# Lecture #40

# ERDM

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# Decision-Making

**The flavor of decision-making we have been discussing**

- **Largely focused on situation where some mathematics / rigor can be applied to the problem**
- **Emphasis is on one person coming up with an answer**
- **For situations where more than one person is involved or objectives / constraints less well defined -- see the social scientists!**

# Linear Programming -- Steps

1. **Identify the objective function: Again, what do we want to minimize or maximize?**

   **Let's say we want to maximize the profit, P, associated with new and remanufactured products**
   **Max: P = 10*N + 5R**

2. **What are the constraints?**
   **Raw matl.: 4N + 1R ≤ 200**
   **Energy: 6N + 4R ≤ 360**
   **Logistics: 2N + 3R ≤ 240**
   **Non-negativity: Both N and R ≥ 0**

# LP & Additional Comments

- **Linear programming requires linear (or at least linearizable) objective function AND constraints.**
- **Non-linear programming**
  - **Beyond scope of course**
  - **Look for computer code to help (e.g., MATLAB)**
  - **Geometric programming is a special case**
- **We've talked about Integer Programming?!? Exact solutions for general case are VERY difficult.**
- **Dynamic programming: very cool - no time to discuss**

# Multiple Criteria Decision Making

**Examples:**

- **Multiple Objectives (need models for these):**

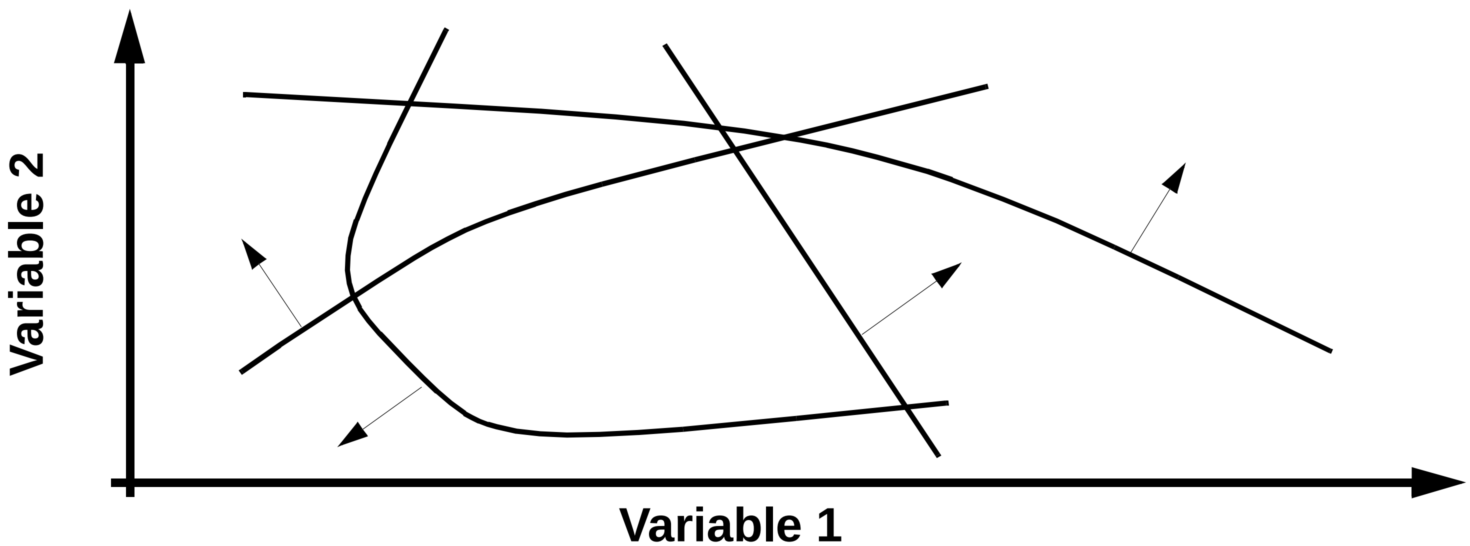
  **Minimize: Cost, materials, energy, waste, time**

  **Maximize: Product function, service life, potential for reuse/remanufacture/recycle, modularity**

- **Constraints (need models for these as well): ????**

# Multi-Criteria Optimization

- **Let's say we have several performance measures or objectives that we wish to simultaneously optimize:** $z_1, z_2, \ldots, z_m$



# Multi-Criteria Optimization (cont.)

- **As we might expect, the objectives are conflicting. What to do???**

  **One approach: use a weighted objective:**

  $$Y = W_1 Z_1 + W_2 Z_2 + \ldots$$

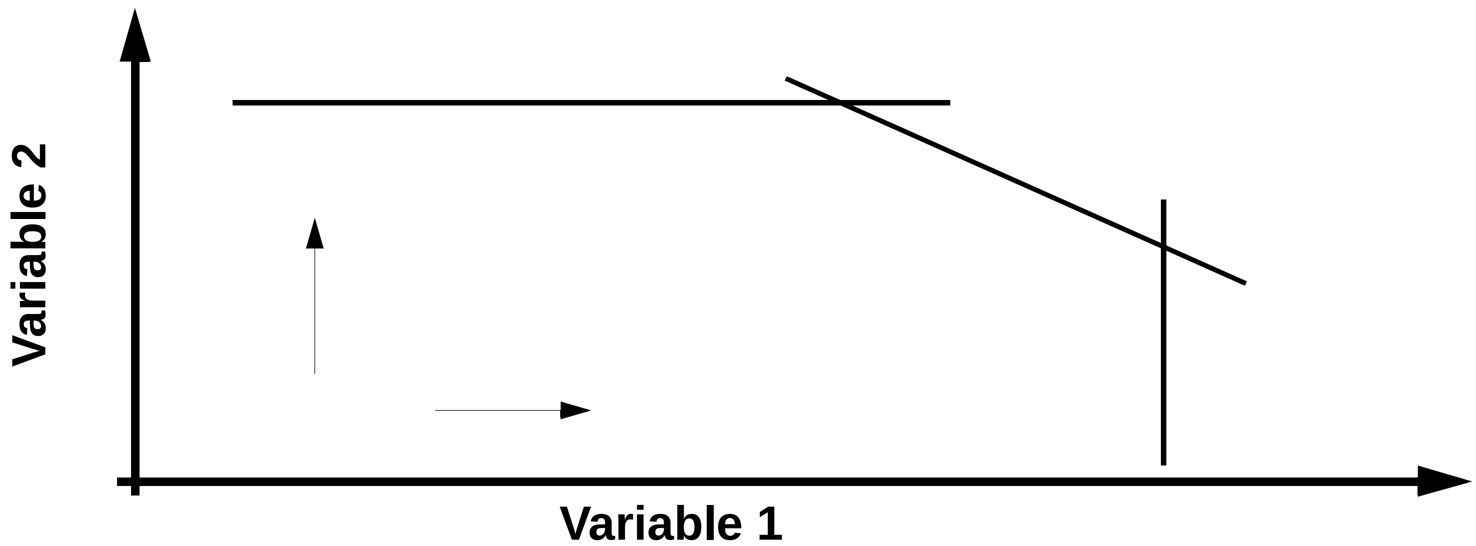
  **Weights put different importance on the performance measure and place diverse metrics on equal footing. Objectives must be consistent (e.g., Max).**

  **Optimize Y!! Subject, of course, to the constraints on the design variables.**

# Multi-Criteria Optimization (cont.)

**Other ideas:**

- **Goal programming**
- **Non-dominated sets**



# Selecting Weights

- **The weighted objective approach seems promising. How do we pick the weights??** $W_1, W_2, \ldots, W_m$**.**

- **If all the objectives are somehow converted into the same units (say dollars or eco-dollars) this may help. But, this does not address the problem that we may value some objectives more than others, e.g., product cost vs. energy cost.**

- **Saaty (1990) in his text, *The Analytic Hierarchy Process*, proposes the use of a <u>Pairwise Comparison Approach</u> to obtain the weights.**

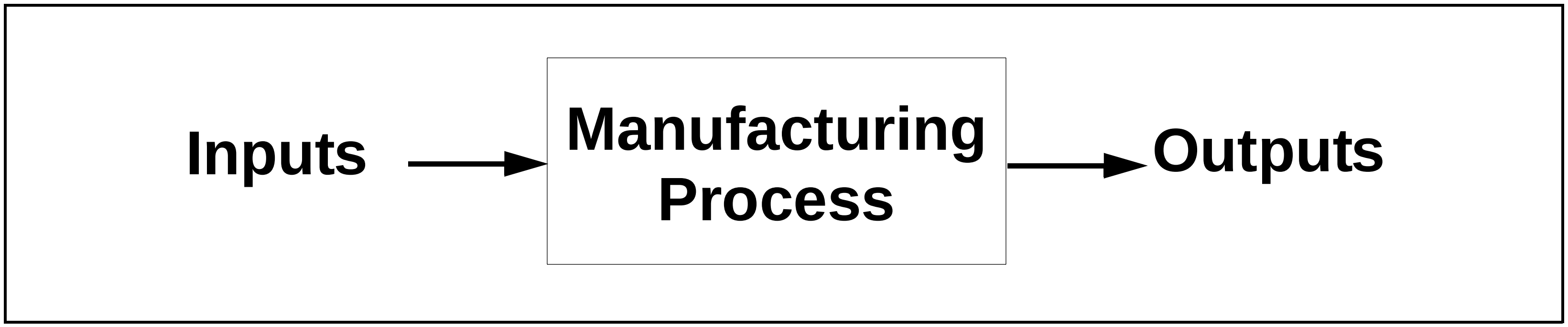
# Manufacturing Decision-Making

- **Operations planning**
  **Focus on a single operation on a single part (machine settings, tool geometry, etc.)**

- **Process planning**
  **Focus on the manufacture of a single product (process selection, process sequencing, etc.)**

- **Production planning**
  **Focus on whole manufacturing facility (job sequencing, inventory decisions, facility planning, etc.)**

# Operations Planning Problem



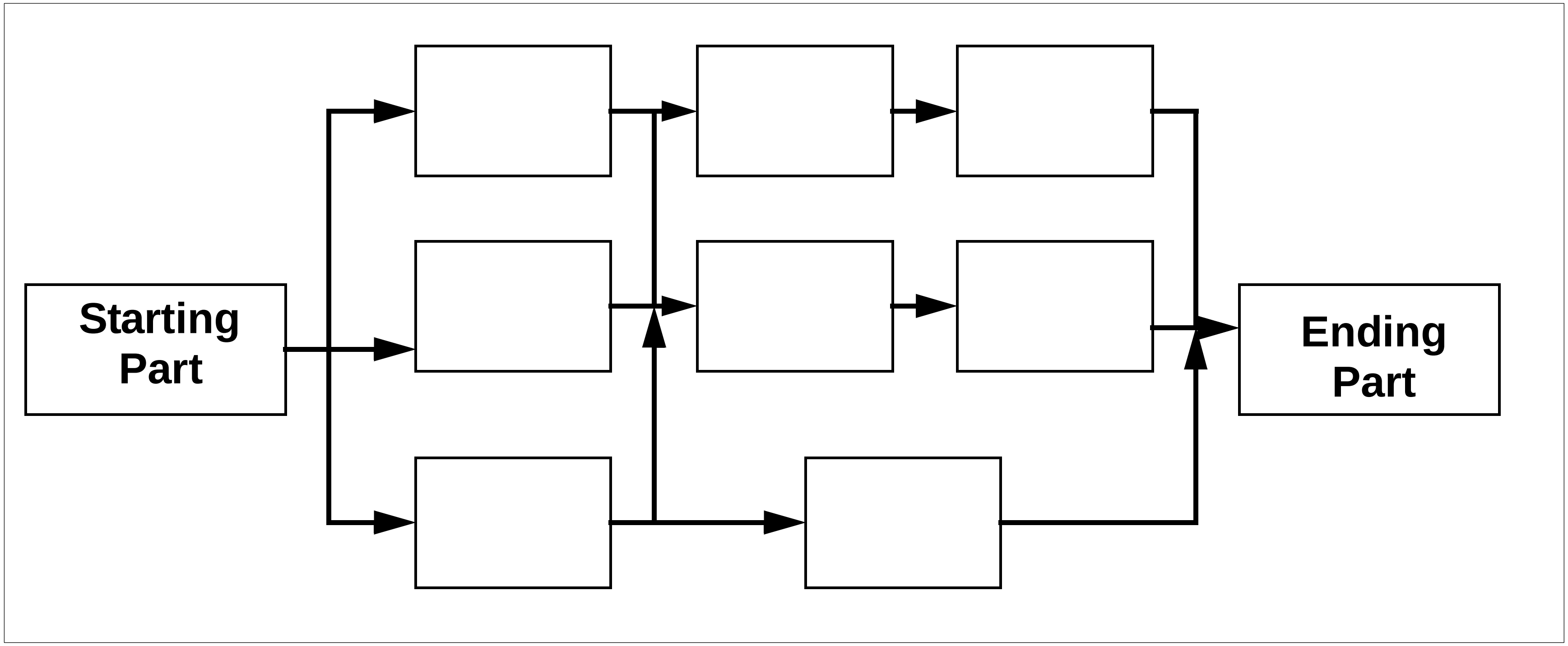

**What settings for the process inputs (machine settings, tooling, fixturing, process configuration) provide the desired levels of process outputs (product characteristics: dimensions, finish, micro-structure; operation cost, operation time, waste stream flow rates and character) - How??**

# Production Planning Problem

- **Job shop: Many jobs to be completed. When should each job begin (scheduling problem)? In what order should the jobs be sequenced? Is the sequence the same for each machine? Inventory handling. Many heuristic algorithms available for decision-making.**

- **Flow shop: High production rate facility. Designed for just a few jobs. Scheduling and sequencing less important. Inventory decisions important. Most critical is the layout of the production facility -- relative positions of stations and material handling/ transport device configurations. Simulation.**

# Process Planning Problem




**What sequence of processes should be performed to transform the raw part into the finished part.**

# Planning Problems

**Many of the planning decisions are dependent on product design characteristics: production quantity, material, design features, etc.**

**Process plans (the process steps to make a part) are dependent on the operation plans (how each process is performed).**

**Since the performance of a process may be very dependent on the processes that preceded it -- operation plans are dependent on the process plan**

# Planning Problems (cont.)

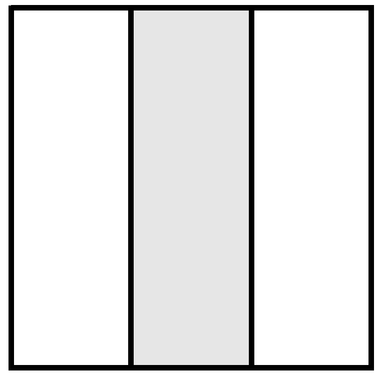
**Production plans (the plant-wide decisions) are dependent on the process plans.**

**In determining operation, process, and production plans, EHS factors should be considered.**

**The interrelated nature of operation - process - production plans makes it difficult to achieve a global optimum.**

**More common - make best decision we can at each planning level (operation - process - production).**

# Process Planning Example



**Desire to create a hole in a part**

| Plan A | Plan B | Plan C |
|---|---|---|
| Drill | Center Drill<br>Bore | EDM |

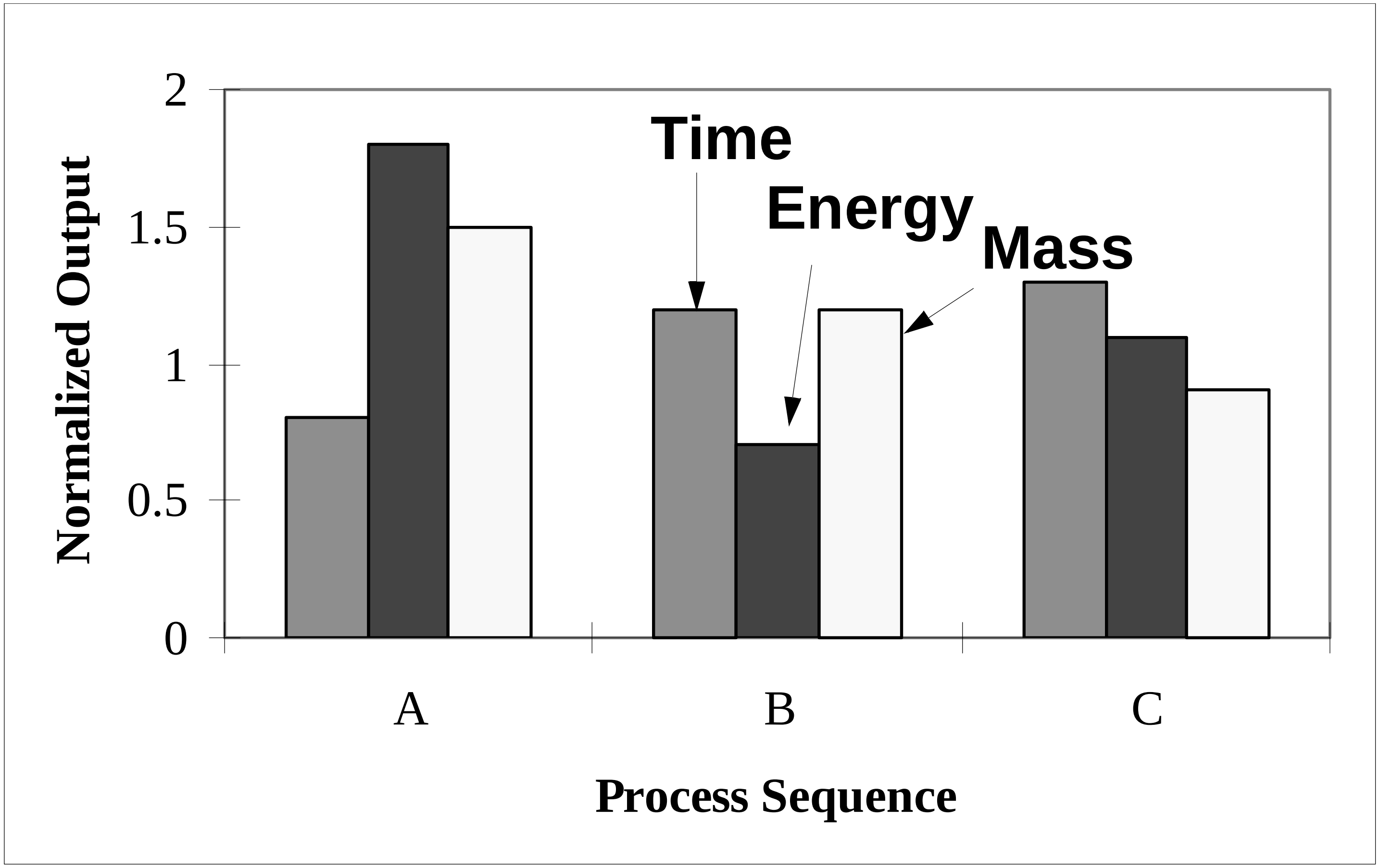
# Example (cont.)

**In deciding which operations (or set of operations) to perform, what do we need to know??**

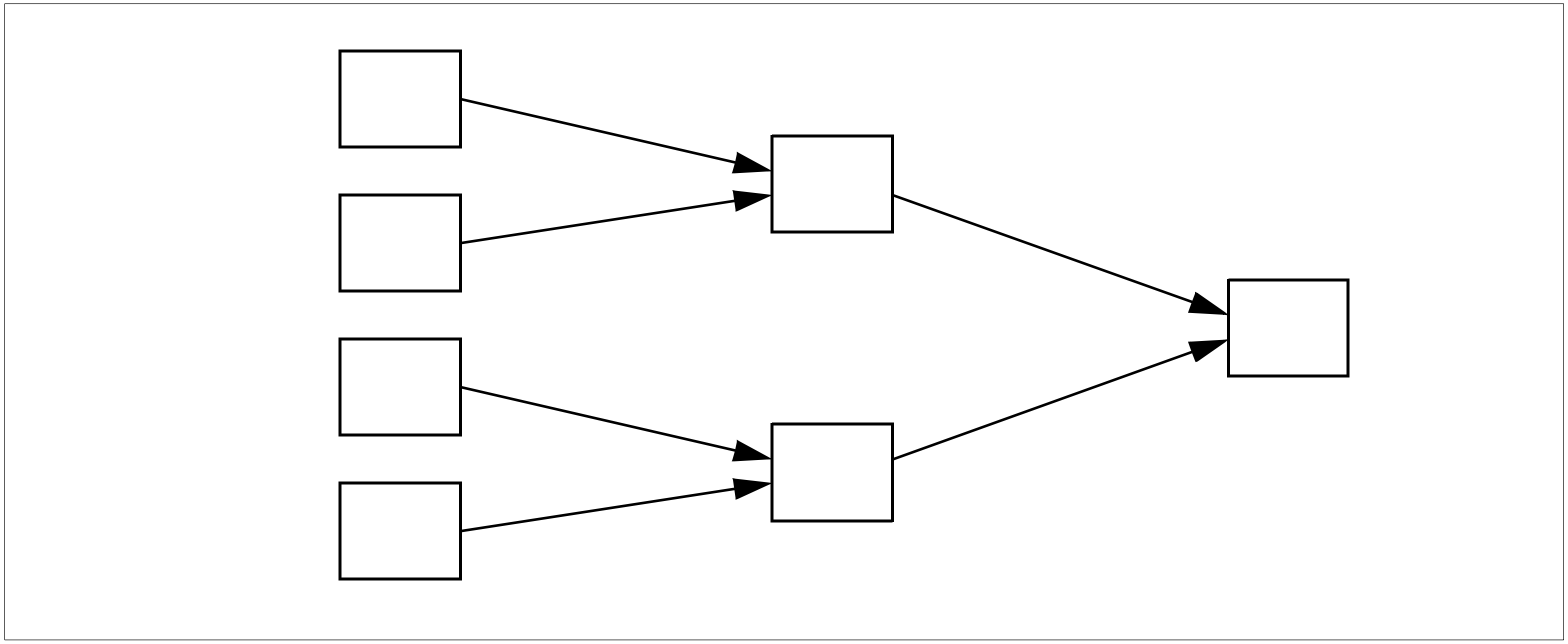
- **The time for each process sequence**
- **The cost for each sequence**
- **Product related characteristics for each sequence (dimensions, finish, microstructure, etc.)**
- **Waste stream generation rate and character - perhaps can use health hazard score to represent this**

**We need models to predict these measures.**
**Also faced w/ multi-criteria decision-making problem.**

# Example (cont.)

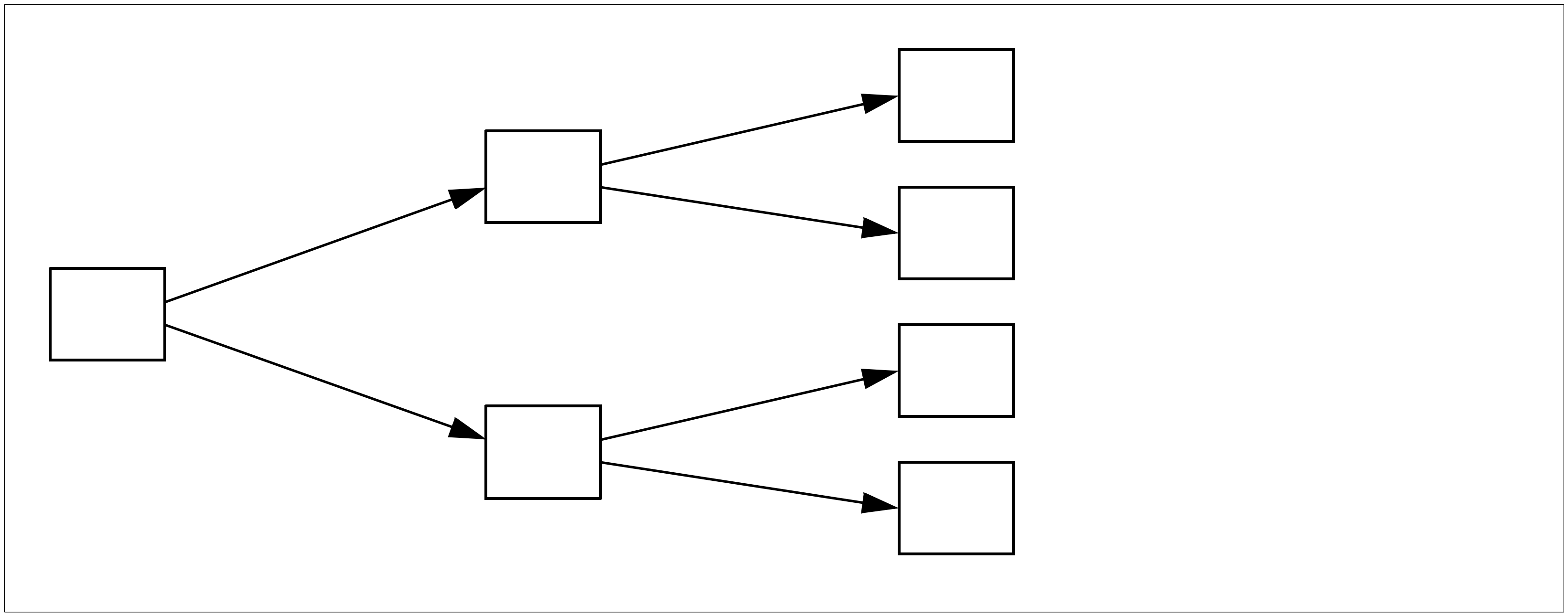


# Process Plan



**The process steps to produce the product (shown above) may include assembly steps. Note that every product is made the same way.**

# Demanufacturing Process Plan



**The process steps to demanufacture the product may include inspection steps. An inspection step may suggest different process plans.**

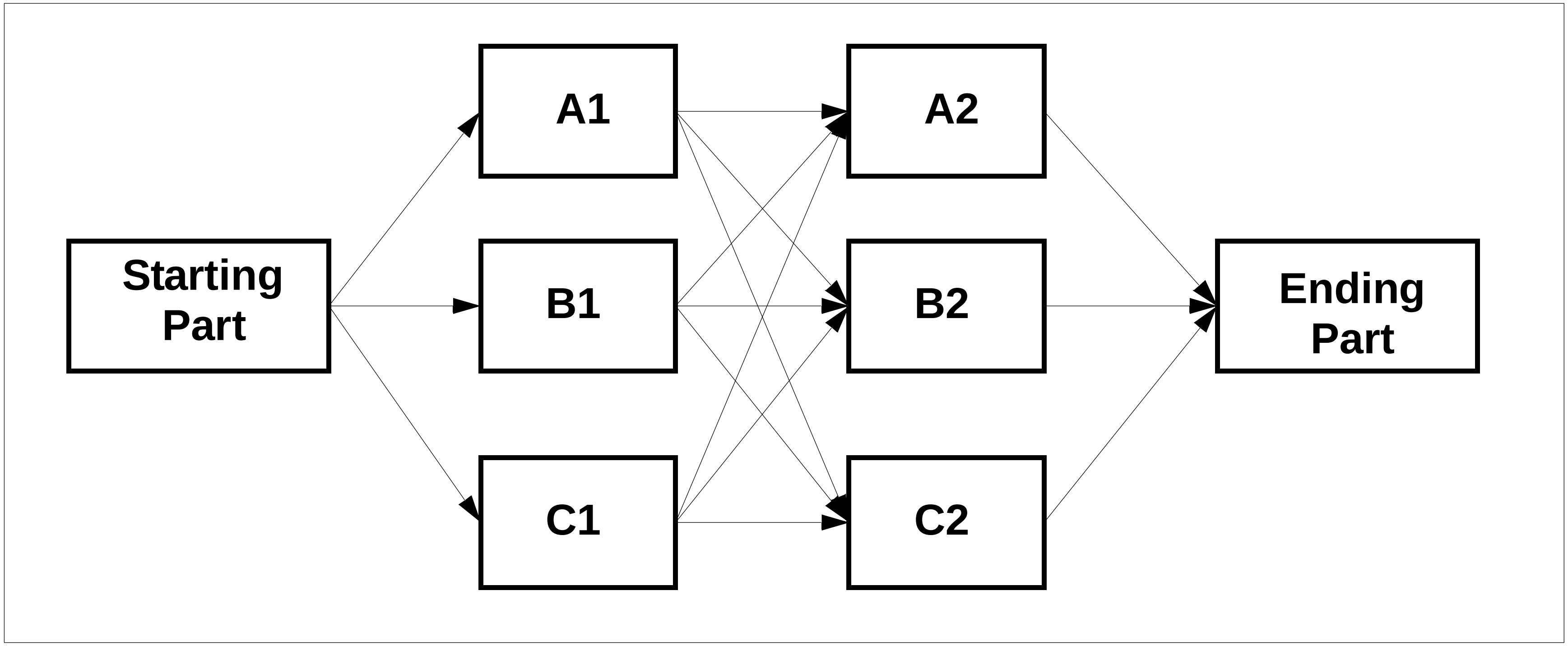
# Process Planning Summary

- **Identify alternative methods (process sequences) for producing a given product. Keep in mind that the sequences need not contain the same number of steps.**

- **Evaluate each process sequence in terms of the measures of interest.**

- **Select the desired process sequence using multi-criteria decision-making techniques**

# Process Planning Complexity




**Three alternatives at each step in the sequence -- each sequence consists of two steps.**

# Complexity (cont.)

**If (as indicated) the process alternatives may be interchanged -- the number of possible sequences grows very quickly.**

**A1-A2, A1-B2, A1-C2, B1-A2, B1-B2, B1-C2, C1-A2, C1-B2, C1-C2**

$$N = n^m$$

**where, N is the number of sequences, n is the number of alternatives, m is the number of steps**

# Complexity (cont.)

**Alternatively, the number of sequences may be expressed as**

$$N = \prod_{i = 1, m} n_i$$

**where, m is the number of process steps and n is the number of process alternatives per step**

**For m = 2 and n = 3, we have N = 9**

**For m = 10 and n = 5, N = 10,000,000**

# Complexity Solution

**Since the number of possible sequences is so large, what do we do??**

**Integer Programming?? Genetic Optimization??**

**Generative Process Planning: Creating a process plan from first principles. Perhaps can employ KBS.**

**Variant Process Planning: Work with an existing process plan - seek modifications that improve the plan.**