, since the extraordinary load is only "on" for a negligible duration of the building lifetime. Using the parameters suggested by JCSS, it is found that for pretty much all occupancies other than hotel rooms the coefficient of variation of 0.55 reported by Ellingwood and Galambos (1982) (listed as typical) is reasonable for large loaded areas, but it may be too low for smaller areas. In this study, we recommend a c.o.v. of 0.95 for smaller influence areas, say, up to 100 m^2.

4. CONCLUSIONS

This study presents a brief review of stochastic models for live loads in buildings. Those models are compared for different occupancy types using Monte Carlo simulation. The main conclusion is that the model parameters given by the JCSS Probabilistic Model Code (JCSS, 2001) are often excessively conservative, especially for building uses that have been less extensively surveyed (classrooms, retail areas) and for the extraordinary load. New and improved load surveys should be carried out to validate and expand the existing data since most of the load surveys used to calibrate model parameters are now more than 40 years old.

An overview of live load statistics used in code calibration is also provided. It is shown that the 5 % exceedance probability in 5 years found in Eurocode background documents is not consistent with the minimum design loads currently given in EN 1991-1-1 (CEN, 2002b), which seems to be closer to the mean 50-year extreme load. With this in mind, new statistics for the arbitrary point-in-time and 50-year extreme live loads are proposed.

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