

ECE 215/S – Principles of Electronic Cyber Warfare

Block 1: Resistive Circuits and Power Distribution

Lesson 11: Decision Matrices

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Objective 1.8

I can use a decision matrix to quantitatively compare various measures of merit.

- This is the objective that turns your analysis into a **recommendation**
- It is **not** on a quiz — it is assessed directly in **Project 1, Part 2**
- The habit generalizes: any time you must choose between designs, this is the artifact that makes the choice reviewable

Where We Are Going

By the end of this lesson, you will be able to:

- Identify appropriate **measures of merit** for an engineering choice
- **Normalize** measures that have different units and different directions of “good”
- Turn a customer’s stated priorities into **weights** that sum to 1.0
- Compute final scores and **defend** the resulting recommendation

The Problem: No Option Wins on Everything

You have finished the analysis. Now someone asks which power supply to buy.

- Option A is the most efficient — and the most expensive
- Option B is the lightest — and the least efficient
- Option C is the cheapest — and the heaviest

There is no “correct” answer hiding in the physics. The choice depends on **what the customer values** — and your job is to make that reasoning explicit and reviewable.

A decision matrix does not make the decision.
It makes the reasoning auditable.

Step 1: Identify the Measures of Merit

A **measure of merit** is a quantity you can actually put a number on.

- Good: efficiency (%), mass (kg), unit cost ($), volume ($m^3$), **MTBF** — mean time between failures (hr)
- Bad: “reliability,” “quality,” “how modern it looks” — not measurable as stated
- Pick **3 to 6**. Fewer and the decision is trivial; more and the weights become noise
- Each measure must be one you can obtain for *every* option

If you cannot say how you would measure it, it is not a measure of merit.

Step 2: Normalization

The measures have different units, so you cannot add them. Normalize each to a 0–1 scale first.

Bigger is better (efficiency, MTBF):

$$x_{\text{norm}} = \frac{x}{x_{\max}}$$

Smaller is better (cost, mass):

$$x_{\text{norm}} = \frac{x_{\min}}{x}$$

- Either way, the best option in that column scores **1.0** and everything else is a fraction of it
- **Getting the direction backward is the most common error** — and it silently produces a confident, wrong recommendation

Normalization in Action

The three power supplies from the last frame, before normalization:

	Efficiency (%)	Mass (kg)	Cost ($)
Option A	96	2.4	1500
Option B	80	2.0	1000
Option C	88	3.2	800

After normalization — efficiency is bigger-is-better; mass and cost are smaller-is-better:

	Efficiency	Mass	Cost
Option A	$96/96 = 1.000$	$2.0/2.4 = 0.833$	$800/1500 = 0.533$
Option B	$80/96 = 0.833$	$2.0/2.0 = 1.000$	$800/1000 = 0.800$
Option C	$88/96 = 0.917$	$2.0/3.2 = 0.625$	$800/800 = 1.000$

Step 3: Weighting

Not every measure matters equally. Assign weights that **sum to 1.0**.

- Weights encode the **customer's priorities**, not yours
- A satellite program weights mass heavily; a ground installation barely weights it at all. Here that is B winning instead of C — same data, different answer, both correct
- On Project 1 the weights are **given** by the solicitation — apply them exactly. In practice *you* choose them, and a reviewer challenges that first

Choosing the weights *is* the engineering judgment.
Everything else is arithmetic.

From Stated Preferences to Weights

Customers state **ratios**, not weights. Converting is the one computation Project 1 requires:

1. Write the stated preference as a ratio of whole numbers
2. Add the parts
3. Divide each part by that sum — the weights now total 1.0

Project 1: cost weighted $2\times$ efficiency, efficiency $2\times$ volume.

cost : efficiency : volume $= 4 : 2 : 1$,
sum $= 7$

$w = 4/7,\ 2/7,\ 1/7 = 0.571,\ 0.286,\ 0.143$

PP10: payload and programming ease are equal, each worth twice cost or flight time.

cost : payload : ease : flight $= 1 : 2 : 2 : 1$,
sum $= 6$

$w = 1/6,\ 1/3,\ 1/3,\ 1/6$
$= 0.167,\ 0.333,\ 0.333,\ 0.167$

Such ratios come from a **pair-wise comparison**: which matters more, and by how much.

Steps 4 and 5: Score and Select

Multiply each normalized value by its weight and sum across the row:

$$\text{Score}_i = \sum_j w_j \cdot x_{ij,\text{norm}}$$

	Eff. (0.5)	**Mass** (0.2)	**Cost** (0.3)	**Score**	**Rank**
Option A	1.000	0.833	0.533	0.827	3
Option B	0.833	1.000	0.800	0.857	2
Option C	0.917	0.625	1.000	$\mathbf{0.883}$	**1**

Option C wins — and it is the *heaviest* of the three. Option A is best on efficiency, the most heavily weighted measure, and still finishes *last*. Margin of C over B: $0.883 - 0.857 = 0.026$.

Reporting the Result Honestly

State the **recommendation**, its **score**, and the **margin** — then move weight between the measures and see whether the winner holds.

Weights (eff / mass / cost)	A	B	C	Winner
$0.5/0.2/0.3$ — as given	0.827	0.857	0.883	**C**
$0.7/0.2/0.1$ — efficiency first	0.920	0.863	0.867	**A**
$0.3/0.5/0.2$ — mass first	0.823	0.910	0.788	**B**

Three defensible weightings, three different winners — and C led B by only 0.026, about 3%. This recommendation does **not** survive: say so, and name the weight the answer turns on.

A recommendation that survives a change of weights is worth defending.

The Method

1. **Identify** 3 to 6 measures of merit — each one a number you can obtain for every option
2. **Normalize** every column: $x/x_{\max}$ where bigger is better, $x_{\min}/x$ where smaller is better
3. **Weight** the measures. Divide each part of the customer's stated ratio by the sum of the parts, so the weights total 1.0
4. **Score** each option: multiply every normalized value by its weight, then sum across the row
5. **Select and report**: highest score wins. State the margin, move weight between measures, and report whether the winner held

Your Turn: Class Competition

Your team must pick a power supply for a **small UAV**.

	Efficiency (%)	Mass (g)	Cost ($)	MTBF (hr)
Option A	96	340	220	4000
Option B	89	180	145	2500
Option C	92	250	310	6000

1. Normalize all four columns. Watch the direction on each
2. State your mission as a ratio, convert it to weights, and justify each one in a sentence
3. Compute the scores and pick a winner
4. Move 0.10 of weight from one measure to another — the weights still sum to 1.0. Does the winner change, and what does that tell you?

Wrap-Up

Key ideas:

- A decision matrix makes a multi-criteria choice **explicit and auditable**
- **Normalize** before combining: $x/x_{\max}$ when bigger is better, $x_{\min}/x$ when smaller is better
- A stated ratio becomes **weights** by dividing each part by the sum of the parts — they must total 1.0
- Report the margin, and check whether the winner survives a change in weights

Next lesson:

- **Lesson 12 — Block Wrap-Up and Project 1 Kickoff. Project 1** assesses this objective
- Project 1 **Submission 1** is due **Mon 14 Sep, 2359**
- **Quiz 3** (Objectives 1.6–1.7) is due **Mon 21 Sep, 2359**