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Appendix 1

Appendix 4

Cost of Construction and Design Parameters of Tower Type Structures

Double Circuit Support Type	Support Cost (LKR)	Erection Cost (LKR)	Foundation Cost (LKR)	Maximum allowable wind span (m)	Maximum allowable weight span (m)
TDL+0	437,872	73,120	310,000	360	600
TDL+3	543,949	91,515			
TDL+6	615,769	103,955			
TDM+0	449,228	11,0890	723,294	360	1200
TDM+3	796,516	136,435			
TDM+6	922,828	158,260			
TDH+0	755,191	129,530	683,852	360	1200
TDH+3	950,190	163,350			
TDH+6	1,066,411	183,500			
TDT+0	675,000	164,950	637,423	360	1200
TDT+3	1,121,760	208,465			
TDT+6	1,269,960	235,600			

MV Line Cost Optimization Macro – User Guide

1. Data arrangement

1.1. Profile Survey Data Arrangement

Survey data co-ordinate file which is provided by the surveyor after detailed survey of the line route can be used for the MV Line Cost Optimization Macro.

	A	B	D	E	F	G	H
1			Profile Surveying Data				
2	Proposed 33kV Express line route From the Gantry at Jayanthipura to the GSS at Polonnaruwa						
3	From A-7 To TT-GSS POLONNARUWA					14	
4		Northing	Easting	Elevation	Height above	Feature	
5	urvey point ID	Cordinate(Y)	Cordinate(X)	(Z)m	ground(H)/m	Description	Remarks
6	9002	610276.315	525127.24	48.58		A-7	
7	578	610275.684	525132.2	48.281		BI S	
8	579	610273.75	525131.56	48.214		CL	
9	580	610271.21	525135.83	48.279		CL	
10	581	610257.618	525158.71	48.213		SH	
11	582	610255.514	525162.25	49.123		CL	
12	583	610251.087	525169.7	48.91		CL	
13	584	610249.973	525171.58	48.149		SH	
14	585	610264.106	525175.47	49.225		RD	
15	586	610261.025	525181.25	49.28		RD	
16	587	610243.983	525147.74	49.199		RD	
17	588	610200.121	525255.49	47.918		CL	
18	589	610142.773	525353.02	47.446		CL	
19	590	610233.05	525285.24	47.101		EP HT	
20	591	610208.162	525241.98	48.21	8.5	CL-33KV	33KV LINE
21	592	610185.444	525224.98	48.637		WMF	

Figure 1: A sample survey data file provided by the surveyor

Before using, the above three dimensional survey data provided by the surveyor should be converted to two dimensional profile survey data by mapping the survey points to centerline in section wise (Z co-ordinate; the ground height co-ordinate should be remained as same), as visualized in Figure 2.

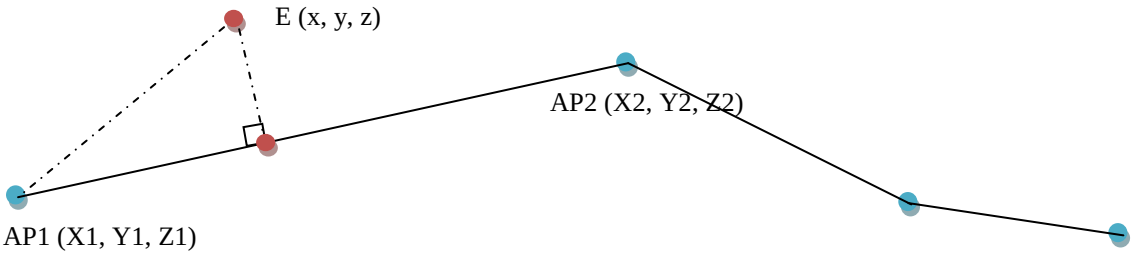
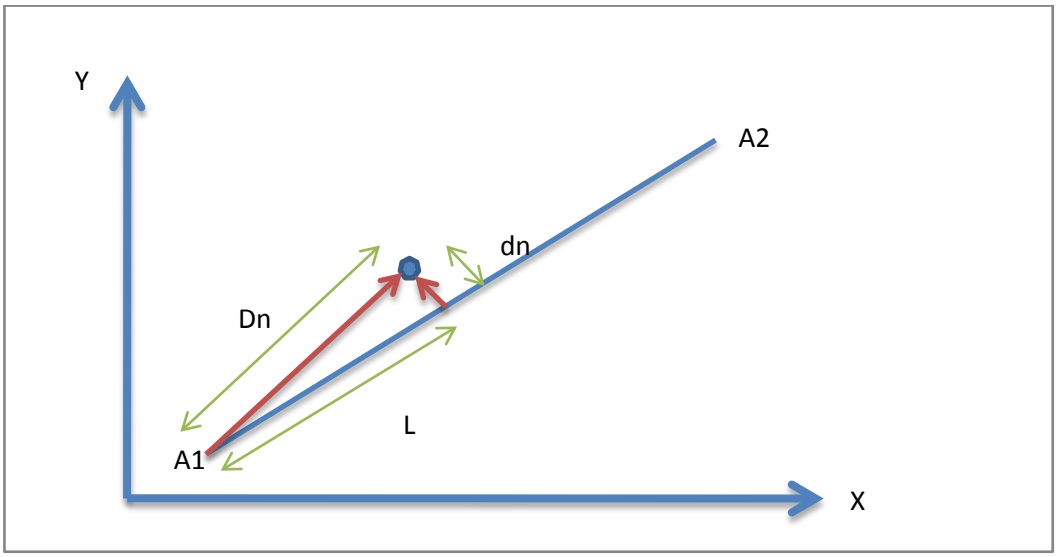


Figure 2: Data mapping to centerline

Equations shown in following excel sheet (Figure 3) can be used for survey data arrangement. Horizontal distances for each survey point from the section starting point can be read from column K of excel work sheet shown in Figure 3.



A	B	C	D	E	F	G	H	I	J	K
x	y	z	h	m= (Ya2-Ya1)/(Xa2-Xa1)	c= Ya1-mXa1	|mXn-Yn+c|	sqrt((m^2)+1)	dn= |mXn-Yn+c| /sqrt((m^2)+1)	Dn= Sqrt((Xn-Xa1)^2+(Yn-Ya1)^2)	Horizontal Distance Ln=Sqrt(Dn^2+dn^2)
609346.80	610474.92	62.869		-0.523.92917.631		0.000	1.128	0.000	0.000	0.000
609353.89	610053.17	62.703				418.039	1.128	370.445	421.805	561.381
609379.92	610055.97	62.928				401.636	1.128	355.909	420.261	550.718
609382.55	610058.36	63.201				397.861	1.128	352.564	418.086	546.898
609381.70	610056.25	62.459				400.421	1.128	354.832	420.123	549.917
609386.79	610023.14	63.19				430.867	1.128	381.811	453.544	592.859
609395.65	610026.97	63.365				422.408	1.128	374.316	450.608	585.799
609395.36	610027.23	63.629				422.295	1.128	374.216	450.311	585.506
609388.89	610033.08	66.692				419.829	1.128	372.030	443.837	579.135
609405.99	610439.73	63.417	6.7			4.235	1.128	3.753	68.856	68.958
609403.53	610439.16	63.243				6.090	1.128	5.397	67.057	67.274
609400.00	610437.63	62.869	3.7			9.469	1.128	8.391	64.966	65.506
609408.97	610437.75	62.728				4.664	1.128	4.133	72.432	72.550
609405.00	610439.59	63.717				4.895	1.128	4.338	68.084	68.222

Figure 3: Section wise data mapping to centerline

Prepare the data table shown in Table 1, using the arranged survey data. Fill “Required ground clearance” and “Required obstacle clearance” values appropriately according to the standards. The data arrangement shown in Table 1 can be directly paste to excel macro work sheet as the survey data input.

Table 1: Arranged survey data format for input to the Macro

Type of terrain - tot	Soil A - 1	Soil B - 2		Soil G - 4	
Required Ground Clearance - rgc	Normal 6.1	Roads 6.4		Railway 7.3	
Required Obstacle Clearance - roc	LT line - 3	Lt/Ht Pole - 4		132 line - 3.7	220 Line - 4.7
Index	Horizontal Dist	Ground HT	Obstacle HT from ground level	Description	Required Ground Clearance	Required Obstacle Clearance
i	d(i) m	g(i) m	o(i) m		rgc(i) m	roc(i) m
0	**0.000**	62.869		A1	6.1	
1	**561.381**	62.703		CL	6.1	
2	**550.718**	62.928		B	6.4	
3	**546.898**	63.201		CL	6.1	
4	**549.917**	62.459		SH	6.1	
5	**592.859**	63.19		B	6.4	
6	**585.799**	63.365		CP	6.1	
7	**585.506**	63.629		CL	6.1	
8	**579.135**	66.692		HR	6.1	
9	**68.958**	63.417	6.7	EP line	6.1	3
10	**67.274**	63.243		CL	6.1	
11	**65.506**	62.869	3.7	TP line	6.1	3
12	**72.550**	62.728		CL	6.1	
13	**68.222**	63.717		B	6.4	

1.2. Conductor Data Arrangement

Two parameters of the conductor is required as input to the Macro program.

1. Conductor unit weight (w) in Nm^{-1}- This parameter can be obtained from conductor data sheet.

2. Conductor horizontal tension (T_H) N of the catenary curve at maximum temperature with zero wind – This parameter should be manually calculated applying conductor state change equation shown below, while satisfying defined conductor safety factors for maximum tension and every day tension conditions.

   Conductor state change equation;

$$f_2^2\left\{f_2-\left(f_1-\frac{a^2\delta^2Q_1^2E}{24f_1^2}-\alpha tE\right)\right\}=\frac{a^2\delta^2Q_2^2E}{24}$$

Where,

A = Cross section area of the conductor

$f_1 = H_1/A$; H_1 = Horizontal tension at state 1 of the conductor

$f_2 = H_2/A$; H_2 = Horizontal tension at state 2 of the conductor

a = Span length AB

$\delta = w/A$; w = unit weight of the conductor

Q_1 = Wind factor at state 1

Q_2 = Wind factor at state 2

α = Coefficient of linear expansion of the conductor

$t = t_2 - t_1$; t_1 = Temperature at state 1, t_2 = Temperature at state 2

E = Modulus of elasticity of the conductor

1.3. Structure data arrangement

Following parameters of the structure family used for the line are required as the input to the Macro program.

1. Height in meters to bottom conductor attachment point of each structure height level for three defined height levels.
2. Tower and erecting cost for each height level of suspension type structure.
3. Tower and erecting cost for each height level of tension type structures.
4. Average foundation cost for a structure.
5. Maximum allowable wind span and weight span for the structure family.

2. Running the program

Step 1 → Open Macro

Double click on “MV Cost Optimization-Macro.xlsm”. In accordance with instructions given in information bar if required enable Macro content for the sheet.

Step 2 → Profile data input

Profile data arranged as explained in section 1.1 of the User Guide, should be copied and pasted to the given area of MV Cost Optimization-Macro.xlsm.

Step 3 → Open UserForm

Use following steps to open Macro UserForm.

View → Macros → View Macros → Macro 1 → Run

UserForm will be appeared as shown in Figure 4.

Step 4 → Conductor parameters input

Enter conductor unit weight and horizontal tension in the two text boxes shown in Area 1 of Figure 5.

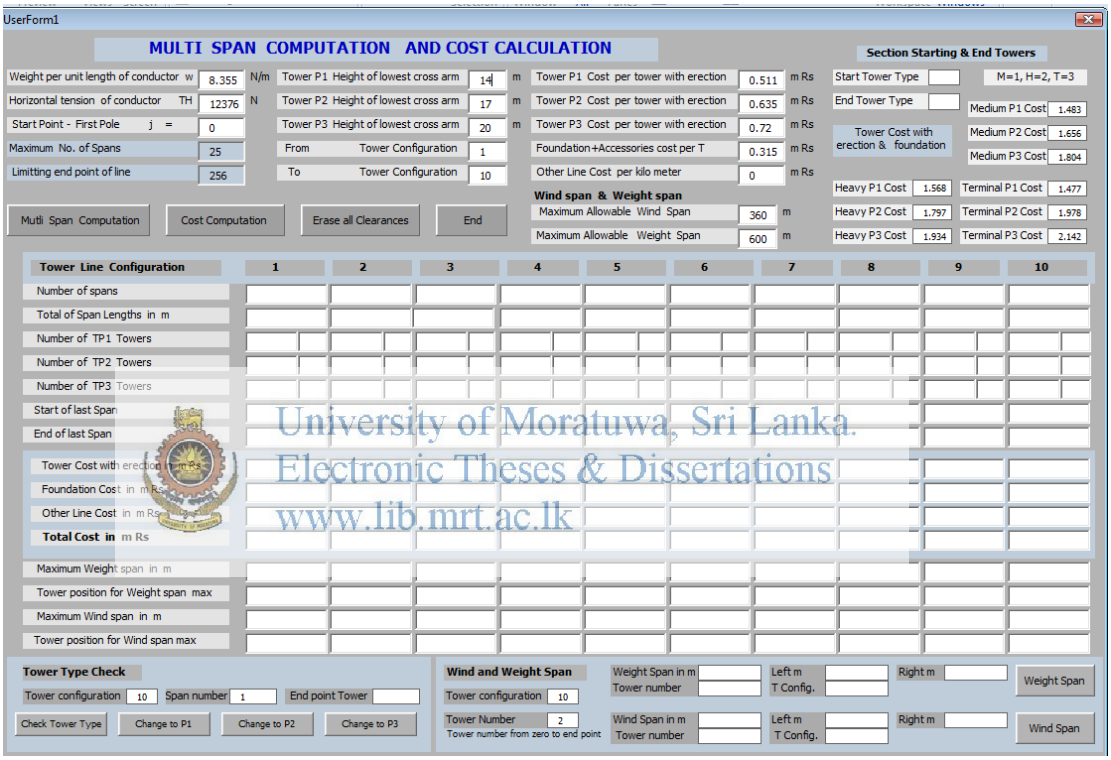


Figure 4: UserForm

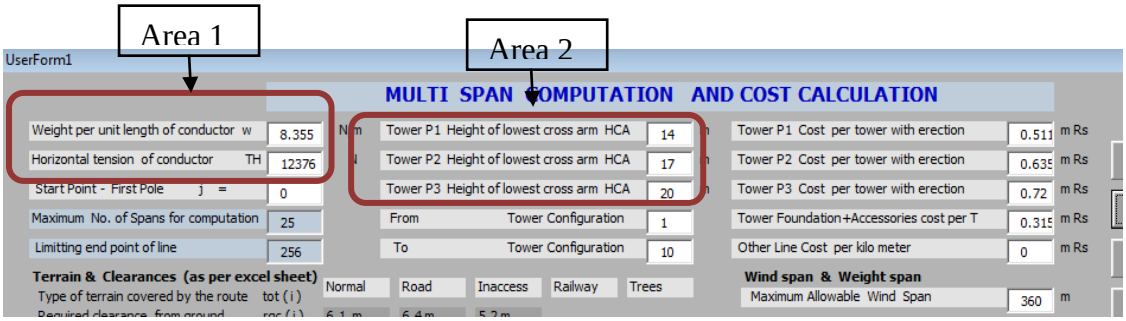


Figure 5: Conductor data input

Step 5 → Tower heights input

Enter tower bottom conductor attachment point height levels in the text boxes shown in Area 2 of Figure 5.

Step 6 →Tower costs and wind span and weight span input

Enter calculated suspension tower costs (tower + erection), tension tower costs (tower + erection + foundation cost) for , average foundation cost for suspension towers, start and end tower angle type for the line section and weight and wind span limits in the area shown in Figure 6.

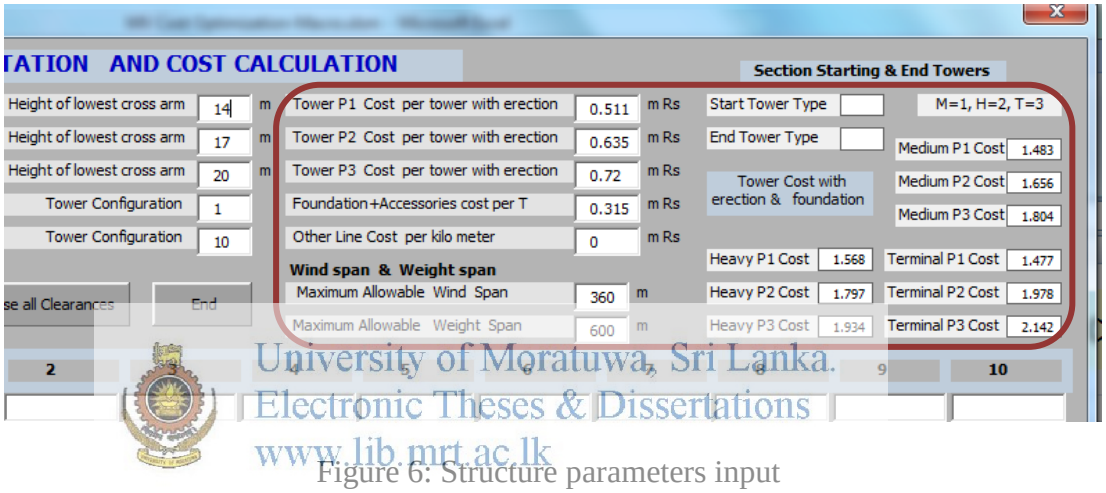


Figure 6: Structure parameters input

Step 7 →Define the design range

Enter starting tower point (j) survey data index and end tower point survey index in given text boxes according to arranged survey data sheet (integer appeared in excel sheet index number column for section starting point)

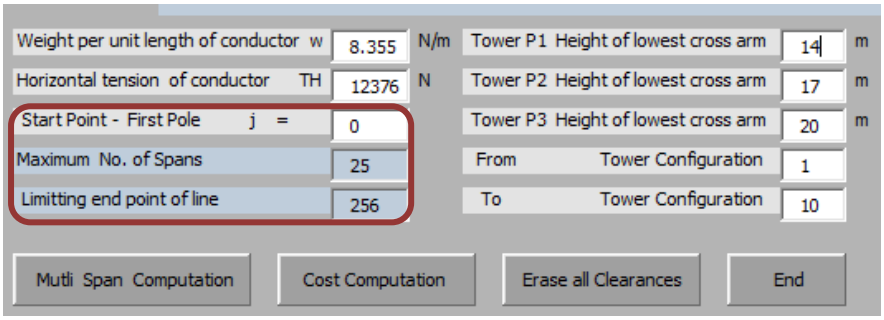
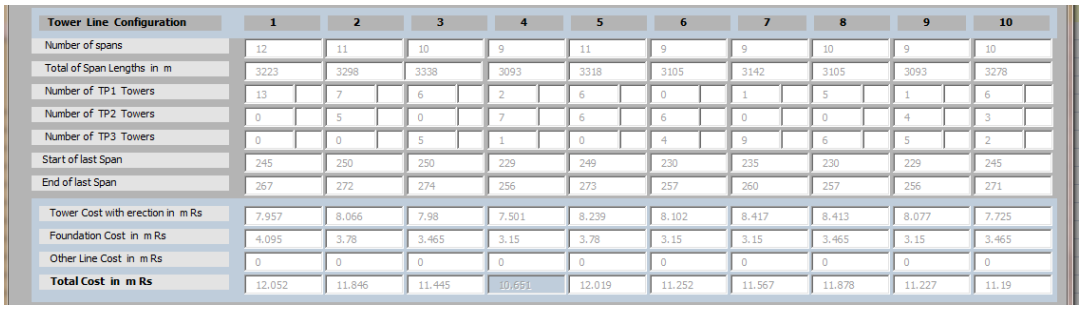


Figure 7: Defining starting and end point of the section

Step 8 → Run the computation

First click “Multi span computation” command. When computation results appeared click on “Cost Computation” command button. Design solutions and cost computations will be shown in the UseFform as shown in Figure 8. The lowest cost solution will be highlighted in light blue color.

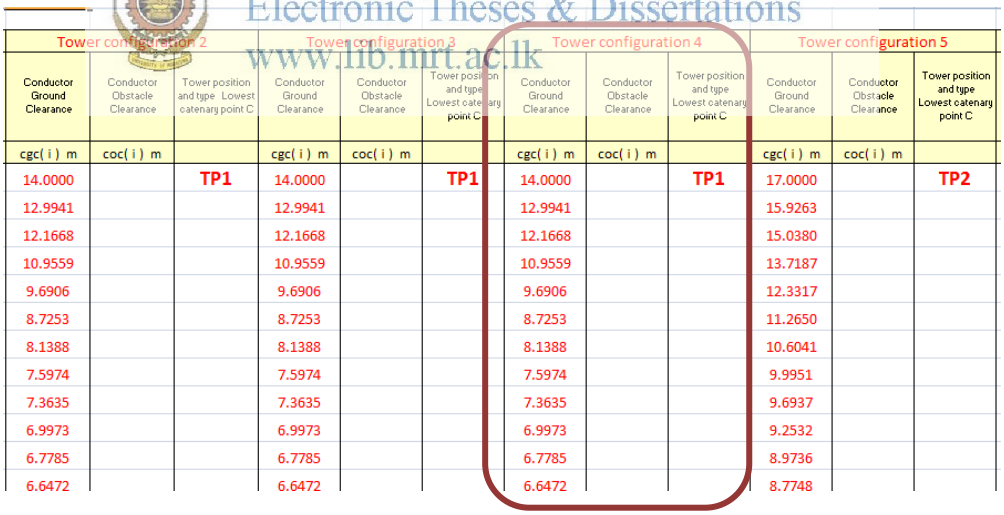


Tower Line Configuration	1	2	3	4	5	6	7	8	9	10
Number of spans	12	11	10	9	11	9	9	10	9	10
Total of Span Lengths in m	3223	3298	3338	3093	3318	3105	3142	3105	3093	3278
Number of TP1 Towers	13	7	6	2	6	0	1	5	1	6
Number of TP2 Towers	0	5	0	7	6	6	0	0	4	3
Number of TP3 Towers	0	0	5	1	0	4	9	6	5	2
Start of last Span	245	250	250	229	249	230	235	230	229	245
End of last Span	267	272	274	256	273	257	260	257	256	271
Tower Cost with erection in m Rs	7.957	8.066	7.98	7.501	8.239	8.102	8.417	8.413	8.077	7.725
Foundation Cost in m Rs	4.095	3.78	3.465	3.15	3.78	3.15	3.15	3.465	3.15	3.465
Other Line Cost in m Rs	0	0	0	0	0	0	0	0	0	0
Total Cost in m Rs	12.052	11.846	11.445	10.651	12.019	11.252	11.567	11.878	11.227	11.19

Figure 8: Results display

Step 9 → Reading optimum design

After reading summary of the lowest cost design solution from the UserForm it can be closed. Detailed design can be read from the excel sheet by three columns under the selected configuration number as shown in Figure 9.



Tower configuration 2			Tower configuration 3			Tower configuration 4			Tower configuration 5		
Conductor Ground Clearance	Conductor Obstacle Clearance	Tower position and type Lowest catenary point C	Conductor Ground Clearance	Conductor Obstacle Clearance	Tower position and type Lowest catenary point C	Conductor Ground Clearance	Conductor Obstacle Clearance	Tower position and type Lowest catenary point C	Conductor Ground Clearance	Conductor Obstacle Clearance	Tower position and type Lowest catenary point C
cgc(i) m	coc(i) m		cgc(i) m	coc(i) m		cgc(i) m	coc(i) m		cgc(i) m	coc(i) m	
14.0000		TP1	14.0000		TP1	14.0000		TP1	17.0000		TP2
12.9941			12.9941			12.9941			15.9263		
12.1668			12.1668			12.1668			15.0380		
10.9559			10.9559			10.9559			13.7187		
9.6906			9.6906			9.6906			12.3317		
8.7253			8.7253			8.7253			11.2650		
8.1388			8.1388			8.1388			10.6041		
7.5974			7.5974			7.5974			9.9951		
7.3635			7.3635			7.3635			9.6937		
6.9973			6.9973			6.9973			9.2532		
6.7785			6.7785			6.7785			8.9736		
6.6472			6.6472			6.6472			8.7748		

Figure 9: Results in excel work sheet

Tower positions with the heights are appeared as “TP1”, “TP2” or “TP3” at each tower location survey point index row. Tower positions can be read along those rows by horizontal distance of each row. This design result can be visually displayed on Auto-CADD or PLS-CADD profile drawings.

Cost of Construction and Design Parameters of Mast Type Structures

Double Circuit Support Type	Support Cost (LKR)	Erection Cost (LKR)	Foundation Cost for Good soil(LKR)	Maximum allowable wind span (m)	Maximum allowable weight span (m)
MDL+0	130,000	55,000	180,000	240	400
MDL+3	195,000	70,000			
MDL+6	242,000	80,000			
MDM+0	315,000	90,000	400,000	240	600
MDM+3	380,000	110,000			
MDM+6	410,000	130,000			
MDH+0	485,000	105,000	600,000	240	600
MDH+3	515,000	140,000			
MDH+6	548,000	155,000			
MDT+0	410,000	130,000	800,000	240	600
MDT+3	630,000	160,000			
MDT+6	675,000	190,000			