Capacity Planning

- Capacity planning in assembly line
- “capacity” of human resources assigned to right tasks
- Assembly line balancing
- Simulation

Motivation
- Flexible manufacturing
- Human resource: flexible, reasonable cost
- Assign capacity of human resources

Human performance is characterized by a stochastic and time dependant variability

Assignment of human resources

Bottleneck worker dictates cycle time (throughput)

Assignment model

$$\min \max_{i,j} \{t_{ij}x_{ij}\}$$

Subject to:

$$\sum_{j=1}^{q} x_{ij} \leq 1 \quad \forall i = 1, \ldots, q$$

$$\sum_{i=1}^{p} x_{ij} = 1 \quad \forall j = 1, \ldots, p$$

$$x_{ij} \in \{0, 1\} \quad \forall i, j$$

where

- $p$ workstations
- $q$ workers
- $x_{ij} = 1$ if worker $i$ is assigned to task $j$
- $t_{ij}$ time of worker $i$ making task $j$

Human performance

- Learning
- Tiredness

$$y(n) = y(1) + (M - y(1))(1 - n^{-\tau}) - (y(1) - m)(1 - n^{-\lambda})$$

where

- $y(n)$ expected task duration of repetition $n$
- $y(1)$ expected task duration of first repetition
- $M$ estimated worst performance
- $m$ ideal performance
- $\lambda$ learning, $0 < \lambda < 1$
- $\tau$ tiredness, $0 < \tau < 1$

Distance between workstations (triangle) act as buffer
Human performance

Subject to:

- \( l = \lambda \) learning
- \( t = \tau \) tiredness

Data collection

- Four days
- 8 surveys of 15 minutes beginning of every new hour
- stopwatch
- lead time (human task duration)
- recorded breakdowns, stops, delays

Statistical analysis show that data can be described by three-parameter Gamma distribution

- (Krarup) Erlang distribution
- Arises naturally in processes for which the waiting times between Poisson distributed events are relevant

Solution method

- Difficult (if not impossible) to solve analytically
- Simulation

Chi simulation language (Hofkamp Rooda 2002)

- Parallel language
- concurrently executing processes
- processes communicate with each other using synchronous channels

Automatic machines: deterministic (90% availability)

Component supply: availability, delay

Model

\[
\min pT - \sum_{i=1}^{q} \sum_{j=1}^{p} \sum_{n=1}^{N(i)} y_{ij}(n)x_{ij}^{(r)}
\]

Subject to:

\[
\sum_{j=1}^{p} x_{ij}^{(r)} \leq 1 \quad \forall i = 1, \ldots, q
\]

\[
\sum_{i=1}^{q} x_{ij}^{(r)} = 1 \quad \forall j = 1, \ldots, p
\]

\[
\sum_{j=1}^{p} \sum_{n=1}^{N(i)} y_{ij}(n)x_{ij}^{(r)} \leq T \quad \forall i = 1, \ldots, q
\]

where

- \( p \) workstations
- \( q \) workers
- \( T \) is available operation time in shift
- \( N^{(r)} \) is cumulated output target assigned at the \( r \)th iteration
- \( y_{ij}^{(n)} \) performance of \( n \)th repetition of \( i \)th worker at \( j \)th workstation
- \( x_{ij}^{(r)} \) is 1 if worker \( i \) is assigned to workstation \( j \)
Optimization algorithm

Assembly line balancing, results

Assemble line balancing, small example

Figure 4: The assembly line

Assembly line, 4 WS
- 1 WA (automatic)
- 3 WM (manual)

Four workers available with following characteristics

Table 1: Parameters of the “learning-forgetting” model estimated before (a) and after (b) the working break.

Conclusion
- Simulation captures elements of production which cannot be represented by analytical model
- Hybrid solution methods: optimization and simulation

Discussion
- Very large data collection — should be automated
- Increased productivity → increased salary
- People do not like waiting time
- Experienced workers (old) in start of assembly line