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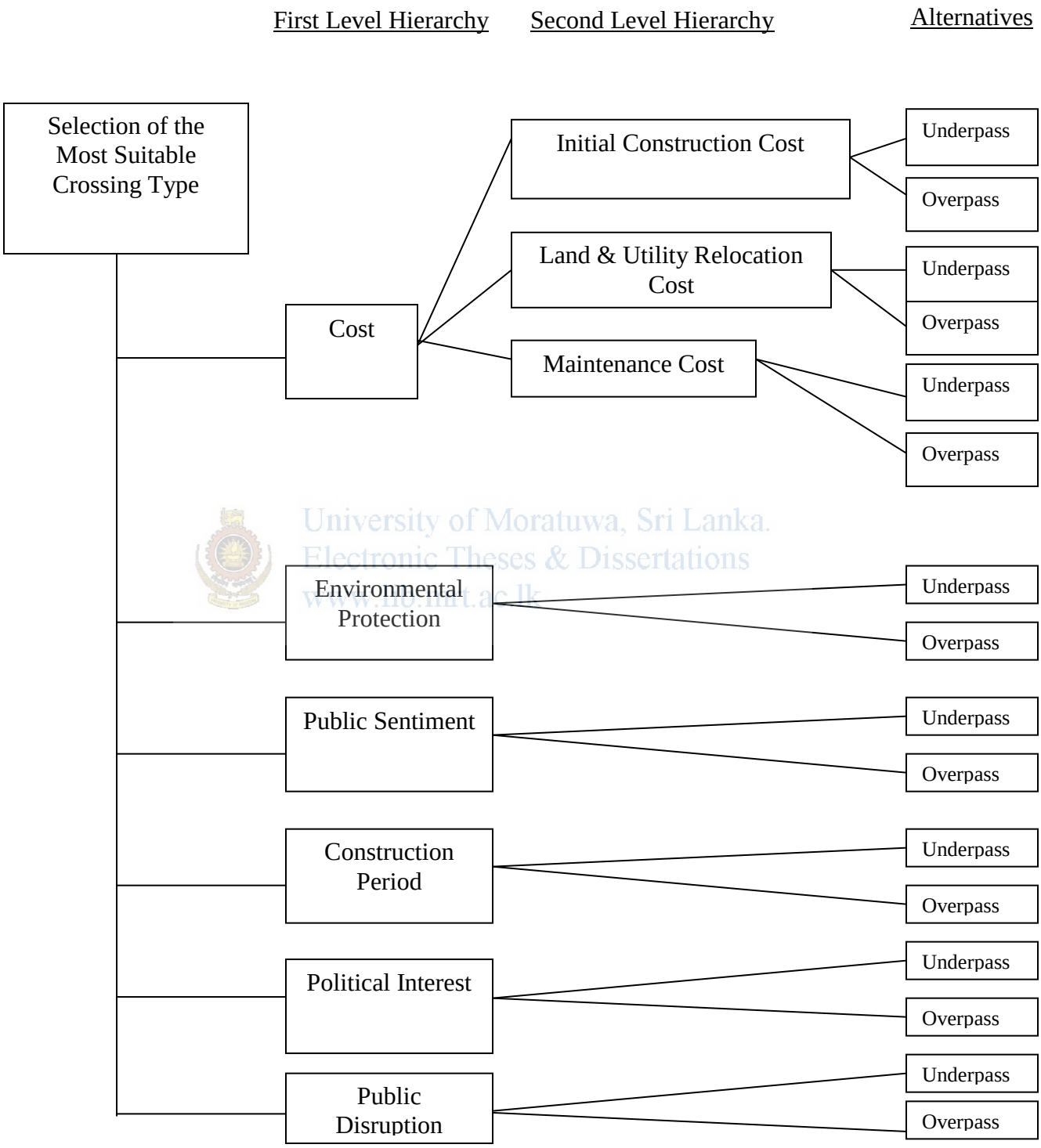
Appendix (I) - Comparison Factors For Initial Construction Cost

COMPARISON FACTOR RANGE BETWEEN ALTERNATIVES CONSIDERED	PAIRWISE COMPARISON FACTOR USED FOR ANALYTIC HIERACHY PROCESS
1.00-1.25	1- Equally preferred
1.25-1.50	2-Equally to moderately preferred
1.50-1.60	3- Moderately preferred
1.60-1.70	4- Moderately to strong preferred
1.70-1.80	5-Strongh preferred
1.80-1.85	6- Strongly to very strongly preferred
1.85-1.90	7- Very strongly preferred
1.90-1.95	8-Very to extremely strongly preferred
1.95-2.00	9- Extremely preferred

Appendix 1 - Comparison Factors For Initial Construction Cost

Appendix (II) - Selection Of Crossing Type At Wanawasala Road

Network for the Selection of Crossing Type at Wanawasala Road (Meegahawatta Ch. 3+209)



Appendix 2 - Selection Of Crossing Type At Wanawasala Road

Evaluation using Analytic Hierarchy Process

Evaluations for the First Level Hierarchy Factor Weightages

Pairwise comparison ratings.

1- Equally preferred
2-Equally to moderately preferred
3- Moderately preferred
4- Moderately to strong preferred
5-Strongly preferred
6- Strongly to very strongly preferred
7- Very strongly preferred
8-Very to extremely strongly preferred
9- Extremely preferred

Step – a

Pair wise Comparison Matrix

Factor	Cost	Environmental Protection	Public Sentiment	Construction Period	Political Interest	Public Disruption
Cost	1	2	1	3	4	3
Environmental Protection	1/2	1	1	3	4	4
Public Sentiment	1	1	1	2	6	3
Construction Period	1/3	1/3	1/2	1	2	1/2
Political Interest	1/4	1/4	1/6	1/2	1	1/4
Public Disruption	1/3	1/4	1/3	2	4	1

Factor	Cost	Environmental Protection	Public Sentiment	Construction Period	Political Interest	Public Disruption
Cost	1	2	1	3	4	3
Environmental Protection	0.5	1	1	3	4	4
Public Sentiment	1	1	1	2	6	3
Construction Period	0.333	0.333	0.5	1	2	0.5
Political Interest	0.25	0.25	0.166	0.5	1	0.25
Public Disruption	0.333	0.25	0.383	2	4	1
Column Total	3.416	4.833	4.049	11.5	21	11.75

Step – b

Normalized Matrix

Numbers in the matrix in Step – 1 is divided by their respective column total.

Factor	Cost	Environmental Protection	Public Sentiment	Construction Period	Political Interest	Public Disruption	Average
Cost	0.292	0.413	0.246	0.260	0.190	0.255	0.276
Environmental Protection	0.146	0.206	0.246	0.260	0.190	0.340	0.231
Public Sentiment	0.292	0.206	0.246	0.173	0.285	0.255	0.242
Construction Period	0.097	0.069	0.123	0.086	0.095	0.042	0.085
Political Interest	0.073	0.051	0.041	0.043	0.047	0.021	0.046
Public Disruption	0.097	0.051	0.094	0.173	0.190	0.085	0.115

From above matrix details of average weightages obtained could be summarized as follow.

Factor	Cost	Environmental Protection	Public Sentiment	Construction Period	Political Interest	Public Disruption
Weightage	0.276	0.231	0.242	0.085	0.046	0.115

Step – c

Determining the Consistency Ratio

Since we need to determine whether our responses are consistent we need to find the consistency ratio.

Finding the Weightage Sum Vector

This is done by multiplying the first column of the original pair wise comparison matrix by the factor of weight calculated. (Average values given in above matrix).

$$\begin{pmatrix} 1 & 2 & 1 & 3 & 4 & 3 \\ 0.5 & 1 & 1 & 3 & 4 & 4 \\ 1 & 1 & 1 & 2 & 6 & 3 \\ 0.333 & 0.333 & 0.5 & 1 & 2 & 0.5 \\ 0.25 & 0.25 & 0.166 & 0.5 & 1 & 0.25 \\ 0.333 & 0.25 & 0.383 & 2 & 4 & 1 \end{pmatrix} \text{X} \begin{pmatrix} 0.276 \\ 0.231 \\ 0242 \\ 0.085 \\ 0.046 \\ 0.115 \end{pmatrix} = \begin{pmatrix} 1.764 \\ 1.510 \\ 1.540 \\ 0.524 \\ 0.284 \\ 0.711 \end{pmatrix}$$

Finding the Consistency Vector

Consistency Vector is the relevant value of the weightage sum vector divided by the corresponding weightage.

$$\begin{pmatrix} 1.764 / 0.276 \\ 1.510 / 0.231 \\ 1.540 / 0.242 \\ 0.524 / 0.085 \\ 0.284 / 0.046 \\ 0.711 / 0.115 \end{pmatrix} = \begin{pmatrix} 6.391 \\ 6.536 \\ 6.363 \\ 6.164 \\ 6.174 \\ 6.182 \end{pmatrix}$$

Computing Lambda & Consistency Index

$$CI = \frac{\lambda.- n}{n - 1}$$

Where CI = Consistency Index

$\lambda =$ Average value of the consistency vector

n = Number of items being compared.

In this case $\lambda = \frac{(6.391+6.536+6.363+6.164+6.174+6.182)}{6.0} = 6.301$

n = 6

Therefore $CI = \frac{\lambda.- n}{n - 1} = \frac{6.301 - 6}{6-1} = 0.060$

Computing the Consistency Ratio

$$\text{Consistency ratio} = \frac{\text{Consistency Index}}{\text{Random Index}}$$

Random Index could be determined from Table 14 given below which has been extracted from reference to Analytic Hierarchy Process Module I presented by Dr. Brucehartman. Random Index is a direct function of the number of alternatives or systems being considered.

Random Index

N	RI
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41

$$CR = \frac{CI}{RI}$$

CR - Consistency Ratio
RI - Random Index
CI - Consistency Index

In this case,

$$CR = \frac{0.060}{1.24} = 0.048$$

Note

If consistency ratio is 0.10 or less the decision makers answers are relatively consistent. In this case the values obtained are consistent since the value of CR is less than 0.1.

Therefore the weightages could be finalized as follows.

Factor	Weightage		Weightage
Construction Cost	0.276		0.28
Environmental Protection	0.231	This could be rounded as	0.23
Public Sentiment	0.242		0.24
Construction Period	0.085		0.08
Political Interest	0.046		0.05
Public Disruption	0.115		0.11

Evaluation for the Second Level Hierarchy Factor Weightages

As per the network now we shall analyze the factor of weights for the cost factor concerned since it has three main secondary components.

Step – a

Pair wise Comparison Matrix

Cost	Initial Construction Cost	Land & Utility Relocation Cost	Maintenance Cost
Initial Construction Cost	1	2	4
Land & Utility Relocation Cost	1/2	1	2
Maintenance Cost	1/4	1/2	1

Cost	Initial Construction Cost	Land & Utility Relocation Cost	Maintenance Cost
Initial Construction Cost	1	2	4
Land & Utility Relocation Cost	0.5	1	2
Maintenance Cost	0.25	0.5	1
Column Total	1.75	3.5	7

Step – b

Preparation of Normalized Matrix

$$\begin{pmatrix} 0.571 & 0.571 & 0.571 \\ 0.285 & 0.285 & 0.285 \\ 0.142 & 0.142 & 0.142 \end{pmatrix}$$

$$\begin{pmatrix} 0.571 \\ 0.285 \\ 0.142 \end{pmatrix} \text{ Rounded to } \begin{pmatrix} 0.57 \\ 0.28 \\ 0.14 \end{pmatrix}$$

Step – c

Determining the Consistency Ratio.

Finding the Weightage Sum Vector

$$\begin{pmatrix} 1 & 2 & 4 \\ 0.5 & 1 & 2 \\ 0.25 & 0.5 & 1 \end{pmatrix} \text{ X } \begin{pmatrix} 0.571 \\ 0.285 \\ 0.143 \end{pmatrix} = \begin{pmatrix} 1.713 \\ 0.856 \\ 0.428 \end{pmatrix}$$

Finding the Consistency Index

Establishment of Consistency Vector

$$\begin{pmatrix} 1.713 / 0.571 \\ 0.856 / 0.285 \\ 0.428 / 0.142 \end{pmatrix} = \begin{pmatrix} 3.0 \\ 3.005 \\ 3.014 \end{pmatrix}$$

From Equation

$$CI = \frac{\lambda.- n}{n - 1}$$

Where CI = Consistency Index

λ = Average value of the consistency vector
n = Number of items being compared ie 3

In this case

$$\lambda = \frac{(3.00 + 3.005 + 3.014)}{3} = 3.006$$

$$CI = \frac{\lambda.- n}{n - 1} = \frac{3.006 - 3}{2} = 0.003$$

For n = 3 from Table 14 RI = 0.58

Therefore, CR = $\frac{0.003}{0.58}$ = 0.005

Since this value is less than 0.1 answers are relatively consistent.

Factor Evaluations for Alternatives

Since Wanawasala Road is a Class C road the alternative of road closure was not considered. Therefore only two alternatives were considered for the crossing type. (i.e. Underpass or Overpass).

Factor evaluations carried out for alternatives are described as follows.

Evaluations Under Third Hierarchy Level

Alternative Evaluation under Initial Construction Cost

Initial construction cost for underpass = Rs. 119,691,560.24 = 1.38
Initial construction cost for overpass Rs. 86,541,871.97

Accordingly, the comparison factor from Annex –I could be taken as 2

Therefore, overpass option is considered as equally preferred with compared to Underpass Option.

Initial Construction Cost	Underpass	Overpass
Underpass	1	1/2
Overpass	2	1

Initial Construction Cost	Underpass	Overpass
Underpass	1	0.5
Overpass	2	1
Column Total	**3**	**1.5**

Preparation of Normalized Matrix

Initial Construction Cost	Underpass	Overpass		Row Average
Underpass	0.333	0.333	=	0.333
Overpass	0.666	0.666		0.666

Alternative Evaluation under Land Acquisition & Utility Relocation

Underpass option is considered as strongly preferred with compared to Overpass Option.

Land Acquisition & Utility Relocation	Underpass	Overpass
Underpass	1	5
Overpass	1/5	1

Land Acquisition & Utility Relocation	Underpass	Overpass
Underpass	1	5
Overpass	0.2	1
Column Total	**1.2**	**6**

Preparation of Normalized Matrix

Land Acquisition & Utility Relocation	Underpass	Overpass		Row Average
Underpass	0.833	0.833	=	0.833
Overpass	0.166	0.166		0.166

Alternative Evaluation under Maintenance Cost

Underpass option is considered as moderately to strongly preferred with compared to Overpass Option.

Maintenance Cost	Underpass	Overpass
Underpass	1	4
Overpass	1/4	1

Maintenance Cost	Underpass	Overpass
Underpass	1	4
Overpass	0.25	1
Column Total	**1.25**	**5**

Preparation of Normalized Matrix

Maintenance Cost	Underpass	Overpass		Row Average
Underpass	0.8	0.8	=	0.8
Overpass	0.2	0.2		0.2

Alternative Evaluation under Environmental Protection

Underpass option is considered as very strongly preferred with compared to Overpass Option.

Environmental Protection	Underpass	Overpass
Underpass	1	7
Overpass	1/7	1

Environmental Protection	Underpass	Overpass
Underpass	1	7
Overpass	0.142	1
Column Total	**1.142**	**8**

Preparation of Normalized Matrix

Environmental Protection	Underpass	Overpass		Row Average
Underpass	0.875	0.875	=	0.875
Overpass	0.125	0.125		0.125

Alternative Factor Evaluation under Public Sentiment

Underpass option is considered as very strongly preferred with compared to Overpass Option.

Public Sentiment	Underpass	Overpass
Underpass	1	7
Overpass	1/7	1

Public Sentiment	Underpass	Overpass
Underpass	1	7
Overpass	0.142	1
Column Total	**1.142**	**8**

Preparation of Normalized Matrix

Public Sentiment	Underpass	Overpass		Row Average
Underpass	0.875	0.875	=	0.875
Overpass	0.124	0.125		0.125

Alternative Evaluation under Construction Period

Underpass option is considered as moderately preferred with compared to Overpass Option.

Construction Period	Underpass	Overpass
Underpass	1	3
Overpass	1/3	1

Construction Period	Underpass	Overpass
Underpass	1	3
Overpass	0.333	1
Column Total	**1.333**	**4**

Preparation of Normalized Matrix

Construction Period	Underpass	Overpass		Row Average
Underpass	0.75	0.75	=	0.75
Overpass	0.249	0.25		0.25

Alternative Evaluation under Political Interest

Underpass option is considered as strongly to very strongly preferred with compared to Overpass Option.

Political Interest	Underpass	Overpass
Underpass	1	6
Overpass	1/6	1

Political Interest	Underpass	Overpass
Underpass	1	6
Overpass	0.166	1
Column Total	**1.166**	**7**

Preparation of Normalized Matrix

Political Interest	Underpass	Overpass		Row Average
Underpass	0.857	0.857	=	0.857
Overpass	0.142	0.142		0.142

Alternative Evaluation under Public Disruption

Underpass option is considered as extremely preferred with compared to Overpass Option.

Public Disruption	Underpass	Overpass
Underpass	1	9
Overpass	1/9	1

Public Disruption	Underpass	Overpass
Underpass	1	9
Overpass	0.111	1
Column Total	**1.111**	**10**

Preparation of Normalized Matrix

Public Disruption	Underpass	Overpass		Row Average
Underpass	0.9	0.9	=	0.9
Overpass	0.1	0.1		0.1

Overall Rating to find the Optimum Solution

The weightages obtained from above calculations at each hierarchy level pertaining to impact issues with the relevant alternatives considered are summarized below.

Resultant weightage for each alternative proposal with respect to an impact issue could be obtained by the multiplication of weightages under each hierarchy level. Finally the total weightage score for each alternative could be obtained by the addition of all individual weightage factors in the relevant column concerned.

Weightage / Impact Issue	1st Level Hierarchy weightage (1)	2nd Level Factors (2)	2nd Level Hierarchy weightage (3)	Alternative Evaluation for Underpass (3rd Level Hierarchy) (4)	Alternative Evaluation for Overpass (3rd Level Hierarchy) (5)	Resultant Weightage for Underpass (6)=(1)x(3)x(5)	Resultant Weightage for Overpass (7)=(1)x(3)x(5)
Cost	0.276	I.C.C	0.571	0.333	0.666	0.052	0.105
		L & UR.C	0.285	0.833	0.166	0.065	0.013
		M.C.	0.143	0.8	0.2	0.031	0.008
Environmental Protection	0.231	-	-	0.875	0.125	0.202	0.029
Public Sentiment	0.242	-	-	0.875	0.125	0.211	0.030
Construction Period	0.085	-	-	0.75	0.25	0.063	0.021
Political Interest	0.046	-	-	0.857	0.143	0.039	0.007
Public Disruption	0.115	-	-	0.9	0.1	0.104	0.011
Total weightage						0.767	0.224

Note - I.C.C – Initial Construction Cost
L & UR.C – Land & Utility Relocation Cost
M.C.- Maintenance Cost

From above analysis we can obtain that the total weighted evaluation for underpass is 0.767 and for overpass 0.224. It is also noted that the weightage for underpass is about 3.5 times the weighted average for overpass. Therefore underpass will be the most suitable solution for this location.

This indicates that the decision arrived as per the case study described in section 3.2.1.7 pertaining to the location agrees with the result obtained under the proposed selection criteria method incorporated with analytic hierarchy process.

Hence this process will be a more accurate method rather than arriving for a solution in an ad-hoc manner. Contemporarily this could be used to find the most optimum solution for other locations while introducing relevant factors with their relative comparisons.