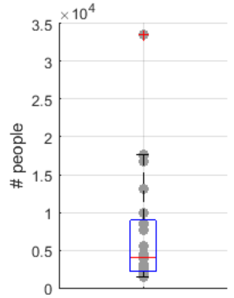
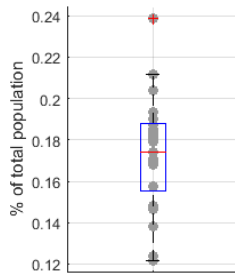
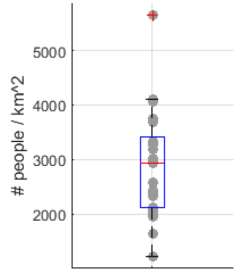
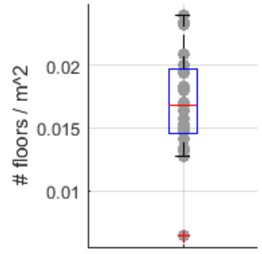
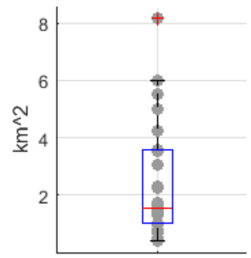
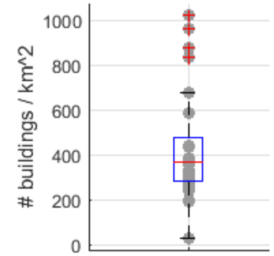
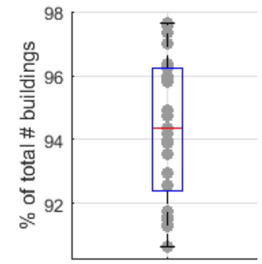
Electronic Supplementary Material

Table S1. Data about land use, buildings and demographic characteristics collected for all major (≥ 1,000 inhabitants) localities in the Rhone valley

Inhabited locality	Demographics (source: SFSO (2017a))			Buildings	Land use (source: SFSO (2018) and swisstopo (2019))		
	Total population [# people]	Population ≥ 65 years [%]	Population density [#people/m2]		Total area [km2]	Building density [#/m2]	Residential buildings [%]
Sion	33532	0.19	4.10	0.021	8.18	0.38	0.949
Martigny	17651	0.17	3.19	0.015	5.54	0.26	0.913
Monthey	17512	0.17	2.93	0.015	5.97	0.30	0.962
Sierre	16711	0.20	3.33	0.020	5.02	0.38	0.958
Brig-Glis	13088	0.19	3.69	0.018	3.55	0.37	0.929
Aigle	9942	0.17	3.27	0.015	3.04	0.03	0.940
Collombey-Muraz	8638	0.12	2.04	0.016	4.24	0.24	0.964
Fully	8524	0.15	5.65	0.023	1.51	0.83	0.906
Conthey	8485	0.18	3.71	0.020	2.29	0.59	0.963
Visp	7665	0.18	2.13	0.013	3.6	0.19	0.913
Saxon	5534	0.15	2.43	0.013	2.28	0.43	0.935
Saint-Maurice	4494	0.17	2.58	0.016	1.74	0.39	0.959
Vouvry	3968	0.16	2.32	0.013	1.71	0.35	0.926
Leuk	3915	0.19	2.94	0.017	1.33	0.68	0.970
Leytron	3084	0.24	3.02	0.019	1.02	0.96	0.977
Ardon	3050	0.15	1.97	0.017	1.55	0.27	0.944
Riddes	2985	0.18	2.96	0.017	1.01	0.43	0.948
Saillon	2482	0.18	2.39	0.006	1.04	0.32	0.939
Saint-Leonard	2269	0.17	1.63	0.018	1.39	0.29	0.960
Gampel-Bratsch	1909	0.21	3.74	0.024	0.51	0.88	0.973
Raron	1905	0.19	1.95	0.013	0.978	0.33	0.917

Vernayaz	1886	0.17	2.37	0.020	0.796	0.37	0.942
Charrat	1666	0.12	1.23	0.015	1.36	0.20	0.915
Saas-Fee	1621	0.14	4.05	0.023	0.4	1.03	0.976
Salgesch	1465	0.21	2.10	0.014	0.699	0.44	0.916
Evionnaz	1242	0.16	2.33	0.020	0.533	0.45	0.959

Table S2. Summary statistic for the characteristics of the inhabited localities in the Rhone valley

a) Demographic			**b) Buildings**	**c) Land use**		
						
Total population	Population ≥ 65 years	Population density	Average height/building area	Total Area	Building density	Residential buildings

● inhabited localities in the Rhone valley, CH

Table S3. Assumptions made for the structural inventory in the loss of shelter module and for the warning and evacuation module in HEC-LIFESim to build the LL-model representation for a Swiss case scenario

a) Assumptions for the structural inventory in the loss of shelter module:

The following table explains how the information on the building category, occupancy type, structural stability criteria, and number of stories in the GWR database has been adopted to the format of the HEC-LIFESim software.

Information in the GWR database		**Information in the HEC-LIFESim software**	
Building Category			
Commercial		COM	
Educational		EDU	
Governmental		GOV	
Industrial		IND	
Religious		REL	
Residential		RES	
Other (other buildings with/without apartment)		COM	
Occupancy Type			
1110 -	Buildings with one apartment	RES1-1SWB, RES1-2SWB, RES1-3SWB, RES1-SLWB	Single family residential house (1-3 stories, with/without basement)
1121 -	Buildings with two apartments	RES3A	Multi Family Residence - Duplex
1122 -	Buildings with three or more apartments	RES3B, RES3C, RES3D, S3E, RES3F	Multi Family Residence - 3 to more than 50 units
1130 -	Residential buildings for communities/associations	RES5, RES6	Institutional dormitories, Nursing Homes
1211 -	Hotels and similar buildings	RES4	Temporary lodging
1212 -	Other buildings for short accommodation	RES4	Temporary lodging
1220 -	Office buildings	COM5, GOV1, GOV2	Banks, Government -l services & emergency response
1230 -	Wholesale and retail buildings	COM1, COM2, COM3	Retail trade, Wholesale trade, Personal and repair services
1241 -	Train stations, terminal buildings	COM4	Professional and technical services

1242 -	Garage	COM10	Parking garages
1251 -	Industrial buildings	IND2, IND3	Light industrial, Food/drugs/chemicals
1252 -	Tanks, warehouses, silos	IND2, IND3	Light industrial, Food/drugs/chemicals
1261 -	Buildings for cultural and recreational purposes	COM8, COM9	Entertainment and recreation, theaters
1262 -	Museums and libraries	COM8	Entertainment and recreation
1263 -	Schools, Colleges, and Research facilities	EDU1, EDU2	Schools, colleges and universities
1264 -	Hospitals and specialized health care facilities	COM7, COM6	Medical office, clinic, hospitals
1265 -	Sport halls	COM8	Entertainment and recreation
1271 -	Agricultural commercial buildings	AGR1	Agriculture facilities and offices
1272 -	Church and other cult buildings	REL1	Churches and non-profit organizations
1273 -	Monuments or Monument conservations	COM8	Entertainment and recreation
1274 -	Other buildings	COM3	Personal and repair services
Structural stability criteria			
		IND3 treated as IND2	
		COM1 and COM2 treated as COM3	
		EDU2 treated as EDU1	
		GOV1 and GOV2 treated as COM5	
		RES3C, RES3D, RES3E, RES3F treated as RES3B	
		RES1-2SWB;-3SWB; -SLWB treated as RES1-1SWB	
		RES6 treated as RES5	
Number of stories			
The number provided in the GWR database		The number provided in the GWR database	
No information provided in the GWR database		1	

Furthermore, for the building type in the loss of shelter module, a separate table is given. This table gives the shares of the buildings with a specific material in each building category. The table is not based on the GWR database, but it is built on expert knowledge.

	Building Type				
Building Category	Wood	Concrete	Steel	Manufactured	Masonry

Residential	25	50	0	0	25
Commercial	0	50	50	0	0
Public	0	50	25	0	25
Industrial	0	50	50	0	0

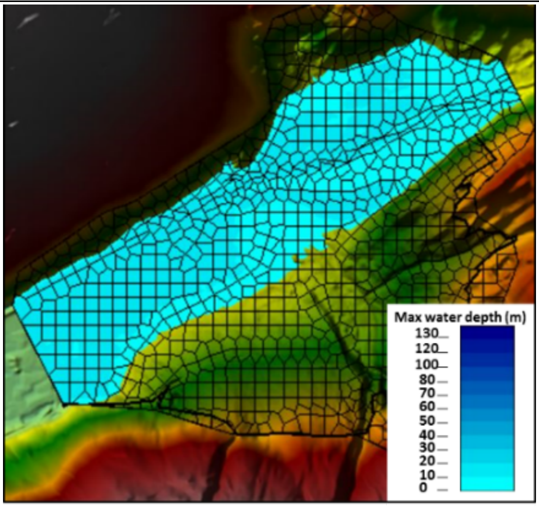
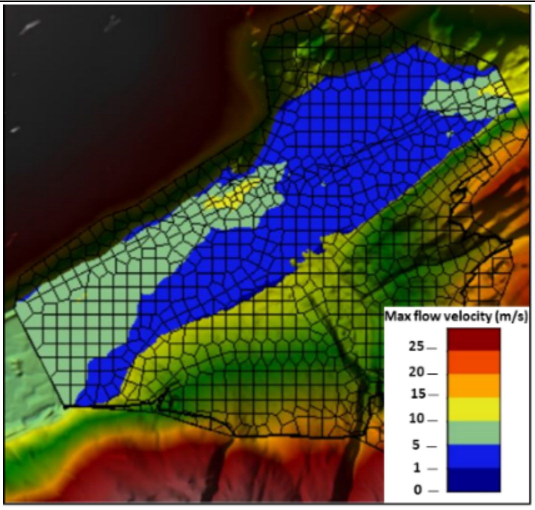
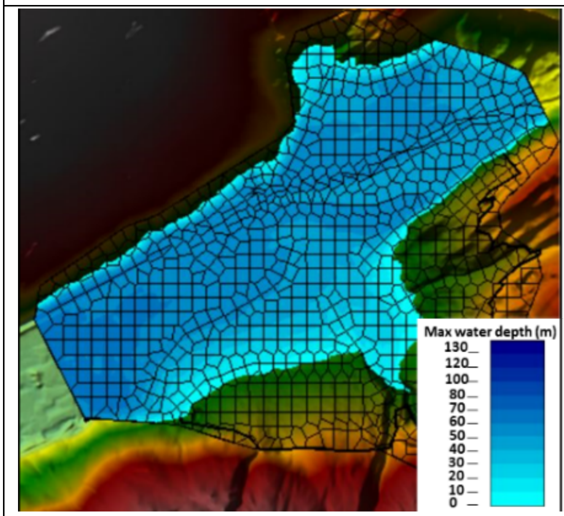
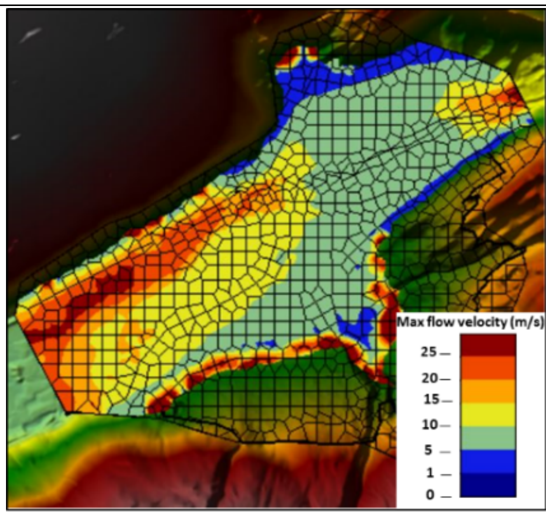
b) Assumptions made for the warning and evacuation module:

The following table contains the assumptions made for the demographic data. In other words, it explains how people are distributed in buildings with different occupancy types. The assumptions are made based on expert knowledge.

Furthermore, the assumptions are different depending on the time of the day. In particular, differentiation is made between night-time (2 a.m.) and daytime (2 p.m.).

Night-time scenario (2 AM)	
Occupancy type	**Information about people**
RES	all population except people located in hospitals
COM6 (hospital)	800 people, occupied 30%; 60% of those are people ≥ 65 years
rest of COM	no people
IND	no people
REL	no people
GOV	no people
EDU	no people
Day-time scenario (2 PM)	
IND (#4 buildings)	200, 100, 50, and 50 people
REL	no people
GOV	no people
EDU	each – 200 people < 65 years
COM5 (bank)	no people
COM6 (hospital)	800 people, occupied 30%
COM7 (# 2 clinic)	each 60 people, occupied 40%; 50% of those are people ≥ 65 years
COM8 & COM 9	no people
COM10 (garage)	no people
RES	people < 65 years - 15% of the night capacity
RES	People ≥ 65 years - 35% of the night capacity

Table S4. Different flood characteristics reflecting scenarios F05, F50, and F95

<table>
<tr><th>Maximal water depth (m)</th><th>Maximal flow velocity (m/s)</th></tr>
<tr><td colspan="2">Scenario F05 corresponding to the 5% flood severity</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">Scenario F50 corresponding to the median flood severity</td></tr>
<tr><td>
</td><td>
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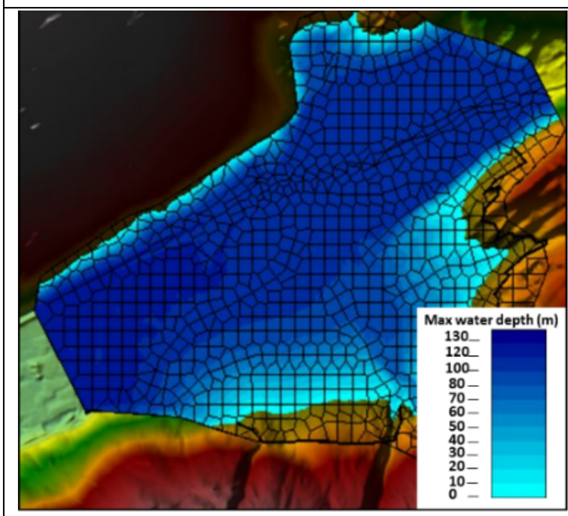
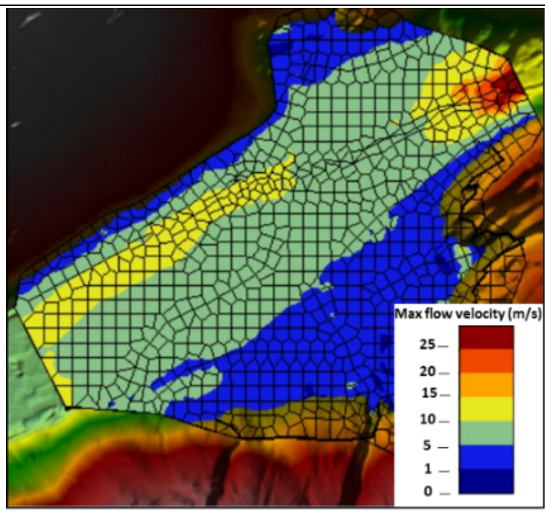
<tr><td colspan="2">Scenario F95 corresponding to the 95% flood severity</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table S5. Overview of the research conducted about LL-modeling: Discussions and results on methods for uncertainty and sensitivity analyses; also input parameters contributing most to uncertainty of the model output. Parameters considered for the uncertainty quantification in this study are given in bold

Author(s)	**Year**	**Title**	**Method for uncertainty analysis**	**Method for sensitivity analysis**	**Uncertain parameters**
Graham, W.J.,	1999	A Procedure for Estimating Loss of Life Caused by Dam Failure, DSO-99-06	This procedure suggests various causes of dam failure will result in differences in PAR and the severity of the flooding. Another type of uncertainty is the time of day, time of week and time of year that failure occurs. Additional uncertainty is associated with when warnings would be initiated. The last type of uncertainty is associated with the fatality rate, with which it is suggested to use the range of fatality rates.		Cause of the failure, time of the failure, **warning time**, **fatality rate**, **PAR**, conditions at a time of the failure (reservoir level, rain)
Aboelata, M., Bowles, D.S., & McClelland, D.M.,	2003	A model for estimating dam failure life loss	The uncertainty simulation procedure includes: Generation of sets of realizations of inputs using a Latin Hypercube sampling technique; model simulations for each set of realizations; Results analysis and presentation.	The different warning times were tested; it was concluded that decrease in warning time leads to increase in fatality rate.	structure damage criteria, human & vehicle stability criteria, **warning initiation time**, **warning diffusion**, mobilization, **fatality rate**
Lee, J.S.,	2003	Uncertainties in the Predicted Number of Life Loss due to the Dam Breach Floods	The uncertainty analyses were conducted using the Monte Carlo simulation based on the Latin Hypercube Sampling technique. The following uncertainties were considered: uncertainty in the flood routing results and uncertainty in the fatality rates, i.e., in the warning time, necessary for determining the fatality rates.	Different scenarios were done for different failure/no failure, distance from the dam site, daytime, day of the week, season.	**maximum flood elevation**, time to maximum flood elevation, **maximum flow**, **fatality rates**, **warning time**
Bowles, D.S., & Aboelata, M.,	2007	Evacuation and LL estimation model for Natural & Dam break floods	The Uncertainty Mode of HEC-LIFESim propagates uncertainties associated with model parameters and inputs through the model to provide probability distributions of LL-estimates.	Sensitivity is tested for different waring times (varied from T=-3 hours to T=2 hours), evacuation destinations (#4) and increasing	**warning initiation time**, **warning diffusion curve**, mobilization time curve, modal split between pedestrians and vehicles, modal split between cars

				population with the same capacity of the road network. Concluded the importance of the warning time, clear evacuation strategy; increase of population with the same road capacity resulted in increasing fatality rates.	and SUVs, vehicle-occupancy rate (people/vehicle), free flow speed (km/h), jam density (vehicles/km-lane), human and vehicle stability criteria, structural damage criteria, height of the first level of buildings, fatality rate
Jonkman, S.N.	2007	Loss of life estimation in flood risk management	The focus is on river and coastal floods on low lying areas. The parameters considered is water depth, velocity, warning and evacuation. The capacity and strength of buildings is mentioned to be of high importance. It is mentioned that the application of the dose response function can influence uncertainty in consequences, i.e., the distribution of the number of fatalities (the standard deviation of the expected number of fatalities). It was shown that the distribution of consequences depends on the standard deviation of the loads and resistances and the dependence between loads and resistances.		**water depth**, water velocity, **warning** and evacuation, capacity and strength of buildings
Aboelata, M., & Bowles, D.S.,	2008	LIFESim: A tool for estimating and reducing life-loss resulting from Dam and Levee Failures	Uncertainty module existing in HEC-LIFESim is used to estimate the distribution of LL with consideration given to uncertainty in the following: evacuation rate; rescue efficiency in the safe zone; rescue efficiency in the compromised and chance zone; fatality rate in the safe, compromised, chance zones. The results are expressed for the particular drainage basin as probability distributions for the mean, for 5% and for 95% percentiles.		evacuation rate, rescue efficiency, **fatality rate**

Jonkman, S.N., & Vrijling, J.K.,	2008	Loss of life due to foods	The work is focused on coastal floods. It mentions uncertainties in the mortality function since there is not enough empirical data available for calibration.		
Graham, W.J.,	2009	A comparison of methods for estimating loss of life from dam failure	The paper contains an evaluation of many different methodologies for LL estimation. For LIFESim particularly, it is said that significant uncertainties are in 1. When warning is issued; 2. how quickly the warning is disseminated and how effective it is in getting people to take unction; 3. how many people do not evacuate; 4. the transportation mode and route used to leave the danger area.		**warning time**, **warning diffusion curve**, mobilization time curve, % of PAR that do not evacuate, transportation mode and routes
Davison, M., Lumbroso, D., & Tagg, A.	2013	The use of a Monte-Carlo analysis to assess the uncertainty in the estimates of loss of life from flooding using an agent-based model.	A Monte-Carlo uncertainty analysis was undertaken for two case study sites in England using the Life Safety Model (LSM) to assess the sources of uncertainty in loss of life estimates from floods. The research used a Monte-Carlo analysis to estimate the sensitivity of evacuation times and LL to the physical characteristics of people (e.g., height, weight); parameters that affects the strengths of buildings and the stability of vehicles in floodwater.		people´s height and weight, parameters of the strengths of buildings, stability of vehicles
U.S. Bureau of Reclamation	2014	RCEM – Reclamation Consequence Estimating Methodology		Example variations in a sensitivity analysis include PAR, flood depth & velocity values, and warning times	**PAR**, **flood depth** & velocity, **warning times**
McCann & Paxson	2016	Uncertainty in Dam Failure Consequence Estimates	For each scenario, 1,000 simulations were performed using the MCBreach model to estimate the aleatory uncertainty in the breach outflow hydrograph. Then, the cumulative pdf was built for the peak outflow and for the peak flood elevations. After, the fatality rate was	18 scenarios for different dam breach widths, time to failure, methods for life loss	dam breach widths, time to failure

			calculated for the chosen three scenarios. In addition, the implementation of a Bayesian risk model demonstrated contribution of different sources of aleatory and epistemic uncertainty to the risk results.	estimation were performed.	
Wang, C., et al.	2017	Life Loss Estimation Based on Dam-Break Flood Uncertainties and Lack of Information in Mountainous Regions of Western China.	The systems as GIS and MIKE were used together with an improved support vector machine (SVM) to estimate life losses. Population at risk was given by overlapping the residential distribution and flooded layers. The results showed that warning time and an understanding by the population at risk the level of a dam-break disaster are the two main factors influencing LL.		**PAR**, **alarm time**, flood intensity, **proportion of young adults in PAR**, weather, occurrence time of the dam failure, distance for the dam site, storage
Lumbroso, D., & Davison, M.,	2018	Use of an agent-based model and Monte Carlo analysis to estimate the effectiveness of emergency management interventions to reduce loss of life during extreme floods	The Life Safety Model (LSM) and a Monte Carlo analysis was used to assess the effectiveness of emergency management interventions in terms of loss of life, considering uncertainties in the physical characteristics of the population at risk, represented by people´s height and mass. Development of probability distributions for highest safe depth, critical depth and velocity combination for toppling, and the same combination for drowning.		people´s height and mass

Table S6. The PCE-degree and values of ϵ_{LOO} and MSE errors (fraction) for different model outputs using different sizes of the experimental design

Full Model Evaluation [#]	**F50**						**F05**						**F95**					
	Night-time [2 a.m.]			**Daytime [2 p.m.]**			**Night-time [2 a.m.]**			**Daytime [2 p.m.]**			**Night-time [2 a.m.]**			**Daytime [2 p.m.]**		
	PCE	ϵ_{LOO}	MSE	PCE	ϵ_{LOO}	MSE	PCE	ϵ_{LOO}	MSE	PCE	ϵ_{LOO}	MSE	PCE	ϵ_{LOO}	MSE	PCE	ϵ_{LOO}	MSE
50	3	0.0374	0.0678	2	0.0751	0.1028	3	0.0336	0.0446	3	0.0916	0.1567	4	0.0041	0.4253	8	0.0176	0.2808
100	2	0.0694	0.1207	2	0.0789	0.1146	6	0.0135	0.0338	2	0.0819	0.1246	2	0.0710	0.1139	2	0.0678	0.0989
150	9	0.0021	0.0408	7	0.0038	0.0406	8	0.0042	0.0176	9	0.0050	0.0523	8	0.0038	0.0264	3	0.0226	0.1330
200	5	0.0062	0.0064	5	0.0092	0.0063	5	0.0060	0.0074	5	0.0080	0.0705	5	0.0066	0.0038	5	0.0062	0.0072
250	7	0.0019	0.0016	9	0.0021	0.0020	7	0.0039	0.0039	7	0.0041	0.0038	7	0.0036	0.0026	9	0.0020	0.0014
300	7	0.0018	0.0015	9	0.0018	0.0015	10	0.0024	0.0032	6	0.0042	0.0130	7	0.0035	0.0016	8	0.0020	0.0019
350	7	0.0014	0.0012	9	0.0019	0.0070	8	0.0031	0.0016	7	0.0035	0.0029						
400	7	0.0016	0.0008	13	0.0014	0.0015	8	0.0026	0.0013	8	0.0032	0.0018						
450	7	0.0013	0.0017	8	0.0017	0.0022	8	0.0022	0.0023	9	0.0029	0.0041						
500	7	0.0014	0.0021	9	0.0016	0.0017	8	0.0023	0.0013	9	0.0028	0.0031						
550	7	0.0013	0.0013	15	0.0015	0.0016	8	0.0023	0.0014	12	0.0027	0.0027						
Threshold of 5 fatalities		0.0019			0.0019			0.0040			0.0034			0.0019			0.0020	

Table S7. Comparison of the LL estimates, including their uncertainty, for the three scenarios F05, F50 and F95 and the two timing 2 a.m. and 2 p.m. considered in this study calculated with the PCE and different MC samples (100, 1,000, 10,000, 100,000) implemented in HEC-LIFESim

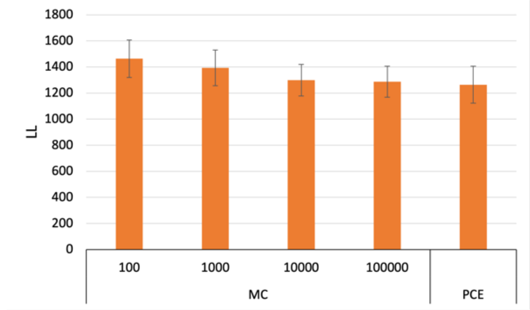
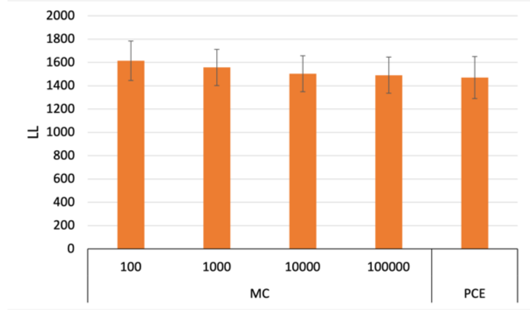
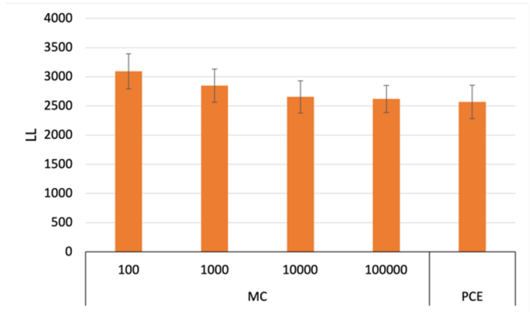
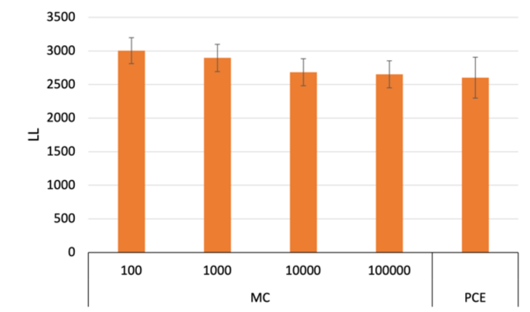
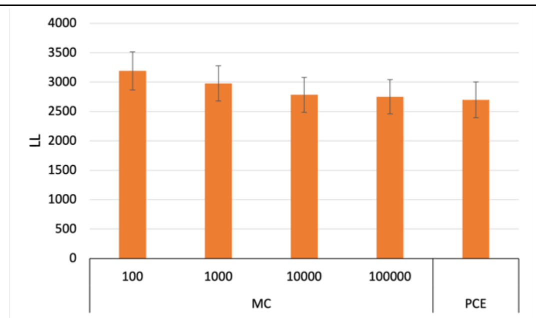
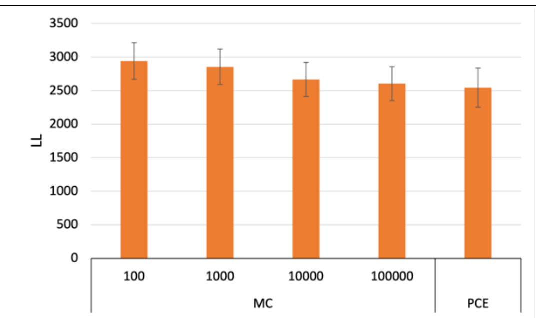
	Night-time (2 a.m.)	Daytime (2 p.m.)
F05		
F50		
F95		

Table S8. The values of the 1st and total Sobol′ indices and Borgonovo indices calculated for different model outputs in all six defined scenarios

Model Input Parameter	F50						F05						F95					
	Night-time [2 a.m.]			Daytime [2 p.m.]			Night-time [2 a.m.]			Daytime [2 p.m.]			Night-time [2 a.m.]			Daytime [2 p.m.]		
	1st Order Sobol	Total Sobol	Borgonovo	1st Order Sobol	Total Sobol	Borgonovo	1st Order Sobol	Total Sobol	Borgonovo	1st Order Sobol	Total Sobol	Borgonovo	1st Order Sobol	Total Sobol	Borgonovo	1st Order Sobol	Total Sobol	Borgonovo
Receptor																		
P_{tot}	8.29E-1	8.29E-1	5.26E-1	8.28E-1	8.28E-1	5.24E-1	8.06E-1	8.06E-1	4.97E-1	8.25E-1	8.25E-1	5.23E-1	8.12E-1	8.12E-1	4.98E-1	7.97E-1	7.97E-1	4.80E-1
P_{o65}	0	8.47E-5	3.67E-2	0	1.04E-4	4.13E-2	2.35E-5	1.23E-4	3.86E-2	0	7.49E-5	3.68E-2	0	9.44E-5	3.80E-2	0	1.25E-4	3.77E-2
H	0	1.11E-5	4.14E-2	0	6.71E-5	4.29E-2	9.72E-5	1.12E-4	3.99E-2	2.00E-4	3.04E-4	3.98E-2	0	0	4.16E-2	0	4.99E-5	4.27E-2
Reaction																		
F_{chance}	1.16E-1	1.16E-1	1.29E-1	1.06E-1	1.06E-1	1.23E-1	1.35E-1	1.35E-1	1.43E-1	1.14E-1	1.14E-1	1.26E-1	1.07E-1	1.07E-1	1.23E-1	1.10E-1	1.11E-1	1.26E-1
F_{compr}	6.41E-6	4.89E-5	3.61E-2	0	5.53E-5	3.93E-2	0	1.55E-4	3.69E-2	0	5.97E-5	4.05E-2	3.15E-5	7.18E-5	3.92E-2	0	2.99E-5	4.12E-2
T_{wid}	5.50E-2	5.53E-2	8.68E-2	6.52E-2	6.54E-2	9.61E-2	5.87E-2	5.90E-2	9.24E-2	6.1E-2	6.04E-2	9.50E-2	8.09E-2	8.12E-2	1.14E-1	9.15E-2	9.19E-2	1.21E-1
T_{hcd}	1.31E-4	3.77E-4	4.28E-2	1.33E-4	4.13E-4	4.09E-2	1.78E-4	3.93E-4	4.17E-2	1.79E-4	3.83E-4	4.13E-2	6.62E-5	3.10E-4	4.34E-2	2.02E-4	4.94E-4	4.06E-2