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# Decision-making in Healthcare using the Analytic Hierarchy Process

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# Conflict of interest

- There is no conflict of interest to declare

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‘Medicine is a science of uncertainty and an art of probability’ Sir William Osler

# Outline

- Decision-making in healthcare
- The Analytic Hierarchy Process (AHP)
- Applications
- Hands on session



# Decision-making in Healthcare

- Diagnosis
- Patient participation
- Therapy / treatment
- Organ transplantation
- Project and technology evaluation and selection
- Human resource planning
- Healthcare evaluation and policy

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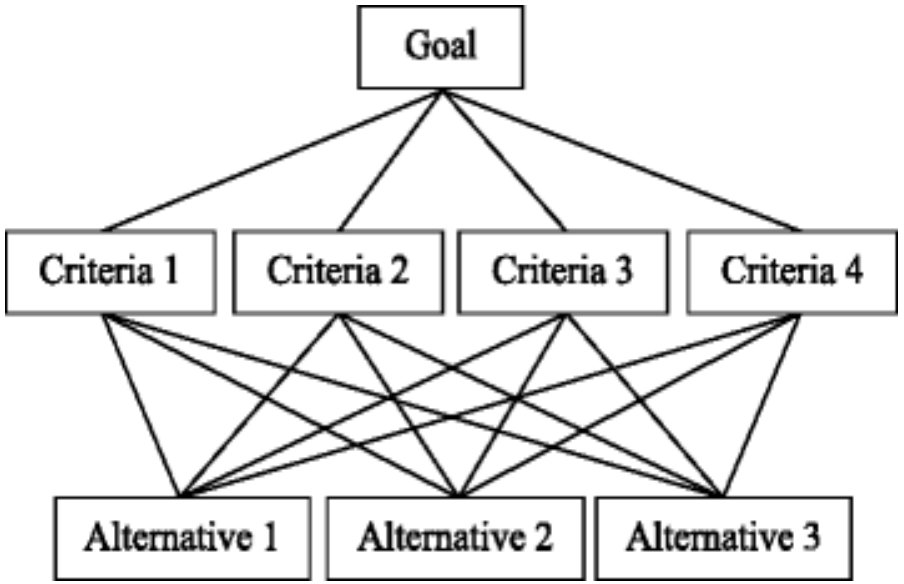
# *The Analytical Hierarchy Process: A Step-by-Step Approach*



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# Step 1

| *The Analytical Hierarchy Process by Thomas Saaty* | | | |
|---|---|---|---|
| | | | |
| **A.** | | | |
| | **Car A** | **Car B** | **Car C** |
| *Price* | 13100 | 11200 | 9500 |
| *MPG* | 18 | 23 | 29 |
| *Interior* | Deluxe | Above Average | Standard |
| *Body* | 4-Door Mid-size | 2-Door Sport | 2-door compact |
| *Radio* | CD, USB | CD + Aux | Radio |
| *Engine* | 6-cylinder | 4-cylinder turbo | 4-cylinder |

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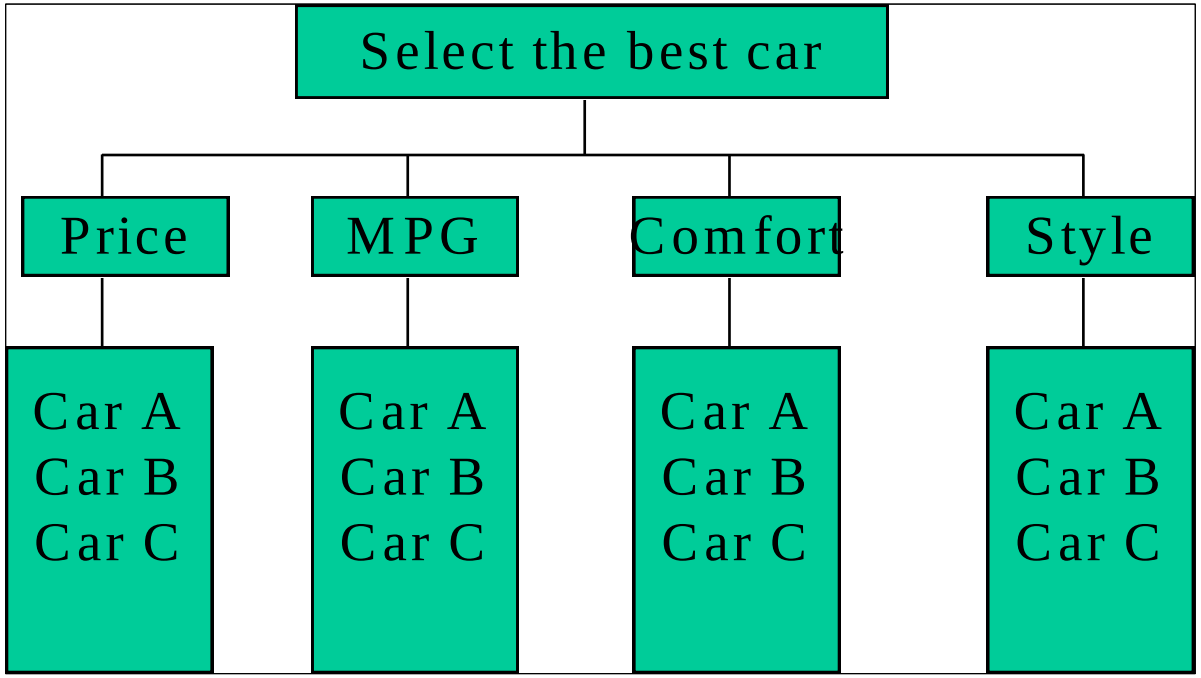
# Step 2:

B. **Hierarchy of Decisions**



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# Step 3:

## C. Establish Priorities

1. The priorities of the four criteria in terms of the overall goal.
2. The priorities of the three cars in terms of the purchase-price criter
3. The priorities of the three cars in terms of the MPG criterion.
4. The priorities of the three cars in terms of the comfort criterion.
5. The priorities of the three cars in terms of the style criterion.

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# Step 4:

**D. Pairwise Comparison Scale**

| Verbal Judgement of Preference | Numerical Rating |
|---|---|
| Extremely Preferred | 9 |
| Very strong to extremely | 8 |
| Very strongly preferred | 7 |
| Strongly to very strongly | 6 |
| Strongly preferred | 5 |
| Moderately to strongly | 4 |
| Moderately preferred | 3 |
| Equally to moderately | 2 |
| Equally preferred | 1 |

# Step 5:

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**D. Pairwise Comparison Scale**

| Verbal Judgement of Preference | Numerical Rating |
|---|---|
| Extremely Preferred | 9 |
| Very strong to extremely | 8 |
| Very strongly preferred | 7 |
| Strongly to very strongly | 6 |
| Strongly preferred | 5 |
| Moderately to strongly | 4 |
| Moderately preferred | 3 |
| Equally to moderately | 2 |
| Equally preferred | 1 |

**E. Pairwise comparison matrix showing preferences for the three cars in terms of comfort**

| Comfort | Car A | Car B | Car C |
|---|---|---|---|
| **Car A** | 1 | 2 | 8 |
| **Car B** | 0.5 | 1 | 6 |
| **Car C** | 0.125 | 0.166666667 | 1 |

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# Step 6:

**D. Pairwise Comparison Scale**

| Verbal Judgement of Preference | Numerical Rating |
|---|---|
| Extremely Preferred | 9 |
| Very strong to extremely | 8 |
| Very strongly preferred | 7 |
| Strongly to very strongly | 6 |
| Strongly preferred | 5 |
| Moderately to strongly | 4 |
| Moderately preferred | 3 |
| Equally to moderately | 2 |
| Equally preferred | 1 |

**F. Synthesizing Judgments**

| Comfort | Car A | Car B | Car C |
|---|---|---|---|
| **Car A** | 1 | 2 | 8 |
| **Car B** | 0.5 | 1 | 6 |
| **Car C** | 0.125 | 0.166666667 | 1 |
| | 1.625 | 3.166666667 | 15 |

Sum the columns in the pairwise comparison matrix.

# Step 7:

**F. Synthesizing Judgments**

| Comfort | Car A | Car B | Car C |
|---|---|---|---|
| **Car A** | 1 | 2 | 8 |
| **Car B** | 0.5 | 1 | 6 |
| **Car C** | 0.125 | 0.166666667 | 1 |
| | 1.625 | 3.166666667 | 15 |

Sum the columns in the pairwise comparison matrix.

| Comfort | Car A | Car B | Car C |
|---|---|---|---|
| Car A | 0.615 | 0.632 | 0.533 |
| Car B | 0.308 | 0.316 | 0.400 |
| Car C | 0.077 | 0.053 | 0.067 |
| | 1 | 1 | 1 |

Divide elements by the column totals.

This will normalise the weightings

# Step 8:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Priority Vector for Comfort** | | | | | | |
| | **Comfort** | **Car A** | **Car B** | **Car C** | | | |
| | **Car A** | 0.615 | 0.632 | 0.533 | 0.593 | | |
| | **Car B** | 0.308 | 0.316 | 0.400 | 0.341 | Average the rows. | |
| | **Car C** | 0.077 | 0.053 | 0.067 | 0.065 | | |
| | | | | | | | |
| **Car A** | 0.593 | | | | | | |
| **Car B** | 0.341 | The priority vector for the cars with respect to comfort. | | | | | |
| **Car C** | 0.065 | | | | | | |

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# Other Pairwise Comparisons

**D. Pairwise Comparison Scale**

| Verbal Judgement of Preference | Numerical Rating |
|---|---|
| Extremely Preferred | 9 |
| Very strong to extremely | 8 |
| Very strongly preferred | 7 |
| Strongly to very strongly | 6 |
| Strongly preferred | 5 |
| Moderately to strongly | 4 |
| Moderately preferred | 3 |
| Equally to moderately | 2 |
| Equally preferred | 1 |

## G. Other Pairwise Comparisons

| Price | Car A | Car B | Car C |
|---|---|---|---|
| **Car A** | 1 | 0.33 | 0.25 |
| **Car B** | 3 | 1 | 0.5 |
| **Car C** | 4 | 2 | 1 |

| MPG | Car A | Car B | Car C |
|---|---|---|---|
| **Car A** | 1 | 0.25 | 0.17 |
| **Car B** | 4 | 1 | 0.33 |
| **Car C** | 6 | 3 | 1 |

| Style | Car A | Car B | Car C |
|---|---|---|---|
| **Car A** | 1 | 0.33 | 4 |
| **Car B** | 3 | 1 | 7 |
| **Car C** | 0.25 | 0.14 | 1 |

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# Other Pairwise Comparisons

**G. Other Pairwise Comparisons**

| Price | Car A | Car B | Car C | Priority Vectors |
|---|---|---|---|---|
| **Car A** | 1 | 0.33 | 0.25 | 0.123 |
| **Car B** | 3 | 1 | 0.5 | 0.32 |
| **Car C** | 4 | 2 | 1 | 0.557 |

| MPG | Car A | Car B | Car C | |
|---|---|---|---|---|
| **Car A** | 1 | 0.25 | 0.17 | 0.087 |
| **Car B** | 4 | 1 | 0.33 | 0.274 |
| **Car C** | 6 | 3 | 1 | 0.639 |

| Style | Car A | Car B | Car C | |
|---|---|---|---|---|
| **Car A** | 1 | 0.33 | 4 | 0.265 |
| **Car B** | 3 | 1 | 7 | 0.655 |
| **Car C** | 0.25 | 0.14 | 1 | 0.08 |

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# Step 9:

**D. Pairwise Comparison Scale**

| Verbal Judgement of Preference | Numerical Rating |
|---|---|
| Extremely Preferred | 9 |
| Very strong to extremely | 8 |
| Very strongly preferred | 7 |
| Strongly to very strongly | 6 |
| Strongly preferred | 5 |
| Moderately to strongly | 4 |
| Moderately preferred | 3 |
| Equally to moderately | 2 |
| Equally preferred | 1 |

**H. Pairwise comparison matrix for the four criteria in the car selection problem.**

| Criterion | Price | MPG | Comfort | Style |
|---|---|---|---|---|
| **Price** | 1 | 3 | 2 | 2 |
| **MPG** | 0.333333333 | 1 | 0.25 | 0.25 |
| **Comfort** | 0.5 | 4 | 1 | 0.5 |
| **Style** | 0.5 | 4 | 2 | 1 |

**I. Priorities for the overall goal.**

| | |
|---|---|
| **Price** | 0.398 |
| **MPG** | 0.085 |
| **Comfort** | 0.218 |
| **Style** | 0.299 |

# Step 10:

**I. Priorities for the overall goal.**

| | |
|---|---|
| **Price** | 0.398 |
| **MPG** | 0.085 |
| **Comfort** | 0.218 |
| **Style** | 0.299 |

**J. Developing an overall priority ranking.**

| | **Criterion** | **Price** | **MPG** | **Comfort** | **Style** |
|---|---|---|---|---|---|
| | **Car A** | 0.123 | 0.087 | 0.593 | 0.265 |
| **Alternative** | **Car B** | 0.32 | 0.274 | 0.341 | 0.655 |
| | **Car C** | 0.557 | 0.639 | 0.065 | 0.08 |

**Overall car A priority** = 0.398(0.123) + 0.085(0.087) +0.218(0.593) + 0.299(0.265) =.265

**Overall car B priority** = 0.398(0.320) + 0.085(0.274) +0.218(0.341) + 0.299(0.655) =.421

**Overall car C priority** = 0.398(0.557) + 0.085(0.639) +0.218(0.066) + 0.299(0.080) =.314

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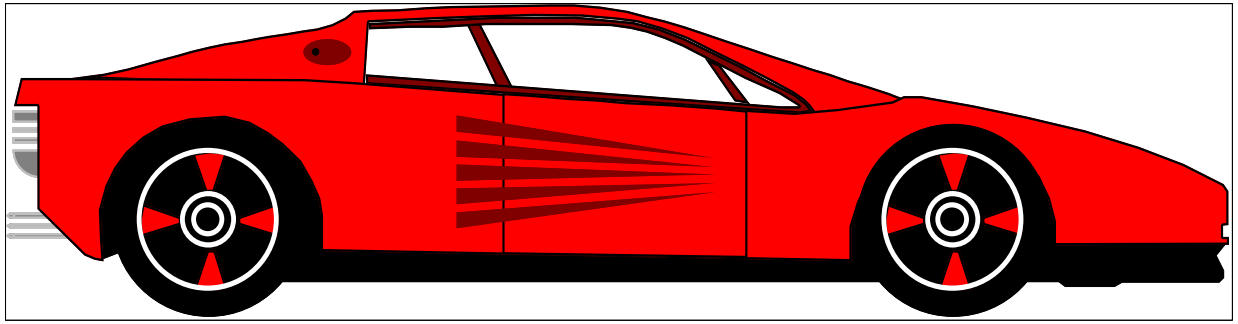
# Step 11:

**K. Final AHP Ranking of Alternatives**

| | |
|---|---|
| **Car B** | 0.421 |
| **Car C** | 0.314 |
| **Car A** | 0.265 |
| | 1 |



***Dr. LaCava's Mid-life Crisis Maserati!***

# The Analytic Hierarchy Process

- Developed by Professor T L Saaty
- https://expertchoice.com/
- http://www.superdecisions.com/

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# Decision-making in Healthcare

- Diagnosis
- Patient participation
- Therapy / treatment
- Organ transplantation
- Project and technology evaluation and selection
- Human resource planning
- Healthcare evaluation and policy

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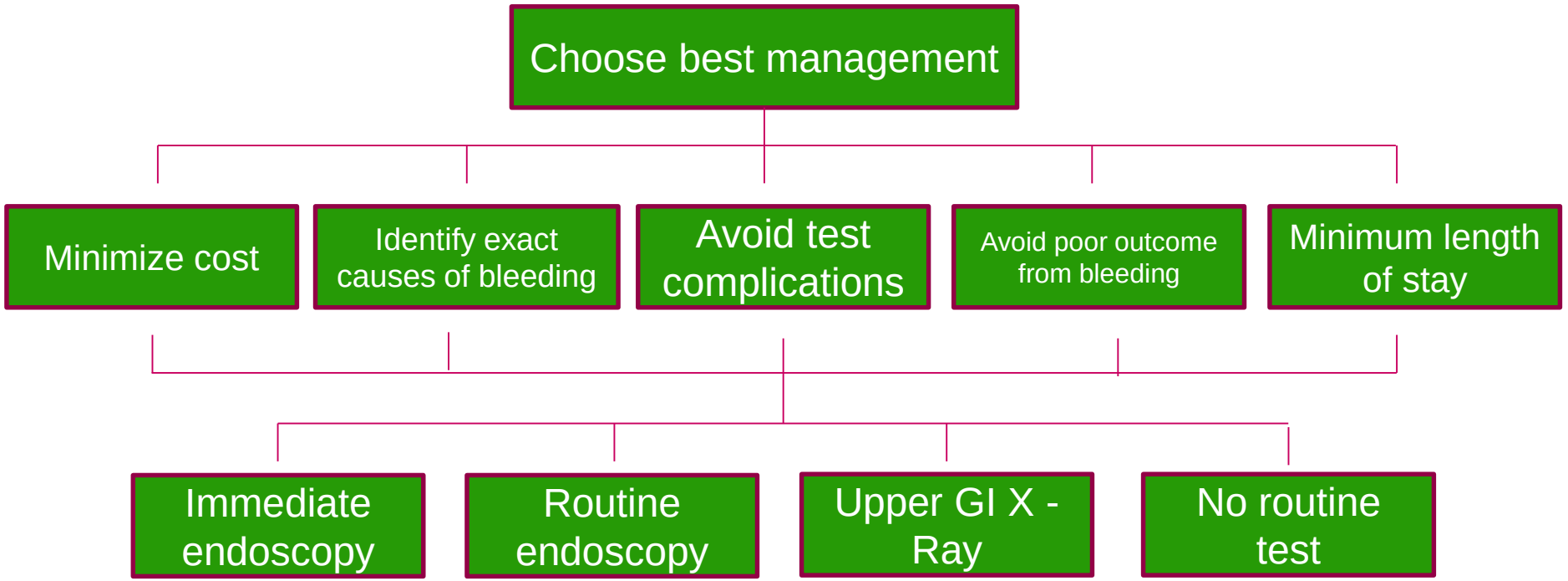
# Diagnosis




**Gastrointestinal bleeding diagnosis model**

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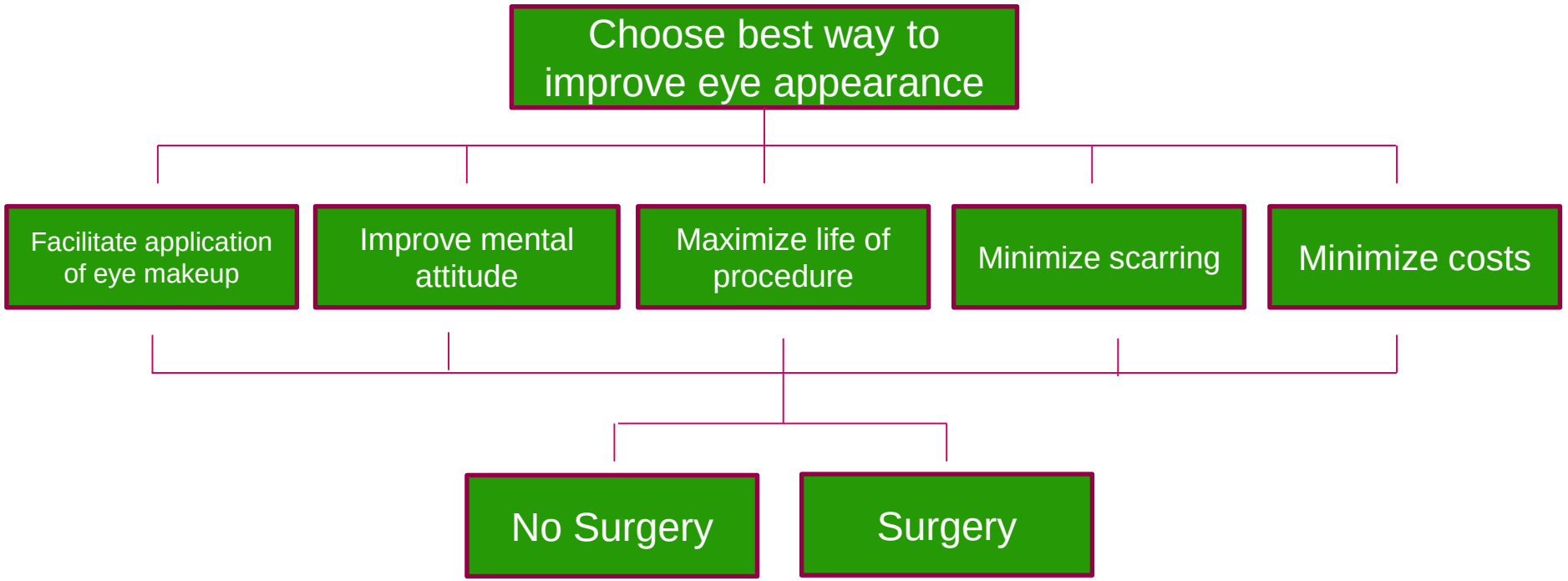
# Patient participation




**Cosmetic Surgery of the eyelid**

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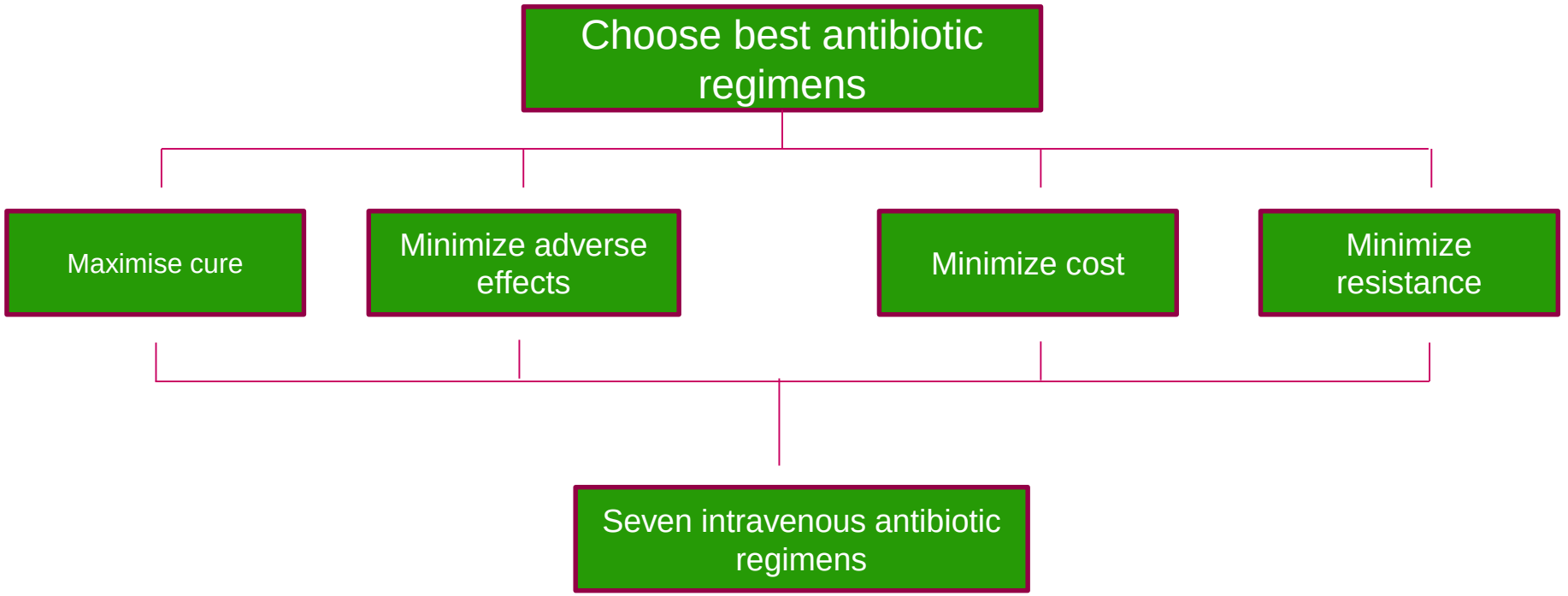
# Therapy / Treatment




**Treatment decision for dog bite wound**

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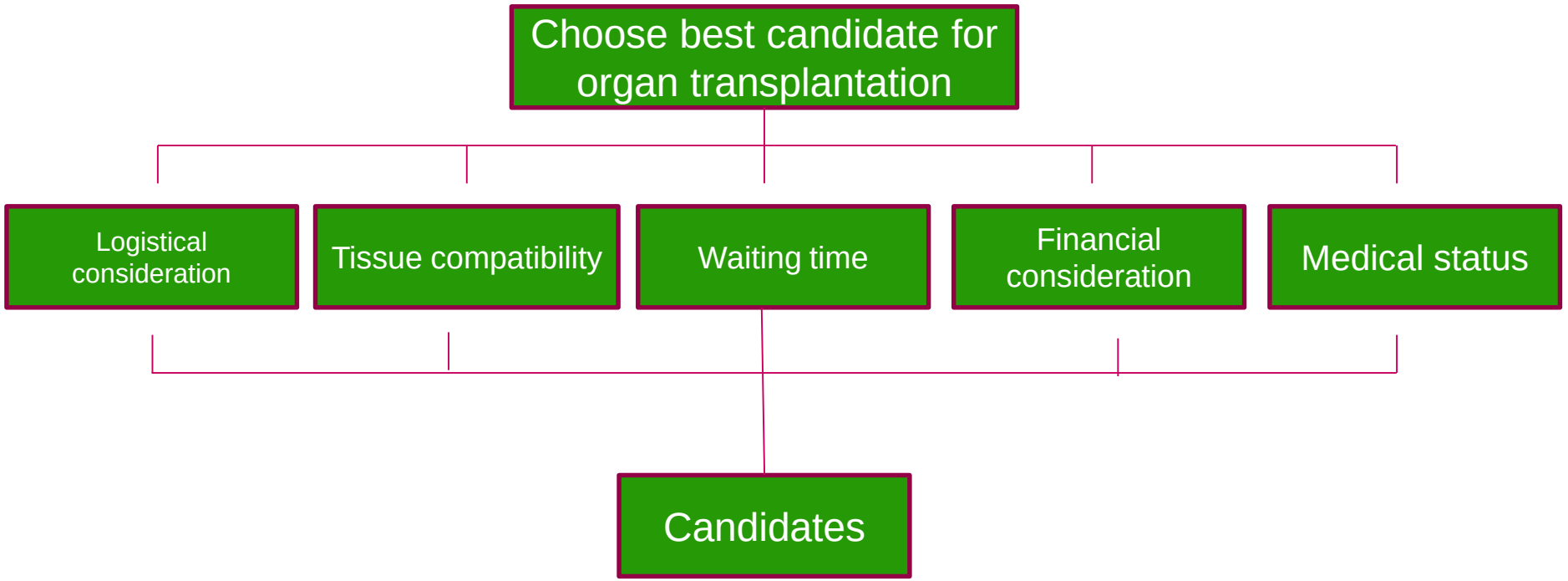
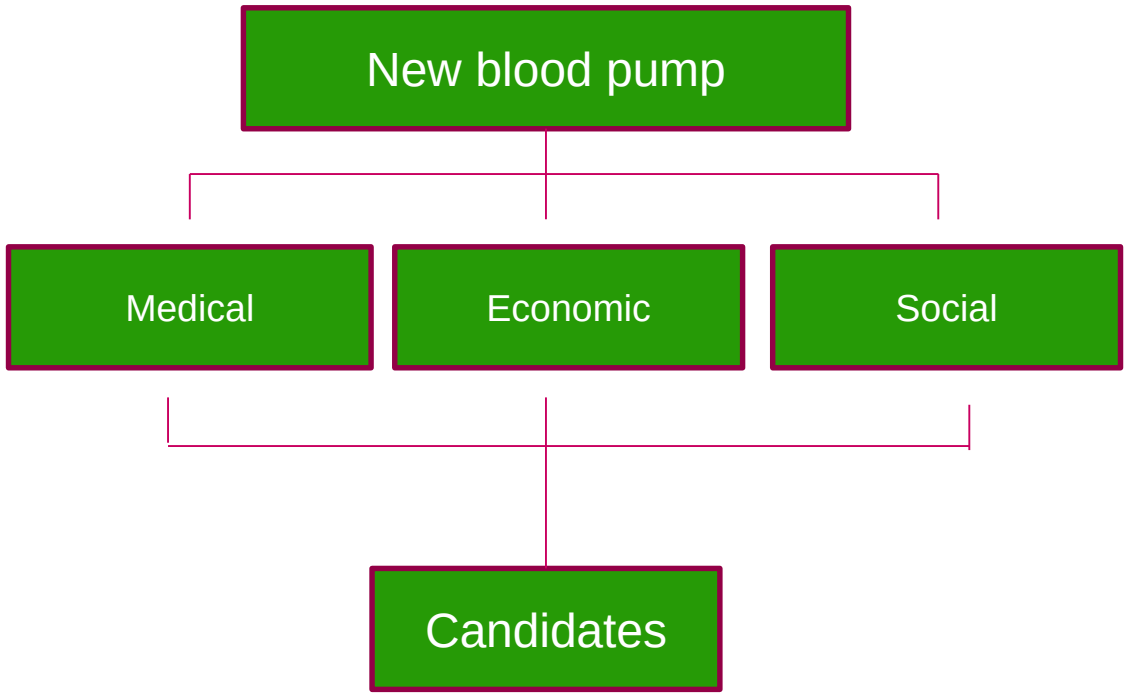
# Organ Transplantation



# Healthcare Technology Assessment



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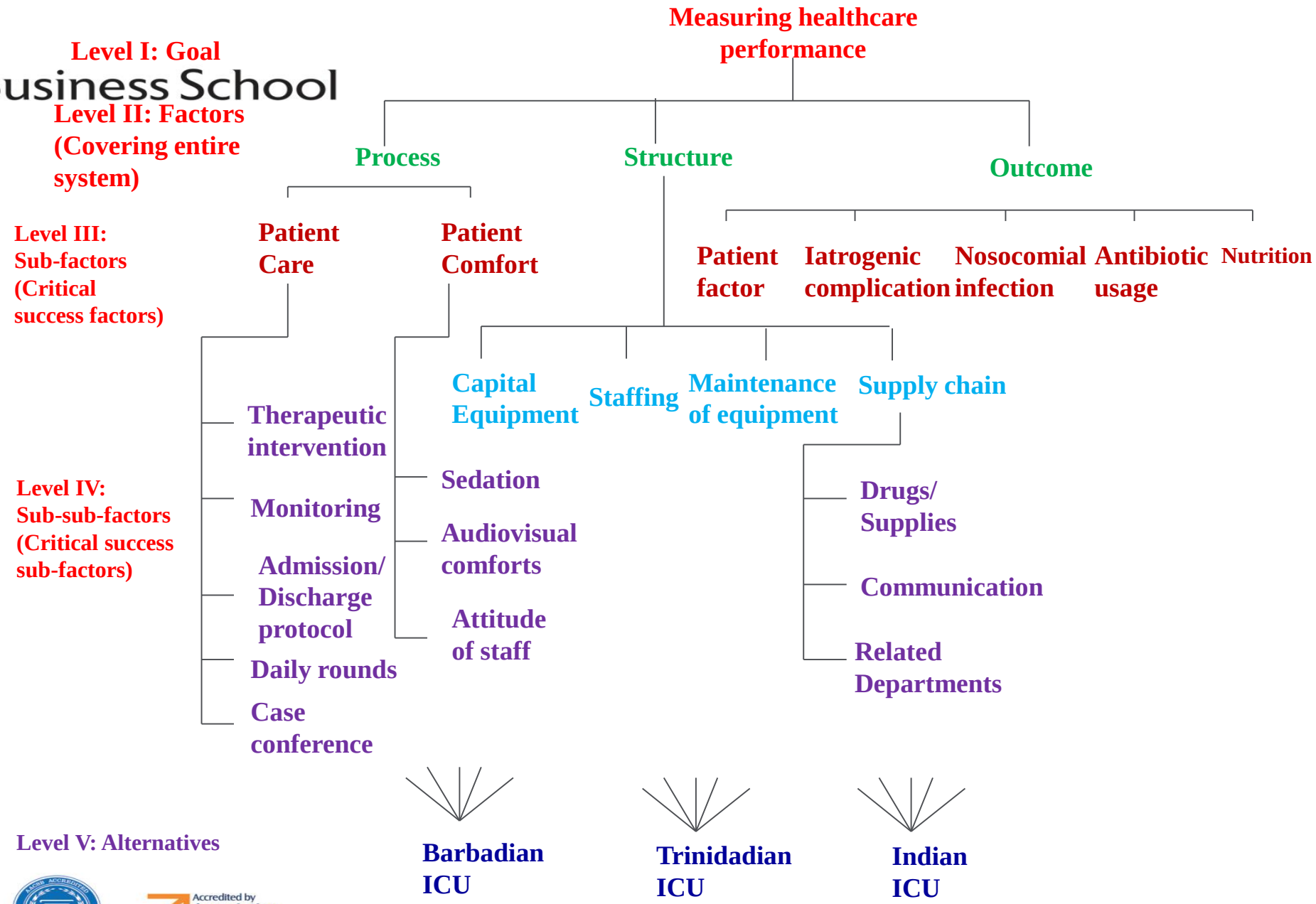



Performance measurement model for Intensive Care Units of hospitals in analytic hierarchy process framework

# Hands on session

- Consider one of the scenarios from the list and develop framework for decision-making using the AHP.

# Scenario 1

- Benchmarking pharmacy services
- What criteria, Key Performance Indicators (KPIs) might we consider using to measure the performance of Pharmacies? A high performing pharmacy will have the right balance between efficiency and responsiveness leading to end user patient satisfaction.
- Considering both efficiency and responsiveness criteria and form a performance measurement model using the AHP framework (i.e. hierarchy of criteria and alternatives)
- Consider how the performance of hospital pharmacies across a region might be compared, using the criteria and establish ranking of the various pharmacies along with improvement measures

# Scenario 2

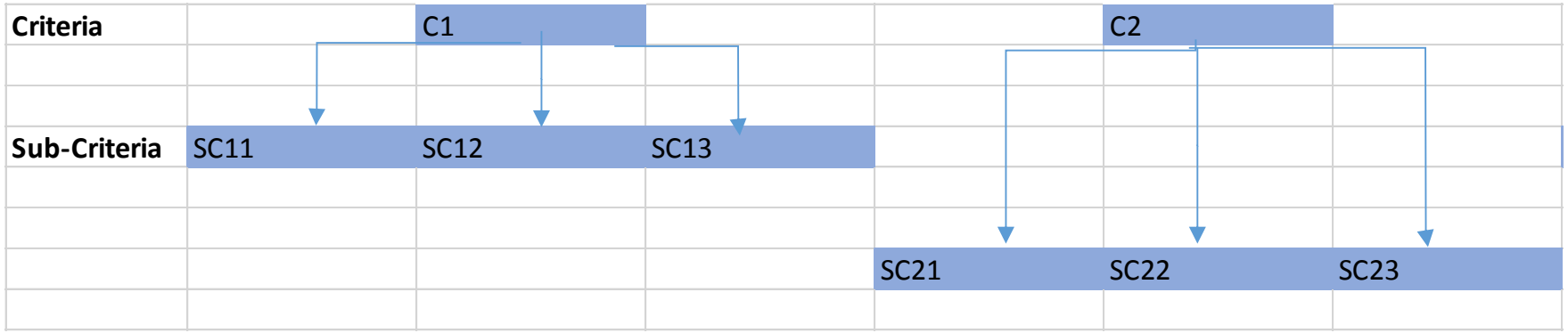
- Ranking of projects and budget allocation to enhance quality or performance
- Consider that the pharmacy concerned needs several improvement projects - Procuring robot to minimize picking errors; training pharmacists to enhance their productivity; Process improvement to enhance quality and reducing cost; enhancing effectiveness of communication through advanced IT tools etc.
- Prioritise these projects with the consideration of multiple criteria that are likely to have varied importance to the stakeholders
- Use the AHP to rank the projects and allocate budget

# Scenario 3

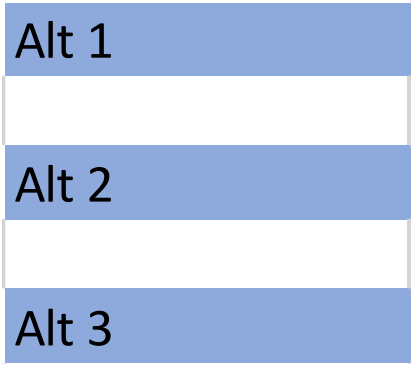
- Performance appraisal of pharmacists to enhance quality of pharmacy operations
- Identify pharmacists' attributes (e.g. technical and/or clinical experience, managerial experience, personal ability, competencies, empathy, Outputs, etc.) that contribute pharmacy performance.
- Develop a performance appraisal model using the Analytic Hierarchy Process (AHP) that enables to measure individual performance of pharmacist and enhance their quality
- Use the proposed model to measure the performance of the pharmacists

# Create Decision Model

- Identify Criteria (4 for the exercise)
  - In the car example, this would be Price, MPG, Comfort
- Identify sub-criteria for each criteria (3 for each criteria)




- Identify 3 (4?) alternatives
  - Define the Alternatives (what options are you choosing from)
    - In the car example, these would be Car A, B and C
  - Identify the characteristics of each one of these alternatives



# Create model

- Carry out Pairwise comparison between Criteria. This will give you the relative importance of each criteria

| 2. Pairwise comparison in criteria level | | | | |
|---|---|---|---|---|
| | | | | |
| | C1 | C2 | C3 | C4 |
| C1 | 1 | | | |
| C2 | #VALUE! | 1 | | |
| C3 | #VALUE! | #VALUE! | 1 | |
| C4 | #VALUE! | #VALUE! | #VALUE! | 1 |

- And Between Sub-criteria. This will give you the weightings for each sub-criteria

| 3. Pairwise comparison in subcriteria level | | | |
|---|---|---|---|
| | SC11 | SC12 | SC13 |
| SC11 | 1 | | |
| SC12 | #VALUE! | 1 | |
| SC13 | #VALUE! | #VALUE! | 1 |

- And between alternatives for each Sub-criteria

| Subcriteria | SC11 | | |
|---|---|---|---|
| | | | |
| | Alt 1 | Alt 2 | Alt 3 |
| Alt 1 | 1 | | |
| Alt 2 | #VALUE! | 1 | |
| Alt 3 | #VALUE! | #VALUE! | 1 |

# Sensitivity Analysis

- What happens if you change those preferences?
- Will the selection be the same?
- Play with the numbers and explore

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# Decision-making in Healthcare using the Analytic Hierarchy Process

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