COMPUTERS IN MANUFACTURING ENTERPRISES

PRODUCTION CONCEPTS AND MATHEMATICAL MODELS

AUGUST 13, 2015

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Introduction

- production is:
  - it consists of a series of individual steps: processing and assembly operations
- activities in production :
  - Operations: takes place when a product is at the production machine
  - Non-operations: handling, storage, inspections and other sources of delay
- let:
  - T_o - time per operation at a given machine
  - T_{no} – non-operation time at the same machine
  - n_m - number of machines or operations through which the product must pass for complete processing
  - if there is a batch production, then let Q units are there in the batch of the product
  - T_{su} : set – up time (procedure required to prepare each production machine for a particular product)

Manufacturing Lead Time (MLT)

$MLT = \sum (T_{sui} + QT_{oi} + T_{noi}), i = 1,2,3,......, n_m$ ....(1)

(does not include time the raw work part spends in storage before production begins)

- If all times are equal, then:

$MLT = n_m \ (T_{su} + QT_o + T_{no})$ ....(2)

(under the assumption that Q and n_m are same for all products)

- in reality, these terms vary by product, so a weighted average values of all the terms is used

Manufacturing Lead Time (MLT)

- MLT for production:
  - job shop (Q = 1)

    $MLT = n_m \ (T_{su} + T_o + T_{no})$ .... (3)
  - mass production (Q is very large)

    $MLT \approx QT_o$ ....(4)
    - quantity-type mass production (large number of units are produced on same machine), :

      $MLT = T_o$ .... (5)
    - flow-type mass production (physical flow of products in oil-refineries/food processing etc or the products which are made to move through a sequence of operations by a material handling device like conveyor belt)

      $MLT = n_m$ (transfer time + longest T_o)

- the entire production line is set up in advance -> $T_{su} = 0$
- non-operation time between processing steps -> time to transfer the product from 1 machine or workstation to the next
- if the workstations are integrated so that the parts are being processed simultaneously at each station, the station with the longest operation time will determine the MLT value

MLT: Example

example 2.1(page 31) of text book

- batch size(Q) = 50 units
- number of operations (n_m) = 8
- average setup time (T_{su}) = 3 h
- average operation time per machine(T_o) = 6 min
- average non-operation time(T_{no}) = 7 h

how many days to produce a batch?

solution:

MLT = 8 (3 + 50* (6/60) + 7) = 120 h

At 7 h per day, this leads to 120/7 = **17.14 days**

MLT: Example

unsolved example 2.1, part (a)(page 42) of text book

machine	Setup time (h)	operation time (min)	operation time (h)
1	4	5.0	0.083
2	2	3.5	0.058
3	8	10.0	0.167
4	3	1.9	0.032
5	3	4.1	0.068
6	4	2.5	0.042

batch size(Q) = 100 units

average non-operation time per machine (T_{noi}) = 12 h

MLT = $\sum (T_{sui} + QT_{oi} + T_{noi})$, i = 1,2,3,……, 6

= (4 + 100*.083 + 12) + (2 + 100*.058 + 12) + (8 + 100*.167 + 12)
+ (3+ 100*.032 + 12) + (3 + 100*.068 + 12) + (4 + 100*.042 + 12)

= **141 h**

Production Rate

- production rate (units of product per hour), denoted by R_p
- for batch production:

  batch time per machine = $T_{su} + QT_o$ .... (1)

  if Q is desired quantity to be produced and q is scrap rate, then:

  initial quantity should be $Q/(1-q)$, so:

  batch time / machine = $T_{su} + (Q/(1-q))\, T_o$ .... (2)

- average production time per unit of product for the given machine

  T_p = (batch time / machine) / Q and

  $\mathbf{R_p = 1/T_p}$ .... (3)

- for job shop production (Q = 1), $\mathbf{T_p = T_{su} + T_o \Rightarrow R_p = 1/(T_{su} + T_o)}$
- for quantity-type mass production: $\mathbf{R_p = 1/QT_o}$ (neglecting set up time)

Production Concepts and Mathematical Models

<u>components of the operation time (T_o)</u>

- time an individual work part spends on a machine
- not all of this time is productive
- example: machining operation (discrete parts manufacturing)
  - T_o for a machining operation is composed of:
    - the actual machining time T_m
    - the work piece handling time T_h
    - any tool handling time per work piece T_{th}
  - Hence:
    - $T_o = T_m + T_h + T_{th}$ ....(1)

Capacity or Plant Capacity

- maximum rate of output that a plant (or other production facility) is able to produce under a *specified set of operating conditions*

  ↑ refers to no of shifts per day, no of days in the week that the plant operates etc

- closely related to *production rate*
- example: for an automobile assembly plant, capacity is typically defined as one shift, but with an allowance for overtime
- usually measured in terms of the type of output produced by the plant (e.g. tons of steel for a steel factory, barrels of oil for a oil refinery etc)
- if output units are non-homogeneous, input units are used to define (e.g. a job-shop may use available labor hours or available machine hours to measure capacity)

Capacity or Plant Capacity

let-

- PC be the plant capacity of a given work center or group of work centres under consideration
- capacity will be measured as the number of good units produced per week
- W be the number of *work centres:*
  - production system , typically consisting one worker and one machine OR
  - one automated machine with no worker OR
  - several workers working together on a production line
- R_p is the production rate (provision for setup time is included)
- H hours per shift is the time for work centres to operate (excludes time for delays, machine breakdown, repairs and maintainance, etc)
- S_w is the number of shifts per week (or other suitable time period for plant)

$$\mathbf{PC = WS_wHR_p}$$

assuming that the units produced through the work centres are homogeneous -> R_p is same for all units produced

Capacity or Plant Capacity

capacity or plant capacity

batch production plant (each product is routed through n_m machines), then:

$$PC = WS_wHR_p / n_m$$

-- can be used to determine how resources may be allocated to meet a certain weekly demand requirement

-- D_w: demand rate for the week (number of units required)

-- replacing PC by D_w,

$$WS_wH = D_wn_m / R_p$$

given a certain hourly production rate, the capacity can be adjusted up / down in 3 ways:

1. changing the number of work centres in the shop, W
2. changing the number of shifts per week, S_w
3. changing the number of hours worked per shift, H

If production rates differ, the equation becomes:

$$WS_wH = \sum D_wn_m / R_p$$

Utilization(U)

- amount of output of a production unit relative to its capacity

  U = output / capacity

- usually expressed as a percentage
- can be used for an entire plant, a single machine in the plant, or any other productive resource(e.g. labor)
- can also be defined as the proportion of time that the facility is operating relative to the time available in capacity

Production Concepts and Mathematical Models - examples

example 2.2(page 34) of reference book

number of machines (W) - 6

Number of shifts per week (S_w) – 10

number of hours per shift (H) – 6.4

production rate (R_p)– 17 units /h

find capacity (PC) !

Solution:

PC = WS_wHR_p = 6*10*6.4*17 = **6528 units / week**

example 2.4(page 36) of reference book

number of hours per week – 65

production rate (R_p)– 20 units /h

number of good parts produced - 1000

find capacity (PC) ! and utilization (U)

Solution:

(a) **PC** = 65*20 = **1300 units per week**

(b) **Utilization (U)** = number of parts made / capacity = 1000/1300 = **76.92%**

Production Concepts and Mathematical Models - examples

example 2.3 (page 35) of reference book

number of machines (n_m) - 1

Number of shifts per week (S_w) – 10

number of hours per shift (H) – 6.5 h on each work centre for each shift

product	weekly demand	production rate (units / h)
1	600	10
2	1000	20
3	2200	40

Determine the number of work centres required to satisfy this demand!

solution

$WS_wH = \sum D_w n_m / R_p$

= 600/10 + 1000/20 + 2200/ 40 = 165 h

W = 165 / SwH = 165 / (10*6.5) = **2.54 work centres**

W ≈ 3

Production Concepts and Mathematical Models - examples

example 2.5 (page 42) of reference book

- average setup time (T_{su}) = 5 h
- number of machines in the plant = 18
- average batch size(Q) = 25 parts
- number of machines used for batch processing (n_m) = 6
- average operation time (T_o) = 6 min = .1 h
- average non-operation time per batch (T_{no}) = 10 h
- number of new batches of parts launched per week = 20
- plant operation average (S_wH) = 70 h per week

Soution:

a) MLT = n_m (T_{su} + QT_o + T_{no}) = 6*(5 + 25*.1 + 10) = **105 h**

b) Plant capacity = WS_wHR_p / n_m = (18* 70*R_p)/6

batch time per machine = T_{su} + QT_o = 5 + 25*.1 = 7.5 h

T_p = 7.5 / 25 = 3/10 = .3 h

R_p = 1/ T_p = 1/.3 = 10/3

Plant Capacity = (18 * 70 *10)/(6*3) = **700** parts/week

c) Utilization (U) = output/capacity = (25*20)/(700) = **71.43%**

Production Concepts and Mathematical Models

Work-in-process (WIP)

- amount of product currently in factory that is:
  - either being processed or
  - in between processing operations
- inventory being transferred from raw material to finished product
- can be obtained by:

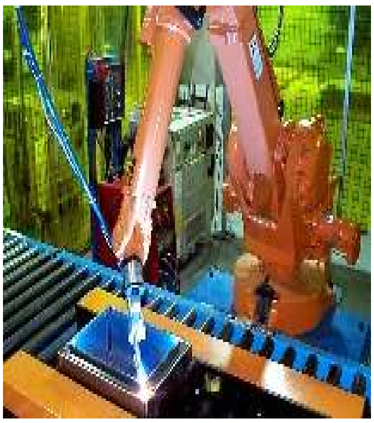
  WIP = (PC* U)*(MLT)/(S_wH) where WIP is number of units in process
- equals to rate at which the parts flow , multiplied by MLT
- represents an investment by the firm which can not be turned into profit until processing is complete
- major costs are incurred by the firms due to high WIP

Automation Strategies

- fundamental strategies to improve productivity
- these strategies are often implemented by automation, hence automation strategies

Automation Strategy 1 – Specialization of Operations

- use of specific equipment designed to perform *one operation* with the greatest possible efficiency
- similar to labor specialization, which was employed to improve labor productivity
- effect: Reduce T_o
- example: automated welding machines



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