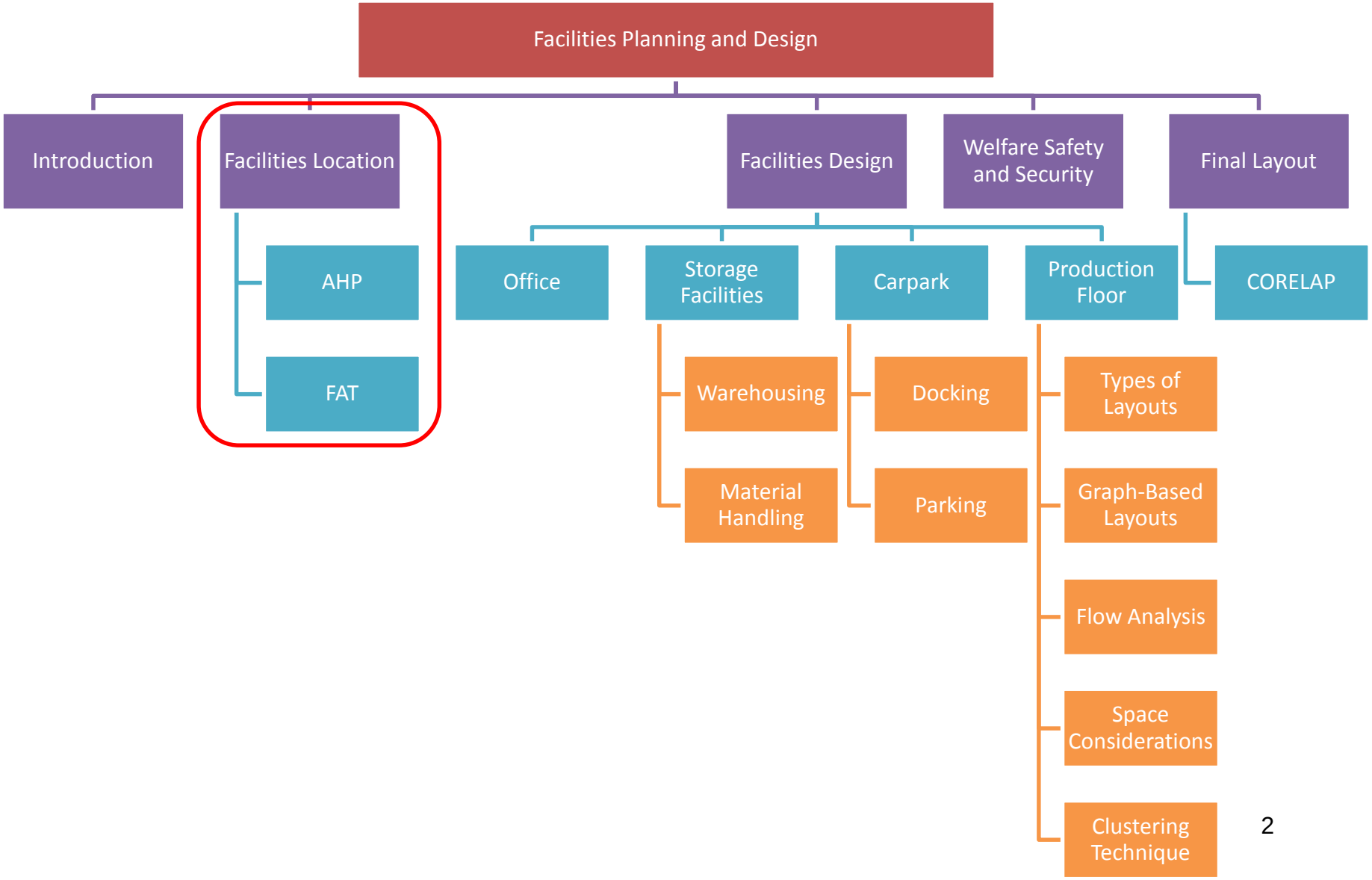
P02
The Kick off

E212 – Facilities Planning and Design

SCHOOL OF ENGINEERING

E212 Facilities Planning & Design - Topic Tree



Learning Objectives

- Identify the needs and objectives of a facility
- Compare and contrast the similarities and differences between Factor Analysis Technique and Analytical Hierarchy Process
- Perform weights assignment to different decision criteria based on their importance (according to management guidelines and decision)
- Apply facility location selection techniques: FAT (Factor Analysis Technique) and AHP (Analytical Hierarchy Process)

Location Selection

- General objective when selecting location:

  To minimize

  - regional costs
  - outbound distribution costs
  - inbound distribution costs

- Types of Analysis:

  Macro analysis

  - To evaluate alternative countries, regions, communities

  Micro analysis

  - To evaluate specific sites in the selected community

Factors Affecting Location Selection

- Regional factors
  - International Company = country
  - National Company = section of country or state
  - Local Company = country or city
- Market location
  - Important for service firms / manufacturers of fragile or perishable goods
  - Cost of shipping to customers
  - Firms that are suppliers for JIT process
  - Customer identification with firm due to proximity
  - Location of competitors
- Raw material and supplier proximity
  - For example, manufacturers that use perishable raw materials locate near source

Factors Affecting Location Selection

- Transportation facilities (currently less important, compared to before 1950s)
  - Airports, Seaports, Highways.

- Labour climate
  Labour force is crucial to operation of the firm
  - Availability: large pool of workers
  - Skills Match the needs of firm
  - Cost: wage rate in that area; level of unionization

- Quality of life
  - Help keep quality workforce

- Government
  - Taxes & Incentives

Factors Affecting Site Selection

- Typical engineering considerations
  - Sufficient land to build and expand
  - Availability of utilities / infrastructure
  - Waste disposal
  - Transportation access
  - Legal and other impediments
  - Proximity to supporting industries
- Land Lease Cost
- Land Zoning

Factor Analysis Technique (FAT)

- Popular
- Subjective- decision making tool
- Relatively easy to use

- First assign an appropriate weight to the 5 factors (typically between 0 to 1) based on the relative importance of each.
  - ➢ Then assign a score (typically between 0 to 100) to each location with respect to each factor.
  - ➢ A weighted score for each factor for each location can then be obtained by multiplying the weight with the score.
  - ➢ Finally, the sum of the weighted scores can be obtained and selection done based on these scores.

Factor Analysis Technique (FAT) Example

	Locations Options (Weighted Score = Weight x Score)		
Factors	**Kyoto** (0-100)	**Tokyo** (0-100)	**Osaka** (0-100)
Customer Volume	55*0.25=13.75	20	16.25
Accessibility	9	12.75	11.25
Rental Cost	25.6	16	20.8
Competition in Area	15	10	16
Customer Profile	5.6	7.2	6
Sum of Weighted Score	**68.95**	**65.95**	**70.3**

Analytic Hierarchy Process (AHP)

- Alternative approach to FAT.

- The basic idea of AHP approach is to convert subjective assessments of relative importance to a set of overall scores or weights.

- The methodology of AHP is based on pairwise comparisons of the following type of question: “How important is criterion Ci relative to criterion Cj ?”.

- Compared to FAT, AHP involves a relatively complex mathematical procedure.

- Computer software, e.g. Expert Choice, has been developed to support this method.

Scale for Pairwise Comparison

- Example of Fundamental Scale for Pairwise Comparison

The Fundamental Scale for Pairwise Comparisons	
Intensity of Importance	Definition
1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important

Intensities of 2, 4, 6, and 8 can be use to express intermediate values.

Intensities 1.1, 1.2, 1.3, etc. can be used for elecments that are very close in importance.

1/2, 1/3, 1/4, etc. to be used for elements that are LESS in importance.

Disadvantages in AHP

- Measurement scale chosen is just ordinal at best. A rating of 10 does not mean the preference, risk or whatever for an item is twice that of an item rated 5.

- When there are more than a few items on the assessment list, it gets hard to keep all the prioritization considerations in one's mind at the same time.

Steps in AHP

- ***Step 1:*** Set up the decision hierarchy. The difference from FAT is that the alternative courses of action also appear on the hierarchy.

- ***Step 2:*** Make pairwise comparisons of factors and alternatives, to determine the relative importance of factors and how well the alternatives perform on the different factors.

- ***Step 3:*** Transform the comparisons into weights and check the consistency of the decision maker's comparisons.

- ***Step 4:*** Use the weights to obtain scores for the different options and make a provisional decision.

An Example of Pairwise Comparison

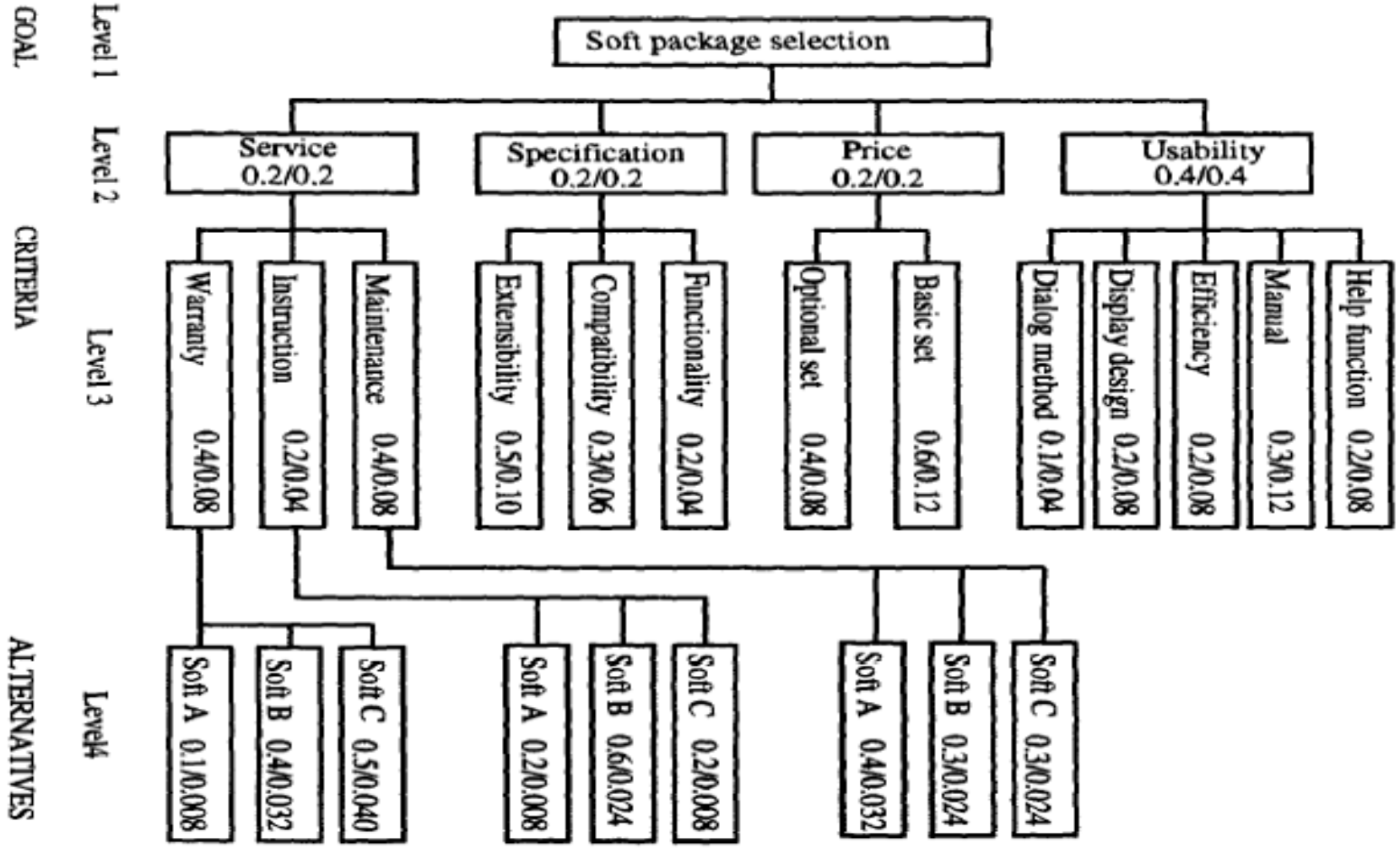
- Assuming that there are 3 factors: Cost, Availability and Human Traffic

Example:

- Cost is **strongly more important** than Availability
- Cost is **moderately lesser important** than Human Traffic
- Human Traffic is **extremely more important** than availability

Cost	9 8 7 6 5 4 3 2 | 2 3 4 5 6 7 8 9	Availability
Cost	9 8 7 6 5 4 3 2 | 2 3 4 5 6 7 8 9	Human Traffic
Availability	9 8 7 6 5 4 3 2 | 2 3 4 5 6 7 8 9	Human Traffic

Example of a Hierarchy Structure



Consistency Index ***(CI)***

- Consistency index *(CI)* is designed to alert the decision maker to any inconsistencies in the comparisons which have been made.

- *CI* can be estimated by: $CI = \frac{\lambda_{\max} - n}{n-1}$

  where

  n = number of factors under consideration in decision making

  $\lambda_{\max}$ (maximum eigenvalue) = sum of each priority multiply by the respective total value of each column in pairwise comparison.

Consistency Ratio ***(CR)***

- After knowing the Consistency Index, this index will be compared with an 'appropriate' Consistency index, which is called Random Consistency Index ***(RI)***.

- Example reference for RI:

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

n = number of factors under consideration in decision making

- ***CR*** can then be obtained by: $CR = \frac{CI}{RI}$

- Value of zero ***CR*** indicates perfect consistency (lower the value, higher the consistency).

Consistency Ratio ***(CR)***

- As a rule of thumb, inconsistency should only be a concern if CR **exceeds 0.1**, where comparisons of alternatives in the pairwise comparison table need to be checked through.

- However, *minimizing inconsistency should not be the main goal of the analysis. A set of erroneous judgments about importance and preference may be perfectly consistency, but they will not lead to the 'best' decision.

* Decision Analysis for Management Judgment, Goodwin & Wright,John Wiley & Sons, 3rd edition

FAT vs. AHP

- Similarities: they are both selection tools

- Differences in dealing with sub criteria:

  ➢ Scoring model (FAT) is a “one-level” process.

  Sub criteria are combined to the get the value for that factor.

  ➢ AHP uses a hierarchy of criteria.

  It has weightings of criteria and sub criteria that compute a composite score for each candidate project as well as an overall score.

Problem 02
Suggested Solution

Problem Objectives

- Identify possible objectives of a facility
- Determine factors for selecting a site based on the objectives of the facility
- Select an appropriate site for a facility after considering the importance of each factors and how well each alternative site fares for each factor

Factors Affecting Location of Production Facility

- Some of the major factors affecting location of the Running shop are:
  - ❑ Proximity to supporting industries (e.g. Proximity to Suppliers / Availability of Raw Materials)
  - ❑ Location Accessibility
  - ❑ Land Cost
  - ❑ Proximity to Customers (Accessibility to Market)
  - ❑ Availability of Infrastructural Facilities
  - ❑ Availability of Manpower
  - ❑ Ecological and Environmental Factors

- Though there are many factors, not all factors need to be used.

Using FAT – Factor Analysis Technique

(a) Decide factors
(b) Assign weights
(c) Assign scores

		(c) Locations Options (Score)		
(b) Weight (Σ W = 1)	**(a) Factors**	**Jurong West (0-100)**	**Woodlands (0-100)**	**Tampines (0-100)**
0.5	Proximity to Supporting Industries	70	55	50
0.3	Manpower Availability	85	60	75
0.2	Location Accessibility	55	65	85

Using FAT – Factor Analysis Technique

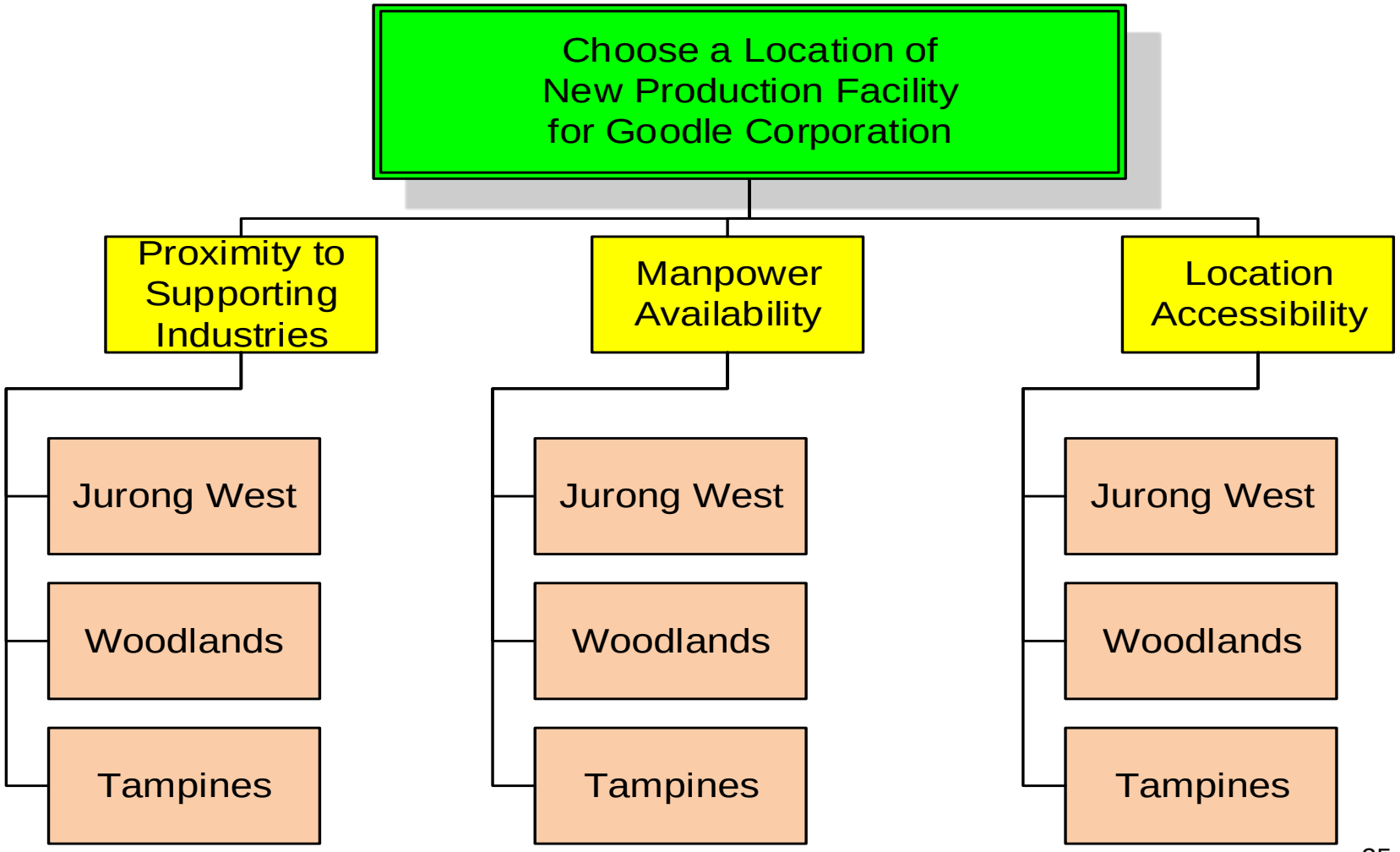
(d) Compute weighted scores
(e) Compute sum of weighted scores

		(d) Locations Options (Weighted Score = Weight x Score)		
Weight (Σ W = 1)	**Factors**	**Jurong West (0-100)**	**Woodlands (0-100)**	**Tampines (0-100)**
0.5	Proximity to Supporting Industries	e.g. (0.5x70) = 35	27.5	25
0.3	Manpower Availability	25.5	18	22.5
0.2	Location Accessibility	11	13	17
	(e) Sum of Weighted Score	71.5	58.5	64.5

Choose "Jurong West"

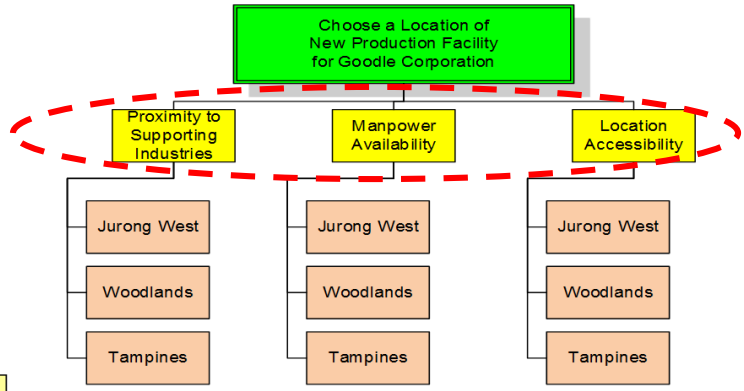
Using AHP – Analytic Hierarchy Process

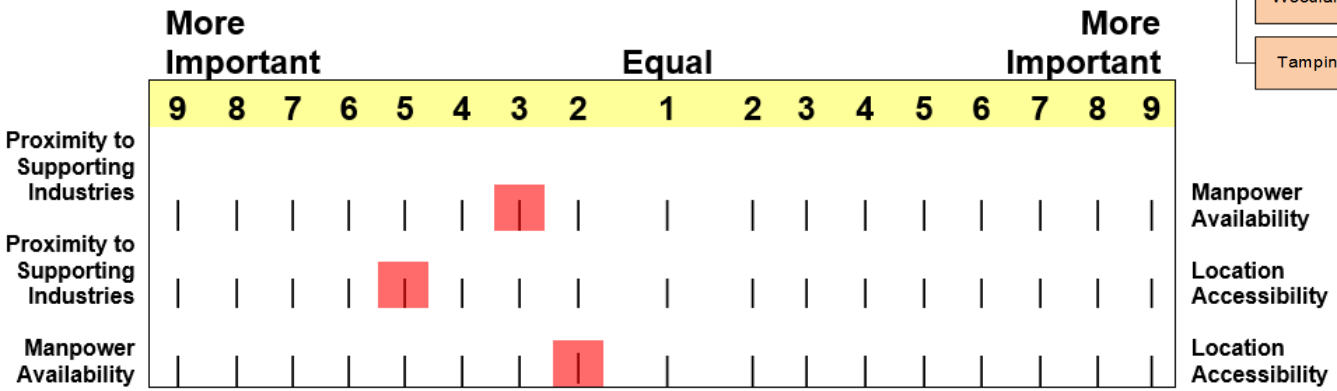
- Decisions in hierarchy



Using AHP – Pairwise Comparison

- Pairwise comparison and intensity assignment
  - Between the factors/criteria/objectives:





Factors	Proximity to Supporting Industries	Manpower Availability	Location Accessibility
Proximity to Supporting Industries	**1**	3	5
Manpower Availability	1/3	**1**	2
Location Accessibility	1/5	1/2	**1**

Using AHP – Pairwise Comparison

- **Synthesisation on pairwise comparison matrix**
  - Step 1: **Sum** values in each column

Factors	Proximity to Supporting Industries	Manpower Availability	Location Accessibility
Proximity to Supporting Industries	1	3	5
Manpower Availability	1/3	1	2
Location Accessibility	1/5	1/2	1
Column Sum	**1.5333**	**4.5000**	**8.0000**

  - Step 2: **Normalise** the matrix (divide each value by the column

Normalize	Proximity to Supporting Industries	Manpower Availability	Location Accessibility
Proximity to Supporting Industries	E.g: (1/1.5333) = 0.6522	0.6667	0.6250
Manpower Availability	0.2174	0.2222	0.2500
Location Accessibility	0.1304	0.1111	0.1250

  - Step 3: **Prioritise** the factors (average of each row)

Normalize	Proximity to Supporting Industries	Manpower Availability	Location Accessibility	Priority(Ave)
Proximity to Supporting Industries	0.6522	0.6667	0.6250	0.6479
Manpower Availability	0.2174	0.2222	0.2500	0.2299
Location Accessibility	0.1304	0.1111	0.1250	0.1222

E.g. (0.1304+0.1111+0.1250)/3 = 0.1222

Using AHP – Consistency Check

Factors	Proximity to Supporting Industries	Manpower Availability	Location Accessibility
Proximity to Supporting Industries	1	3	5
Manpower Availability	1/3	1	2
Location Accessibility	1/5	1/2	1
Column Sum	1.5333	4.5000	8.0000

Normalize	Proximity to Supporting Industries	Manpower Availability	Location Accessibility	Priority(Ave)
Proximity to Supporting Industries	0.6522	0.6667	0.6250	0.6479
Manpower Availability	0.2174	0.2222	0.2500	0.2299
Location Accessibility	0.1304	0.1111	0.1250	0.1222

Step 1: Estimated λ_{max}

= sum product of { (factor priority) and (factor sum) }

= (0.6479)(1.5333) + (0.2299)(4.5000) + (0.1222)(8.0000)

= **3.0054**

Step 2 (Calculate Consistency Index, CI):

$$CI = \frac{\lambda_{max} - n}{n-1}$$

$$CI = \frac{3.0054 - 3}{3-1} = 0.0027$$

Step 3 (Calculate Consistency Ratio):

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

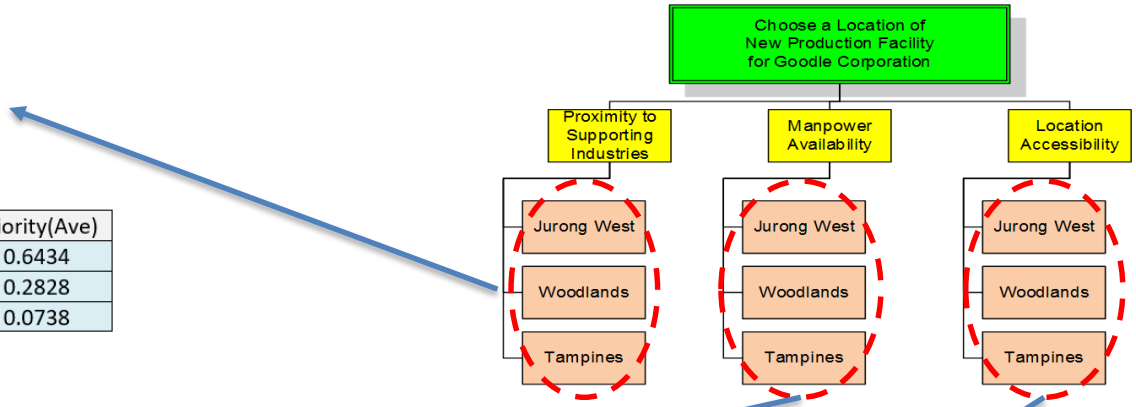
n	*RI*
1	0
2	0
3	0.58
4	0.9

$$CR = \frac{0.0027}{0.58} = 0.0047$$ <0.1 (Consistent)

AHP – Pairwise Comparison & Consistency Check

- E.g. Pairwise comparison and consistency check among the alternative locations for each factor:

Evaluate the Proximity to Supporting Industries (Factor 1)				
Proximity to Supporting Industries	Jurong West	Woodlands	Tampines	
Jurong West	1	3	7	
Woodlands	1/3	1	5	
Tampines	1/7	1/5	1	
Column Sum	**1.4762**	**4.2000**	**13.0000**	
Normalize	Jurong West	Woodlands	Tampines	Priority(Ave)
Jurong West	0.6774	0.7143	0.5385	0.6434
Woodlands	0.2258	0.2381	0.3846	0.2828
Tampines	0.0968	0.0476	0.0769	0.0738
λ_{max}	3.0967			
CI	**0.0484**			
CR	0.0834	<0.1 (Acceptable)		

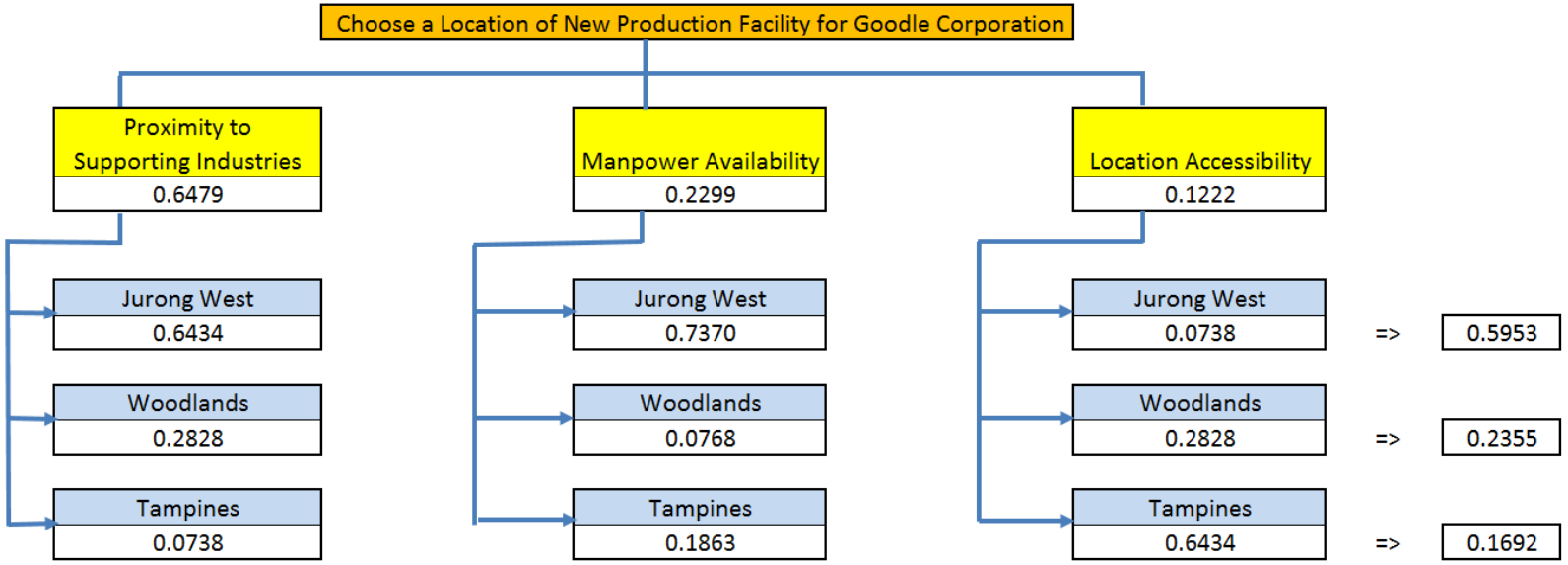


Evaluate the Manpower Availability (Factor 2)				
Manpower Availability	Jurong West	Woodlands	Tampines	
Jurong West	1	8	5	
Woodlands	1/8	1	1/3	
Tampines	1/5	3	1	
Column Sum	**1.3250**	**12.0000**	**6.3333**	
Normalize	Jurong West	Woodlands	Tampines	Priority(Ave)
Jurong West	0.7547	0.6667	0.7895	0.7370
Woodlands	0.0943	0.0833	0.0526	0.0768
Tampines	0.1509	0.2500	0.1579	0.1863
λ_{max}	3.0774			
CI	**0.0387**			
CR	0.0668	<0.1 (Acceptable)		

Evaluate the Location Accessibility (Factor 3)				
Location Accessibility	Jurong West	Woodlands	Tampines	
Jurong West	1	1/5	1/7	
Woodlands	5	1	1/3	
Tampines	7	3	1	
Column Sum	**13.0000**	**4.2000**	**1.4762**	
Normalize	Jurong West	Woodlands	Tampines	Priority(Ave)
Jurong West	0.0769	0.0476	0.0968	0.0738
Woodlands	0.3846	0.2381	0.2258	0.2828
Tampines	0.5385	0.7143	0.6774	0.6434
λ_{max}	3.0967			
CI	**0.0484**			
CR	0.0834	<0.1 (Acceptable)		

Using AHP – Making a Decision

- Insert the priorities to the respective cells in the AHP Hierarchy:



- Overall priority score (PS) for each alternative is developed:
  - Score for Jurong West:
    (0.6479 x 0.6434) + (0.2299 x 0.7370) + (0.1222 x 0.0738) = 0.5953
  - Score for Woodlands:
    (0.6479 x 0.2828) + (0.2299 x 0.0768) + (0.1222 x 0.2828) = 0.2355
  - Score for Tampines:
    (0.6479 x 0.0738) + (0.2299 x 0.1863) + (0.1222 x 0.6434) = 0.1692

Based on the 3 factors, the best decision is to choose **Jurong West**

Conclusions

- Factor Analysis Technique (FAT) or Analytical Hierarchy Process (AHP) can be used to help select suitable location/s for shops.

- Though FAT is relatively easier to use, AHP can capture both subjective and objective evaluation measures.

- In order to do location analysis, you need to decide on factors and alternatives. Data and information are also needed to help in your analysis.

- Some software are available in the market (e.g. Expert Choice) which you can use for the decision making.

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- Apply facility location selection techniques: FAT (Factor Analysis Technique) and AHP (Analytical Hierarchy Process)

Overview of E212 Facilities Planning and Design