

B. National Model Construction: Example for reinforced concrete buildings

This example illustrates how the 2002-2014 UESF and the 2002 Census data are used to estimate the number of reinforced concrete (RC) buildings in a certain commune. This estimation is necessary because census data is referred to dwellings (apartments), and the classification by typologies is referred to structures. To obtain the number of RC buildings, census data is combined with two key data from the UESF per commune: distribution of number of stories in RC buildings, and the average number of apartments per story.

Consider RC buildings in a fictitious *Commune Y*, which is divided in two census blocks. 2002 Census dwelling information is shown in Table B.1. The RC apartments prior to 2002 are separated in the census blocks and location (urban and rural). These apartments are identified in the 2002 Census from the material of the exterior walls (concrete or stone).

Table B.1: Information of apartments in RC buildings in *Commune Y* from the 2002 Census

Location	Census blocks of Commune Y		Total
	1	2	
Urban	9,500	350	9,850
Rural	1,400	1,800	3,200
Total	10,900	2,150	13,050

Table B.2 shows the UESF information, which provides the number of RC apartments and buildings built between 2002 and 2014 in the commune, identifying if they are located at the urban or rural area. Percentages of participation for apartments of each type of RC building in the city are shown in Table B.2. It is important to note that in order to have a simplified example, the maximum number of stories for the RC buildings are 10. Percentages of participation for apartments according to the number of stories by location (urban and rural) from the UESF data (PN_{ij}^{UESF}) are calculated as follows:

$$PN_{ij}^{UESF} = \frac{N_{ij}^{UESF}}{\sum_{j=3}^{10} N_{ij}^{UESF}} * 100, \quad \forall i, j \quad (\text{Equation B.1})$$

Note that:

$$\sum_{j=3}^5 PN_{ij}^{UESF} = 100, \quad \forall i$$

Where,

- i : location = $\begin{cases} 1, & \text{for urban} \\ 2, & \text{for rural} \end{cases}$

- j : number of stories = $\begin{cases} 3, & \text{for three-story building} \\ \vdots \\ 10, & \text{for ten-story building} \end{cases}$
- N_{ij}^{UESF} : Total number of apartments according to building height by location (urban or rural) obtained from UESF data for *Commune Y*.

The number of apartments per story from UESF data (A_{ij}^{UESF}) is important to estimate the number of buildings from the census number of apartments. This number is calculated according to building height and location as follows:

$$A_{ij}^{UESF} = \frac{N_{ij}^{UESF}}{B_{ij}^{UESF} * j}, \quad \forall i, j \text{ (Equation B.2)}$$

Where,

B_{ij}^{UESF} : Total number of buildings according to building height by location (urban or rural) obtained from UESF data for *Commune Y*.

Table B.2: Information of RC apartments in *Commune Y* from the UESF (2002-2014)

Location	Number of stories	N_{ij}^{UESF} : Number of apartments	PN_{ij}^{UESF} : Participation of apartments per stories (%)	B_{ij}^{UESF} : Number of buildings	A_{ij}^{UESF} : Calculated average number of apartments per story
Urban	3	21	2.4	1	7
	4	56	6.5	2	7
	5	70	8.1	2	7
	6	126	14.6	3	7
	7	196	22.8	4	7
	8	56	6.5	1	7
	9	126	14.6	2	7
	10	210	24.4	4	5
	Subtotal	861	100	19	-
Rural	3	52	23.4	2	9
	4	0	0	0	0
	5	0	0	0	0
	6	42	18.9	1	7
	7	0	0	0	0
	8	65	29.3	2	4
	9	0	0	0	0
	10	63	28.4	1	6
	Subtotal	222	100	6	-
Total	1,083	-	25	-	

Subsequently, using apartment and buildings distribution (Table B.2), it is possible to estimate the number of RC buildings of each building typology in the commune for the residential stock built before 2002. The percentages of apartments per number of stories (for urban or rural) from UESF data are used to convert the number of apartments from Table B.1 into number of apartments in buildings with different heights, as follows:

$$PN_{ijk}^{Census} = PN_{ij}^{UESF}, \quad \forall i, j, k \quad (\text{Equation B.3})$$

$$N_{ijk}^{Census} = \frac{PN_{ijk}^{Census}}{100} * N_{ik}^{Census}, \quad \forall i, j, k \quad (\text{Equation B.4})$$

Where,

- i : location = $\begin{cases} 1, & \text{for urban} \\ 2, & \text{for rural} \end{cases}$
- j : number of stories = $\begin{cases} 3, & \text{for three-story building} \\ \vdots \\ 10, & \text{for ten-story building} \end{cases}$
- k : census block in *Commune Y* = $\begin{cases} 1, & \text{for Census block 1} \\ 2, & \text{for Census block 2} \end{cases}$
- PN_{ijk}^{Census} : Percentage of participation of apartments built prior to 2002 according to building height by census block and location (urban or rural).
- N_{ik}^{Census} : Total number of apartments according to census block by location (urban or rural) obtained from 2002 Census data for *Commune Y* (see Table B.1).
- N_{ijk}^{Census} : Total number of apartments built prior to 2002 calculated according to building height by census block and location (urban or rural).

Finally, with apartments built prior to 2002 for *Commune Y* (N_{ijk}^{Census}) is possible to estimate the number of buildings related (B_{ijk}^{Census}) as follows (see the results in Table B.3):

$$A_{ijk}^{Census} = A_{ij}^{UESF}, \quad \forall i, j, k \quad (\text{Equation B.5})$$

$$B_{ijk}^{Census} = \frac{N_{ijk}^{Census}}{A_{ijk}^{Census} * j}, \quad \forall i, j, k \quad (\text{Equation B.6})$$

Where,

A_{ijk}^{Census} : Average number of apartments per story according to building height by census block and location (urban or rural).

Table B.3: Estimation of the number of RC buildings per census block according to the number of stories in *Commune Y*. This estimation covers the building stock built previous to 2002, and was calculated using the building distribution of the UESF.

Location	Census block	Number of stories	PN_{ijk}^{Census} : Participation of apartments per stories (%)	N_{ijk}^{Census} : Number of apartments	A_{ijk}^{Census} : Apartments per story	B_{ijk}^{Census} : Number of buildings
Urban	1	3	2.4	232	7	11.0
		4	6.5	618	7	22.1
		5	8.1	772	7	22.1
		6	14.6	1,390	7	33.1
		7	22.8	2,163	7	44.1
		8	6.5	618	7	11.0
		9	14.6	1,390	7	22.1
		10	24.4	2,317	5	44.1
		Subtotal	100	9,500	-	209.6
	2	3	2.4	9	7	0.4
		4	6.5	23	7	0.8
		5	8.1	28	7	0.8
		6	14.6	51	7	1.2
		7	22.8	80	7	1.6
		8	6.5	23	7	0.4
		9	14.6	51	7	0.8
		10	24.4	85	5	1.6
		Subtotal	100	350	-	7.7
Subtotal	-	-	9,850	-	217.4	
Rural	1	3	23.4	328	9	12.6
		4	0.0	0	0	0.0
		5	0.0	0	0	0.0
		6	18.9	265	7	6.3
		7	0.0	0	0	0.0
		8	29.3	410	4	12.6
		9	0.0	0	0	0.0
		10	28.4	397	6	6.3
		Subtotal	100	1,400	-	37.8
	2	3	23.4	422	9	16.2
		4	0.0	0	0	0.0
		5	0.0	0	0	0.0
		6	18.9	341	7	8.1
		7	0.0	0	0	0.0
		8	29.3	527	4	16.2
		9	0.0	0	0	0.0
		10	28.4	511	6	8.1
		Subtotal	100	1,800	-	48.6
Subtotal	-	-	3,200	-	86.5	
Total	-	-	13,050	-	303.9	

Finally, to estimate the number of RC buildings per census block (B_{ijk}^{Total}) in the National Exposure Model (Table B.4), the buildings built before 2002 (Table B.3) are added to the number of buildings from 2002 to 2014 (Table B.2), which are uniformly distributed in all the census blocks of *Commune Y*. See Equation B.6.

$$B_{ijk}^{Total} = \frac{B_{ij}^{UESF}}{Cb} + B_{ijk}^{Census}, \quad \forall i, j, k \text{ (Equation B.6)}$$

Where,

Cb : Total number of census blocks in *Commune Y* = 2

Table B.4: Total RC buildings in *Commune Y*

Location	Number of stories	B_{ijk}^{Census} : Number of buildings prior to 2002		B_{ij}^{UESF}/Cb : Number of buildings 2002-2014		B_{ijk}^{Total} : Total number of buildings		Total
		Census block 1	Census block 2	Census block 1	Census block 2	Census block 1	Census block 2	
Urban	3 stories	11.0	0.4	0.5	0.5	11.5	0.9	12.4
	4 stories	22.1	0.8	1.0	1.0	23.1	1.8	24.9
	5 stories	22.1	0.8	1.0	1.0	23.1	1.8	24.9
	6 stories	33.1	1.2	1.5	1.5	34.6	2.7	37.3
	7 stories	44.1	1.6	2.0	2.0	46.1	3.6	49.8
	8 stories	11.0	0.4	0.5	0.5	11.5	0.9	12.4
	9 stories	22.1	0.8	1.0	1.0	23.1	1.8	24.9
	10 stories	44.1	1.6	2.0	2.0	46.1	3.6	49.8
Rural	3 stories	12.6	16.2	1.0	1.0	13.6	17.2	30.8
	4 stories	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5 stories	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	6 stories	6.3	8.1	0.5	0.5	6.8	8.6	15.4
	7 stories	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8 stories	12.6	16.2	1.0	1.0	13.6	17.2	30.8
	9 stories	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10 stories	6.3	8.1	0.5	0.5	6.8	8.6	15.4
Total		247.5	56.4	12.5	12.5	260.0	68.9	328.9