APPENDIX I

Table I.1: Distance calculated for 179 nodes of Mukim Telok Panglima Garang

						179 nodes	
Node	SD	SL	KM	KB	TPG	own service boundary (Demand)	min distance (km)
1	2.14	4.00	6.93	10.43	8.86	130	2.14
2	1.21	3.71	6.64	9.86	8.14	130	1.21
3	0.29	3.64	6.43	9.50	7.43	130	0.29
4	0.64	3.79	6.43	9.07	6.79	130	0.64
5	1.57	4.21	6.43	8.79	6.29	130	1.57
6	2.50	4.71	6.64	8.57	5.86	0	2.50
7	3.43	5.36	7.00	8.57	5.57	0	3.43
8	4.36	6.00	7.36	8.57	5.43	0	4.36
9	5.21	6.79	7.79	8.57	5.36	0	5.21
10	2.29	3.21	6.14	9.71	8.36	130	2.29
11	1.50	2.86	5.86	9.07	7.57	130	1.50
12	0.93	2.79	5.57	8.71	6.86	130	0.93
13	1.00	3.00	5.50	8.29	6.21	130	1.00
14	1.79	3.50	5.64	8.00	5.64	130	1.79
15	2.64	4.07	5.86	7.71	5.07	0	2.64
16	3.57	4.86	6.14	7.57	4.64	0	3.57
17	4.43	5.57	6.50	7.64	4.50	0	4.43
18	5.36	6.36	7.14	7.79	4.43	0	4.43
19	2.86	2.50	5.36	9.00	7.93	192	2.50
20	2.14	2.00	4.86	8.36	7.07	192	2.00
21	1.86	1.86	3.21	7.86	6.36	192	1.86
22	1.93	2.14	4.57	7.43	5.50	192	1.93
23	2.36	2.71	4.57	7.00	4.86	130	2.36
24	3.07	3.43	4.93	6.79	4.21	0	3.07
25	3.79	4.29	5.29	6.64	3.79	0	3.79
26	4.71	5.14	5.86	6.71	3.50	0	3.50
27	5.50	6.00	6.50	6.93	3.57	0	3.57
28	3.43	1.93	4.64	8.36	7.57	192	1.93
29	3.00	1.14	4.07	7.64	6.71	192	1.14
30	2.79	0.86	3.79	7.07	5.86	194	0.86
31	2.86	1.50	3.64	6.57	5.00	192	1.50
32	3.07	2.21	3.71	6.21	4.29	249	2.21
33	3.71	3.14	4.07	5.93	3.50	0	3.14
34	4.29	4.00	4.57	5.79	3.00	0	3.00
35	5.21	4.93	5.14	5.71	2.64	0	2.64
36	5.86	5.86	5.71	5.86	2.64	0	2.64
37	4.29	1.71	4.00	7.71	7.36	192	1.71
38	3.86	0.71	3.29	6.93	6.29	192	0.71
39	3.57	0.14	2.93	6.36	5.57	192	0.14
40	3.71	1.14	2.71	5.79	4.57	194	1.14
41	3.93	2.00	2.86	5.36	3.79	249	2.00
42	4.36	2.93	3.21	5.00	2.93	249	2.93
43	4.86	3.86	3.86	4.86	2.29	373	2.29

						179 nodes	
Node	SD	SL	KM	KB	TPG	own service boundary(Demand)	min distance (km)
44	5.64	4.86	4.57	4.86	1.71	373	1.71
45	6.29	5.64	5.36	5.14	1.79	373	1.79
46	5.00	2.00	3.43	7.07	7.14	192	2.00
47	4.71	1.21	2.57	6.36	6.14	192	1.21
48	4.50	1.00	2.00	5.71	5.36	194	1.00
49	4.57	1.50	1.79	5.00	4.29	194	1.50
50	5.64	2.21	2.00	4.57	3.50	249	2.00
51	5.14	3.14	2.50	4.14	2.57	249	2.50
52	5.57	3.93	3.29	4.00	1.71	373	1.71
53	6.57	4.93	4.14	4.00	0.86	375	0.86
54	6.86	5.79	4.93	4.29	0.86	375	0.86
55	5.86	2.57	3.00	6.71	7.14	192	2.57
56	5.57	2.07	2.07	5.86	6.07	192	2.07
57	5.43	1.86	1.36	5.21	5.29	192	1.36
58	5.57	2.21	0.86	4.29	4.29	249	0.86
59	5.57	2.64	1.21	3.79	3.50	249	1.21
60	6.00	3.50	2.00	3.07	2.50	249	2.00
61	6.29	4.21	2.71	3.07	1.64	373	1.64
62	7.00	5.14	3.79	3.07	0.57	375	0.57
63	7.50	5.93	4.64	3.29	0.29	375	0.29
64	6.71	3.29	2.86	6.36	7.21	189	2.86
65	6.50	2.93	1.86	5.43	6.21	254	1.86
66	6.43	2.79	1.00	4.71	5.43	255	1.00
67	6.29	3.07	0.07	3.71	4.43	249	0.07
68	6.43	3.29	0.71	3.14	3.71	249	0.71
69	6.86	4.14	1.79	2.43	2.71	373	1.79
70	7.14	10.43	2.64	2.14	1.93	375	1.93
71	7.71	5.57	3.71	2.14	1.29	373	1.29
72	8.21	6.36	4.50	2.50	1.14	373	1.14
73	7.57	4.14	3.07	6.14	7.43	0	3.07
74	7.43	3.79	2.07	5.14	6.00	0	2.07
75	7.57	3.79	1.43	4.29	5.71	0	1.43
76	7.36	3.93	1.00	3.36	4.79	0	1.00
77	7.57	4.29	1.36	2.57	4.14	189	1.36
78	7.71	4.79	2.14	1.71	3.21	189	1.71
79	8.00	5.29	2.86	1.21	2.64	189	1.21
80	8.57	6.14	3.86	1.29	2.14	189	1.29
81	8.93	6.86	4.64	1.79	2.14	373	1.79
82	8.57	4.93	3.43	6.00	7.79	0	3.43
83	8.29	4.71	2.64	5.00	6.86	0	2.64
84	8.21	4.71	2.21	4.14	6.07	0	2.21
85	8.21	4.79	1.93	3.14	5.29	189	1.93
86	8.43	5.14	2.14	2.43	4.71	189	2.14
87	8.57	5.57	2.71	1.29	3.93	189	1.29
88	9.00	6.07	3.36	0.50	3.36	189	0.50
89	9.29	6.86	4.29	0.64	3.07	189	0.64
90	9.86	7.36	5.00	1.36	3.07	189	1.36
91	9.57	5.79	4.00	6.07	8.14	0	4.00
92	9.29	5.57	3.36	5.00	7.21	0	3.36

						179 nodes	
Node	SD	SL	KM	KB	TPG	own service boundary(Demand)	min distance (km)
93	9.14	5.57	3.00	4.29	6.57	0	3.00
94	9.29	5.86	2.93	3.29	5.86	189	2.93
95	9.21	5.86	2.93	2.43	5.21	189	2.43
96	9.64	6.36	3.50	1.43	4.71	194	1.43
97	9.64	6.71	3.86	0.86	4.21	195	0.86
98	10.21	7.43	4.71	1.00	4.00	189	1.00
99	10.43	7.86	5.21	1.43	3.86	189	1.43
100	1.71	3.36	6.36	9.79	8.21	130	1.71
101	0.86	3.21	6.00	9.29	7.50	135	0.86
102	0.43	3.21	6.00	8.86	6.86	134	0.43
103	1.14	3.50	5.93	8.50	6.14	134	1.14
104	2.07	4.00	6.07	8.29	5.57	134	2.07
105	3.00	4.64	6.29	8.07	5.21	0	3.00
106	3.86	5.29	6.71	8.07	4.93	0	3.86
107	4.86	6.00	7.21	8.14	4.79	0	4.79
108	2.14	2.43	5.57	9.00	7.64	192	2.14
109	1.57	2.29	5.21	8.43	6.93	192	1.57
110	1.36	2.36	5.07	8.00	6.14	130	1.36
111	1.71	2.79	5.07	7.57	5.57	130	1.71
112	2.36	3.43	5.29	7.43	4.93	130	2.36
113	3.14	4.14	5.57	7.14	4.50	0	3.14
114	4.00	4.86	6.00	7.14	4.14	0	4.00
115	2.79	5.71	6.57	7.29	4.00	0	2.79
116	2.86	1.79	4.64	8.14	7.21	195	1.79
117	2.43	1.36	4.29	7.71	6.43	194	1.36
118	2.29	1.50	4.14	7.14	5.57	192	1.50
119	2.50	2.07	4.14	6.71	4.86	130	2.07
120	3.00	2.86	4.36	6.50	4.21	249	2.86
121	3.71	3.71	4.71	6.29	3.64	0	3.64
122	4.50	4.57	5.21	6.21	3.21	0	3.21
123	5.29	5.43	5.79	6.29	3.00	0	3.00
124	3.64	1.21	3.86	7.57	6.93	192	1.21
125	3.29	0.50	3.43	7.07	6.00	192	0.50
126	3.21	0.79	3.21	6.43	5.21	192	0.79
127	3.36	1.64	3.21	5.93	4.36	249	1.64
128	3.71	2.57	3.50	5.64	3.57	249	2.57
129	4.29	3.43	3.93	5.43	2.93	0	2.93
130	4.93	4.36	4.50	5.36	2.36	0	2.36
131	5.71	5.29	5.21	5.36	2.14	0	2.14
132	4.50	1.29	3.21	7.00	6.71	192	1.29
133	4.21	0.57	2.57	6.21	5.71	192	0.57
134	4.14	0.93	2.29	5.64	4.86	192	0.93
135	4.29	1.71	2.29	5.00	3.93	249	1.71
136	4.64	2.57	2.64	4.64	3.14	249	2.57
137	5.07	3.50	3.21	4.43	2.29	373	2.29
138	5.57	4.43	3.93	4.29	1.50	373	1.50
139	6.29	5.43	4.71	4.43	1.14	373	1.14
140	5.21	1.79	2.64	6.43	6.57	192	1.79
141	5.00	1.43	1.93	5.71	5.57	192	1.43

						179 nodes	
Node	SD	SL	KM	KB	TPG	own service boundary(Demand)	min distance (km)
142	5.00	1.57	1.43	5.00	4.71	249	1.43
143	5.07	2.14	1.43	4.36	3.79	249	1.43
144	5.29	2.93	2.00	3.86	2.86	249	2.00
145	5.79	3.71	2.71	3.57	1.86	373	1.86
146	6.29	4.64	3.50	3.50	1.00	373	1.00
147	7.00	5.50	4.36	3.64	0.21	375	0.21
148	6.14	2.64	2.29	6.07	6.64	249	2.29
149	6.00	2.43	1.43	5.14	5.71	249	1.43
150	6.00	2.50	0.57	4.43	4.86	249	0.57
151	6.07	2.86	0.57	3.71	3.93	249	0.57
152	6.29	3.50	1.43	3.00	2.93	249	1.43
153	6.71	4.21	2.36	2.64	2.07	373	2.07
154	7.14	5.00	3.29	2.50	1.29	375	1.29
155	7.64	5.86	4.14	2.64	0.71	373	0.71
156	7.00	3.57	2.43	5.71	6.79	0	2.43
157	7.00	3.43	1.50	4.86	5.93	0	1.50
158	6.93	3.43	0.79	3.93	5.07	0	0.79
159	7.07	3.71	0.71	3.14	4.21	249	0.71
160	7.29	4.21	1.43	2.36	3.36	373	1.43
161	7.57	4.79	2.29	1.79	2.64	373	1.79
162	8.00	5.50	3.21	1.50	2.00	373	1.50
163	8.43	6.21	4.14	1.79	1.71	373	1.71
164	8.00	4.43	2.79	5.50	7.07	0	2.79
165	7.71	4.29	2.07	4.64	6.21	0	2.07
166	7.86	4.36	1.57	3.71	5.43	0	1.57
167	7.86	4.50	1.57	2.79	4.57	189	1.57
168	8.14	4.93	2.00	1.86	3.93	189	1.86
169	8.29	5.43	2.71	1.07	3.29	189	1.07
170	8.64	6.07	3.50	0.64	2.79	189	0.64
171	9.14	6.79	4.36	1.14	2.57	189	1.14
172	8.86	5.29	3.36	5.50	7.50	0	3.36
173	8.71	5.21	2.79	4.57	6.64	0	2.79
174	8.71	5.29	2.50	3.71	5.93	0	2.50
175	8.86	5.43	2.50	2.71	5.21	189	2.50
176	9.00	5.71	2.86	1.86	4.57	189	1.86
177	9.29	6.14	3.36	0.93	4.07	189	0.93
178	9.64	6.71	4.00	0.29	3.71	189	0.29
179	10.07	7.43	4.71	1.00	3.57	189	1.00
TOTAL						**30458**	

APPENDIX II

List of ILOG CPLEX code for the models used in the thesis

II.1 ILOG CPLEX 10.2 Code for MCLP (Chapter 4)

Model

```
//Data
int P =...;
int S =...;
{string} Demand =...;
{string} FacilitySite =...;
int Population [Demand] =...;
int Capacity [FacilitySite] =...;
float Distance [Demand][FacilitySite] =...;

//Variables
dvar boolean Coverage[Demand][FacilitySite];
dvar boolean SelectFacility[Demand][FacilitySite];
dvar boolean OpenFacility[FacilitySite];

//Objective Function

maximize
  sum (i in Demand, j in FacilitySite)
  Coverage[i][j]*Population[i]*SelectFacility[i][j];

//Constraints
subject to {

  ctOpen:
  sum (j in FacilitySite)
  OpenFacility[j] <=P;

  forall (i in Demand)
  ctSelect:
  sum (j in FacilitySite)
  SelectFacility[i][j]==1;

  forall (i in Demand, j in FacilitySite)
  ctUseOpenFacility:
  SelectFacility[i][j]<=OpenFacility[j];

  forall (i in Demand, j in FacilitySite)
  if (Distance[i][j]<=S)
  Coverage[i][j]==1;
```

```
  else
  Coverage[i][j]==0;

}
```

Data File

```
S=5;

P=3;
Demand={"1", "2", "3", "4", "5","6","7","8","9","10","11","12",
        "13","14","15","16","17","18","19","20","21","22","23","24",
        "25","26","27","28","29","30","31","32","33","34","35","36",
        "37","38","39","40","41","42","43","44","45","46","47","48",
        "49","50","51","52","53","54","55","56","57","58","59","60",
        "61","62","63","64","65","66","67","68","69","70","71","72",
        "73","74","75","76","77","78","79","80","81","82","83","84",
        "85","86","87","88","89","90","91","92","93","94","95","96",
        "97","98","99","100","101","102","103","104","105","106","107","108",

"109","110","111","112","113","114","115","116","117","118","119","120",

"121","122","123","124","125","126","127","128","129","130","131","132",

"133","134","135","136","137","138","139","140","141","142","143","144",

"145","146","147","148","149","150","151","152","153","154","155","156",

"157","158","159","160","161","162","163","164","165","166","167","168",
        "169","170","171","172","173","174","175","176","177","178","179"};

FacilitySite={"SD","SL","KM","KB","TPG"};
Population=[130,130,130,130,130,0,0,0,0,130,130,130,130,130,0,
0,0,0,192,192,192,192,130,0,0,0,0,192,192,194,192,249,0,0,0,0,
192,192,192,194,249,249,373,373,373,192,192,194,194,249,249,
373,375,375,192,192,192,249,249,249,373,375,375,189,254,255,
249,249,373,375,373,373,0,0,0,0,189,189,189,189,373,0,0,0,189,
189,189,189,189,189,0,0,0,189,189,194,195,189,189,130,135,134,
134,134,0,0,0,192,192,130,130,130,0,0,0,195,194,192,130,249,
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192,192,249,249,249,373,373,375,249,249,249,249,249,373,375,373,
0,0,0,249,373,373,373,373,0,0,0,189,189,189,189,189,0,0,0,189,189,
189,189,189];
Capacity = [8000, 4000, 14000, 4000, 20000];
Distance=
[[2.14, 4.00, 6.93,10.43, 8.86],
[1.21 ,  3.71 ,  6.64  , 9.86  , 8.14],
[0.29  , 3.64 ,  6.43  , 9.50  , 7.43],
[0.64  , 3.79 ,  6.43 ,  9.07 ,  6.79],
[1.57 ,  4.21 ,  6.43,   8.79  , 6.29],
[2.50 ,  4.71 ,  6.64 ,  8.57 ,  5.86],
```

[3.43, 5.36 , 7.00 , 8.57 , 5.57],
[4.36 , 6.00 , 7.36 , 8.57 , 5.43],
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[1.00 , 3.00 , 5.50, 8.29, 6.21],
[1.79 , 3.50 , 5.64 , 8.00 , 5.64],
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[2.14 , 2.00 , 4.86 , 8.36 , 7.07],
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[3.00 , 1.14 , 4.07 , 7.64 , 6.71],
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[2.86 , 1.50, 3.64 , 6.57 , 5.00],
[3.07 , 2.21 , 3.71 , 6.21 , 4.29],
[3.71 , 3.14 , 4.07 , 5.93 , 3.50],
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[5.21 , 4.93, 5.14 , 5.71 , 2.64],
[5.86 , 5.86 , 5.71 , 5.86 , 2.64],
[4.29, 1.71 , 4.00 , 7.71 , 7.36],
[3.86 , 0.71 , 3.29, 6.93 , 6.29],
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[3.71 , 1.14 , 2.71 , 5.79, 4.57],
[3.93, 2.00 , 2.86 , 5.36, 3.79],
[4.36 , 2.93 , 3.21 , 5.00 , 2.93],
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[6.29 , 5.64 , 5.36 , 5.14, 1.79],
[5.00 , 2.00 , 3.43 , 7.07, 7.14],
[4.71 , 1.21 , 2.57 , 6.36 , 6.14],
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[5.86 , 2.57, 3.00 , 6.71, 7.14],
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[6.50 , 2.93 , 1.86 , 5.43, 6.21],
[6.43 , 2.79 , 1.00 , 4.71 , 5.43],
[6.29 , 3.07 , 0.07, 3.71 , 4.43],
[6.43 , 3.29 , 0.71 , 3.14 , 3.71],
[6.86 , 4.14 , 1.79 , 2.43, 2.71],
[7.14 , 10.43 , 2.64 , 2.14, 1.93],
[7.71 , 5.57 , 3.71 , 2.14 , 1.29],
[8.21 , 6.36 , 4.50 , 2.50 , 1.14],
[7.57 , 4.14 , 3.07 , 6.14 , 7.43],
[7.43 , 3.79 , 2.07, 5.14 , 6.00],
[7.57 , 3.79, 1.43, 4.29, 5.71],
[7.36, 3.93 , 1.00 , 3.36 , 4.79],
[7.57 , 4.29 , 1.36 , 2.57, 4.14],
[7.71 , 4.79 , 2.14, 1.71 , 3.21],
[8.00 , 5.29 , 2.86 , 1.21 , 2.64],
[8.57 , 6.14 , 3.86 , 1.29 , 2.14],
[8.93, 6.86, 4.64 , 1.79 , 2.14],
[8.57 , 4.93 , 3.43, 6.00 , 7.79],
[8.29 , 4.71 , 2.64, 5.00 , 6.86],
[8.21 , 4.71 , 2.21 , 4.14 , 6.07],
[8.21 , 4.79 , 1.93 , 3.14 , 5.29],
[8.43, 5.14 , 2.14 , 2.43 ,4.71],
[8.57, 5.57 , 2.71 , 1.29, 3.93],
[9.00, 6.07 , 3.36 , 0.50, 3.36],
[9.29, 6.86 , 4.29 , 0.64, 3.07],
[9.86, 7.36 , 5.00 , 1.36, 3.07],
[9.57, 5.79 , 4.00 , 6.07, 8.14],
[9.29, 5.57 , 3.36 , 5.00 , 7.21],
[9.14, 5.57 , 3.00 , 4.29 , 6.57],
[9.29, 5.86 , 2.93 , 3.29 , 5.86],
[9.21, 5.86 , 2.93 , 2.43 , 5.21],
[9.64, 6.36 , 3.50 , 1.43 , 4.71],
[9.64, 6.71 , 3.86 , 0.86 , 4.21],
[10.21, 7.43 , 4.71 , 1.00, 4.00],
[10.43 , 7.86 , 5.21 , 1.43, 3.86],
[1.71 , 3.36 , 6.36 , 9.79 , 8.21],
[0.86 , 3.21 , 6.00 , 9.29 , 7.50],
[0.43 , 3.21 , 6.00 , 8.86 , 6.86],
[1.14 , 3.50 , 5.93 , 8.50 , 6.14],
[2.07 , 4.00 , 6.07 , 8.29 , 5.57],
[3.00 , 4.64 , 6.29 , 8.07 , 5.21],
[3.86 , 5.29 , 6.71 , 8.07 , 4.93],
[4.86 , 6.00 , 7.21 , 8.14 , 4.79],
[2.14 , 2.43 , 5.57 , 9.00 , 7.64],
[1.57 , 2.29 , 5.21 , 8.43 , 6.93],
[1.36 , 2.36 , 5.07 , 8.00 , 6.14],

[1.71 , 2.79 , 5.07 , 7.57 , 5.57],
[2.36 , 3.43 , 5.29 , 7.43 , 4.93],
[3.14 , 4.14 , 5.57 , 7.14 , 4.50],
[4.00 , 4.86 , 6.00 , 7.14 , 4.14],
[2.79 , 5.71 , 6.57 , 7.29 , 4.00],
[2.86 , 1.79 , 4.64 , 8.14 , 7.21],
[2.43 , 1.36 , 4.29 , 7.71 , 6.43],
[2.29 , 1.50 , 4.14 , 7.14 , 5.57],
[2.50 , 2.07 , 4.14 , 6.71 , 4.86],
[3.00 , 2.86 , 4.36 , 6.50 , 4.21],
[3.71 , 3.71 , 4.71 , 6.29 , 3.64],
[4.50 , 4.57 , 5.21 , 6.21 , 3.21],
[5.29 , 5.43 , 5.79 , 6.29 , 3.00],
[3.64 , 1.21 , 3.86 , 7.57 , 6.93],
[3.29 , 0.50 , 3.43 , 7.07 , 6.00],
[3.21 , 0.79 , 3.21 , 6.43 , 5.21],
[3.36 , 1.64 , 3.21 , 5.93 , 4.36],
[3.71 , 2.57 , 3.50 , 5.64 , 3.57],
[4.29 , 3.43 , 3.93 , 5.43 , 2.93],
[4.93 , 4.36 , 4.50 , 5.36 , 2.36],
[5.71 , 5.29 , 5.21 , 5.36 , 2.14],
[4.50 , 1.29 , 3.21 , 7.00 , 6.71],
[4.21 , 0.57 , 2.57 , 6.21 , 5.71],
[4.14 , 0.93 , 2.29 , 5.64 , 4.86],
[4.29 , 1.71 , 2.29 , 5.00 , 3.93],
[4.64 , 2.57 , 2.64 , 4.64 , 3.14],
[5.07 , 3.50 , 3.21 , 4.43 , 2.29],
[5.57 , 4.43 , 3.93 , 4.29 , 1.50],
[6.29 , 5.43, 4.71 , 4.43 , 1.14],
[5.21 , 1.79 , 2.64 , 6.43, 6.57],
[5.00 , 1.43 , 1.93 , 5.71, 5.57],
[5.00 , 1.57 , 1.43 , 5.00, 4.71],
[5.07 , 2.14 , 1.43 , 4.36 , 3.79],
[5.29 , 2.93 , 2.00 , 3.86 , 2.86],
[5.79 , 3.71 , 2.71 , 3.57 , 1.86],
[6.29 , 4.64 , 3.50 , 3.50 , 1.00],
[7.00 , 5.50 , 4.36 , 3.64 , 0.21],
[6.14 , 2.64 , 2.29 , 6.07 , 6.64],
[6.00 , 2.43 , 1.43 , 5.14 , 5.71],
[6.00 , 2.50 , 0.57 , 4.43 , 4.86],
[6.07 , 2.86 , 0.57 , 3.71 , 3.93],
[6.29 , 3.50 , 1.43 , 3.00 , 2.93],
[6.71 , 4.21 , 2.36 , 2.64 , 2.07],
[7.14 , 5.00 , 3.29 , 2.50 , 1.29],
[7.64 , 5.86 , 4.14 , 2.64 , 0.71],
[7.00 , 3.57 , 2.43 , 5.71 , 6.79],
[7.00 , 3.43 , 1.50 , 4.86 , 5.93],
[6.93 , 3.43 , 0.79 , 3.93 , 5.07],
[7.07 , 3.71 , 0.71 , 3.14 , 4.21],
[7.29 , 4.21 , 1.43 , 2.36 , 3.36],
[7.57 , 4.79 , 2.29 , 1.79 , 2.64],
[8.00 , 5.50 , 3.21 , 1.50 , 2.00],

```
[8.43 ,  6.21 ,  4.14 ,  1.79 ,  1.71],
[8.00 ,  4.43 ,  2.79 ,  5.50 ,  7.07],
[7.71 ,  4.29 ,  2.07 ,  4.64 ,  6.21],
[7.86 ,  4.36  , 1.57 ,  3.71 ,  5.43],
[7.86 ,  4.50 ,  1.57 ,  2.79 ,  4.57],
[8.14 ,  4.93 ,  2.00 ,  1.86 ,  3.93],
[8.29 ,  5.43 ,  2.71 ,  1.07 ,  3.29],
[8.64 ,  6.07 ,  3.50 ,  0.64 ,  2.79],
[9.14 ,  6.79 ,  4.36 ,  1.14 ,  2.57],
[8.86 ,  5.29 ,  3.36 ,  5.50 ,  7.50],
[8.71 ,  5.21 ,  2.79 ,  4.57 ,  6.64],
[8.71 ,  5.29 ,  2.50 ,  3.71 ,  5.93],
[8.86 ,  5.43 ,  2.50 ,  2.71 ,  5.21],
[9.00 , 5.71  , 2.86  , 1.86  , 4.57],
[9.29 ,  6.14 ,  3.36 ,  0.93 ,  4.07],
[9.64 ,  6.71 ,  4.00 ,  0.29 ,  3.71],
[10.07,   7.43,   4.71,   1.00,   3.57]];
```

II.2 ILOG CPLEX 10.2 Code for *p*-median (Chapter 4)

Model

```
//Data
int P = ...;
{string} Customers = ...;
{string} Warehouses = ...;
int Demand[Customers] = ...;
float Distance[Customers][Warehouses] = ...;

//Variables
dvar boolean OpenWarehouse[Warehouses];
dvar boolean ShipToCustomer[Customers][Warehouses];

//Objective
minimize
  sum( c in Customers , w in Warehouses )
    Demand[c]*Distance[c][w]*ShipToCustomer[c][w];

//Constraints
subject to {
  forall( c in Customers )
    ctShip:
      sum( w in Warehouses )
        ShipToCustomer[c][w] == 1;

  ctOpen:
    sum( w in Warehouses )
      OpenWarehouse[w] == P;

  forall( c in Customers , w in Warehouses )
    ctShipOpen:
```

```
    ShipToCustomer[c][w] <= OpenWarehouse[w];
}
```

Same data file as MCLP is used

II.3 ILOG CPLEX 10.2 Code for CMCLP (Chapter 5)

The code is the same as for MCLP but with additional variable Capacity.

```
int Capacity [FacilitySite] =...;

  forall (j in FacilitySite)
  ctMaxUseofCapacity:
  sum (i in Demand)
  Population[i]*SelectFacility[i][j]<= OpenFacility[j] *Capacity[j];
```

Same data file being used except for additional information of capacity volume for each facility.

```
Capacity = [4000, 4000, 4000, 4000, 20000];
```

II.4 ILOG CPLEX 10.2 Code for CPMP (Chapter 6)

```
  forall (j in FacilitySite)
  ctMaxUseofCapacity:
  sum (i in Demand)
  Population[i]*SelectFacility[i][j]<=Capacity[j]*OpenFacility[j];
```

APPENDIX III

List of Communications with Malaysian Ministry of Health (MOH) Personnel

III.1 Interview 1:

Dr Othman Warijo
Ketua Penolong Pengarah,
Bahagian Pembangunan kesihatan Keluarga
Kementerian Kesihatan Malaysia
Aras 7, Blok E10, Parcel E Putrajaya,
Tel 03-88834088, fax=03-88886150

Date: 23 May 2008

Figure III.1: Dr Othman Warijo

Thank you very much for agreeing to see me on Friday, 23 may. Below is the list of questions that I would like to ask:

Q1. Health Policy of Government. What is the target for Coverage Percentage? 100%? How about the Maximum Distance Traveled?

A1. The target is Health for All or full coverage where you can find in the National Health Plan and the Annual MOH Report

Q2. What are the Factors that affect the location decision?

A2. Based on proposal that looks at availability of land and total volume of visits

Q3. Is there any specific distance between unit (KDs , KKs and Hospitals)?

A3. It depends on the density of population; however, nominally it should be around 7 km each.

Q4. How do you calculate the population density by unit? KDs, KKs and Hospitals? I understand that there are different types of KDs) ? Is the population density also different according to types?

A4. Yes, every type of clinics has its level within. For example: for the KD the minimum level is 1500 and the second level is 4000 population. For KK, the minimum level is 15000 and the maximum is 20000, however, the plan is to upgrade the level to be able to serve up till 40000 populations for KK which is located is high density area.

Q5. What are the criteria for determining the service boundary per KDs, KKs or Hospitals?

A5. It depends on the address of the visitors and also types of health service required.

Q6. Is the capacity of each clinic based on types?

A6. Yes, nominally, KD or RC should serve between 1500 to 4000 population and KK or HC serves between 15000 to 20000 populations.

Q7. How others services and facilities affect the location decision?

A7. Different types of facilities serve different group of visitors or different types of health services. For example, KD or RC only serves mothers and children and if there is a need for further check-ups, they will be referred to nearby KK or HC. Similarly, those who cannot get required services from HC can be referred to nearby KK with doctors. As KD is only attended by JM (Jururawat Masyarakat or Community Nurse), doctors will only visit HC.

Q8. How about Private Clinics? Is there any criteria for approval, like distance from the public facility?

A8. Distance is not part of the criteria.

Q9. How about expansion plans? Say for potential new sites for clinics (KDs, KKs or Hospitals). What are the criteria for new sites?

A9. The plan is based on the volume of visits at each clinic, land availability and clinic congestion.

Q10. Thanks again for your attention and hope we will have a fruitful meeting. Wasalam.

III.2 Interview 2:

Jururawat Masyarakat (JM)
Klinik Desa Sijangkang (KD S)

Date : 15 October 2007

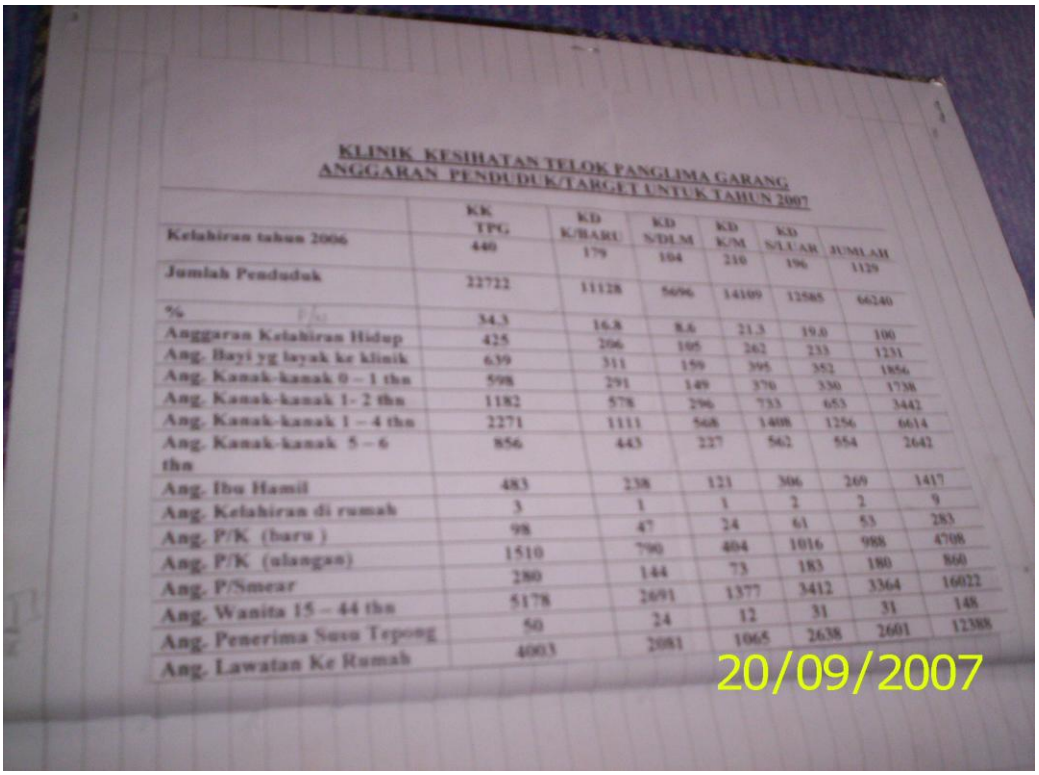
Thank you very much for agreeing to have this interview

Q1. What is the capacity of this clinic?
A1. The capacity of the clinics in based on the design of the building, which is whether the building can accommodate how many patients at one time.

Q2. What is the building design has to do with capacity of the clinic?
A2. This is because the operations of the clinics are based on daily schedule. Each day within the week, the clinics will serve different types of patients, say on Monday we will only serve kids below 6 years old. Tuesday will be for pregnant mothers, Wednesday is for family planning and so on.

Q3. What about this clinic? What is the capacity?
A3. The capacity of this clinic is 4000 population because it is in the old building (RBK). We only have one room for check-up. However, we are operating above the capacity as per the forecast volume given by the Staff in Charge in KK Telok Panglima Garang. You can see from the forecast the pattern of the volume is following the size of the building.

Q4. What about the service boundary? Who can come to this clinic and who should go to KD Sijangkang Dalam?
A4. That depends on the address of the patients and the distance from the clinics. Each clinic is roughly 7 km apart from each other. Hence, the patient should ravel less than 7 km to the nearby clinics.

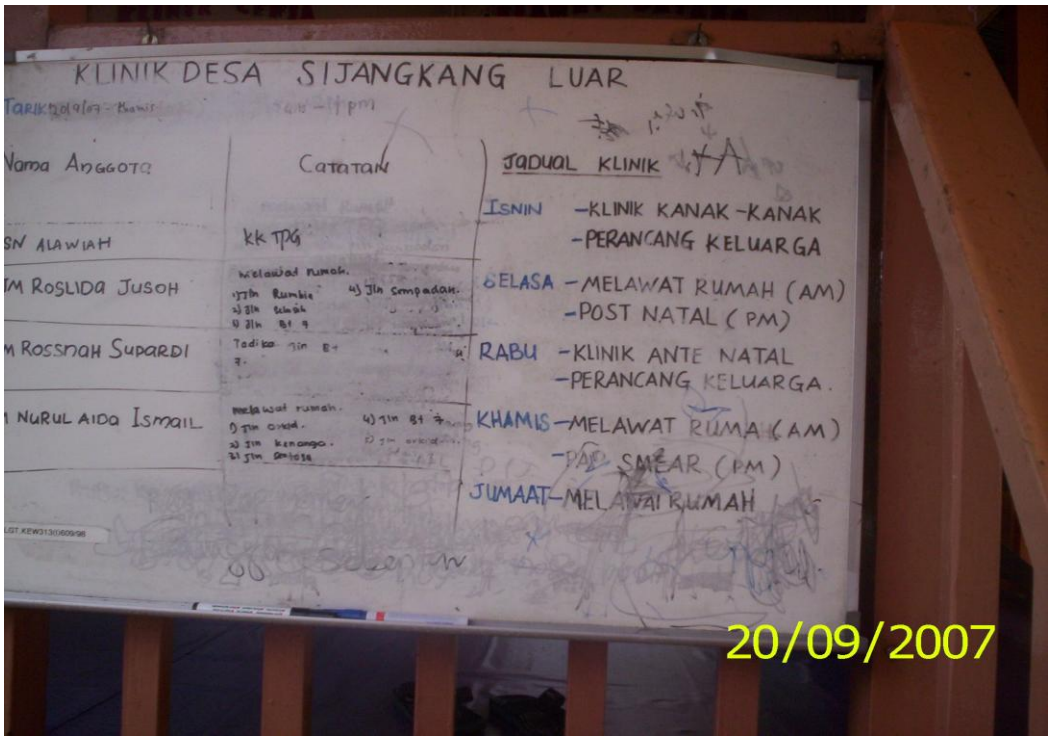


KLINIK KESIHATAN TELOK PANGLIMA GARANG
ANGGARAN PENDUDUK/TARGET UNTUK TAHUN 2007

	KK TPG	KD K/BARU	KD S/DLM	KD K/M	KD S/LUAR	JUMLAH
Kelahiran tahun 2006	440	179	104	210	196	1129
Jumlah Penduduk	22722	11128	5696	14109	12585	66240
%	34.3	16.8	8.6	21.3	19.0	100
Anggaran Kelahiran Hidup	425	206	105	262	233	1231
Ang. Bayi yg layak ke klinik	639	311	159	395	352	1856
Ang. Kanak-kanak 0 – 1 thn	598	291	149	370	330	1738
Ang. Kanak-kanak 1- 2 thn	1182	578	296	733	653	3442
Ang. Kanak-kanak 1 – 4 thn	2271	1111	568	1408	1256	6614
Ang. Kanak-kanak 5 – 6 thn	856	443	227	562	554	2642
Ang. Ibu Hamil	483	238	121	306	269	1417
Ang. Kelahiran di rumah	3	1	1	2	2	9
Ang. P/K (baru)	98	47	24	61	53	283
Ang. P/K (ulangan)	1510	790	404	1016	988	4708
Ang. P/Smear	280	144	73	183	180	860
Ang. Wanita 15 – 44 thn	5178	2691	1377	3412	3364	16022
Ang. Penerima Suvo Tepong	50	24	12	31	31	148
Ang. Lawatan Ke Rumah	4003	2081	1065	2638	2601	12388

20/09/2007

Figure III.2: The Forecast Volume by Clinics for MTPG



KLINIK DESA SIJANGKANG LUAR

Nama Anggota

SN ALAWIAH

M ROSLIDA JUSOH

M ROSSNAH SUPARDI

NURUL AIDA ISMAIL

Catatan

kk TPG

melawat rumah.

JADUAL KLINIK

ISNIN –KLINIK KANAK-KANAK
–PERANCANG KELUARGA

SELASA –MELAWAT RUMAH (AM)
–POST NATAL (PM)

RABU –KLINIK ANTE NATAL
–PERANCANG KELUARGA.

KHAMIS –MELAWAT RUMA (AM)
–PAP SMEAR (PM)

JUMAAT–MELAWAT RUMAH

20/09/2007

Figure III.3: The Daily Schedule of KD Sijangkang Luar (SL)

III.3 Approval Letter from MOH and Selangor Health State Department

Bahagian Pembangunan Kesihatan Keluarga
Jabatan Kesihatan Awam (*Public Health Department*)
Kementerian Kesihatan Malaysia (*Ministry of Health Malaysia*)
Aras 5, Blok E6, Kompleks E
Pusat Pentadbiran Kerajaan Persekutuan
62590 Putrajaya

No. Telefon: 03-88833888
No. Faksimile: 03-88832210
Lamant: www.fh.moh.gov.my

Ruj. Tuan:
Ruj. Kami: Bil (9) dlm. KKM/62/BPKK(P)/ HR 2-6 bhg 3
Tarikh : 29 Februari 2008

S Sarifah Radiah Shariff
International Education Centre
Universiti Teknologi MARA
Kampus Seksyen 17
40200 Shah Alam

Puan

PERMOHONAN UNTUK MENDAPAT KEBENARAN MELIHAT DAN MENGUMPUL MAKLUMAT DI PUSAT-PUSAT KESIHATAN MALAYSIA

Adalah saya dengan hormatnya merujuk kepada perkara di atas, surat puan bertarikh 7 November 2007 mengenai perkara yang sama adalah berkenaan.

Sukacita dimaklumkan bahawa Bahagian ini tiada halangan dengan cadangan puan untuk melihat dan mengumpul maklumat di klinik-klinik kesihatan bagi kajian ilmiah kedoktoran falsafah puan yang bertajuk 'Location Allocation Modelling of Public Health Facilities' dengan beberapa syarat berikut:

a) Puan perlulah berbincang dan mendapat persetujuan pihak Pengarah Kesihatan Negeri yang berkenaan sebelum melawat dan mengumpul data/maklumat dari klinik kesihatan atau klinik desa yang akan terlibat dalam kajian.

b) Bagi melindungi kepentingan pesakit/pelanggan, maklumat yang dibenarkan 'dilihat dan dikumpul' adalah maklumat yang dipaparkan untuk orang awam.

c) Hasil kajian hendaklah dimaklumkan kepada pihak Kementerian Kesihatan.

d) Sebarang penerbitan, pembentangan atau pendedahan awam atau melalui media massa yang melibatkan maklumat atau data dari kemudahan kesihatan Kementerian Kesihatan hendaklah terlebih dahulu mendapat kebenaran pihak Kementerian.

(Sila catatkan rujukan surat ini apabila menjawab)

Puan juga digalakkan mendapatkan maklumat mengenai perkhidmatan Kementerian Kesihatan melalui semakan laporan-laporan rasmi dan laman maya Kementerian ini.

Sekian, terima kasih.

BERKHIDMAT UNTUK NEGARA

Saya yang menurut perintah,

DR HJH SAFURAH JAAFAR
Pengarah Pembangunan Kesihatan Keluarga
KEMENTERIAN KESIHATAN MALAYSIA

s.k.

Timbalan Ketua Pengarah Kesihatan (KA)	- Untuk Makluman YBhg Dato'
Pengarah Perancangan dan Pembangunan (u.p. Timbalan Pengarah, Pusat Informatik Kesihatan)	- Memo Puan bil (30) dlm KKM(SMD) 9/6 Jld IV bertarikh 17 Januari 2008 adalah berkenaan

OHA/Kualiti:Kajian/ Surat Kajian Sh Radiah.doc/080227

(Sila catatkan rujukan surat ini apabila menjawab)

JABATAN KESIHATAN NEGERI SELANGOR
TINGKAT 9, 10, & 11, WISMA SUNWAYMAS,
LOT 1, JALAN PERSIARAN KAYANGAN,
40100 SHAH ALAM,
SELANGOR DARUL EHSAN
TEL: 03 - 51237333, 51237334, 51237335
FAX: 03 - 51237202 (Pengarah), 51237209 (Pengurusan)
03 - 51237299 (Perubatan), 51237389 (Pergigian), 51237399 (Kes. Awam)

Ruj Kami : bil(52) dlm JKNS/KA/Q-712/04-02
Tarikh : 3 April 2008

Puan S. Sarifah Radiah bt Shariff
INTEC, Universiti Teknologi MARA,
Kampus Seksyen 17,
40200 Shah Alam, Selangor.

Puan,

PERMOHONAN UNTUK MENDAPAT KEBENARAN MENGUMPUL MAKLUMAT DI KLINIK-KLINIK KESIHATAN SELURUH NEGERI SELANGOR

Dengan hormatnya saya merujuk kepada surat Puan **bertarikh 25 Mac 2008** mengenai perkara di atas.

2 Memandangkan puan telah menerima kelulusan dari pihak Kementerian Kesihatan Malaysia, sukacita dimaklumkan bahawa jabatan ini **tiada halangan** untuk memberikan kebenaran kepada puan untuk tujuan di atas di semua daerah di negeri Selangor.

3 Penyelidik adalah dikehendaki mematuhi syarat-syarat seperti **sebagaimana yang telah ditetapkan oleh Urusetia Penyelidikan Kementerian Kesihatan Malaysia (www.nmrr.gov.my)**. Penyelidik juga adalah dipohon supaya tidak melibatkan anggota klinik yang bertugas agar tidak menjejaskan perjalanan sessi klinik semasa kajian dijalankan.

4 Sila hubungi Pegawai Kesihatan Daerah berkenaan untuk tindakan seterusnya.

Sekian. terima kasih.

"PENYAYANG, KERJA BERPASUKAN DAN PROFESIONALISMA ADALAH BUDAYA KERJA KITA"

Saya yang menurut perintah,

DR. RAHIMAH BT MOHD ARIFIN
Timbalan Pengarah Kesihatan Negeri (Kesihatan Awam)
Jabatan Kesihatan Negeri Selangor.

S.K. Semua Pegawai Kesihatan Daerah (Petaling / Gombak / Hulu Langat / Klang / Kuala Langat / Kuala Selangor / Sabak Bernam / Sepang / Hulu Selangor).

III.4 List of Clinics Used in A Small Case Study: Telok Panglima Garang

The design and size of the building presumed its capacities as explained by the Clinics Personnel

1. Klinik Desa Sijangkang Dalam (RC SD) – presumed capacity of 8000 population

2. Klinik Desa Sijangkang Luar (RC SL) – presumed capacity of 4000 population

3. **Klinik Desa Kampung Medan –** presumed capacity of 11000 population

4. Klinik Desa Kebun Baru – presumed capacity of 400 population

5. **Klinik Kesihatan Telok Panglima Garang-**presumed capacity of 20000 population

APPENDIX IV

List of MATLAB Code for models used in the thesis

IV.1 MATLAB Code for CMCLP (Chapter 5)

IV.1.1 Sample code for Benchmark data (30, 324, 818 node network)

```
%Filename: GA_toolbox\modifiedGAfiles\main30_1.m
% to apply to 30 node network for capacitated MCLP


%To get the initial parents

tt=cputime;

MAXGEN=100;
GGAP=0.9;
Pc=0.7;
Pm=0.1;
InitPop=10;

Number_nodes=30;
OPenfac=5;

%To randomize no of facility open

tempopen=[];
for i=1:2
    tempopen=[tempopen;randint(OPenfac)];

end

c=zeros(InitPop,OPenfac);
for i=1:InitPop
c=[c;tempopen(i,:)];
end

Chrom1=[];

for j=1:InitPop
Chrom1=[Chrom1;c(j,:)];
end

%To randomize order of assignment based on number of nodes

Chrom2=[];
for i=1:InitPop
    Chrom2 = [Chrom2; randperm(Number_nodes)];
end

TempChrom=[];
for i=1:InitPop
    TempChrom=[TempChrom;[Chrom1(i,:) Chrom2(i,:)]];
end
```

```
Chrom = TempChrom;
y=length(Chrom);
ObjV=objfun30AA(Chrom);

gen=0;


%To call the genetic algorithm functions

while gen~=MAXGEN
    FitnV=ranking2(ObjV,[2,0],1);
    SelCh=SELECT('SUS', Chrom, FitnV,GGAP);

    %To call the cross over functions

    SelCh=xovmp1(SelCh, Pc, 1, 0,OPenfac);

    %To call the mutation functions

     SelCh=CombinedMut(SelCh,Pm);
       ObjV2=objfun30AA(SelCh);
      [Chrom ObjV]=REINS(Chrom,SelCh,1,1,ObjV,ObjV2);
      gen=gen+1;
    Best = min(ObjV);
    Bestgen(1,gen + 1)=Best;
end

%To record the best result

plot(1:gen+1,Bestgen)
[Bestoverall, IndOverall]=min(ObjV);
Bestoverall
BestChrom=Chrom(IndOverall,:);
BestChrom

ObjV3=calcbest_30(BestChrom);

tiMe=cputime-tt
```

Objective Function file

```
%Filename: objfun30AA.m
% to apply to 30 node network for capacitated MCLP

function ObjVal = objfun30AA(Chrom)

%Compute population parameters

[L y] = size(Chrom);

Nvar=5;
Number_nodes= y-Nvar;

Chrom_a=[];
for i=1:L
       Chrom_a =[Chrom_a;Chrom(i,1:Nvar)];
end
Chrom1=Chrom_a;
```

```
Chrom_b=[];
for j=1:L
    Chrom_b=[Chrom_b;Chrom(j,Nvar+1:y)];
end
Chrom2=Chrom_b;

ObjVal=zeros(L,1);

% To read the distance values

distance=[0.32  ,   1.12    ,   2.56    ,   0.50    ,   0.00
;
0.00    ,   0.92    ,   2.27    ,   0.50    ,   0.32    ;
0.45    ,   0.50    ,   1.86    ,   0.92    ,   0.71    ;
0.30    ,   1.22    ,   2.48    ,   0.20    ,   0.36    ;
0.42    ,   1.30    ,   2.69    ,   0.36    ,   0.20    ;
0.76    ,   1.60    ,   2.61    ,   0.36    ,   0.85    ;
0.51    ,   0.85    ,   1.84    ,   0.78    ,   0.82    ;
0.32    ,   0.67    ,   2.16    ,   0.81    ,   0.45    ;
0.50    ,   1.41    ,   2.62    ,   0.00    ,   0.50    ;
1.10    ,   2.01    ,   3.11    ,   0.60    ,   1.04    ;
0.57    ,   1.43    ,   2.83    ,   0.41    ,   0.32    ;
2.42    ,   1.56    ,   0.78    ,   2.86    ,   2.66    ;
0.54    ,   1.30    ,   2.78    ,   0.58    ,   0.22    ;
2.83    ,   1.91    ,   1.84    ,   3.32    ,   2.98    ;
0.89    ,   1.43    ,   2.10    ,   0.81    ,   1.14    ;
1.90    ,   1.04    ,   1.84    ,   2.40    ,   2.01    ;
1.80    ,   1.00    ,   0.70    ,   2.24    ,   2.06    ;
1.20    ,   1.28    ,   1.49    ,   1.34    ,   1.51    ;
1.06    ,   0.51    ,   1.22    ,   1.48    ,   1.35    ;
1.84    ,   2.71    ,   3.55    ,   1.36    ,   1.84    ;
2.00    ,   2.91    ,   3.89    ,   1.50    ,   1.92    ;
1.68    ,   0.76    ,   1.20    ,   2.16    ,   1.88    ;
1.56    ,   1.00    ,   0.71    ,   1.92    ,   1.86    ;
3.16    ,   3.62    ,   5.24    ,   3.10    ,   2.84    ;
1.49    ,   2.15    ,   2.69    ,   1.17    ,   1.64    ;
1.90    ,   1.92    ,   1.51    ,   1.96    ,   2.20    ;
2.45    ,   1.66    ,   2.38    ,   2.94    ,   2.51    ;
2.27    ,   1.62    ,   0.00    ,   2.62    ,   2.56    ;
1.17    ,   0.85    ,   1.14    ,   1.49    ,   1.48    ;
0.92    ,   0.00    ,   1.62    ,   1.41    ,   1.12    ];

% To read the demand values

demand= [710    ;620    ;560    ;390    ;350    ;210    ;
      200 ;190    ;170    ;170    ;160    ;150    ;
      140 ;120    ;120    ;110    ;100    ;100    ;
      90  ;90 ;90 ;80 ;80 ;80 ;
      80  ;70 ;60 ;60 ;60 ;60];
 capacity =[1900,1900,1900,1900,1900];

 totassign=zeros(L,1);
 totaltraveled=zeros(L,1);


for m=1: L

    TempChrom1=Chrom1(m,:);
    TempChrom2=Chrom2(m,:);

            indexP=find(TempChrom1>0);
            tempdist=[];
```

```
            assign=zeros(1,Nvar);
            tempcap=zeros(1,Nvar);
            nodes=zeros(1,Nvar);

             disttravel=zeros(1,Nvar);

          i=1 ;

        while i <= Number_nodes

         tempdist = distance(TempChrom2(i),indexP);
         [Sdist SIndex]=sort(tempdist);

         y2=length(indexP);


  %To assign only to the open available facility

              for k=1:y2
                 z=indexP(1,k);
                 tempcap(z)=tempcap(z) + demand(TempChrom2(i));
                if (Sdist(k)<=1.52)&&(tempcap(z)<=capacity(z))
                 assign(z)=tempcap(z);
                 disttravel(k)=demand(TempChrom2(i))*Sdist(k);
                 totaltraveled(m)=totaltraveled(m)+
                 disttravel(k);
                 nodes(z)=nodes(z)+1;
                 tempcap(z)=assign(z);
                 totassign(m)=sum(assign);
                break
                else tempcap(z)=tempcap(z)-demand(TempChrom2(i));
                end % End of the If then Else statement
              end %End of For k statement

           i=i+1;

         end; % end for While statement

  end  ;  % End for For m statement

ObjVal=-(totassign);
```

IV.1.2 Sample MATLAB Code for modified order based cross over for 30 node network

```
function NewChrom = orderbasedtry30(OldChrom,DoCross)

% Identify the population size (Nind) and the chromosome length
(Lind)

[Nind Lind]=size(OldChrom);

Xops = floor(Nind/2);
odd = 1:2:Nind-1;
even = 2:2:Nind;

% Compute cross sites for each pair of individuals, according to
their effective length and Px (two equal cross sites mean no
crossover)
```

```
NewChrom=[];

for i=1:Xops
if DoCross(i)==1
    p1=OldChrom(odd(i),:);
    p2=OldChrom(even(i),:);

%TO RANDOMIZE NUMBER OF POSITION TO BE CROSSED OVER, the value
is temppost

    tempx=10:15;
    temp1=randperm(6);
    temp2=temp1(1);
    temppost=tempx(temp2);

% to randomize the order of position to be crossed over

    tempposition=randperm(Lind);

    position=[];
    for j=1:temppost
      position=[position;tempposition(j)];
    end
   position1=position;

% To arrange the position in order and get the value from the
  second parent
    position2=sort(position1);
    tempval=zeros(1,temppost);

    for j=1:temppost
        tempval(j)=p2(position2(j));
    end

% To initialize the new offspring value
% To find the same value within parent 1 and set to 0

for j=1:Lind
    for k=1:temppost
        if p1(j)==tempval(k)
            p1(j)=0;
        end
    end
end


% to put in the value in order of parent 2
 for j=1:temppost

     for k=1:Lind

        if p1(k)==0
            p1(k)=tempval(j);
        break
        else
            p1(k)=p1(k);
        end

    end
```

```
 end

%=================================================================
=
% To arrange the position in order and get the value from the
  first parent

    tempval2=zeros(1,temppost);
    for j=1:temppost
        tempval2(j)=p1(position2(j));
    end

% To initialize the new offspring value
% To find the same value within parent 2 and set to 0

for j=1:Lind
    for k=1:temppost
        if p2(j)==tempval2(k)
            p2(j)=0;
        end
    end
end

% to put in the value in order of parent 1
 for j=1:temppost

     for k=1:Lind

        if p2(k)==0
            p2(k)=tempval2(j);
        break
        else
            p2(k)=p2(k);
        end

    end
 end

 % To assign the new offspring value after cross over

      NewChrom(odd(i),:)=p1;
      NewChrom(even(i),:)=p2;

 else %(if DoCross)

      NewChrom(odd(i),:)=OldChrom(odd(i),:);
      NewChrom(even(i),:)=OldChrom(even(i),:);
 end
 end
```

IV.2 MATLAB Code for CPMP (Chapter 6)

IV.2.1 Sample MATLAB Code for creating the initial population for CPMP using Set A data (100 x 10 network)

```
MAXGEN=100;
GGAP=0.9;
Pc=0.7;
Pm=0.1;
```

```
InitPop= 500;

Number_nodes=100;
OPenfac=10;



%To randomize no of facility open

Chrom1=zeros(InitPop,Number_nodes);

for i=1:InitPop
      xx=randperm(Number_nodes);
      yy=xx(1:OPenfac);
      Chrom1(i,yy)=ones(1,OPenfac);
end

%To randomize order of assignment

Chrom2=zeros(InitPop,Number_nodes);

for i=1:InitPop
    Chrom2(i,:) = randperm(Number_nodes);
end

TempChrom=zeros(InitPop,2 * Number_nodes);

TempChrom=[Chrom1 Chrom2];

Chrom = TempChrom;
```

IV.2.2 Sample MATLAB Code for the objective function for CPMP using Set A data (100 x 10 network)

```
for m=1: L

    TempChrom1=Chrom1(m,:);
    TempChrom2=Chrom2(m,:);
    indexP=find(TempChrom1>0);
if ~isempty(indexP)
    tempdist=[];
    assign=zeros(1,Nvar);
    tempcap=zeros(1,Nvar);
    nodes=zeros(1,Nvar);
    y2=length(indexP);
    disttravel=zeros(1,Nvar);

    i=1 ;
    while i <= Number_nodes

        tempdist = distance(TempChrom2(i),indexP);
        [Sdist SIndex]=sort(tempdist);
```

```
  % To determine no of facilities open
        h=1;
        while h>0
           tempvar=0;
           z=indexP(SIndex(h));
           tempvar=tempcap(z) + demand(TempChrom2(i));
           if (tempvar<=capacity(z))
            tempcap(z)=tempcap(z) +
              demand(TempChrom2(i));
            assign(z)=tempcap(z);
            disttravel(TempChrom2(i))=Sdist(h);
           totaltraveled(m)=totaltraveled(m)+
              disttravel(TempChrom2(i));
           nodes(z)=nodes(z)+1;
           tempcap(z)=assign(z);
           totassign(m)=sum(assign);
           h=0;

           break
           elseif h<y2
               h= h+1;
           else
               h=0;
               exceedcap(m)=exceedcap(m)+1;
           end % End of the If then Else statement
         end %while

         i=i+1;

     end; % end for While statement

 else
     totaltraveled(m)= 100*654000;
 end

end  ;  % End for For m statement

fclose(fid);

% To ensure that all the nodes are assigned to a facility
and the number of facilities open is not minimized

alpha=100000000000;
for i=1:L
TempObjVal(i,1)=totaltraveled(i) + alpha*exceedcap(i);

end

ObjVal=TempObjVal;
```

IV.3 MATLAB Code for a bi-objective model (Chapter 7)

IV.3.1 Sample MATLAB Code for allowing partial assignment in a 20 node network (Chapter 7)

```
% To determine no of facilities open and assign

   h=1;
     tempvar=0; tempdemand=demand(TempChrom2(i));
     while h>0
```

```
        z=indexP(SIndex(h));
            if  ((Sdist(h))<=S)
                balance(z)=capacity(z)-tempcap(z);
                if (balance(z)>0)
                   if (tempdemand < balance(z))
                      tempcap(z)=tempcap(z) + tempdemand;
                      assign(z)=tempcap(z);
                      nodes(z)=nodes(z)+1;
                      h=0;
                    else
                      tempcap(z)=tempcap(z) + balance(z);
                      assign(z)=tempcap(z);
                      tempdemand=tempdemand-balance(z);
                    end  % end of if tempdemand
                       totassign(m)=sum(assign);
                 elseif h<y2
                       h=h+1;
                 end % end of bal > 0
             else
               unassigned(i)=tempdemand;
               unas2(i)=TempChrom2(i);
               totunassign(1,:)=unassigned;
               totunassign(2,:)=unas2;
               totunassign;
               h=0;
             end % end of if < S
    end %while h>0


% to check for the available facilities
    chcbal=zeros(1,y2);
    chcbal2=zeros(1,y2);

    for i=1:y2
        chcbal2(i)=indexP(i);
        chcbal(i)=UB-tempcap(indexP(i));

    end



    indexp2=find(chcbal>0);
    avail=chcbal(indexp2);
    z1 =chcbal2(indexp2);
    availfac=avail(1,:);
    availfac(2,:)=z1;
    p=length(z1);

 % to assign the unassigned

   z2=find(unassigned>0);
   unas1=unassigned(z2);
   unas2a=unas2(z2);
   y3=length(z2);

 %sort the distance of the available facilities

  tempcap2=zeros(1,p);
  assign2=zeros(1,p);
  distravel=zeros(1,y3);
  unassigned2=zeros(1,y3);
  asdem=0;
```

```
   j=1;
   xx=availfac(1,:);
   availbal=xx;

   while j<=y3
        tempdist2 = distance(unas2a(j),z1);
        [Sdist2 SIndex2]=sort(tempdist2);
        tempdemand=unas1(j);
        h2=1;
      while h2<=p
         xy=xx(SIndex2(h2));
         yy=availbal(SIndex2(h2));
         if (yy>0)
            if (tempdemand <= availbal(SIndex2(h2)))
            tempcap2(SIndex2(h2))=tempcap2(SIndex2(h2)) +
                tempdemand;
            assign2(SIndex2(h2))=tempcap2(SIndex2(h2));
            distravel(j)=distravel(j)+
                (tempdemand*Sdist2(h2));
            availbal(SIndex2(h2))=xy-
                tempcap2(SIndex2(h2));
            h2=p+1;
            break
            else
            asdem =tempdemand-availbal(SIndex2(h2));
            tempdemand=asdem;
            tempcap2(SIndex2(h2))=
              tempcap2(SIndex2(h2))+availbal(SIndex2(h2));
            tempassign=availbal(SIndex2(h2));
            availbal(SIndex2(h2))=0;
            distravel(j)=distravel(j)+
              (tempassign*Sdist2((h2)));
            assign2(SIndex2(h2))= tempcap2(SIndex2(h2));
            end  % end of if tempdemand

            else
            unassigned2(j)=unassigned2(j)+tempdemand;
         end % end of availbal > 0

                        h2=h2+1;
      end % end of while h2

      totaltraveled(m)=totaltraveled(m)+distravel(j);
      j=j+1;
   end % end of while j

       totassign2(m)=sum(tempcap2);
end; % end of if ~is empty


% To assign weight to each of the objectives

weight=600000;
weight2=1;
F3=totassign2;
for i=1:L
    F1(i)=totassign(i);
    F2(i)=totaltraveled(i);

   object1=(weight*F1(i))-weight2*F2(i);
tempObjVal(i,1)=-(object1);
end
```

```
ObjVal=tempObjVal;
```

IV.3.2 Sample MATLAB Code for dynamic model 809 network (Chapter 7)

```
%To create the initial population

MAXGEN=100;
GGAP=0.9;
Pc=0.7;
Pm=0.1;
InitPop=100;

Number_nodes=809;
OPenfac=27;

%To ensure all existing facilities are open
Chrom1=ones(InitPop,27);

%To randomize no of facility open for the new potential
sites and for upgrade

Chrom3=crtbp(InitPop,6);

%To randomize order of assignment of number of nodes
Chrom2=zeros(InitPop, Number_nodes);
for i=1:InitPop
    Chrom2(i,:) = randperm(Number_nodes);
end

%To combine the all the portion to form a complete
chromosome

TempChrom=[Chrom1 Chrom3 Chrom2];
Chrom = TempChrom;
```

Objective function file

```
function ObjVal = objfun809weightedALLfac_2(Chrom)

%Compute population parameters from the chromosome

S=3;

[L y] = size(Chrom);

Nvar=34;
Number_nodes= y-Nvar;

Chrom_a2=[];
for i2=1:L
      Chrom_a2 =[Chrom_a2;Chrom(i2,1:27)];
end
Chrom3=Chrom_a2;

Chrom_a=[];
for i=1:L
      Chrom_a =[Chrom_a;Chrom(i,28:Nvar)];
end
 Chrom1=Chrom_a;
```

```
Chrom_b=[];
for j=1:L
    Chrom_b=[Chrom_b;Chrom(j,Nvar+1:y)];
end
Chrom2=Chrom_b;
```

APPENDIX V

Data for details analysis of parameter values for a bi-objective model (Chapter 7)

	alpha (α)	bheta (β)	% covered	Total traveled distance	Average distance (in km)
1	0.6	0.4	0.73	0	
2	0.7	0.3	0.74	0	
3	0.8	0.2	0.82	61142.4	
4	0.85	0.15	0.79	22207.1	1
5	0.87	0.13	0.79	2456.8	0
6	0.89	0.11	0.87	96105.3	7
7	0.895	0.105	0.88	183101	17
8	0.897	0.103	0.87	185366	13
9	0.899	0.101	0.88	122714.9	10
10	0.9	0.1	0.92	244006	91
11	0.95	0.05	0.91	268149	13
12	1.5	0.05	0.92	202280	11
13	2	0.05	0.91	277497	13

APPENDIX VI

List of Publications

Journals

1. S.Sarifah Radiah Shariff, Noor Hasnah Moin & Mohd Omar (2012), Location Allocation Modeling for Healthcare Facility Planning in Malaysia, In *Computers and Industrial Engineering Journal* Volume 62 Issue 4, May, 2012 Pages 1000-1010 (Indexed by ISI)

2. S.Sarifah Radiah Shariff, Noor Hasnah Moin & Mohd Omar (2011), Planning of public healthcare facilities using location allocation model: A Case Study of District of Kuala Langat, Selangor, Malaysia, *Bulletin of Academy of Physician Malaysia*, supplementary issue (Indexed by SCOPUS)

3. S.Sarifah Radiah Shariff, Mohd Omar & Noor Hasnah Moin (2010) Locational analysis of public healthcare facilities: A Case Study of Telok Panglima Garang, Malaysia, *Malaysia Journal of Science*, 29(2), pp 3 -98 (ISSN:1394-3065 (Indexed by Scopus)

4. S.Sarifah Radiah Shariff, Noor Hasnah Moin & Mohd Omar (2010) An Alternative Approach for Capacitated Maximal Covering Location Allocation problem, *Operations and Supply Chain Management: An International Journal*, pp 36-48

Proceedings

1. S.Sarifah Radiah Shariff, Noor Hasnah Moin & Mohd Omar (2010), Using location allocation model to optimize current and future healthcare facility planning, Proceedings of Applied Mathematics International Conference 2010 & the 6th EASIAM conference, 22-24 June 2010, PNB Darby Park Executive Suite, KL

2. S.Sarifah Radiah Shariff, Noor Hasnah Moin & Mohd Omar (2009) An Alternative Approach for Capacitated Maximal Covering Location Allocation problem, Proceedings of 3rd International Conference on operations and Supply Chain Management, 9-11 Dec 2009, AIMST Univ, Lembah Bujang, Kedah

3. S.Sarifah Radiah Shariff, Mohd Omar & Noor Hasnah Moin (2008) Locational analysis: Using Uncapacitated and Capacitated p-median Models: A Case study, proceedings of International Conference on Health and the Changing World 2008, 10-13 Nov 2008, Bangkok, Thailand

4. S.Sarifah Radiah Shariff, Mohd Omar & Noor Hasnah Moin (2008) Locational analysis: Using Uncapacitated and Capacitated Maximal Covering Location (MCLP) Models: A Case study, proceedings of International Conference 2008 on Mathematics and Natural Sciences, 28 -30 October, Bandung, Indonesia