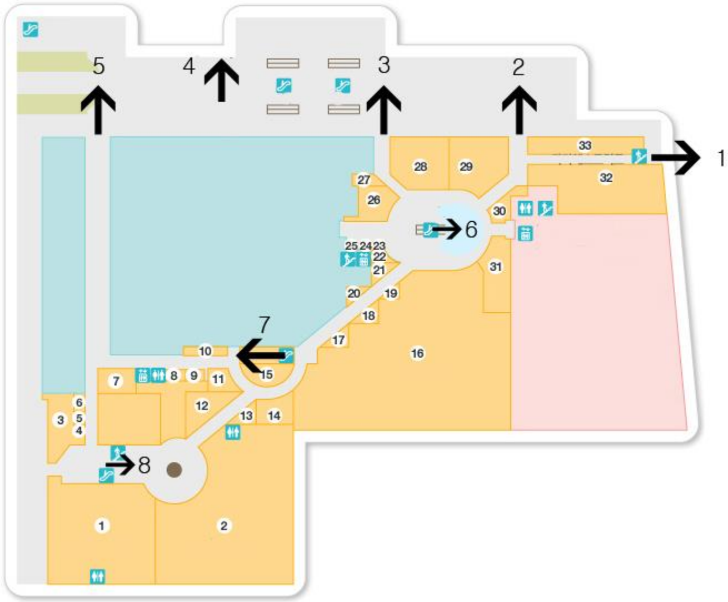
Facilities planning

Design project

Problem description

- Consider an underground mega shopping mall called Central Park in Seoul, Korea. Central Park has a vast area with a variety of spaces, including a shopping center, a movie theater, a bookstore, a food court, and some department stores. Central Park has 53 facilities and 8 exits.



Problem description

- The models for occupant movement enable us to analytically determine the number of occupants who can leave a building at a certain time.
- Let a_j(m^2) be the access area of exit j where the occupants crowd around and a congestion phenomenon occurs. Also, let ρ_j be the number of occupants at exit area a_j. Then, the occupant density (people/m^2) at exit j can be calculated as follows:
- $$\rho_j = \frac{p_j}{a_j} \qquad (1)$$
- The value of f_j(people/m·sec) is the specific flow that is equal to the product of the evacuation speed v_j(m/sec) and the occupation density at the area as follows:
- $$f_j = v_j \times \rho_j \qquad (2)$$
- The specific flow represents the number of people who cross a unit of width of exit j per unit time.

Problem description

- Then, flow F_j , which is equal to the product of f_j and the width of exit j, w_j , represents the number of people who cross exit j in a unit of time as follows:
- $$F_j = f_j \times w_j \qquad (3)$$
- Finally, the evacuation time t_j of evacuees p_j through exit area a_j is as follows:
- $$t_j = \frac{p_j}{F_j} \qquad (4)$$
- If these evacuees are coming from facility i, then the total evacuation time t_{ij} must be the sum of the traveling time that the occupants will take to reach exit j and the evacuation time through exit j is as follows:
- $$t_{ij} = \frac{d_{ij}}{v_i} + \frac{p_j}{F_j} \qquad (5)$$
- where d_{ij} is the shortest distance from facility i to exit j.

Problem description

- It has long been established from field surveys that higher crowd density leads to interaction between individuals, and this eventually reduces individual walking speeds. Consider the following walking speed:

- $$v = \frac{1.129}{\rho} \qquad (6)$$

- The objective of the problem is to assign a facility to an exit such that the overall evacuation time (i.e., the maximum evacuation time of all exits) is minimized. One to one relationship between a facility and an exit must be satisfied.

Problem data

- Distance

Exit / Facility	1	2	3	4	5	6	7	8
1	271.8	224.3	203.5	198.1	149	186.7	115.2	30
2	232.6	185.1	164.3	194.8	146	147.5	73.8	17.9
3	258.1	210.6	189.8	213.8	163.4	173	99.5	34.2
4	269.6	222.1	201.3	244.8	199.3	184.5	114.5	70.3
5	268.4	220.9	200.1	262.6	200.3	183.3	125.5	81.4
6	258.3	210.8	190	252.5	188.7	173.2	112.1	70.1
7	241.6	194.1	173.3	235.8	178.1	156.5	101.5	59.3
8	227.6	180.1	159.3	221.8	182.5	142.5	91.5	63.8
9	277.3	229.8	209	171.4	149.4	192.2	126.3	25
10	262.9	215.4	194.6	180.3	127.3	177.8	116.3	42.3
11	282.1	234.6	213.8	170.2	118.2	196	133.3	14.8
12	281.8	234.3	213.5	154.8	102.6	195.7	117.7	13.6
13	286.3	238.8	208.7	150	98.3	200.2	113.5	17.4
14	290.3	242.8	212.7	146.2	94.7	204.2	109.9	21.7
15	270.3	222.8	212.3	145.8	94.2	184.2	109.2	34.5
16	234.4	186.9	164.6	158.9	108.9	147	72.3	66.7
17	220.2	172.7	150.4	166.3	120.4	132.9	57.9	75.5
18	216.7	169.2	146.9	169.7	120.9	129.4	54.5	77.2
19	206.9	159.4	137.1	186.4	136.7	119.6	43.7	72
20	212.8	165.3	143	204.5	157	125.5	51.4	57.8
21	198.5	151	128.7	190.2	147.2	111.2	37	65.4
22	190.5	143	120.2	182.2	154.2	103.2	30.8	75.4
23	181	133.5	110.7	172.7	141.7	93.7	20.5	82
24	143.1	95.6	76.2	138.7	186.5	57.9	49.1	123.9
25	154.2	106.7	83.9	145.9	181.8	66.9	24.8	103.5
26	142.4	94.9	72.1	134.1	176.3	55.2	37	116.5
27	129.8	82.3	59.5	121.5	164.4	42.5	48.7	128.2
28	134.7	87.2	64.4	126.4	169.2	47.4	43.9	123.2
29	123	75.5	52.7	114.7	157.3	35.7	58.7	137.8
30	111.1	63.6	39.7	99.8	144.5	24	68.9	148.2
31	111.9	64.4	37.4	96	140.8	24.5	47.8	153.2
32	116.5	69	39.1	85.7	129.5	29.1	81.2	161.5
33	124.1	76.6	46.7	78.3	123.3	36.7	88	169.1
34	113	65.5	31.9	96.5	141.7	31.5	92.6	170
35	114.9	67.4	5.8	119.2	163.2	39.7	102.5	180.2
36	105.8	58.3	27.4	124	162.5	35.2	99.6	177.6
37	63.6	16.1	50.2	135.6	179.4	46.8	111	188.8
38	77.3	29.8	56.8	138.4	181.4	49.6	108.2	123.2
39	96.2	48.7	73.2	144.4	188.3	55.6	106.6	185.6
40	36.5	39.2	96.5	178.6	222	89.8	154	232.6
41	18.1	34.6	98	179.3	226.4	94.5	155	234.9
42	170.2	122.9	100.6	29.2	73.8	83.4	138.3	135.9
43	97.7	50.4	28.1	102.7	146.3	10.9	75.6	153.6
44	234.1	187	163.6	90.1	44.4	146.4	144.7	85.4
45	76.9	30	52.8	134	179.6	33.1	98.1	175.8
46	23.3	27.3	92.5	172.7	217.9	71.9	151.8	229.7
47	56.6	9.7	59.2	139.4	184.6	38.6	118.5	196.4
48	140.1	93.2	66.8	131.6	176.8	46.2	35	112.6
49	183	136.1	109.7	174.5	149.8	89.1	21.3	69.7
50	211.3	164.4	138	203.4	154	117.5	49.3	41.3
51	231.9	185	157.2	150	101	136.6	68.4	59.9
52	233.6	186.3	154.2	89.8	40.4	146.1	129.6	70.1
53	285.6	238.3	102.2	141.8	92.4	178.8	110.7	17.9

Problem data

- Occupants, Access area, density

Facility	p_i(people)	A_i(m^2)	ρ_i(people/m^2)
1	410	1333	0.308
2	100	387	0.258
3	191	273	0.700
4	125	198	0.631
5	147	238	0.618
6	207	279	0.742
7	185	272	0.680
8	186	268	0.694
9	109	154	0.708
10	115	174	0.661
11	15	288	0.052
12	2	9	0.222
13	2	10	0.200
14	2	10	0.200
15	35	103	0.340
16	15	81	0.185
17	13	32	0.406
18	40	65	0.615
19	25	84	0.298
20	27	161	0.168
21	10	62	0.161
22	25	126	0.198
23	120	191	0.628
24	1500	3897	0.385
25	7	26	0.269
26	12	44	0.273
27	7	26	0.269
28	7	26	0.269
29	10	70	0.143
30	2	4	0.500
31	2	26	0.077
32	3	5	0.600
33	2	9	0.222
34	60	244	0.246
35	3	3	1.000
36	250	328	0.762
37	60	285	0.211
38	6	54	0.111
39	15	288	0.052
40	200	732	0.273
41	35	110	0.318
42	2000	4416	0.453
43	120	575	0.209
44	950	283	3.357
45	40	329	0.122
46	20	160	0.125
47	15	100	0.150
48	45	276	0.163
49	50	230	0.217
50	45	153	0.294
51	30	157	0.191
52	80	331	0.242
53	30	187	0.160
Total	7712	18172	0.424

Problem data

- Width and access area of exits

	$w_j(m)$	$a_j(m^2)$
Exit 1	1.8	160
Exit 2	3	100
Exit 3	3	276
Exit 4	3	230
Exit 5	3	153
Exit 6	1.2	157
Exit 7	0.75	331
Exit 8	4.5	187