Optimal location of Disaster Support Centres in Vancouver

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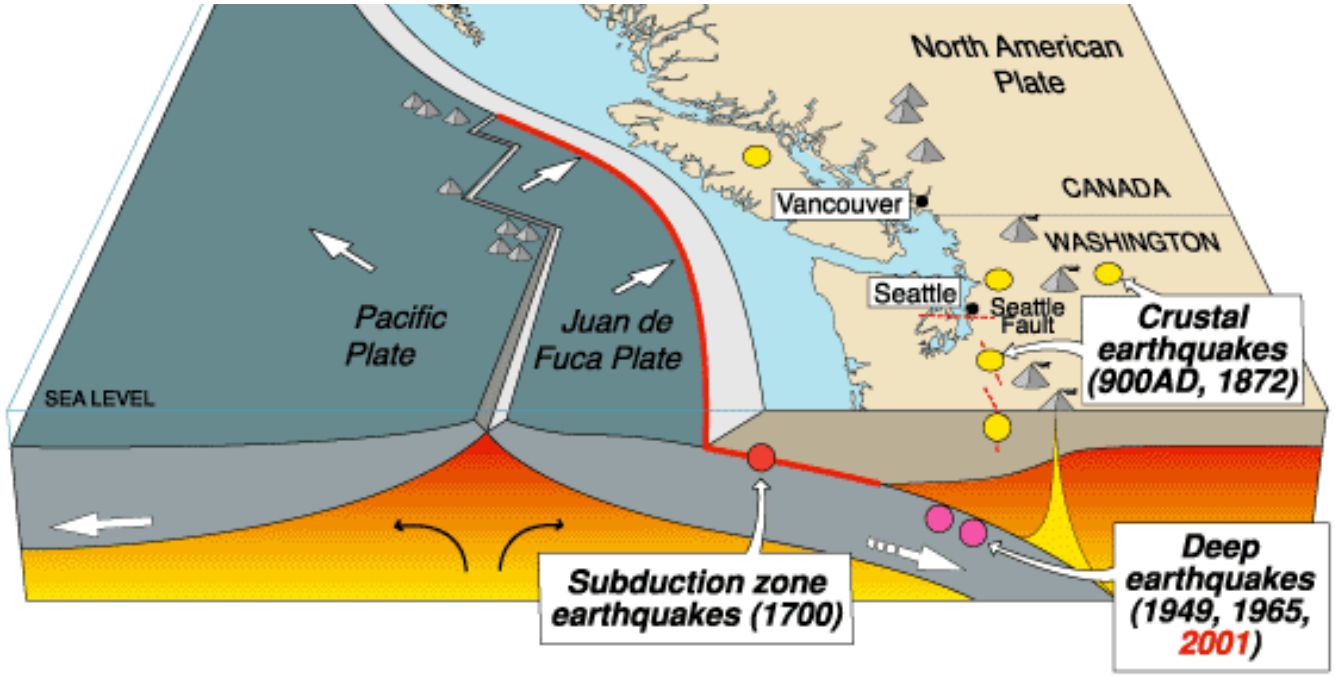
Motivation

1. Cascadia subduction zone



2. Flood (The city of Richmond)
3. Existing disaster supporting centre

Mathematical Models and Applications

We begin with dividing the map of the city of Vancouver into m x n grid cells

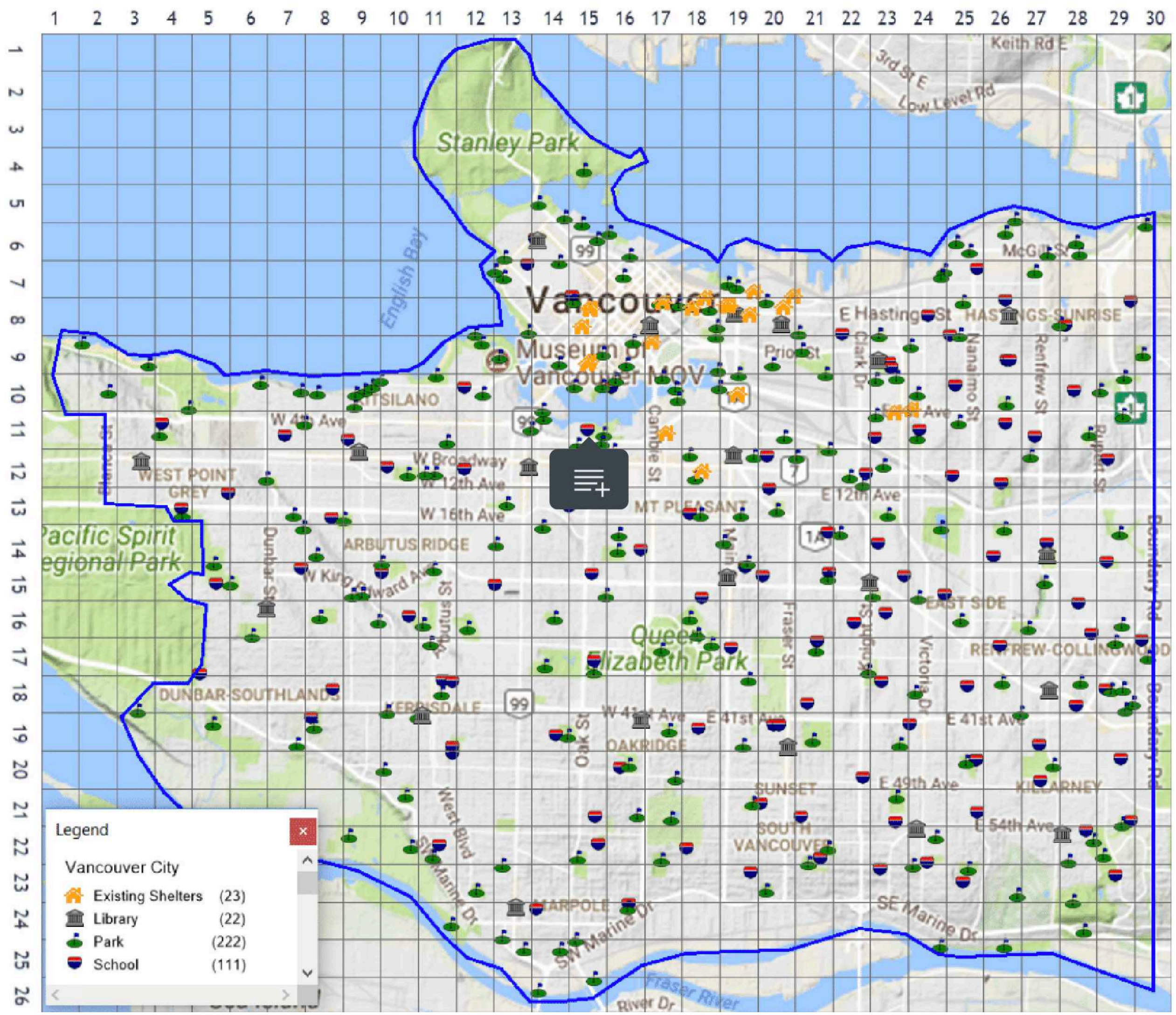


Fig. 1: City of Vancouver with potential facility locations divided into 26×30 grid cells with 500 m^2 area for each grid

Mathematical Models and Applications

Model I: Maximizing Weight Scores

$$\text{Maximize } Z_I = \sum_{(i,j)\in S} w_{ij}x_{ij} \tag{7}$$

such that

$$w_{ij} = \sum_{i-2}^{i+2}\sum_{j-2}^{j+2}(w_p P_{ij} + w_r R_{ij}) \tag{8}$$

$$w_p + w_r = 1 \tag{9}$$

$$\sum_{(i,j)\in D_k \cap S} x_{ij} \geq 1 \tag{10}$$

$$\sum_{(i,j)\in S} x_{ij} \leq 25 \tag{11}$$

$$\mu_{ij} = \sum_{i-2}^{i+2}\sum_{j-2}^{j+2}\rho_{ij} \tag{12}$$

$$\mu_{ij}x_{ij} \leq Cap_{x_{ij}} \tag{13}$$

$$x_{ij}, y_{ij} \in \{0, 1\} \tag{14}$$

Mathematical Models and Applications

Model II: Multiple Objective Model

$$\text{Minimize } d_1^+ + d_2^+ + \sum_{z=3}^{254}(d_z^+ + d_z^-)$$

subject to:

$$\sum_{(i,j)\in S} x_{ij} - d_1^+ \leq \mathcal{D} \qquad \text{(Facility Demand Target)} \qquad (15)$$

$$\sum_{(i,j)\in S} w_{ij}x_{ij} + d_2^- \geq Z_I^* \qquad \text{(Score Target)} \qquad (16)$$

$$\mu_{ij}x_{ij} + d_z^- - d_z^+ = Cap_{x_{ij}}y_{ij} \qquad \forall(i,j),z \qquad \text{(Capacity Utilization Goal)} \qquad (17)$$

$$x_{ij} = y_{ij} \qquad (18)$$

$$\sum_{(i,j)\in D_k\cap S} x_{ij} \geq 1 \qquad \forall k \qquad \text{(District Requirement)} \qquad (19)$$

$$x_{ij}, y_{ij} \in \{0,1\} \qquad \text{(Binary)} \qquad (20)$$

Data Collection

1.http://vancouver.ca

2. http://www.statcan.gc.ca/eng/start

Subjects

- Aboriginal peoples
- Agriculture
- Business, consumer and property services
- Business performance and ownership
- Children and youth
- Construction
- Crime and justice
- Culture and leisure
- Economic accounts
- Education, training and learning
- Energy
- Environment
- Ethnic diversity and immigration
- Families, households and housing
- Government
- Health
- Income, pensions, spending and wealth
- Information and communications technology
- International trade
- Labour
- Languages
- Manufacturing
- Population and demography
- Prices and price indexes
- Reference
- Retail and wholesale
- Science and technology
- Seniors
- Society and community
- Statistical methods
- Transportation
- Travel and tourism

Data Collection

TABLE I: Vancouver city data along with rank and risk factors

Sr. No.	Area	Population	Population_Rank	Locations Density	Density_Rank	Altitude (m)	Risk Factor
1	West Point Grey	12795	2	10	2	50	5
2	Dunbar Southlands	21745	4	12	2	90	2
3	Kitsilano	41,375	8	25	7	25	8
4	Arbutus Ridge	15,910	3	17	5	75	3
5	Kerrisdale	14,735	2	15	4	20	9
6	Stanley Park	0	0	4	0	30	8
7	West End	44,540	8	12	2	33	7
8	Downtown	54,690	10	36	9	25	8
9	Fairview	31,440	6	10	2	20	9
10	Shaughnessy	8,810	1	9	1	89	2
11	South Cambie	7,680	1	7	1	85	2
12	Oakridge	12,440	2	11	2	78	3
13	Marpole	23,835	4	16	4	25	8
14	Downtown Eastside	27,305	5	13	3	9	9
15	Strathcona	12,165	2	17	5	5	10
16	Mount Pleasant	26,400	5	20	5	51	5
17	Riley Park	21,795	4	12	2	80	2
18	Kensignton Cedar Cottage	47470	9	18	5	62	4
19	Sunset	36285	7	15	4	81	2
20	Hastings Sunrise	33990	6	38	10	50	5
21	Renfrew Collignwood	50505	10	30	8	97	1
22	Victoria Fraserview	30710	6	16	4	87	2
23	Killarney	28450	5	16	4	103	0

Data Collection

$$PopulationRank/RiskFactor = \frac{k_{max} - k_{min}}{\tau}; \quad k \in \{P, R\}$$

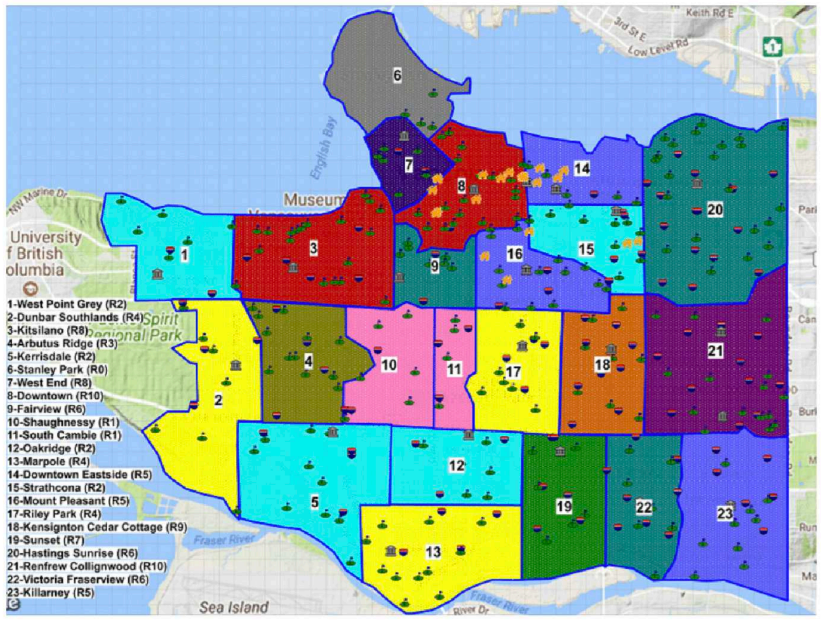


Fig. 2: Vancouver map depicting population density

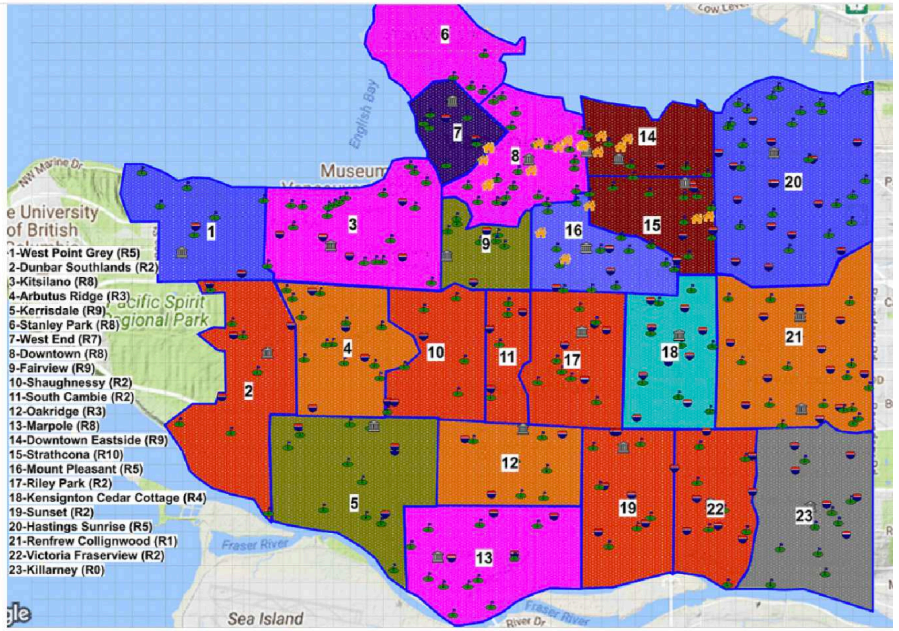


Fig. 3: Vancouver map depicting flood risk factors

Data Collection

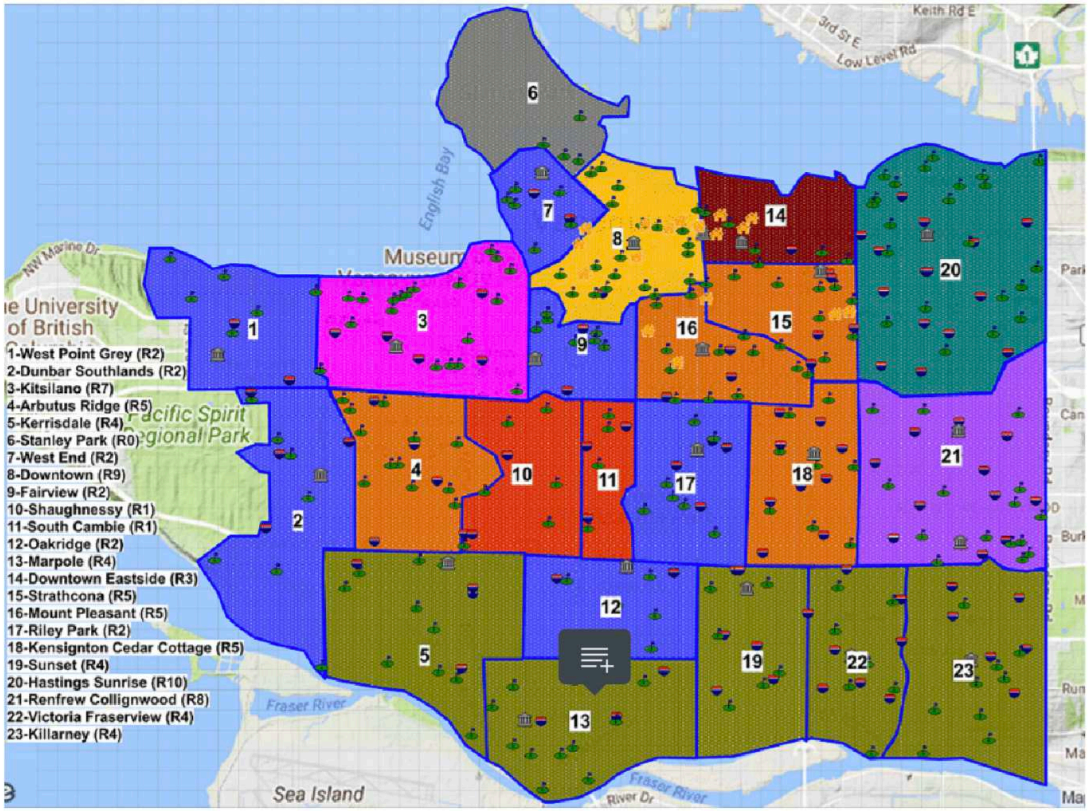


Fig. 4: Vancouver map depicting potential locations density

Data Mapping and Generation

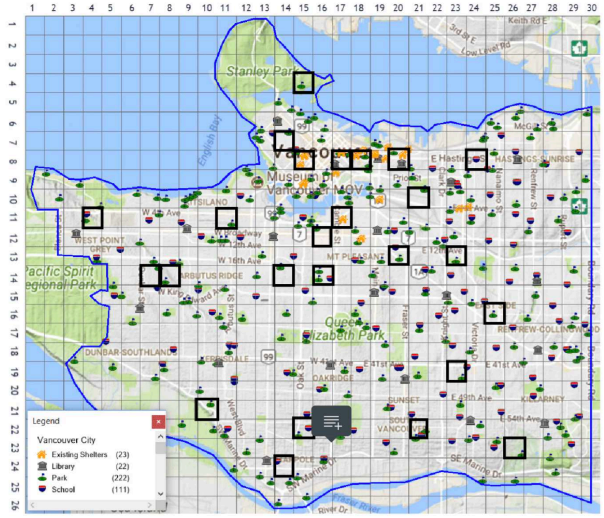


Fig. 5: Optimal facility locations for the original model with risk and population weight scores of (risk score weight, population score weight) = $(\frac{1}{3}, \frac{2}{3})$

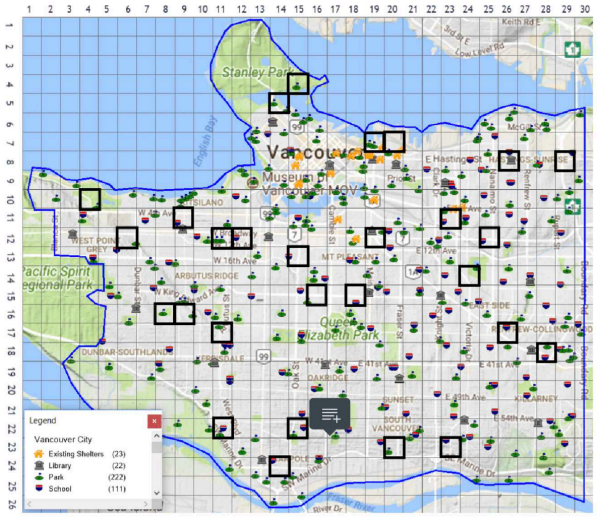


Fig. 6: Optimal facility locations for the second model with risk and population weight scores of (risk score weight, population score weight) = $(\frac{1}{3}, \frac{2}{3})$

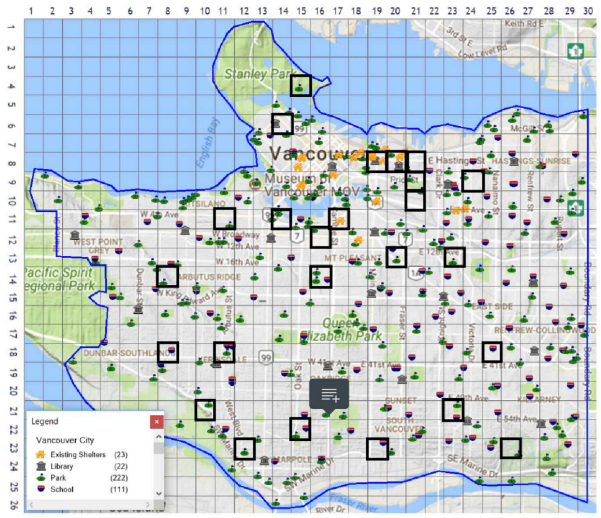


Fig. 7: Optimal facility locations for the original model with risk and population weight scores of (risk score weight, population score weight) = $(0, 1)$.

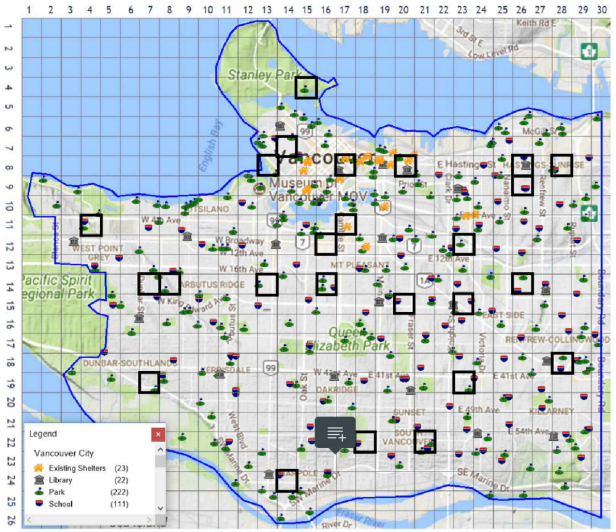


Fig. 8: Optimal facility locations for the original model with risk and population weight scores of (risk score weight, population score weight) = $(1, 0)$.

Data Mapping and Generation

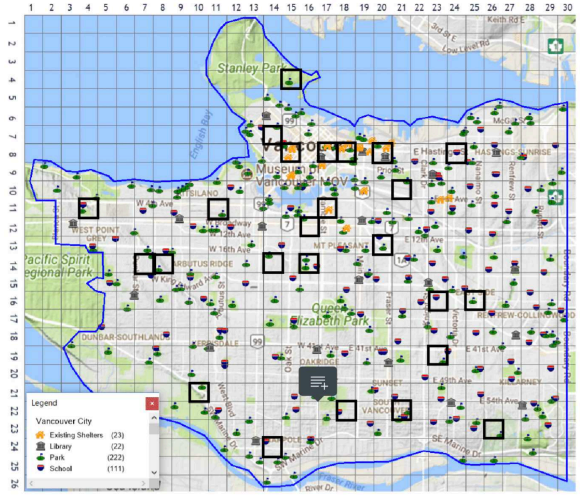


Fig. 9: Optimal facility locations for the original model with risk and population weight scores of (risk score weight, population score weight) = $(\frac{1}{5}, \frac{1}{5})$.

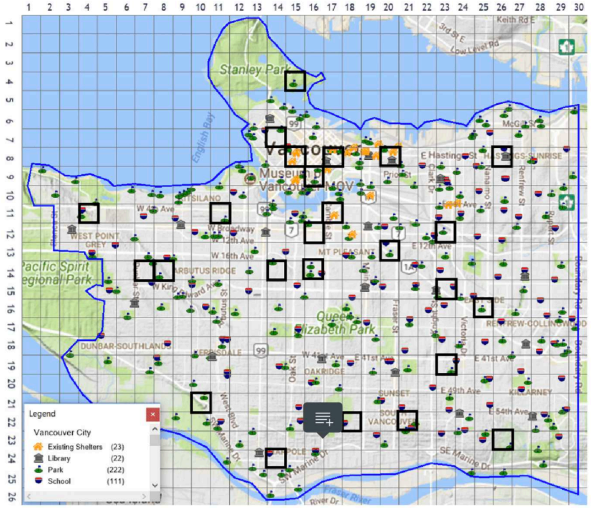


Fig. 10: Optimal facility locations for the original model with risk and population weight scores of (risk score weight, population score weight) = $(\frac{2}{3}, \frac{1}{3})$

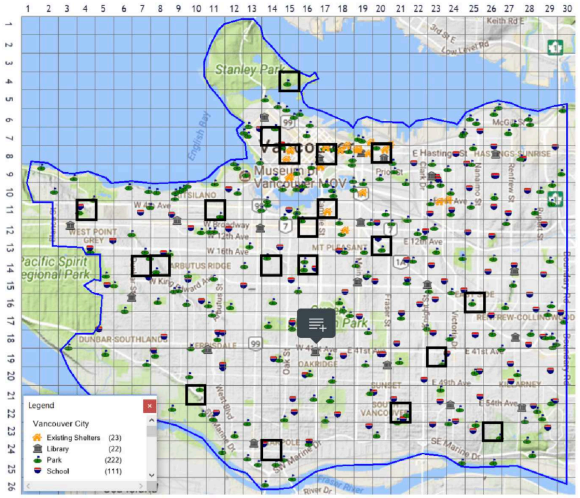


Fig. 11: Similar optimal facility locations of the two different variants and the original model formulation

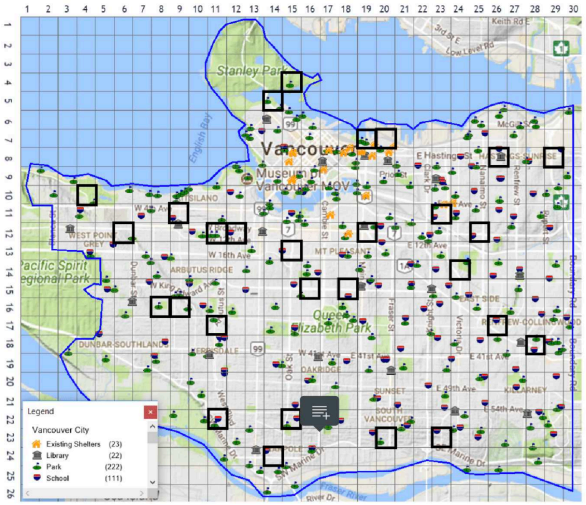


Fig. 12: Optimal facility locations for the second model with risk and population weight scores of (risk score weight, population score weight) = $(\frac{1}{3}, \frac{2}{3})$

Data Mapping and Generation

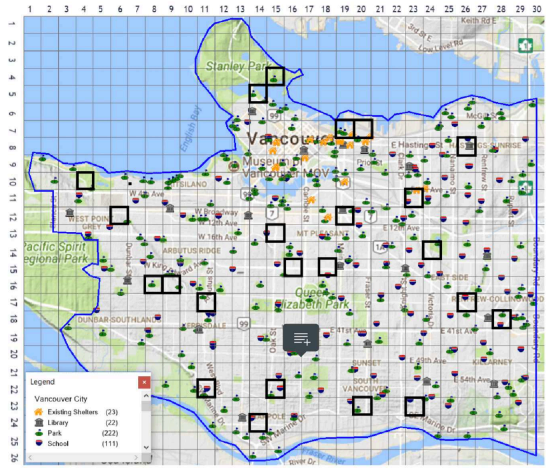


Fig. 13: Optimal facility locations for the second model where the main priority is the maximization of the capacity of each chosen facility

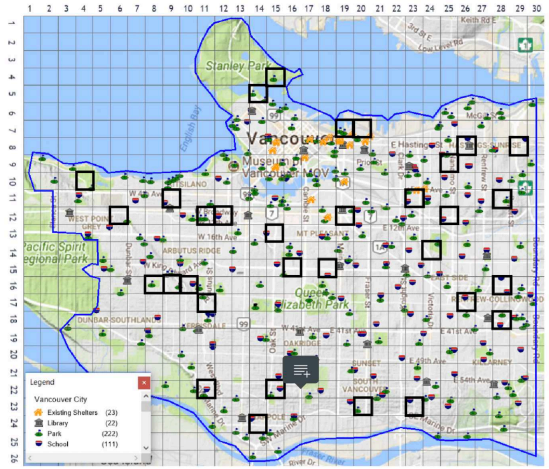


Fig. 14: Optimal facility locations for the second model where the main priority is the minimization of the negative deviation of the total score from the goal of 33,336

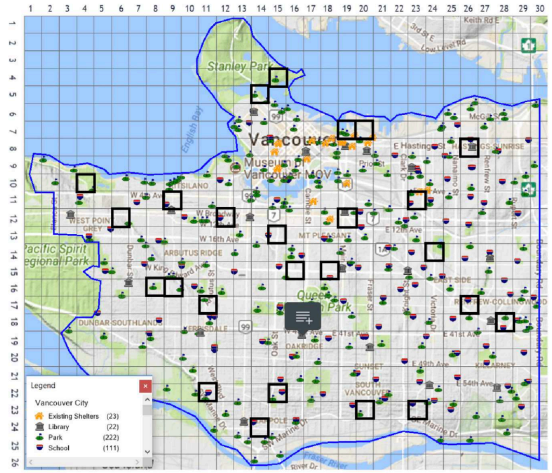


Fig. 15: Optimal facility locations for the second model where the main priority is the minimization of the number of facilities over 25

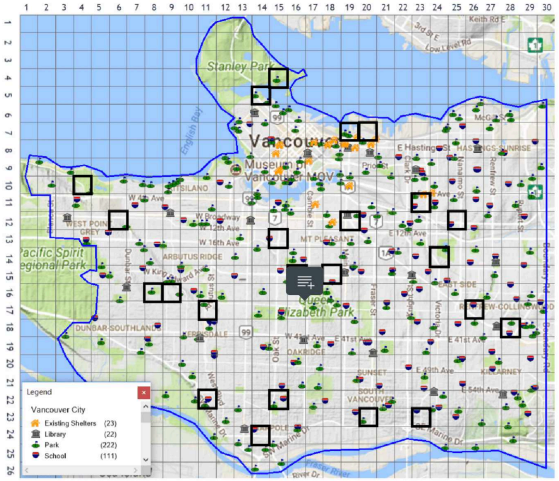


Fig. 16: Similar facility locations among the three variants and the original model formulation

Conclusion

We have considered two different models.

1. Maximize the total sum of weights given the population and risk levels of each district.
2. find an optimal location for the facilities given three separate goals.

References

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