PROBLEM DEFINITION

In the Rieti plant, we have $\boldsymbol{R}$ resources which are cleaned by $\boldsymbol{N}$ machine groups having $\boldsymbol{K}$ Pipes each. Each Resource takes $\boldsymbol{W_t}$(Washing Time) to be cleaned(hours).

Available Parameters with us are:

$\boldsymbol{W_t}$- Time taken to wash the resource by the kth pipe of the Nth Machine Group

$\boldsymbol{DHT_{Max}}$ - Maximum duration of time the tank can be left without cleaning

$\boldsymbol{CHT_{Max}}$ -Maximum duration of time the tank can be left after cleaning.

$\boldsymbol{T_s}$- Start of Parent Production Schedule- Input (Subject to change based on Factory Working Hours)

$\boldsymbol{t_0}$- Start of Pth process at Rth resource

$\boldsymbol{t_1}$- End of Pth process at Rth resource

$\boldsymbol{T_e}$- End of Parent Production Schedule (Subject to change based on Factory Working Hours)

$\boldsymbol{b_0}$- start of buffer period at Rth resource

$\boldsymbol{b_1}$-end of buffer period at Rth resource

$\boldsymbol{c_0}$-start of cleaning at Rth resource

$\boldsymbol{c_1}$- end of cleaning at Rth resource

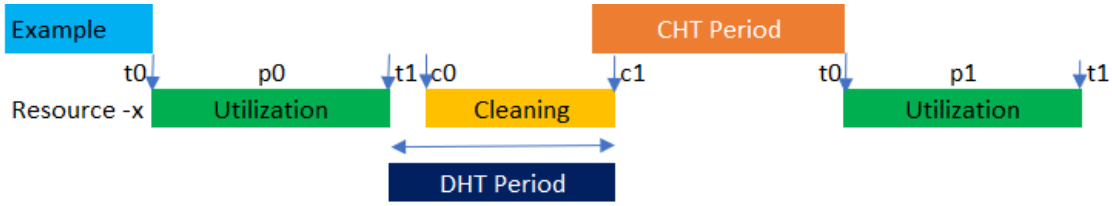
$\boldsymbol{AH}$- Available Hours for Schedule Run (Subject to change based on Factory Working Hours)

$\boldsymbol{p_i}$- No of utilizations for Rth resource where i is the first utilization of the resource

$\boldsymbol{m}$- No of cleanings for Rth Resource by Kth Pipe of Nth Machine Group

$\boldsymbol{b}$- No of buffers in between the Resources where no activity is going on (Includes Cleaning and Utilized Tank)

Consider a standard process:



Standard Metrics

1. **Resource Utilized Time:** $R_u = t_1 - t_0$

Total working time elapsed for the resource.

(Subject to all utilizations taking the same time if not then its Ru will be different for every utilization), where

t_1- End of Pth process at Rth resource

t_0- Start of Pth process at Rth resource

2. **Resource Idle Time**: $R_i = T_e - T_s - p * (R_u)$

Total time when the resource is not being utilized or is ideal where,

T_s- Start of Parent Production Schedule

T_e- End of Parent Production Schedule

p- No of utilizations for Rth resource

R_u- Resource Utilized Time

3. **Total Buffer Time Utilized**: $B_t = b * (b_1 - b_0)$

Total Buffer Time used for a resource R where

b- No of buffers in between the Resources where no activity is going on

b_0- start of buffer period at Rth resource

b_1-end of buffer period at Rth resource

4. **Cleaning Time Available per resource**: $CTR = R_i - B_t$

Time available to clean the resource before next usage where.

$\boldsymbol{B_t}$= Total Buffer Time Utilized

$\boldsymbol{R_i}$= Resource Idle Time

5. Total Cleaning Time per resource = $\boldsymbol{m} * (\boldsymbol{R_i} - \boldsymbol{B_t})$

Time taken to clean the resource in the entire schedule period where,

$\boldsymbol{m}$- No of cleanings for Rth Resource

$\boldsymbol{B_t}$= Total Buffer Time Utilized

$\boldsymbol{R_i}$= Resource Idle Time

6. Cleaning Hold Time: $\boldsymbol{CHT} = \{\boldsymbol{t_0}\}_{\boldsymbol{p=i}} - \boldsymbol{c_1}$

Maximum amount of time in which the resource needs to be utilized otherwise it would need to go through another cleaning process where

$\{\boldsymbol{t_0}\}_{\boldsymbol{p=i}}$ = Starting Time of the Utilization of the next resource

$\boldsymbol{c_1}$= End of Cleaning Period for the preceding Utilized Resource

- Formula only represents the time period in which CHT is applicable. The maximum constraint is listed below and will be used as a constant specified value for each resource

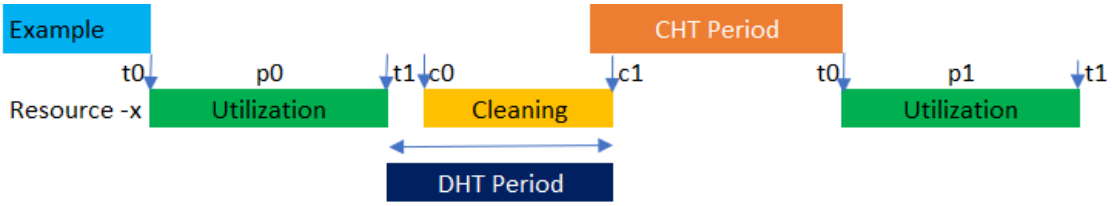
7. Dirt Hold Time: $\boldsymbol{DHT} = \boldsymbol{c_1} - \{\boldsymbol{t_1}\}_{\boldsymbol{p=i-1}}$

Maximum amount of time under which the resource needs to be cleaned where,

$\boldsymbol{c_1}$ =End of Cleaning Period

$\{\boldsymbol{t_1}\}_{\boldsymbol{p=i-1}}$ = End of Utilization of the Preceding Resource

- Formula only represents the time period in which DHT is applicable. The maximum constraint is listed below and will be used as a constant specified value for each resource



Business Metrics – Derived from Standard Metrics

1. Average Downtime –**Resource idle time/ Total working hours**

$$\frac{R_i}{T_e - T_s(In\ Hours)}$$

Where,

R_i= Resource Idle Time (Includes Cleaning and Buffer Time)

T_s- Start of Parent Production Schedule

T_e- End of Parent Production Schedule

2. Number of Cleanings per Resource: m

Where,

m- No of cleanings for Rth Resource

3. Total No of Cleanings for a Production Schedule: $m * no\ of\ Resources$

4. Total no of CHT Re-cleanings: **No of times Max CHT Constraint is broken**

5. Total no of DHT Re-cleanings: **No of times Max DHT Constraint is broken**

6. % CIP Usage:

$$\frac{Cleaning\ Time\ Available\ (R_i - B_t)}{Resource\ Idle\ Time\ (R_i)}$$

- In the above metric, the Available Cleaning time should exclude the time of the pipe if it cannot be used due to some constraint.

Constraints

1. Max CHT Constraint:

$$\{t_0\}_{p=i} - c_1 \leq CHT_{max}$$

2. Max DHT Constraint:

$$c_0 - \{t_1\}_{p=i-1} \leq DHT_{max}$$

3. Unique Pipe Constraint:

At any time t_a , when the cleaning process is running if any pipe K is assigned to resource R then the assignment is as follows:

$$X_r = 1 \; if \; a \; pipe \; K \; of \; group \; N \; is \; assigned \; to \; Resource \; R$$
$$0 \; otherwise$$

Then the constraint is as follows: X_r cannot be assigned for cleaning of other resource in the same time but can use any pipe belonging to ($k \in \forall K <> X_r$)

4. General Constraint:

If a pipe has multiple start times and end times for multiple processes but has the **same lot code**, the earliest start time and the latest end time should be considered.

No cleaning is required in this case and the schedule can be continues as it is.

5. Special Constraint
   - For T58 and DDCPP Transfer Line - L2438, if the end outflow time is the same it can be cleaned via the same CIP – For the current Department, only this pair is the unique constraint

- For some resources which have a different name in INFOR display are exported as the below unique names, which needs to be taken care of while importing or exporting the data. Conversion Table as below

Conversion table	
Process resource to be cleaned	**Resource exported**
AS26 TD Line - L2464	AS26TD
AS16 Line - L2103	AS16
Factor Line - L777	AS16
AS26 VII Line - L2464	AS26VII