Minimizing Cost and Environmental Impact of Product Manufacture

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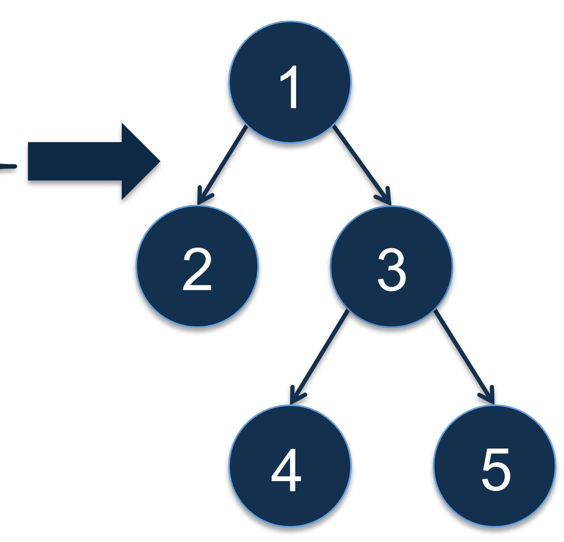
Introduction

- There are many options for manufacturing a part. Process planners must choose among numerous manufacturing processes, machine tools, cutting tools and process parameters.
- How do you optimize for lowest cost and environmental impact?

Process Planning Decisions	Constraints
1.) Manufacturing Process	Workpiece Shape Feature Shape Feature Tolerance Surface Roughness
2.) Machine Tool	Workpiece Size Feature Tolerance Surface Roughness
3.) Cutting Tools & Process Parameters	Feature Size Feature Tolerance Surface Roughness

Part's Precedence Diagram

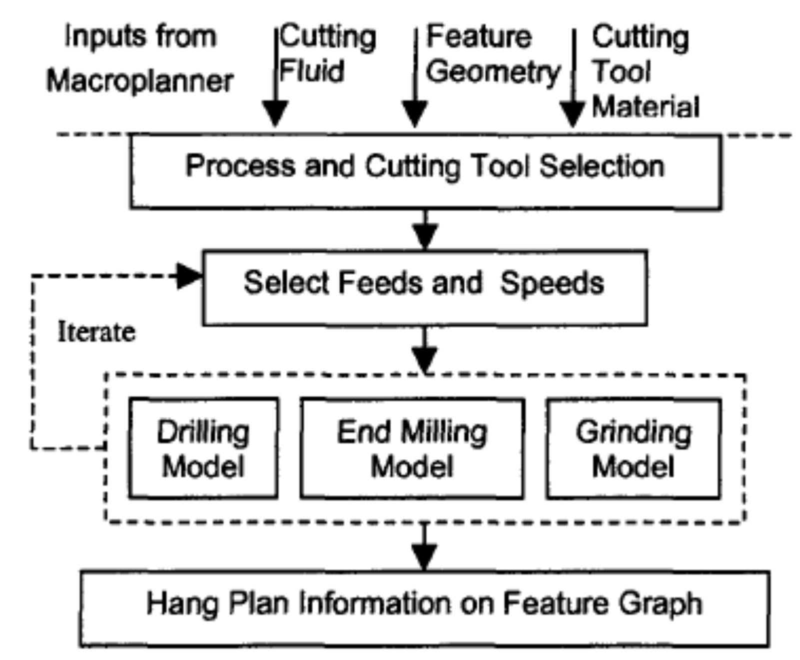


Background and Project Objective

- Previous work has focused on *process* planning strategies for reduction of environmental impact
  - Process planning system [1]
  - Environmental burden calculator of machining [2]
- Parts typically require a range of manufacturing processes, so available facility resources should be accounted for
- Project objective:

  minimize cost and environmental impact at the facility level

Environmental Process Planning System from [1]



[1] Krishnan, et. al., (2000), Environmental versus conventional planning for machined components

[2] Narita, et. al., (2008), Analysis of environmental impact due to machining operation

Manufacturing Cost

- Metrics:
  - Machining cost
    - Purchase cost amortized over lifetime of machine tool
    - Labor rate of operator
    - Cost of consumables (tooling, coolant, water, etc.)
    - Maintenance cost (lubricating oil)
  - Inventory cost
  - Cost to transfer part between machining stations
- Total Manufacturing Cost

$$C_{Total} = \sum_{i=1}^{n} (C_{M_i}) + C_I + C_T$$

Manufacturing Process Environmental Impact

- Metrics:
  - Process energy consumption
  - Green House Gas (GHG) emissions
- Specific energy for the *ith* process

$$e_i = a_i * \frac{1}{MRR_i} + b_i$$

- Energy for *ith* process

$$E_i = e_i * V_i$$

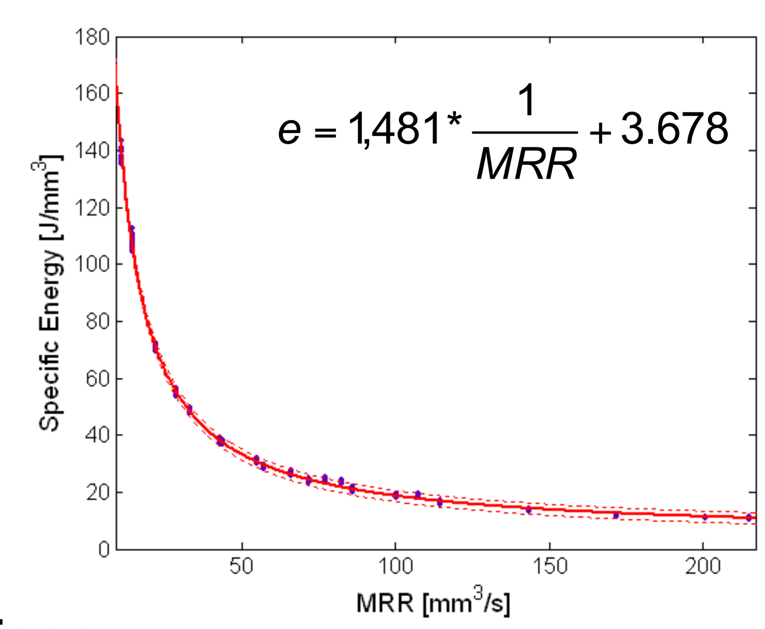
- Total energy for part production

$$E_{process} = \sum_{i=1}^{n} E_i$$

- Green House Gas (GHG) emissions

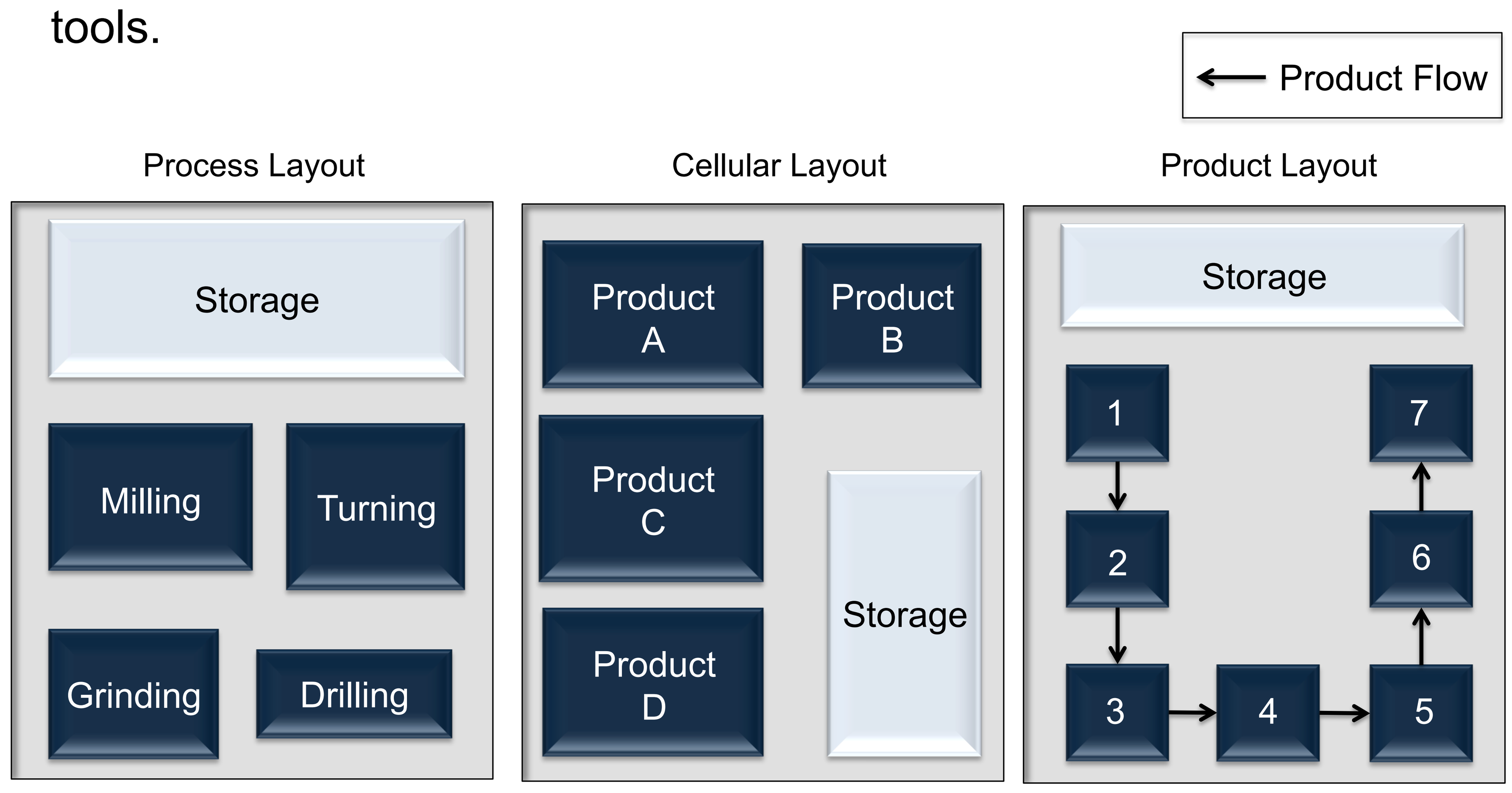
$$G_{process} = c_{GHG} * E_{process}$$

Specific Energy of Mori Seiki NV1500 DCG



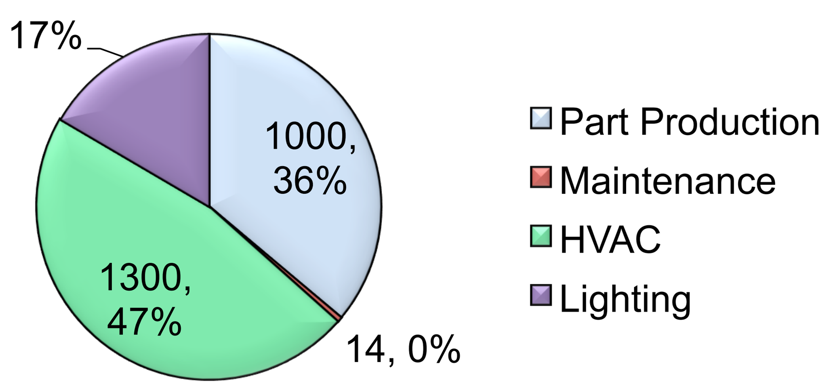
Facility Impacts

- Facility layout dictates the part's transfer time between machine tools.



- Facility HVAC and lighting are non-negligible and can account for 40-65% of total use phase energy consumption for part production [3].

Energy Consumption During Use Phase of Mori Seiki DuraVertical 5060 in Community Shop (kJ/part) from [3]



- Facility impacts will therefore be amortized by machine tool and workspace footprint, f.

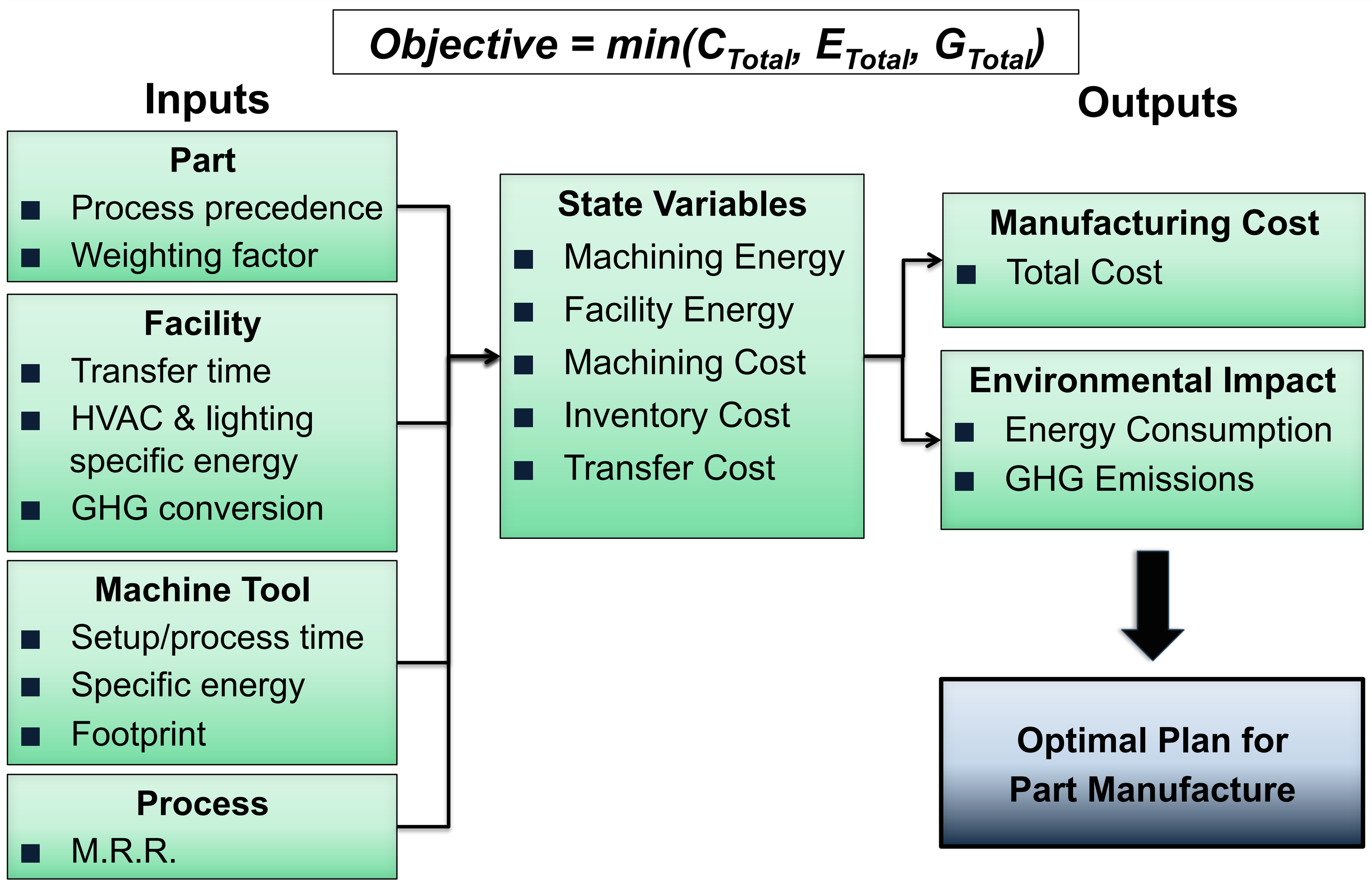
$$E_{facility} = (e_{HVAC} + e_{light}) * f$$

$$G_{facility} = c_{GHG} * E_{facility}$$

[3] Diaz, et. al., (2010), Environmental Analysis of Milling Machine Tool Use in Various Manufacturing Environments

Minimizing Cost and Environmental Impact

$$\boxed{Objective = min(C_{Total}, E_{Total}, G_{Total})}$$



Advantages and Limitations of Method

- Advantages:
  - Simulation is less expensive than running test pieces.
  - Cost and environmental impact do not necessarily have to have the same weight; weighting factor is user-defined.
  - Specific energy model of a particular machine tool is used instead of aggregate machining data, so accuracy is increased.
  - Comprehensive with the inclusion of facility HVAC and lighting impacts, components that are significant yet often ignored.
- Limitations:
  - This project focuses on the macro-planning level, but cost and environmental impact improvements can also be made at the process level.

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