

## References

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## **Appendices**

## Appendix A

### Existing plant layout's simulation program

#### ARENA Simulation Results

##### Summary for Replication 1 of 1

Project: Existing Plant                      Run execution date : 8/15/2004  
Analyst: Jobshop                              Model revision date: 8/15/2004

Replication ended at time : 75850.0

#### TALLY VARIABLES

| Identifier        | Average | Half Width | Minimum | Maximum | Observations |
|-------------------|---------|------------|---------|---------|--------------|
| avgflowtime       | 12998.  | (Insuf)    | 6510.0  | 14500.  | 80           |
| cycletime         | 877.72  | (Insuf)    | 245.33  | 1325.3  | 79           |
| overallidletime   | 186.25  | 13.058     | .00000  | 6998.6  | 2800         |
| actualavgflowtime | 12998.  | (Insuf)    | 6510.0  | 14500.  | 80           |
| idletimeq1        | 631.14  | (Insuf)    | .00000  | 4560.0  | 160          |
| idletimeq3        | 136.55  | (Insuf)    | .00000  | 920.00  | 80           |
| idletimeq5        | 142.55  | (Insuf)    | .00000  | 960.00  | 80           |
| idletimeq8        | 162.86  | (Insuf)    | .00000  | 945.33  | 80           |
| idletimeq10       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq11       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq12       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq14       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq15       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq16       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq18       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq19       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq22       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq24       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq26       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq28       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimecraneq1   | 37.358  | (Insuf)    | .00000  | 64.666  | 80           |
| idletimecraneq5   | 3.0000  | (Insuf)    | .00000  | 20.000  | 80           |
| idletimecraneq8   | 12.733  | (Insuf)    | .00000  | 54.666  | 80           |
| idletimecraneq12  | 8.5583  | (Insuf)    | .00000  | 24.666  | 80           |
| idletimecraneq16  | 6.0000  | (Insuf)    | .00000  | 20.000  | 80           |
| idletimecraneq22  | 8.8000  | (Insuf)    | .00000  | 44.666  | 80           |
| idletimecraneq19  | 6.2416  | (Insuf)    | .00000  | 14.666  | 80           |
| idletimecraneq24  | 9.3416  | (Insuf)    | .00000  | 40.000  | 80           |
| idletimecraneq3   | 1.6500  | (Insuf)    | .00000  | 14.666  | 80           |
| idletimescanq1    | 4720.3  | (Insuf)    | .00000  | 6998.6  | 80           |
| idletimescanq3    | .05833  | (Insuf)    | .00000  | 4.6666  | 80           |
| idletimescanq5    | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimescanq8    | .05833  | (Insuf)    | .00000  | 4.6666  | 80           |
| idletimescanq12   | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimescanq16   | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimescanq19   | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimescanq22   | .38333  | (Insuf)    | .00000  | 16.000  | 80           |
| idletimescanq24   | .02500  | (Insuf)    | .00000  | 1.3333  | 80           |

#### DISCRETE-CHANGE VARIABLES

| Identifier           | Average | Half Width | Minimum | Maximum | Final Value |
|----------------------|---------|------------|---------|---------|-------------|
| machine1utilization  | .91773  | (Insuf)    | .00000  | 1.0000  | 1.0000      |
| machine3utilization  | .91773  | (Insuf)    | .00000  | 1.0000  | 1.0000      |
| machine5utilization  | .75953  | (Insuf)    | .00000  | 1.0000  | 1.0000      |
| machine8utilization  | .72788  | (Insuf)    | .00000  | 1.0000  | 1.0000      |
| machine10utilization | .72788  | (Insuf)    | .00000  | 2.0000  | 1.0000      |
| machine11utilization | .79117  | (Insuf)    | .00000  | 2.0000  | 1.0000      |

|                      |        |         |        |        |        |
|----------------------|--------|---------|--------|--------|--------|
| machine12utilization | 1.1708 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine14utilization | .91773 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine15utilization | .79117 | (Insuf) | .00000 | 2.0000 | 1.0000 |
| machine16utilization | .79117 | (Insuf) | .00000 | 2.0000 | 1.0000 |
| machine18utilization | .66460 | (Insuf) | .00000 | 2.0000 | 1.0000 |
| machine19utilization | .79117 | (Insuf) | .00000 | 2.0000 | 1.0000 |
| machine22utilization | .82281 | (Insuf) | .00000 | 2.0000 | 1.0000 |
| machine24utilization | .85445 | (Insuf) | .00000 | 2.0000 | 1.0000 |
| machine26utilization | .72788 | (Insuf) | .00000 | 2.0000 | 1.0000 |
| machine28utilization | .72788 | (Insuf) | .00000 | 2.0000 | 1.0000 |
| craneutilization     | .1285  | .02597  | .00000 | 1.0000 | .00000 |

## COUNTERS

| Identifier | Count | Limit    |
|------------|-------|----------|
| jobdone    | 80    | Infinite |

Simulation run time: 0.00 minutes.  
Simulation run complete.

## Experiment

Begin;  
Project,Existing Plant, Jobshop;

Begin;

Variables: Batchsize,80:

Processtime1,240:  
Processtime3,240:  
Processtime5,90:  
Processtime8,60:  
Processtime10,60:  
Processtime11,120:  
Processtime12,480:  
Processtime14,240:  
Processtime15,120:  
Processtime16,120:  
Processtime18,0:  
Processtime19,120:  
Processtime22,150:  
Processtime24,180:  
Processtime26,60:  
Processtime28,60:  
Paintwaiting7,30:  
Paintwaiting20,1080:  
Paintwaiting27,480:  
Paintwaiting29,1440:

craneuse1,0:  
craneuse3,0:  
craneuse5,0:  
craneuse8,0:  
craneuse12,0:  
craneuse16,0:  
craneuse19,0:  
craneuse22,0:  
craneuse24,0:

cuttingpart,0:  
sandblastingpart,0:  
paintingpart,0:  
machiningpart,0:  
fitupareapart,0:  
weldingareapart,0:  
paintingareapart,0:  
storageareapart,0:

number:  
 workingminutes,480:  
 idleminutes,960;

Attributes: process3done,0:  
 process20done,0:  
 process22done,0:

timein:  
 timeq1:  
 timeq3:  
 timeq5:  
 timeq8:  
 timeq10:  
 timeq11:  
 timeq12:  
 timeq14:  
 timeq15:  
 timeq16:  
 timeq18:  
 timeq19:  
 timeq22:  
 timeq24:  
 timeq26:  
 timeq28:

timecraneq1:  
 timecraneq5:  
 timecraneq8:  
 timecraneq12:  
 timecraneq16:  
 timecraneq22:  
 timecraneq19:  
 timecraneq24:  
 timecraneq3:

timescanq1:  
 timescanq3:  
 timescanq5:  
 timescanq8:  
 timescanq12:  
 timescanq16:  
 timescanq19:  
 timescanq22:  
 timescanq24;

Queues: 1,processqueue1:  
 2,processqueue3:  
 3,processqueue5:  
 4,processqueue8:  
 5,processqueue10:  
 6,processqueue11:  
 7,processqueue12:  
 8,processqueue14:  
 9,processqueue15:  
 10,processqueue16:  
 11,processqueue18:  
 12,processqueue19:  
 13,processqueue22:  
 14,processqueue24:  
 15,processqueue26:  
 16,processqueue28:

17,craneq1:  
 18,craneq5:  
 19,craneq8:  
 20,craneq12:  
 21,craneq16:  
 22,craneq22:

23,craneq19:  
 24,craneq24:  
 25,craneq3:  
 26,scanq8:  
 27,scanq12:  
 28,scanq16:  
 29,scanq19:  
 30,scanq22:  
 31,scanq24:  
 scanq0:  
 scanq1:  
 scanq3:  
 scanq5:

preemptq1:  
 preemptq3:  
 preemptq5:  
 preemptq8:  
 preemptq10:  
 preemptq11:  
 preemptq12:  
 preemptq14:  
 preemptq15:  
 preemptq16:  
 preemptq18:  
 preemptq19:  
 preemptq22:  
 preemptq24:  
 preemptq26:  
 preemptq28;

Resources: 1,machine1,1:

2,machine3,1:  
 3,machine5,1:  
 4,machine8,1:  
 5,machine10,4:  
 6,machine11,4:  
 7,machine12,4:  
 8,machine14,4:  
 9,machine15,4:  
 10,machine16,4:  
 11,machine18,4:  
 12,machine19,4:  
 13,machine22,4:  
 14,machine24,4:  
 15,machine26,4:  
 16,machine28,4;

Stations: 1,cuttingarea:

2,machiningarea:  
 3,fituparea:  
 4,weldingarea:  
 5,paintingarea:  
 6,sandblastingroom:  
 7,storagearea;

Transporters: 1,crane,2,1,1.5,cuttingarea-Active,cuttingarea-Active;

Distances:1, cuttingarea-machiningarea-45,  
 cuttingarea-fituparea-60,  
 cuttingarea-weldingarea-67,  
 cuttingarea-paintingarea-75,  
 cuttingarea-sandblastingroom-30,  
 cuttingarea-storagearea-97,

machiningarea-cuttingarea-22,  
 machiningarea-fituparea-15,  
 machiningarea-weldingarea-52,  
 machiningarea-paintingarea-60,  
 machiningarea-sandblastingroom-82,

machiningarea-storagearea-82,

fituparea-cuttingarea-60,  
 fituparea-machiningarea-7,  
 fituparea-weldingarea-15,  
 fituparea-paintingarea-15,  
 fituparea-sandblastingroom-37,  
 fituparea-storagearea-37,

weldingarea-cuttingarea-67,  
 weldingarea-machiningarea-52,  
 weldingarea-fituparea-7,  
 weldingarea-paintingarea-15,  
 weldingarea-sandblastingroom-22,  
 weldingarea-storagearea-45,

paintingarea-cuttingarea-75,  
 paintingarea-machiningarea-60,  
 paintingarea-fituparea-15,  
 paintingarea-weldingarea-15,  
 paintingarea-sandblastingroom-22,  
 paintingarea-storagearea-45,

sandblastingroom-cuttingarea-30,  
 sandblastingroom-machiningarea-82,  
 sandblastingroom-fituparea-37,  
 sandblastingroom-weldingarea-30,  
 sandblastingroom-paintingarea-22,  
 sandblastingroom-storagearea-0,

storagearea-cuttingarea-97,  
 storagearea-machiningarea-82,  
 storagearea-fituparea-37,  
 storagearea-weldingarea-30,  
 storagearea-paintingarea-22,  
 storagearea-sandblastingroom-0;

Counters:jobdone;

tallies:1,avgflowtime:

2,cycletime:

overallidletime:

actualavgflowtime:

idletimeq1:

idletimeq3:

idletimeq5:

idletimeq8:

idletimeq10:

idletimeq11:

idletimeq12:

idletimeq14:

idletimeq15:

idletimeq16:

idletimeq18:

idletimeq19:

idletimeq22:

idletimeq24:

idletimeq26:

idletimeq28:

idletimecraneq1:

idletimecraneq5:

idletimecraneq8:

idletimecraneq12:

idletimecraneq16:

idletimecraneq22:

idletimecraneq19:

idletimecraneq24:

idletimecraneq3:

```

        idletimescanq1:
        idletimescanq3:
        idletimescanq5:
        idletimescanq8:
        idletimescanq12:
        idletimescanq16:
        idletimescanq19:
        idletimescanq22:
        idletimescanq24;

dstats:nr(machine1),machine1utilization:
        nr(machine3),machine3utilization:
        nr(machine5),machine5utilization:
        nr(machine8),machine8utilization:
        nr(machine10),machine10utilization:
        nr(machine11),machine11utilization:
        nr(machine12),machine12utilization:
        nr(machine14),machine14utilization:
        nr(machine15),machine15utilization:
        nr(machine16),machine16utilization:
        nr(machine18),machine18utilization:
        nr(machine19),machine19utilization:
        nr(machine22),machine22utilization:
        nr(machine24),machine24utilization:
        nr(machine26),machine26utilization:
        nr(machine28),machine28utilization:
        nt(crane),craneutilization;

Replicate,1,0,75850;

Model
Begin;

        create,batchsize;

        queue,scanq0;
        scan:cuttingpart<8;
        station,cuttingarea;

        Branch,1:
                if, process3done==1,Pro5;
                if, process3done==0,Pro1;

Pro1    assign:cuttingpart=cuttingpart+1;
        queue,processqueue1:mark(timeq1);

        tally:idletimeq1,int(timeq1);
        tally:overallidletime,int(timeq1);

        seize:machine1:mark(timein);

        tally:idletimeq1,int(timeq1);
        tally:overallidletime,int(timeq1);

        Delay:processtime1;
        Release:machine1;

        queue,scanq1:mark(timescanq1);
        scan:sandblastingpart<1.AND.NT(crane)<2.AND.craneuse1<=0;

        tally:idletimescanq1,int(timescanq1);
        tally:overallidletime,int(timescanq1);

        assign:craneuse1=1;

        queue,craneq1:mark(timecraneq1);
        request:crane(SDS);

```



```

tally:idletimecraneq1,int(timecraneq1);
tally:overallidletime,int(timecraneq1);

assign:cuttingpart=cuttingpart-1;
transport:crane,sandblastingroom;

Pro5 free:crane;
assign:craneuse3=0;
assign:paintingpart=paintingpart+1;
queue,processqueue5:mark(timeq5);
seize:machine5;

tally:idletimeq5,int(timeq5);
tally:overallidletime,int(timeq5);

Delay:processtime5;
Release:machine5;

queue,scanq5:mark(timescanq5);
scan:machiningpart<4.AND.NT(crane)<=1.AND.craneuse5<=0;

tally:idletimescanq5,int(timescanq5);
tally:overallidletime,int(timescanq5);

assign:craneuse5=1;
queue,craneq5:mark(timecraneq5);
request:crane(SDS);

tally:idletimecraneq5,int(timecraneq5);
tally:overallidletime,int(timecraneq5);

assign:paintingpart=paintingpart-1;
transport:crane,machiningarea;

station,machiningarea;

free:crane;
assign:craneuse5=0;
assign:machiningpart=machiningpart+1;

Delay:paintwaiting7;

queue,processqueue8:mark(timeq8);
seize:machine8;

tally:idletimeq8,int(timeq8);
tally:overallidletime,int(timeq8);

Delay:processtime8;
Release:machine8;

queue,scanq8:mark(timescanq8);
scan:fitupareapart<4.AND.NT(crane)<2.AND.craneuse8<=0;

tally:idletimescanq8,int(timescanq8);
tally:overallidletime,int(timescanq8);

assign:craneuse8=1;
queue,craneq8:mark(timecraneq8);
request:crane(SDS);

tally:idletimecraneq8,int(timecraneq8);
tally:overallidletime,int(timecraneq8);

assign:machiningpart=machiningpart-1;
transport:crane,fituparea;

```

```

station,fituparea;

free:crane;

assign:craneuse8=0;
assign:fitupareapart=fitupareapart+1;

queue,processqueue10:mark(timeq10);
seize:machine10;

tally:idletimeq10,int(timeq10);
tally:overallidletime,int(timeq10);

Delay:processtime10;
Release:machine10;

queue,processqueue11:mark(timeq11);
seize:machine11;

tally:idletimeq11,int(timeq11);
tally:overallidletime,int(timeq11);

Delay:processtime11;
Release:machine11;

queue,processqueue12:mark(timeq12);
seize:machine12;

tally:idletimeq12,int(timeq12);
tally:overallidletime,int(timeq12);

Delay:processtime12;
Release:machine12;

queue,scanq12:mark(timescanq12);
scan:weldingareapart<4.AND.NT(crane)<2.AND.craneuse12<=0.AND.craneuse19<=0;

tally:idletimescanq12,int(timescanq12);
tally:overallidletime,int(timescanq12);

assign:craneuse12=1;

queue,craneq12:mark(timecraneq12);
request:crane(SDS);

assign:fitupareapart=fitupareapart-1;

tally:idletimecraneq12,int(timecraneq12);
tally:overallidletime,int(timecraneq12);

transport:crane,weldingarea;

station,weldingarea;

free:crane;

assign:weldingareapart=weldingareapart+1;

Branch,1:
    if,process20done==0,Pro14:
    if,process20done==1,Pro22;

Pro14    assign:craneuse12=0;

```

queue,processqueue14:mark(timeq14);  
seize:machine14;

tally:idletimeq14,int(timeq14);  
tally:overallidletime,int(timeq14);

Delay:processtime14;  
Release:machine14;

queue,processqueue15:mark(timeq15);  
seize:machine15;

tally:idletimeq15,int(timeq15);  
tally:overallidletime,int(timeq15);

Delay:processtime15;  
Release:machine15;

queue,processqueue16:mark(timeq16);  
seize:machine16;

tally:idletimeq16,int(timeq16);  
tally:overallidletime,int(timeq16);

Delay:processtime16;  
Release:machine16;

queue,scanq16:mark(timescanq16);  
scan:paintingareapart<4.AND.NT(crane)<2.AND.craneuse16<=0.AND.craneuse22<=0;

tally:idletimescanq16,int(timescanq16);  
tally:overallidletime,int(timescanq16);

assign:craneuse16=1;  
queue,craneq16:mark(timecraneq16);

request:crane(SDS);

tally:idletimecraneq16,int(timecraneq16);  
tally:overallidletime,int(timecraneq16);

assign:weldingareapart=weldingareapart-1;

transport:crane,paintingarea;

Pro22 assign:craneuse19=0;

MC22 queue,processqueue22:mark(timeq22);  
seize:machine22;

tally:idletimeq22,int(timeq22);  
tally:overallidletime,int(timeq22);

Delay:processtime22;  
Release:machine22;

assign:process22done=1;

queue,scanq22:mark(timescanq22);  
scan:paintingareapart<4.AND.NT(crane)<2.AND.craneuse22<=0;

tally:idletimescanq22,int(timescanq22);  
tally:overallidletime,int(timescanq22);

assign:craneuse22=1;

queue,craneq22:mark(timecraneq22);  
request:crane(SDS);

tally:idletimecraneq22,int(timecraneq22);

```

tally:overallidletime,int(timecraneq22);
assign:weldingareapart=weldingareapart-1;
transport:crane,paintingarea;
station, paintingarea;
free:crane;
assign:paintingareapart=paintingareapart+1;
Branch,1:
    if, process22done==0,Pro18;
    if, process22done==1,Pro24;
Pro18 assign:craneuse16=0;
MC18 queue,processqueue18:mark(timeq18);
seize:machine18;
tally:idletimeq18,int(timeq18);
tally:overallidletime,int(timeq18);
Delay:processtime18;
Release:machine18;
queue,processqueue19:mark(timeq19);
seize:machine19;
tally:idletimeq19,int(timeq19);
tally:overallidletime,int(timeq19);
Delay:processtime19;
Release:machine19;
Delay:paintwaiting20;
assign:process20done=1;
queue,scanq19:mark(timescanq19);
scan:weldingareapart<4.AND.NT(crane)<2.AND.craneuse19<=0;
tally:idletimescanq19,int(timescanq19);
tally:overallidletime,int(timescanq19);
assign:craneuse19=1;
queue,craneq19:mark(timecraneq19);
request:crane(SDS);
tally:idletimecraneq19,int(timecraneq19);
tally:overallidletime,int(timecraneq19);
assign:paintingareapart=paintingareapart-1;
transport:crane,weldingarea;
Pro24 assign:craneuse22=0;
MC24 queue,processqueue24:mark(timeq24);
seize:machine24;
tally:idletimeq24,int(timeq24);
tally:overallidletime,int(timeq24);
Delay:processtime24;
Release:machine24;
queue,scanq24:mark(timescanq24);

```

scan:storageareapart<4.AND.NT(crane)<2.AND.craneuse24<=0;

tally:idletimescanq24,int(timescanq24);  
tally:overallidletime,int(timescanq24);

assign:craneuse24=1;

queue,craneq24:mark(timecraneq24);  
request:crane(SDS);

tally:idletimecraneq24,int(timecraneq24);  
tally:overallidletime,int(timecraneq24);

assign:paintingareapart=paintingareapart-1;  
transport:crane,storagearea;

station,sandblastingroom;

free:crane;  
assign:craneuse1=0;  
assign:sandblastingpart=1;

queue,processqueue3:mark(timeq3);  
seize:machine3;

tally:idletimeq3,int(timeq3);  
tally:overallidletime,int(timeq3);

Delay:processtime3;  
Release:machine3;

assign:process3done=1;

queue,scanq3:mark(timescanq3);  
scan:paintingpart<4.AND.NT(crane)<2.AND.craneuse3<=0;

tally:idletimescanq3,int(timescanq3);  
tally:overallidletime,int(timescanq3);

assign:craneuse3=1;

queue,craneq3:mark(timecraneq3);  
request:crane(SDS);

tally:idletimecraneq3,int(timecraneq3);  
tally:overallidletime,int(timecraneq3);

assign:sandblastingpart=0;  
transport:crane,cuttingarea;

station,storagearea;

free:crane;

assign:craneuse24=0;  
assign:storageareapart=storageareapart+1;

queue,processqueue26:mark(timeq26);  
seize:machine26;

tally:idletimeq26,int(timeq26);  
tally:overallidletime,int(timeq26);

Delay:processtime26;  
Release:machine26;

Delay:paintwaiting27;

```

queue,processqueue28:mark(timeq28);
seize:machine28;

tally:idletimeq28,int(timeq28);
tally:overallidletime,int(timeq28);
Delay:processtime28;
Release:machine28;

Delay:paintwaiting29;

assign:storageareapart=storageareapart-1;

tally:avgflowtime,int(timein);
tally:cycletime,BET;
tally:actualavgflowtime,int(timeq1);

count:jobdone;
dispose;

create,1;

CHECK1
scan:paintingareapart>=4.AND.nq(scanq24)<=0.AND.nr(machine24)<=0.AND.nq(processqueue24)<=0.AND.weldingar
eapart>=4.AND.nq(scanq19)>=4.AND.nq(scanq16)+nq(scanq22)>=4;
branch,1:
    if,nq(scanq22)==0,pick16:
    if,nq(scanq22)>=0,pick22;

pick16 delay:20;
duplicate:1,AA;

pickup:scanq16,1,1;
dropoff,1,1:MC18:next(CHECK1);

AA pickup:scanq19,1,1;
dropoff,1,1:MC22;
dispose;

pick22 delay:20;
duplicate:1,BB;

pickup:scanq22,1,1;
dropoff,1,1:MC24:next(CHECK1);

BB pickup:scanq19,1,1;
dropoff,1,1:MC22;
dispose;

create,1;
fail1 Delay:workingminutes;
queue,preemptq1;
preempt:machine1;
Delay:idleminutes;
Release:machine1:next(fail1);

create,1;
fail3 Delay:workingminutes;
queue,preemptq3;
preempt:machine3;
Delay:idleminutes;
Release:machine3:next(fail3);

create,1;
fail5 Delay:workingminutes;
queue,preemptq5;
preempt:machine5;
Delay:idleminutes;

```

```
Release:machine5:next(fail5);

create,1;
fail8 Delay:workingminutes;
      queue,preemptq8;
      preempt:machine8;
      Delay:idleminutes;
      Release:machine8:next(fail8);

create,1;
fail10 Delay:workingminutes;
       queue,preemptq10;
       preempt:machine10;
       Delay:idleminutes;
       Release:machine10:next(fail10);

create,1;
fail11 Delay:workingminutes;
       queue,preemptq11;
       preempt:machine11;
       Delay:idleminutes;
       Release:machine11:next(fail11);

create,1;
fail12 Delay:workingminutes;
       queue,preemptq12;
       preempt:machine12;
       Delay:idleminutes;
       Release:machine12:next(fail12);

create,1;
fail14 Delay:workingminutes;
       queue,preemptq14;
       preempt:machine14;
       Delay:idleminutes;
       Release:machine14:next(fail14);

create,1;
fail15 Delay:workingminutes;
       queue,preemptq15;
       preempt:machine15;
       Delay:idleminutes;
       Release:machine15:next(fail15);

create,1;
fail16 Delay:workingminutes;
       queue,preemptq16;
       preempt:machine16;
       Delay:idleminutes;
       Release:machine16:next(fail16);

create,1;
fail18 Delay:workingminutes;
       queue,preemptq18;
       preempt:machine18;
       Delay:idleminutes;
       Release:machine18:next(fail18);

create,1;
fail19 Delay:workingminutes;
       queue,preemptq19;
       preempt:machine19;
       Delay:idleminutes;
       Release:machine19:next(fail19);

create,1;
fail22 Delay:workingminutes;
       queue,preemptq22;
       preempt:machine22;
       Delay:idleminutes;
       Release:machine22:next(fail22);
```

```
        create,1;  
fail24 Delay:workingminutes;  
        queue,preemptq24;  
        preempt:machine24;  
        Delay:idleminutes;  
        Release:machine24:next(fail24);
```

```
        create,1;  
fail26 Delay:workingminutes;  
        queue,preemptq26;  
        preempt:machine26;  
        Delay:idleminutes;  
        Release:machine26:next(fail26);
```

```
        create,1;  
fail28 Delay:workingminutes;  
        queue,preemptq28;  
        preempt:machine28;  
        Delay:idleminutes;  
        Release:machine28:next(fail28);
```

```
End;
```



## Appendix B

### Process layout plant's simulation program

#### ARENA Simulation Results

##### Summary for Replication 1 of 1

Project: New Layout                      Run execution date : 8/15/2004  
Analyst: Process Layout                Model revision date: 8/15/2004

Replication ended at time : 28174.0

#### TALLY VARIABLES

| Identifier       | Average | Half Width | Minimum | Maximum | Observations |
|------------------|---------|------------|---------|---------|--------------|
| avgflowtime      | 10054.  | (Insuf)    | 5590.0  | 15364.  | 80           |
| cycletime        | 285.87  | (Insuf)    | 24.000  | 3226.6  | 79           |
| overallidletime  | 130.26  | (Corr)     | .00000  | 4224.6  | 2616         |
| idletimeq1       | 1087.4  | (Insuf)    | .00000  | 1200.0  | 80           |
| idletimeq3       | 1.2833  | (Insuf)    | .00000  | 34.666  | 80           |
| idletimeq5       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq8       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq9       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq11      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq12      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq13      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq14      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq15      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq17      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq20      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq22      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq24      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq26      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimecraneq2  | 8.1500  | (Insuf)    | .00000  | 39.333  | 80           |
| idletimecraneq4  | 5.3833  | (Insuf)    | .00000  | 27.333  | 80           |
| idletimecraneq7  | 6.3416  | (Insuf)    | .00000  | 22.666  | 80           |
| idletimecraneq10 | 8.6166  | (Insuf)    | .00000  | 30.000  | 80           |
| idletimecraneq16 | 12.726  | (Insuf)    | .00000  | 35.333  | 78           |
| idletimecraneq19 | 11.063  | (Insuf)    | .00000  | 26.000  | 74           |
| idletimecraneq21 | 9.7807  | (Insuf)    | .00000  | 40.666  | 76           |
| idletimecraneq23 | 7.1500  | (Insuf)    | .00000  | 17.333  | 80           |
| idletimecraneq27 | 11.125  | (Insuf)    | .00000  | 17.333  | 80           |
| idletimescanq2   | 9.1666  | (Insuf)    | .00000  | 53.333  | 80           |
| idletimescanq4   | 72.741  | (Insuf)    | .00000  | 1947.3  | 80           |
| idletimescanq7   | 441.92  | (Insuf)    | .00000  | 4064.0  | 80           |
| idletimescanq10  | 1039.5  | (Insuf)    | .00000  | 4224.6  | 80           |
| idletimescanq16  | 781.93  | (Insuf)    | .00000  | 3097.3  | 78           |
| idletimescanq19  | 744.19  | (Insuf)    | .00000  | 3051.3  | 74           |
| idletimescanq21  | 78.798  | (Insuf)    | .00000  | 765.33  | 76           |
| idletimescanq23  | 1.6833  | (Insuf)    | .00000  | 31.333  | 80           |
| idletimescanq27  | 1.5166  | (Insuf)    | .00000  | 32.000  | 80           |

#### DISCRETE-CHANGE VARIABLES

| Identifier           | Average | Half Width | Minimum | Maximum | Final Value |
|----------------------|---------|------------|---------|---------|-------------|
| machine1utilization  | 1.3407  | (Insuf)    | .00000  | 2.0000  | 1.0000      |
| machine3utilization  | 1.3407  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine5utilization  | .91482  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine8utilization  | .82963  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine9utilization  | .82963  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine11utilization | 1.0000  | (Insuf)    | .00000  | 4.0000  | 1.0000      |
| machine12utilization | 2.0222  | (Insuf)    | .00000  | 7.0000  | 1.0000      |

|                      |        |         |        |        |        |
|----------------------|--------|---------|--------|--------|--------|
| machine13utilization | 1.3407 | (Insuf) | .00000 | 5.0000 | 1.0000 |
| machine14utilization | 1.0000 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine15utilization | 1.0000 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine17utilization | 1.0000 | (Insuf) | .00000 | 5.0000 | 1.0000 |
| machine20utilization | 1.0851 | (Insuf) | .00000 | 6.0000 | 1.0000 |
| machine22utilization | 1.1703 | (Insuf) | .00000 | 5.0000 | 1.0000 |
| machine24utilization | .82963 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine26utilization | .82963 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| craneutilization     | .2587  | (Corr)  | .00000 | 1.0000 | .00000 |

## COUNTERS

| Identifier | Count | Limit    |
|------------|-------|----------|
| jobdone    | 80    | Infinite |

Simulation run time: 0.00 minutes.  
Simulation run complete.

Experiment  
Begin;

Project, New Layout, Process Layout;

Variables: batchsize, 80:

processtime1,240:  
processtime3,240:  
processtime5,90:  
processtime8,60:  
processtime9,60:  
processtime11,120:  
processtime12,480:  
processtime13,240:  
processtime14,120:  
processtime15,120:  
processtime17,120:  
processtime20,150:  
processtime22,180:  
processtime24,60:  
processtime26,60:

paintwaiting6,60:  
paintwaiting18,1080:  
paintwaiting25,480:  
paintwaiting28,1440:

craneuse2:  
craneuse4:  
craneuse7,0:  
craneuse10,0:  
craneuse16,0:  
craneuse19,0:  
craneuse21,0:  
craneuse23,0:  
craneuse27,0:

cuttingpart,0:  
sandblastingpart,0:  
paintingpart,0:  
preconstructpart,0:  
weldingareapart,0:  
paintingareapart,0:  
finalpaintingpart,0:  
storageareapart,0:

workingminutes,480:

idleminutes,960;

Attributes: process3done,0:

process17done,0:  
process20done,0:

timein:

timeq1:

timeq3:

timeq5:

timeq8:

timeq9:

timeq11:

timeq12:

timeq13:

timeq14:

timeq15:

timeq17:

timeq20:

timeq22:

timeq24:

timeq26:

timecraneq2:

timecraneq4:

timecraneq7:

timecraneq10:

timecraneq16:

timecraneq19:

timecraneq21:

timecraneq23:

timecraneq27:

timescanq2:

timescanq4:

timescanq7:

timescanq10:

timescanq16:

timescanq19:

timescanq21:

timescanq23:

timescanq27;

Queues:

1,processqueue1:

2,processqueue3:

3,processqueue5:

4,processqueue8:

5,processqueue9:

6,processqueue11:

7,processqueue12:

8,processqueue13:

9,processqueue14:

10,processqueue15:

11,processqueue17:

12,processqueue20:

13,processqueue22:

14,processqueue24:

15,processqueue26:

16,craneq2:

17,craneq4:

18,craneq7:

19,craneq10:

20,craneq16:

21,craneq19:

22,craneq21:

23,craneq23:

24,craneq27:

25,scanq7:  
 26,scanq10:  
 27,scanq16:  
 28,scanq19:  
 29,scanq21:  
 30,scanq23:  
 31,scanq27:

32,preemptq1:  
 33,preemptq3:  
 34,preemptq5:  
 35,preemptq8:  
 36,preemptq9:  
 37,preemptq11:  
 38,preemptq12:  
 39,preemptq13:  
 40,preemptq14:  
 41,preemptq15:  
 42,preemptq17:  
 43,preemptq20:  
 44,preemptq22:  
 45,preemptq24:  
 46,preemptq26:

100,scanq2:  
 101,scanq4:  
 102,scanq0;

Resources: 1,machine1,2:

2,machine3,3:  
 3,machine5,8:  
 4,machine8,8:  
 5,machine9,8:  
 6,machine11,8:  
 7,machine12,8:  
 8,machine13,8:  
 9,machine14,8:  
 10,machine15,8:  
 11,machine17,8:  
 12,machine20,8:  
 13,machine22,8:  
 14,machine24,8:  
 15,machine26,8;

Stations: 1,cuttingarea:

2,sandblastingroom:  
 3,preconstructarea:  
 4,weldingarea:  
 5,paintingarea:  
 6,finalpaintingarea:  
 7,storagearea;

Transporters: 1,crane,2,1,1.5,cuttingarea-active,cuttingarea-active;

Distances: 1, cuttingarea-sandblastingroom-15,  
 cuttingarea-preconstructarea-45,  
 cuttingarea-weldingarea-9,  
 cuttingarea-paintingarea-13,  
 cuttingarea-finalpaintingarea-26,  
 cuttingarea-storagearea-34,

sandblastingroom-cuttingarea-15,  
 sandblastingroom-preconstructarea-4,  
 sandblastingroom-weldingarea-9,  
 sandblastingroom-paintingarea-13,  
 sandblastingroom-finalpaintingarea-26,  
 sandblastingroom-storagearea-34,

preconstructarea-cuttingarea-4,

preconstructarea-sandblastingroom-4,  
 preconstructarea-weldingarea-18,  
 preconstructarea-paintingarea-10,  
 preconstructarea-finalpaintingarea-22,  
 preconstructarea-storagearea-31,

weldingarea-cuttingarea-9,  
 weldingarea-sandblastingroom-9,  
 weldingarea-preconstructarea-5,  
 weldingarea-paintingarea-18,  
 weldingarea-finalpaintingarea-17,  
 weldingarea-storagearea-26,

paintingarea-cuttingarea-13,  
 paintingarea-sandblastingroom-13,  
 paintingarea-preconstructarea-10,  
 paintingarea-weldingarea-18,  
 paintingarea-finalpaintingarea-18,  
 paintingarea-storagearea-21,

finalpaintingarea-cuttingarea-26,  
 finalpaintingarea-sandblastingroom-26,  
 finalpaintingarea-preconstructarea-10,  
 finalpaintingarea-weldingarea-17,  
 finalpaintingarea-paintingarea-13,  
 finalpaintingarea-storagearea-18,

storagearea-cuttingarea-34,  
 storagearea-sandblastingroom-34,  
 storagearea-preconstructarea-31,  
 storagearea-weldingarea-26,  
 storagearea-paintingarea-21,  
 storagearea-finalpaintingarea-18;

Counters: 1, jobdone;

tallies: 1, avgflowtime:  
 2, cycletime:  
 overallidletime:

idletimeq1:  
 idletimeq3:  
 idletimeq5:  
 idletimeq8:  
 idletimeq9:  
 idletimeq11:  
 idletimeq12:  
 idletimeq13:  
 idletimeq14:  
 idletimeq15:  
 idletimeq17:  
 idletimeq20:  
 idletimeq22:  
 idletimeq24:  
 idletimeq26:

idletimecraneq2:  
 idletimecraneq4:  
 idletimecraneq7:  
 idletimecraneq10:  
 idletimecraneq16:  
 idletimecraneq19:  
 idletimecraneq21:  
 idletimecraneq23:  
 idletimecraneq27:

idletimescanq2:  
 idletimescanq4:  
 idletimescanq7:  
 idletimescanq10:  
 idletimescanq16:

```

        idletimescanq19;
        idletimescanq21;
        idletimescanq23;
        idletimescanq27;

dstats:nr(machine1),machine1utilization:
        nr(machine3),machine3utilization:
        nr(machine5),machine5utilization:
        nr(machine8),machine8utilization:
        nr(machine9),machine9utilization:
        nr(machine11),machine11utilization:
        nr(machine12),machine12utilization:
        nr(machine13),machine13utilization:
        nr(machine14),machine14utilization:
        nr(machine15),machine15utilization:
        nr(machine17),machine17utilization:
        nr(machine20),machine20utilization:
        nr(machine22),machine22utilization:
        nr(machine24),machine24utilization:
        nr(machine26),machine26utilization:
        nt(crane),craneutilization;

Replicate,1,0,28174;

End;

Model
Begin;

        create, batchsize;

        queue,scanq0;
        scan:cuttingpart<8;
        station, cuttingarea;

        branch,1:
                if, process3done==1, Pro5;
                if, process3done==0, Pro1;

Pro1    assign:cuttingpart=cuttingpart+1;
        queue, processqueue1: mark(timeq1);
        seize: machine1:mark(timein);

        tally:idletimeq1,int(timeq1);
        tally:overallidletime,int(timeq1);

        delay: processtime1;
        release: machine1;

        queue,scanq2:mark(timescanq2);
        scan:sandblastingpart<3.AND.NT(crane)<2.AND.craneuse2<=0;

        tally:idletimescanq2,int(timescanq2);
        tally:overallidletime,int(timescanq2);

        assign:craneuse2=1;

        queue, craneq2: mark(timecraneq2);
        request: crane(SDS);

        tally:idletimecraneq2,int(timecraneq2);
        tally:overallidletime,int(timecraneq2);

        assign:cuttingpart=cuttingpart-1;

        transport: crane, sandblastingroom;

```

```

Pro5    free: crane;
        assign:craneuse4=0;
        assign:paintingpart=paintingpart+1;
        queue, processqueue5: mark(timeq5);
        seize: machine5;

        tally:idletimeq5,int(timeq5);
        tally:overallidletime,int(timeq5);

        delay: processtime5;
        release: machine5;

        delay: paintwaiting6;

        queue, scanq7: mark(timescanq7);
        scan: preconstructpart<8 .AND. NT(crane)<=1 .AND. craneuse7<=0;

        tally:idletimescanq7,int(timescanq7);
        tally:overallidletime,int(timescanq7);

        assign: craneuse7=1;

        queue, craneq7: mark(timecraneq7);
        request: crane(SDS);

        tally:idletimecraneq7,int(timecraneq7);
        tally:overallidletime,int(timecraneq7);

        assign:paintingpart=paintingpart-1;

        transport: crane, preconstructarea;

        station, sandblastingroom;

        free: crane;
        assign:craneuse2=0;
        assign:sandblastingpart=sandblastingpart+1;

        queue, processqueue3: mark(timeq3);
        seize: machine3;

        tally:idletimeq3,int(timeq3);
        tally:overallidletime,int(timeq3);

        delay: processtime3;
        release: machine3;

        assign: process3done=1;

        queue,scanq4:mark(timescanq4);
        scan:paintingpart<8.AND.NT(crane)<2.AND.craneuse4<=0;

        tally:idletimescanq4,int(timescanq4);
        tally:overallidletime,int(timescanq4);

        assign:craneuse4=1;

        queue, craneq4: mark(timecraneq4);
        request: crane(SDS);

        tally:idletimecraneq4,int(timecraneq4);
        tally:overallidletime,int(timecraneq4);

        assign:sandblastingpart=sandblastingpart-1;
        transport: crane, cuttingarea;

        station, preconstructarea;

        free: crane;
        assign: craneuse7=0;

```

```

assign: preconstructpart=preconstructpart+1;

queue, processqueue8: mark(timeq8);
seize: machine8;

tally:idletimeq8,int(timeq8);
tally:overallidletime,int(timeq8);

delay: processtime8;
release: machine8;

queue, processqueue9: mark(timeq9);
seize: machine9;

tally:idletimeq9,int(timeq9);
tally:overallidletime,int(timeq9);

delay: processtime9;
release: machine9;

queue, scanq10: mark(timescanq10);
scan: weldingareapart<8 .AND. NT(crane)<=1 .AND. craneuse10<=0;

tally:idletimescanq10,int(timescanq10);
tally:overallidletime,int(timescanq10);

assign: craneuse10=1;

queue, craneq10: mark(timecraneq10);
request: crane(SDS);

tally:idletimecraneq10,int(timecraneq10);
tally:overallidletime,int(timecraneq10);

assign: preconstructpart=preconstructpart-1;

transport: crane, weldingarea;

station, weldingarea;

free: crane;

assign: weldingareapart=weldingareapart+1;

branch,1:
    if, process17done==0, Pro11;
    if, process17done==1, Pro20;

Pro11 assign: craneuse10=0;

queue, processqueue11: mark(timeq11);
seize: machine11;

tally:idletimeq11,int(timeq11);
tally:overallidletime,int(timeq11);

delay: processtime11;
release: machine11;

queue, processqueue12: mark(timeq12);
seize: machine12;

tally:idletimeq12,int(timeq12);
tally:overallidletime,int(timeq12);

delay: processtime12;
release: machine12;

queue, processqueue13: mark(timeq13);
seize: machine13;

```



```

tally:idletimeq13,int(timeq13);
tally:overallidletime,int(timeq13);

delay: processtime13;
release: machine13;

queue, processqueue14: mark(timeq14);
seize: machine14;

tally:idletimeq14,int(timeq14);
tally:overallidletime,int(timeq14);

delay: processtime14;
release: machine14;

queue, processqueue15: mark(timeq15);
seize: machine15;

tally:idletimeq15,int(timeq15);
tally:overallidletime,int(timeq15);

delay: processtime15;
release: machine15;

queue, scanq16: mark(timescanq16);
scan: paintingareapart<8 .AND. NT(crane)<=1 .AND. craneuse16<=0 .AND. craneuse19<=0;

tally:idletimescanq16,int(timescanq16);
tally:overallidletime,int(timescanq16);

assign: craneuse16=1;

queue, craneq16: mark(timecraneq16);
request: crane(SDS);

tally:idletimecraneq16,int(timecraneq16);
tally:overallidletime,int(timecraneq16);

assign: weldingareapart=weldingareapart-1;
transport: crane, paintingarea;

Pro20 assign: craneuse19=0;

MC20 queue, processqueue20: mark(timeq20);
seize: machine20;

tally:idletimeq20,int(timeq20);
tally:overallidletime,int(timeq20);

delay: processtime20;
release: machine20;

assign: process20done=1;

queue, scanq21: mark(timescanq21);
scan: paintingareapart<8 .AND. NT(crane)<=1 .AND. craneuse21<=0;

tally:idletimescanq21,int(timescanq21);
tally:overallidletime,int(timescanq21);

assign: craneuse21=1;

queue, craneq21: mark(timecraneq21);
request: crane(SDS);

tally:idletimecraneq21,int(timecraneq21);
tally:overallidletime,int(timecraneq21);

assign: weldingareapart=weldingareapart-1;

```

```

transport: crane, paintingarea;

station, paintingarea;

free: crane;

assign: paintingareapart=paintingareapart+1;

branch,1:
    if, process20done==0, Pro17;
    if, process20done==1, Pro22;

Pro17 assign: craneuse16=0;

MC17 queue, processqueue17: mark(timeq17);
seize: machine17;

tally:idletimeq17,int(timeq17);
tally:overallidletime,int(timeq17);

delay: processtime17;
release: machine17;

delay: paintwaiting18;

assign: process17done=1;

queue, scanq19: mark(timescanq19);
scan: weldingareapart<8 .AND. NT(crane) .AND. craneuse19<=0;

tally:idletimescanq19,int(timescanq19);
tally:overallidletime,int(timescanq19);

assign: craneuse19=1;

queue, craneq19: mark(timecraneq19);
request: crane(SDS);

tally:idletimecraneq19,int(timecraneq19);
tally:overallidletime,int(timecraneq19);

assign: paintingareapart=paintingareapart-1;

transport: crane, weldingarea;

Pro22 assign: craneuse21=0;

MC22 queue, processqueue22: mark(timeq22);
seize: machine22;

tally:idletimeq22,int(timeq22);
tally:overallidletime,int(timeq22);

delay: processtime22;
release: machine22;

queue, scanq23: mark(timescanq23);
scan: finalpaintingpart<8 .AND. NT(crane)<=1 .AND. craneuse23<=0;

tally:idletimescanq23,int(timescanq23);
tally:overallidletime,int(timescanq23);

assign: craneuse23=1;

queue, craneq23: mark(timecraneq23);
request: crane(SDS);

tally:idletimecraneq23,int(timecraneq23);
tally:overallidletime,int(timecraneq23);

```

```

assign: paintingareapart=paintingareapart-1;
transport: crane, finalpaintingarea;

station, finalpaintingarea;

free: crane;
assign: craneuse23=0;
assign: finalpaintingpart=finalpaintingpart+1;

queue, processqueue24: mark(timeq24);
seize: machine24;

tally:idletimeq24,int(timeq24);
tally:overallidletime,int(timeq24);

delay: processtime24;
release: machine24;

delay: paintwaiting25;

queue, processqueue26: mark(timeq26);
seize: machine26;

tally:idletimeq26,int(timeq26);
tally:overallidletime,int(timeq26);

delay: processtime26;
release: machine26;

queue, scanq27: mark(timescanq27);
scan: storageareapart<24 .AND. NT(crane)<=1 .AND. craneuse27<=0;

tally:idletimescanq27,int(timescanq27);
tally:overallidletime,int(timescanq27);

assign: craneuse27=1;

queue, craneq27: mark(timecraneq27);
request: crane(SDS);

tally:idletimecraneq27,int(timecraneq27);
tally:overallidletime,int(timecraneq27);

assign: finalpaintingpart=finalpaintingpart-1;
transport: crane, storagearea;

station, storagearea;

free: crane;

assign: craneuse27=0;
assign: storageareapart=storageareapart+1;

delay: paintwaiting28;

assign: storageareapart=storageareapart-1;

tally:avgflowtime,int(timein);
tally:cycletime,BET;

count: jobdone;
dispose;

create,1;
Check1 scan: paintingareapart>=8 .AND. nq(scanq23)<=0 .AND. nr(machine22)<=0 .AND. nq(processqueue22)<=0 .AND.
weldingareapart>=8 .AND. nq(scanq19)>=8 .AND. nq(scanq16)+nq(scanq21)>=8;
branch,1:
    if, nq(scanq21)=0, Pick16:
    if, nq(scanq21)>=0, Pick21;

```

```

Pick16  delay: 20;
        duplicate: 1, AA;

        pickup: scanq16,1,1;
        dropoff,1,1: MC17: next(Check1);

AA      pickup: scanq19,1,1;
        dropoff,1,1: MC20;
        dispose;

Pick21  delay: 20;
        duplicate: 1, BB;

        pickup: scanq21,1,1;
        dropoff,1,1: MC22: next(Check1);

BB      pickup: scanq19,1,1;
        dropoff,1,1: MC20;
        dispose;

        create,1;

fail1  Delay:workingminutes;
        queue,preemptq1;
        preempt:machine1;
        Delay:idleminutes;
        Release:machine1:next(fail1);

        create,1;

fail3  Delay:workingminutes;
        queue,preemptq3;
        preempt:machine3;
        Delay:idleminutes;
        Release:machine3:next(fail3);

        create,1;

fail5  Delay:workingminutes;
        queue,preemptq5;
        preempt:machine5;
        Delay:idleminutes;
        Release:machine5:next(fail5);

        create,1;

fail8  Delay:workingminutes;
        queue,preemptq8;
        preempt:machine8;
        Delay:idleminutes;
        Release:machine8:next(fail8);

        create,1;

fail9  Delay:workingminutes;
        queue,preemptq9;
        preempt:machine9;
        Delay:idleminutes;
        Release:machine9:next(fail9);

        create,1;

fail11 Delay:workingminutes;
        queue,preemptq11;
        preempt:machine11;
        Delay:idleminutes;
        Release:machine11:next(fail11);

        create,1;

fail12 Delay:workingminutes;
        queue,preemptq12;
        preempt:machine12;
        Delay:idleminutes;
        Release:machine12:next(fail12);

```

```
    create,1;
fail13 Delay:workingminutes;
      queue,preemptq13;
      preempt:machine13;
      Delay:idleminutes;
      Release:machine13:next(fail13);

    create,1;
fail14 Delay:workingminutes;
      queue,preemptq14;
      preempt:machine14;
      Delay:idleminutes;
      Release:machine14:next(fail14);

    create,1;
fail15 Delay:workingminutes;
      queue,preemptq15;
      preempt:machine15;
      Delay:idleminutes;
      Release:machine15:next(fail15);

    create,1;
fail17 Delay:workingminutes;
      queue,preemptq17;
      preempt:machine17;
      Delay:idleminutes;
      Release:machine17:next(fail17);

    create,1;
fail20 Delay:workingminutes;
      queue,preemptq20;
      preempt:machine20;
      Delay:idleminutes;
      Release:machine20:next(fail20);

    create,1;
fail22 Delay:workingminutes;
      queue,preemptq22;
      preempt:machine22;
      Delay:idleminutes;
      Release:machine22:next(fail22);

    create,1;
fail24 Delay:workingminutes;
      queue,preemptq24;
      preempt:machine24;
      Delay:idleminutes;
      Release:machine24:next(fail24);

    create,1;
fail26 Delay:workingminutes;
      queue,preemptq26;
      preempt:machine26;
      Delay:idleminutes;
      Release:machine26:next(fail26);
End;
```

## Appendix C

### Modified Process layout plant's simulation program



#### ARENA Simulation Results Summary for Replication 1 of 1

Project: New Layout                      Run execution date : 8/23/2004  
Analyst: Process Layout                Model revision date: 8/23/2004

Replication ended at time : 30000.0

#### TALLY VARIABLES

Identifier      Average   Half Width   Minimum   Maximum   Observations

| Identifier       | Average | Half Width | Minimum | Maximum | Observations |
|------------------|---------|------------|---------|---------|--------------|
| avgflowtime      | 9536.8  | (Insuf)    | 6239.3  | 10848.  | 80           |
| cycletime        | 264.90  | (Insuf)    | 45.333  | 655.33  | 79           |
| overallidletime  | 111.69  | (Corr)     | .00000  | 2065.3  | 2640         |
| idletimeq1       | 420.91  | (Insuf)    | .00000  | 1200.0  | 80           |
| idletimeq3       | .30000  | (Insuf)    | .00000  | 14.666  | 80           |
| idletimeq5       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq8       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq9       | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq11      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq12      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq13      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq14      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq15      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq17      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq20      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq22      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq24      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq26      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimecraneq2  | 112.25  | (Insuf)    | .00000  | 277.33  | 80           |
| idletimecraneq4  | 133.52  | (Insuf)    | .00000  | 286.00  | 80           |
| idletimecraneq7  | 137.98  | (Insuf)    | .00000  | 270.66  | 80           |
| idletimecraneq10 | 81.266  | (Insuf)    | .00000  | 205.33  | 80           |
| idletimecraneq16 | 52.908  | (Insuf)    | .00000  | 150.66  | 80           |
| idletimecraneq19 | 32.266  | (Insuf)    | .00000  | 110.66  | 80           |
| idletimecraneq21 | 79.575  | (Insuf)    | .00000  | 192.00  | 80           |
| idletimecraneq23 | 65.050  | (Insuf)    | .00000  | 172.00  | 80           |
| idletimecraneq27 | 42.916  | (Insuf)    | .00000  | 75.333  | 80           |
| idletimescanq2   | 1116.8  | (Insuf)    | .00000  | 2065.3  | 80           |
| idletimescanq4   | 152.30  | (Insuf)    | .00000  | 646.00  | 80           |
| idletimescanq7   | 544.43  | (Insuf)    | .00000  | 1426.0  | 80           |
| idletimescanq10  | 90.250  | (Insuf)    | .00000  | 256.00  | 80           |
| idletimescanq16  | 226.32  | (Insuf)    | .00000  | 846.00  | 80           |
| idletimescanq19  | 3.3666  | (Insuf)    | .00000  | 112.00  | 80           |
| idletimescanq21  | 119.81  | (Insuf)    | .00000  | 482.00  | 80           |
| idletimescanq23  | 121.86  | (Insuf)    | .00000  | 444.00  | 80           |
| idletimescanq27  | 151.67  | (Insuf)    | .00000  | 504.66  | 80           |

#### DISCRETE-CHANGE VARIABLES

Identifier      Average   Half Width   Minimum   Maximum   Final Value

| Identifier           | Average | Half Width | Minimum | Maximum | Final Value |
|----------------------|---------|------------|---------|---------|-------------|
| machine1utilization  | 1.3040  | (Insuf)    | .00000  | 2.0000  | 1.0000      |
| machine3utilization  | 1.3040  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine5utilization  | .90400  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine8utilization  | .82400  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine9utilization  | .82400  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine11utilization | .98400  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine12utilization | 1.9440  | (Insuf)    | .00000  | 5.0000  | 1.0000      |
| machine13utilization | 1.3040  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine14utilization | .98400  | (Insuf)    | .00000  | 3.0000  | 1.0000      |

|                      |        |         |        |        |        |
|----------------------|--------|---------|--------|--------|--------|
| machine15utilization | .98400 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine17utilization | .98400 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine20utilization | 1.0640 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine22utilization | 1.1440 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine24utilization | .82400 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine26utilization | .82400 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| craneutilization     | 0.3347 | (Corr)  | .00000 | 1.0000 | .00000 |

## COUNTERS

| Identifier | Count | Limit    |
|------------|-------|----------|
| jobdone    | 80    | Infinite |

Simulation run time: 1.07 minutes.  
Simulation run complete.

Experiment  
Begin;

Project, New Layout, Process Layout;

Variables: batchsize, 80:

processtime1,240:  
processtime3,240:  
processtime5,90:  
processtime8,60:  
processtime9,60:  
processtime11,120:  
processtime12,480:  
processtime13,240:  
processtime14,120:  
processtime15,120:  
processtime17,120:  
processtime20,150:  
processtime22,180:  
processtime24,60:  
processtime26,60:

paintwaiting6,60:  
paintwaiting18,1080:  
paintwaiting25,480:  
paintwaiting28,1440:

craneuse2:  
craneuse4:  
craneuse7,0:  
craneuse10,0:  
craneuse16,0:  
craneuse19,0:  
craneuse21,0:  
craneuse23,0:  
craneuse27,0:

cuttingpart,0:  
sandblastingpart,0:  
paintingpart,0:  
preconstructpart,0:  
weldingareapart,0:  
paintingareapart,0:  
finalpaintingpart,0:  
storageareapart,0:

workingminutes,480:  
idleminutes,960;

Attributes: process3done,0:

process17done,0:  
process20done,0:

timein:  
timeq1:  
timeq3:  
timeq5:  
timeq8:  
timeq9:  
timeq11:  
timeq12:  
timeq13:  
timeq14:  
timeq15:  
timeq17:  
timeq20:  
timeq22:  
timeq24:  
timeq26:

timecraneq2:  
timecraneq4:  
timecraneq7:  
timecraneq10:  
timecraneq16:  
timecraneq19:  
timecraneq21:  
timecraneq23:  
timecraneq27:

timescanq2:  
timescanq4:  
timescanq7:  
timescanq10:  
timescanq16:  
timescanq19:  
timescanq21:  
timescanq23:  
timescanq27;

**Queues:**

1,processqueue1:  
2,processqueue3:  
3,processqueue5:  
4,processqueue8:  
5,processqueue9:  
6,processqueue11:  
7,processqueue12:  
8,processqueue13:  
9,processqueue14:  
10,processqueue15:  
11,processqueue17:  
12,processqueue20:  
13,processqueue22:  
14,processqueue24:  
15,processqueue26:

16,craneq2:  
17,craneq4:  
18,craneq7:  
19,craneq10:  
20,craneq16:  
21,craneq19:  
22,craneq21:  
23,craneq23:  
24,craneq27:

25,scanq7:  
26,scanq10:  
27,scanq16:



28,scanq19:  
 29,scanq21:  
 30,scanq23:  
 31,scanq27:

32,preemptq1:  
 33,preemptq3:  
 34,preemptq5:  
 35,preemptq8:  
 36,preemptq9:  
 37,preemptq11:  
 38,preemptq12:  
 39,preemptq13:  
 40,preemptq14:  
 41,preemptq15:  
 42,preemptq17:  
 43,preemptq20:  
 44,preemptq22:  
 45,preemptq24:  
 46,preemptq26:

craneq16b:  
 craneq19b:  
 craneq21b:

100,scanq2:  
 101,scanq4:  
 102,scanq0;

Resources: 1,machine1,2:

2,machine3,3:  
 3,machine5,8:  
 4,machine8,8:  
 5,machine9,8:  
 6,machine11,8:  
 7,machine12,8:  
 8,machine13,8:  
 9,machine14,8:  
 10,machine15,8:  
 11,machine17,8:  
 12,machine20,8:  
 13,machine22,8:  
 14,machine24,8:  
 15,machine26,8;

Stations: 1,cuttingarea:

2,sandblastingroom:  
 3,preconstructarea:  
 4,weldingarea:  
 5,paintingarea:  
 6,finalpaintingarea:  
 7,storagearea:  
 8,buffer;

Transporters: 1,crane,2,1,1.5,cuttingarea-active,cuttingarea-active;

Distances: 1,

cuttingarea-sandblastingroom-15,  
 cuttingarea-preconstructarea-45,  
 cuttingarea-weldingarea-45,  
 cuttingarea-buffer-68,  
 cuttingarea-paintingarea-90,  
 cuttingarea-finalpaintingarea-113,  
 cuttingarea-storagearea-135,  
  
 sandblastingroom-cuttingarea-15,  
 sandblastingroom-preconstructarea-23,  
 sandblastingroom-weldingarea-45,  
 sandblastingroom-buffer-68,

sandblastingroom-paintingarea-90,  
 sandblastingroom-finalpaintingarea-113,  
 sandblastingroom-storagearea-135,

preconstructarea-cuttingarea-23,  
 preconstructarea-sandblastingroom-23,  
 preconstructarea-weldingarea-45,  
 preconstructarea-buffer-45,  
 preconstructarea-paintingarea-68,  
 preconstructarea-finalpaintingarea-90,  
 preconstructarea-storagearea-113,

weldingarea-cuttingarea-45,  
 weldingarea-sandblastingroom-45,  
 weldingarea-preconstructarea-23,  
 weldingarea-buffer-45,  
 weldingarea-paintingarea-45,  
 weldingarea-finalpaintingarea-68,  
 weldingarea-storagearea-90,

buffer-cuttingarea-68,  
 buffer-sandblastingroom-68,  
 buffer-preconstructarea-45,  
 buffer-weldingarea-23,  
 buffer-paintingarea-45,  
 buffer-finalpaintingarea-45,  
 buffer-storagearea-68,

paintingarea-cuttingarea-90,  
 paintingarea-sandblastingroom-90,  
 paintingarea-preconstructarea-68,  
 paintingarea-weldingarea-45,  
 paintingarea-buffer-23,  
 paintingarea-finalpaintingarea-45,  
 paintingarea-storagearea-45,

finalpaintingarea-cuttingarea-113,  
 finalpaintingarea-sandblastingroom-113,  
 finalpaintingarea-preconstructarea-90,  
 finalpaintingarea-weldingarea-68,  
 finalpaintingarea-buffer-45,  
 finalpaintingarea-paintingarea-23,  
 finalpaintingarea-storagearea-45,

storagearea-cuttingarea-135,  
 storagearea-sandblastingroom-135,  
 storagearea-preconstructarea-113,  
 storagearea-weldingarea-90,  
 storagearea-buffer-68,  
 storagearea-paintingarea-45,  
 storagearea-finalpaintingarea-23;

Counters: 1, jobdone;

tallies:1,avgflowtime:  
 2,cycletime:  
 overallidletime:

idletimeq1:  
 idletimeq3:  
 idletimeq5:  
 idletimeq8:  
 idletimeq9:  
 idletimeq11:  
 idletimeq12:  
 idletimeq13:  
 idletimeq14:  
 idletimeq15:  
 idletimeq17:  
 idletimeq20:  
 idletimeq22:

```

idletimeq24:
idletimeq26:

idletimecraneq2:
idletimecraneq4:
idletimecraneq7:
idletimecraneq10:
idletimecraneq16:
idletimecraneq19:
idletimecraneq21:
idletimecraneq23:
idletimecraneq27:

idletimescanq2:
idletimescanq4:
idletimescanq7:
idletimescanq10:
idletimescanq16:
idletimescanq19:
idletimescanq21:
idletimescanq23:
idletimescanq27;

dstats:nr(machine1),machine1utilization:
nr(machine3),machine3utilization:
nr(machine5),machine5utilization:
nr(machine8),machine8utilization:
nr(machine9),machine9utilization:
nr(machine11),machine11utilization:
nr(machine12),machine12utilization:
nr(machine13),machine13utilization:
nr(machine14),machine14utilization:
nr(machine15),machine15utilization:
nr(machine17),machine17utilization:
nr(machine20),machine20utilization:
nr(machine22),machine22utilization:
nr(machine24),machine24utilization:
nr(machine26),machine26utilization:
nt(crane),craneutilization;

Replicate,1,0,27167;

End;

Model
Begin;

create, batchsize;

queue,scanq0;
scan:cuttingpart<8;
station, cuttingarea;

branch,1:
if, process3done==1, Pro5:
if, process3done==0, Pro1;

Pro1 assign:cuttingpart=cuttingpart+1;
queue, processqueue1: mark(timeq1);
seize: machine1:mark(timein);

tally:idletimeq1,int(timeq1);
tally:overallidletime,int(timeq1);

delay: processtime1;
release: machine1;

queue,scanq2:mark(timescanq2);

```

```

scan:sandblastingpart<3.AND.NT(crane)<2.AND.craneuse2<=0;

tally:idletimescanq2,int(timescanq2);
tally:overallidletime,int(timescanq2);

assign:craneuse2=1;

queue, craneq2: mark(timecraneq2);
request: crane(SDS);

tally:idletimecraneq2,int(timecraneq2);
tally:overallidletime,int(timecraneq2);

assign:cuttingpart=cuttingpart-1;

transport: crane, sandblastingroom;

Pro5 free: crane;
assign:craneuse4=0;
assign:paintingpart=paintingpart+1;
queue, processqueue5: mark(timeq5);
seize: machine5;

tally:idletimeq5,int(timeq5);
tally:overallidletime,int(timeq5);

delay: processtime5;
release: machine5;

delay: paintwaiting6;

queue, scanq7: mark(timescanq7);
scan: preconstructpart<8 .AND. NT(crane)<=1 .AND. craneuse7<=0;

tally:idletimescanq7,int(timescanq7);
tally:overallidletime,int(timescanq7);

assign: craneuse7=1;

queue, craneq7: mark(timecraneq7);
request: crane(SDS);

tally:idletimecraneq7,int(timecraneq7);
tally:overallidletime,int(timecraneq7);

assign:paintingpart=paintingpart-1;

transport: crane, preconstructarea;

station, sandblastingroom;

free: crane;
assign:craneuse2=0;
assign:sandblastingpart=sandblastingpart+1;

queue, processqueue3: mark(timeq3);
seize: machine3;

tally:idletimeq3,int(timeq3);
tally:overallidletime,int(timeq3);

delay: processtime3;
release: machine3;

assign: process3done=1;

queue,scanq4:mark(timescanq4);
scan:paintingpart<8.AND.NT(crane)<2.AND.craneuse4<=0;

tally:idletimescanq4,int(timescanq4);

```

```

tally:overallidletime,int(timescanq4);

assign:craneuse4=1;

queue, craneq4: mark(timecraneq4);
request: crane(SDS);

tally:idletimecraneq4,int(timecraneq4);
tally:overallidletime,int(timecraneq4);

assign:sandblastingpart=sandblastingpart-1;
transport: crane, cuttingarea;

station, preconstructarea;

free: crane;
assign: craneuse7=0;
assign: preconstructpart=preconstructpart+1;

queue, processqueue8: mark(timeq8);
seize: machine8;

tally:idletimeq8,int(timeq8);
tally:overallidletime,int(timeq8);

delay: processtime8;
release: machine8;

queue, processqueue9: mark(timeq9);
seize: machine9;

tally:idletimeq9,int(timeq9);
tally:overallidletime,int(timeq9);

delay: processtime9;
release: machine9;

queue, scanq10: mark(timescanq10);
scan: weldingareapart<8 .AND. NT(crane)<=1 .AND. craneuse10<=0;

tally:idletimescanq10,int(timescanq10);
tally:overallidletime,int(timescanq10);

assign: craneuse10=1;

queue, craneq10: mark(timecraneq10);
request: crane(SDS);

tally:idletimecraneq10,int(timecraneq10);
tally:overallidletime,int(timecraneq10);

assign: preconstructpart=preconstructpart-1;

transport: crane, weldingarea;

station, weldingarea;

free: crane;

assign: weldingareapart=weldingareapart+1;

branch,1:
    if, process17done==0, Pro11:
    if, process17done==1, Pro20;

Pro11 assign: craneuse10=0;

queue, processqueue11: mark(timeq11);
seize: machine11;

```

```

tally:idletimeq11,int(timeq11);
tally:overallidletime,int(timeq11);

delay: processtime11;
release: machine11;

queue, processqueue12: mark(timeq12);
seize: machine12;

tally:idletimeq12,int(timeq12);
tally:overallidletime,int(timeq12);

delay: processtime12;
release: machine12;

queue, processqueue13: mark(timeq13);
seize: machine13;

tally:idletimeq13,int(timeq13);
tally:overallidletime,int(timeq13);

delay: processtime13;
release: machine13;

queue, processqueue14: mark(timeq14);
seize: machine14;

tally:idletimeq14,int(timeq14);
tally:overallidletime,int(timeq14);

delay: processtime14;
release: machine14;

queue, processqueue15: mark(timeq15);
seize: machine15;

tally:idletimeq15,int(timeq15);
tally:overallidletime,int(timeq15);

delay: processtime15;
release: machine15;

queue,craneq16b;
request:crane(SDS);
assign: weldingareapart=weldingareapart-1;
transport: crane,buffer;

```

Pro20 assign: craneuse19=0;

```

MC20 queue, processqueue20: mark(timeq20);
seize: machine20;

tally:idletimeq20,int(timeq20);
tally:overallidletime,int(timeq20);

delay: processtime20;
release: machine20;

assign: process20done=1;

queue,craneq21b;
request:crane(SDS);
assign: weldingareapart=weldingareapart-1;
transport: crane,buffer;

```

```

station, buffer;

free: crane;

branch,1:
    if, process17done==0, B1:
    if, process17done==1, B2;

B1
queue, scanq16: mark(timescanq16);
scan: paintingareapart<8 .AND. NT(crane)<=1 .AND. craneuse16<=0 .AND. craneuse19<=0;

tally:idletimescanq16,int(timescanq16);
tally:overallidletime,int(timescanq16);

assign: craneuse16=1;

queue, craneq16: mark(timecraneq16);
request: crane(SDS);

tally:idletimecraneq16,int(timecraneq16);
tally:overallidletime,int(timecraneq16);

transport: crane, paintingarea;

B2
branch,1:
    if, process20done==0, B3:
    if, process20done==1, B4;

B3
queue, scanq19: mark(timescanq19);
scan: weldingareapart<8 .AND. NT(crane) .AND. craneuse19<=0;

tally:idletimescanq19,int(timescanq19);
tally:overallidletime,int(timescanq19);

assign: craneuse19=1;

queue, craneq19: mark(timecraneq19);
request: crane(SDS);

tally:idletimecraneq19,int(timecraneq19);
tally:overallidletime,int(timecraneq19);

transport: crane, weldingarea;

B4
queue, scanq21: mark(timescanq21);
scan: paintingareapart<8 .AND. NT(crane)<=1 .AND. craneuse21<=0;

tally:idletimescanq21,int(timescanq21);
tally:overallidletime,int(timescanq21);

assign: craneuse21=1;

queue, craneq21: mark(timecraneq21);
request: crane(SDS);

tally:idletimecraneq21,int(timecraneq21);
tally:overallidletime,int(timecraneq21);

transport: crane, paintingarea;

station, paintingarea;

free: crane;
assign: paintingareapart=paintingareapart+1;

```

```

branch,l:
    if, process20done==0, Pro17:
    if, process20done==1, Pro22;

Pro17    assign: craneuse16=0;

MC17    queue, processqueue17: mark(timeq17);
        seize: machine17;

        tally:idletimeq17,int(timeq17);
        tally:overallidletime,int(timeq17);

        delay: processtime17;
        release: machine17;

        delay: paintwaiting18;

        assign: process17done=1;

        queue,craneq19b;
        request:crane(SDS);
        assign: paintingareapart=paintingareapart-1;
        transport: crane,buffer;

Pro22    assign: craneuse21=0;

MC22    queue, processqueue22: mark(timeq22);
        seize: machine22;

        tally:idletimeq22,int(timeq22);
        tally:overallidletime,int(timeq22);

        delay: processtime22;
        release: machine22;

        queue, scanq23: mark(timescanq23);
        scan: finalpaintingpart<8 .AND. NT(crane)<=1 .AND. craneuse23<=0;

        tally:idletimescanq23,int(timescanq23);
        tally:overallidletime,int(timescanq23);

        assign: craneuse23=1;

        queue, craneq23: mark(timecraneq23);
        request: crane(SDS);

        tally:idletimecraneq23,int(timecraneq23);
        tally:overallidletime,int(timecraneq23);

        assign: paintingareapart=paintingareapart-1;
        transport: crane, finalpaintingarea;

        station, finalpaintingarea;

        free: crane;
        assign: craneuse23=0;
        assign: finalpaintingpart=finalpaintingpart+1;

        queue, processqueue24: mark(timeq24);
        seize: machine24;

        tally:idletimeq24,int(timeq24);
        tally:overallidletime,int(timeq24);

        delay: processtime24;
        release: machine24;

```



```

delay: paintwaiting25;

queue, processqueue26: mark(timeq26);
seize: machine26;

tally:idletimeq26,int(timeq26);
tally:overallidletime,int(timeq26);

delay: processtime26;
release: machine26;

queue, scanq27: mark(timescanq27);
scan: storageareapart<24 .AND. NT(crane)<=1 .AND. craneuse27<=0;

tally:idletimescanq27,int(timescanq27);
tally:overallidletime,int(timescanq27);

assign: craneuse27=1;

queue, craneq27: mark(timecraneq27);
request: crane(SDS);

tally:idletimecraneq27,int(timecraneq27);
tally:overallidletime,int(timecraneq27);

assign: finalpaintingpart=finalpaintingpart-1;
transport: crane, storagearea;

station, storagearea;

free: crane;

assign: craneuse27=0;
assign: storageareapart=storageareapart+1;

delay: paintwaiting28;

assign: storageareapart=storageareapart-1;

tally:avgflowtime,int(timein);
tally:cycletime,BET;

count: jobdone;
dispose;

create,1;
Check1 scan: paintingareapart>=8 .AND. nq(scanq23)<=0 .AND. nr(machine22)<=0 .AND. nq(processqueue22)<=0 .AND.
weldingareapart>=8 .AND. nq(scanq19)>=8 .AND. nq(scanq16)+nq(scanq21)>=8;
branch,1:
    if, nq(scanq21)=0, Pick16:
    if, nq(scanq21)>=0, Pick21;

Pick16 delay: 20;
duplicate: 1, AA;

pickup: scanq16,1,1;
dropoff,1,1: MC17: next(Check1);

AA pickup: scanq19,1,1;
dropoff,1,1: MC20;
dispose;

Pick21 delay: 20;
duplicate: 1, BB;

pickup: scanq21,1,1;
dropoff,1,1: MC22: next(Check1);

BB pickup: scanq19,1,1;

```

```
dropoff,1,1: MC20;
dispose;

create,1;

fail1 Delay:workingminutes;
queue,preemptq1;
preempt:machine1;
Delay:idleminutes;
Release:machine1.next(fail1);

create,1;

fail3 Delay:workingminutes;
queue,preemptq3;
preempt:machine3;
Delay:idleminutes;
Release:machine3.next(fail3);

create,1;

fail5 Delay:workingminutes;
queue,preemptq5;
preempt:machine5;
Delay:idleminutes;
Release:machine5.next(fail5);

create,1;

fail8 Delay:workingminutes;
queue,preemptq8;
preempt:machine8;
Delay:idleminutes;
Release:machine8.next(fail8);

create,1;

fail9 Delay:workingminutes;
queue,preemptq9;
preempt:machine9;
Delay:idleminutes;
Release:machine9.next(fail9);

create,1;

fail11 Delay:workingminutes;
queue,preemptq11;
preempt:machine11;
Delay:idleminutes;
Release:machine11.next(fail11);

create,1;

fail12 Delay:workingminutes;
queue,preemptq12;
preempt:machine12;
Delay:idleminutes;
Release:machine12.next(fail12);

create,1;

fail13 Delay:workingminutes;
queue,preemptq13;
preempt:machine13;
Delay:idleminutes;
Release:machine13.next(fail13);

create,1;

fail14 Delay:workingminutes;
queue,preemptq14;
preempt:machine14;
Delay:idleminutes;
Release:machine14.next(fail14);

create,1;

fail15 Delay:workingminutes;
queue,preemptq15;
preempt:machine15;
```

```
    Delay:idleminutes;
    Release:machine15:next(fail15);

    create,1;
fail17 Delay:workingminutes;
       queue,preemptq17;
       preempt:machine17;
       Delay:idleminutes;
       Release:machine17:next(fail17);

    create,1;
fail20 Delay:workingminutes;
       queue,preemptq20;
       preempt:machine20;
       Delay:idleminutes;
       Release:machine20:next(fail20);

    create,1;
fail22 Delay:workingminutes;
       queue,preemptq22;
       preempt:machine22;
       Delay:idleminutes;
       Release:machine22:next(fail22);

    create,1;
fail24 Delay:workingminutes;
       queue,preemptq24;
       preempt:machine24;
       Delay:idleminutes;
       Release:machine24:next(fail24);

    create,1;
fail26 Delay:workingminutes;
       queue,preemptq26;
       preempt:machine26;
       Delay:idleminutes;
       Release:machine26:next(fail26);

End;
```

## Appendix D

### Product layout plant's simulation program

#### ARENA Simulation Results Summary for Replication 1 of 1

Project:New Plant                      Run execution date : 8/15/2004  
Analyst:Flowline                      Model revision date: 8/15/2004

Replication ended at time    : 20856.0

#### TALLY VARIABLES

| Identifier      | Average | Half Width | Minimum | Maximum | Observations |
|-----------------|---------|------------|---------|---------|--------------|
| avgflowtime     | 7575.9  | (Insuf)    | 6430.6  | 8038.6  | 80           |
| overallidletime | 51.575  | 10.833     | .00000  | 1200.0  | 2960         |
| cycletime       | 182.59  | (Insuf)    | 18.000  | 1044.6  | 79           |
| idletimeq1      | 1081.2  | (Insuf)    | .00000  | 1200.0  | 80           |
| idletimeq3      | 2.5750  | (Insuf)    | .00000  | 56.666  | 80           |
| idletimeq5      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq8      | 562.04  | (Insuf)    | .00000  | 958.00  | 80           |
| idletimeq9      | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq11     | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq12     | 7.4583  | (Insuf)    | .00000  | 97.333  | 80           |
| idletimeq13     | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq14     | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq16     | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq18     | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq22     | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq24     | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq26     | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimeq28     | .00000  | (Insuf)    | .00000  | .00000  | 80           |
| idletimecrane1  | 16.733  | (Insuf)    | .00000  | 62.000  | 80           |
| idletimecrane3  | 14.708  | (Insuf)    | .00000  | 62.000  | 80           |
| idletimecrane6  | 10.750  | (Insuf)    | .00000  | 38.666  | 80           |
| idletimecrane9  | 15.983  | (Insuf)    | .00000  | 78.000  | 80           |
| idletimecrane14 | 12.283  | (Insuf)    | .00000  | 50.000  | 80           |
| idletimecrane16 | 15.058  | (Insuf)    | .00000  | 56.666  | 80           |
| idletimecrane18 | 14.216  | (Insuf)    | .00000  | 56.000  | 80           |
| idletimecrane20 | 11.933  | (Insuf)    | .00000  | 50.000  | 80           |
| idletimecrane22 | 13.066  | (Insuf)    | .00000  | 38.666  | 80           |
| idletimecrane24 | 9.5833  | (Insuf)    | .00000  | 24.000  | 80           |
| idletimecrane28 | 11.066  | (Insuf)    | .00000  | 26.000  | 80           |
| idletimescanq0  | 5857.7  | (Insuf)    | .00000  | 12989.  | 80           |
| idletimescanq1  | 13.275  | (Insuf)    | .00000  | 92.000  | 80           |
| idletimescanq2  | 7.1833  | (Insuf)    | .00000  | 36.666  | 80           |
| idletimescanq6  | 5.2833  | (Insuf)    | .00000  | 52.000  | 80           |
| idletimescanq9  | 11.516  | (Insuf)    | .00000  | 51.333  | 80           |
| idletimescanq14 | 4.6166  | (Insuf)    | .00000  | 39.333  | 80           |
| idletimescanq16 | 14.683  | (Insuf)    | .00000  | 82.666  | 80           |
| idletimescanq18 | 14.983  | (Insuf)    | .00000  | 70.000  | 80           |
| idletimescanq20 | 7.4250  | (Insuf)    | .00000  | 73.333  | 80           |
| idletimescanq22 | 11.800  | (Insuf)    | .00000  | 94.000  | 80           |
| idletimescanq24 | 13.791  | (Insuf)    | .00000  | 66.000  | 80           |
| idletimescanq28 | 5.0500  | (Insuf)    | .00000  | 61.333  | 80           |

#### DISCRETE-CHANGE VARIABLES

| Identifier          | Average | Half Width | Minimum | Maximum | Final Value |
|---------------------|---------|------------|---------|---------|-------------|
| machine1utilization | 1.5753  | (Insuf)    | .00000  | 2.0000  | 1.0000      |
| machine3utilization | 1.5753  | (Insuf)    | .00000  | 3.0000  | 1.0000      |
| machine5utilization | 1.0000  | (Insuf)    | .00000  | 3.0000  | 1.0000      |

|                      |        |         |        |        |        |
|----------------------|--------|---------|--------|--------|--------|
| machine8utilization  | .88493 | (Insuf) | .00000 | 1.0000 | 1.0000 |
| machine9utilization  | .88493 | (Insuf) | .00000 | 2.0000 | 1.0000 |
| machine11utilization | 1.1150 | (Insuf) | .00000 | 5.0000 | 1.0000 |
| machine12utilization | 2.4959 | (Insuf) | .00000 | 8.0000 | 1.0000 |
| machine13utilization | 1.5753 | (Insuf) | .00000 | 6.0000 | 1.0000 |
| machine14utilization | 1.1150 | (Insuf) | .00000 | 5.0000 | 1.0000 |
| machine16utilization | 1.1150 | (Insuf) | .00000 | 4.0000 | 1.0000 |
| machine18utilization | 1.1150 | (Insuf) | .00000 | 4.0000 | 1.0000 |
| machine22utilization | 1.2301 | (Insuf) | .00000 | 4.0000 | 1.0000 |
| machine24utilization | 1.3452 | (Insuf) | .00000 | 4.0000 | 1.0000 |
| machine26utilization | .88493 | (Insuf) | .00000 | 3.0000 | 1.0000 |
| machine28utilization | .88493 | (Insuf) | .00000 | 4.0000 | 1.0000 |
| craneutilization     | .4802  | (Corr)  | .00000 | 1.0000 | .00000 |

## COUNTERS

| Identifier | Count | Limit |
|------------|-------|-------|
|------------|-------|-------|

|         |    |          |
|---------|----|----------|
| jobdone | 80 | Infinite |
|---------|----|----------|

Simulation run time: 0.00 minutes.

Simulation run complete.

## Experiment

Begin;

Variables: Batchsize,80:

Processtime1,240:

Processtime3,240:

Processtime5,90:

Processtime8,60:

Processtime9,60:

Processtime11,120:

Processtime12,480:

Processtime13,240:

Processtime14,120:

Processtime16,120:

Processtime18,120:

Processtime22,150:

Processtime24,180:

Processtime26,60:

Processtime28,60:

Paintwaiting6,60:

Paintwaiting20,1080:

Paintwaiting27,480:

Paintwaiting30,1440:

transferring31,60:

Cuttingpart,0:

sandblastingpart,0:

Firstlayerpart,0:

Preconpart,0:

Weldingpart,0:

Cleaningpart,0:

Internalpart,0:

Curingpart,0:

Finalweldingpart,0:

Storagepart1,0:

Finalpaintingpart,0:

Storagepart2,0:

workingminutes,480:

idleminutes,960:

craneuse1,0:

```

craneuse3,0:
craneuse6,0:
craneuse9,0:
craneuse14,0:
craneuse16,0:
craneuse18,0:
craneuse20,0:
craneuse22,0:
craneuse24,0:
craneuse28,0;

Attributes:
timein:
timeq1:
timeq3:
timeq5:
timeq8:
timeq9:
timeq11:
timeq12:
timeq13:
timeq14:
timeq16:
timeq18:
timeq22:
timeq24:
timeq26:
timeq28:

timecrane1:
timecrane3:
timecrane6:
timecrane9:
timecrane14:
timecrane16:
timecrane18:
timecrane20:
timecrane22:
timecrane24:
timecrane28:

timescanq0:
timescanq1:
timescanq2:
timescanq6:
timescanq9:
timescanq14:
timescanq16:
timescanq18:
timescanq20:
timescanq22:
timescanq24:
timescanq28;

Tallies :avgflowtime:
overallidletime:
cycletime:
idletimeq1:
idletimeq3:
idletimeq5:
idletimeq8:
idletimeq9:
idletimeq11:
idletimeq12:
idletimeq13:
idletimeq14:
idletimeq16:
idletimeq18:
idletimeq22:
idletimeq24:
idletimeq26:

```

idletimeq28:

idletimecrane1:  
idletimecrane3:  
idletimecrane6:  
idletimecrane9:  
idletimecrane14:  
idletimecrane16:  
idletimecrane18:  
idletimecrane20:  
idletimecrane22:  
idletimecrane24:

idletimecrane28:

idletimescanq0:  
idletimescanq1:  
idletimescanq2:  
idletimescanq6:  
idletimescanq9:  
idletimescanq14:  
idletimescanq16:  
idletimescanq18:  
idletimescanq20:  
idletimescanq22:  
idletimescanq24:  
idletimescanq28;

Queues: 1,processqueue1:

2,processqueue3:  
3,processqueue5:  
4,processqueue8:  
5,processqueue9:  
6,processqueue11:  
7,processqueue12:  
8,processqueue13:  
9,processqueue14:  
10,processqueue16:  
11,processqueue18:  
12,processqueue22:  
13,processqueue24:  
14,processqueue26:  
15,processqueue28:  
17,craneq1:  
18,craneq3:  
19,craneq6:  
20,craneq9:  
21,craneq14:  
22,craneq16:  
23,craneq18:  
24,craneq20:  
25,craneq22:  
26,craneq24:  
27,craneq28:

28,scanq0:  
29,scanq1:  
30,scanq2:  
31,scanq6:  
32,scanq9:  
33,scanq14:  
34,scanq16:  
35,scanq18:  
36,scanq20:  
37,scanq22:

38,scanq24:  
39,scanq28:

40,preemptq1:  
41,preemptq3:  
42,preemptq5:  
43,preemptq8:  
44,preemptq9:  
45,preemptq11:  
46,preemptq12:  
47,preemptq13:  
48,preemptq14:  
49,preemptq16:  
50,preemptq18:  
51,preemptq22:  
52,preemptq24:  
53,preemptq26:  
54,preemptq28;

Resources: 1,machine1,2:  
2,machine3,3:  
3,machine5,8:  
4,machine8,1:  
5,machine9,8:  
6,machine11,8:  
7,machine12,8:  
8,machine13,8:  
9,machine14,8:  
10,machine16,8:  
11,machine18,8:  
12,machine22,8:  
13,machine24,16:  
14,machine26,4:  
15,machine28,4;

Stations:  
1,cuttingarea:  
2,sandblastingroom:  
3,Firstlayerarea:  
4,Preconstructarea:  
5,weldingarea:  
6,Cleaninginspect:  
7,Internalpainting:  
8,Curingarea:  
9,Finalweldingarea:  
10,Finalpaintingarea:  
11,storagearea2:  
12,Storagearea1;

Transporters: 1,crane,2,1,1.5,cuttingarea-Active;

Distances:1, Cuttingarea-sandblastingroom-15,  
Cuttingarea-Firstlayerarea-4,  
Cuttingarea-Preconstructarea-8,  
Cuttingarea-Weldingarea-12,  
Cuttingarea-Cleaninginspect-17,  
Cuttingarea-Internalpainting-21,  
Cuttingarea-Curingarea-26,  
Cuttingarea-Finalweldingarea-30,  
Cuttingarea-Finalpaintingarea-39,  
Cuttingarea-Storagearea2-47,  
Cuttingarea-Storagearea1-36,



Sandblastingroom-Cuttingarea-7,  
 Sandblastingroom-Firstlayerarea-22,  
 Sandblastingroom-Preconstructarea-8,  
 Sandblastingroom-Weldingarea-12,  
 Sandblastingroom-Cleaninginspect-17,  
 Sandblastingroom-Internalpainting-21,  
 Sandblastingroom-Curingarea-26,  
 Sandblastingroom-Finalweldingarea-30,  
 Sandblastingroom-Finalpaintingarea-39,  
 Sandblastingroom-Storagearea2-47,  
 Sandblastingroom-Storagearea1-36,

Preconstructarea-Cuttingarea-6,  
 Preconstructarea-Sandblastingroom-8,  
 Preconstructarea-Firstlayerarea-22,  
 Preconstructarea-Weldingarea-18,  
 Preconstructarea-Cleaninginspect-9,  
 Preconstructarea-Internalpainting-13,  
 Preconstructarea-Curingarea-18,  
 Preconstructarea-Finalweldingarea-22,  
 Preconstructarea-Finalpaintingarea-32,  
 Preconstructarea-Storagearea2-35,  
 Preconstructarea-Storagearea1-27,

Firstlayerarea-Cuttingarea-4,  
 Firstlayerarea-Sandblastingroom-11,  
 Firstlayerarea-Preconstructarea-45,  
 Firstlayerarea-Weldingarea-8,  
 Firstlayerarea-Cleaninginspect-13,  
 Firstlayerarea-Internalpainting-18,  
 Firstlayerarea-Curingarea-22,  
 Firstlayerarea-Finalweldingarea-27,  
 Firstlayerarea-Finalpaintingarea-35,  
 Firstlayerarea-Storagearea2-43,  
 Firstlayerarea-Storagearea1-32,

weldingarea-Cuttingarea-12,  
 weldingarea-Sandblastingroom-12,  
 weldingarea-Preconstructarea-9,  
 weldingarea-Firstlayerarea-8,  
 weldingarea-Cleaninginspect-18,  
 weldingarea-Internalpainting-9,  
 weldingarea-Curingarea-13,  
 weldingarea-Finalweldingarea-18,  
 weldingarea-Finalpaintingarea-27,  
 weldingarea-Storagearea2-32,  
 weldingarea-Storagearea1-22,

Cleaninginspect-Cuttingarea-17,  
 Cleaninginspect-Sandblastingroom-17,  
 Cleaninginspect-Preconstructarea-9,  
 Cleaninginspect-Firstlayerarea-13,  
 Cleaninginspect-weldingarea-9,  
 Cleaninginspect-Internalpainting-18,  
 Cleaninginspect-Curingarea-9,  
 Cleaninginspect-Finalweldingarea-13,  
 Cleaninginspect-Finalpaintingarea-22,  
 Cleaninginspect-Storagearea2-27,  
 Cleaninginspect-Storagearea1-18,

internalpainting-Cuttingarea-21,  
 internalpainting-Sandblastingroom-21,  
 internalpainting-Preconstructarea-13,  
 internalpainting-Firstlayerarea-18,  
 internalpainting-weldingarea-9,  
 internalpainting-Cleaninginspect-9,  
 internalpainting-Curingarea-18,  
 internalpainting-Finalweldingarea-9,  
 internalpainting-Finalpaintingarea-18,

internalpainting-Storagearea2-22,  
internalpainting-Storagearea1-13,

curingarea-Cuttingarea-26,  
curingarea-Sandblastingroom-26,  
curingarea-Preconstructarea-18,  
curingarea-Firstlayerarea-22,  
curingarea-weldingarea-13,  
curingarea-Cleaninginspect-9,  
curingarea-internalpainting-9,  
curingarea-Finalweldingarea-18,  
curingarea-Finalpaintingarea-13,  
curingarea-Storagearea2-18,  
curingarea-Storagearea1-8,

finalweldingarea-Cuttingarea-30,  
finalweldingarea-Sandblastingroom-30,  
finalweldingarea-Preconstructarea-22,  
finalweldingarea-Firstlayerarea-27,  
finalweldingarea-weldingarea-18,  
finalweldingarea-Cleaninginspect-13,  
finalweldingarea-internalpainting-9,  
finalweldingarea-curingarea-9,  
finalweldingarea-Finalpaintingarea-8,  
finalweldingarea-Storagearea2-17,  
finalweldingarea-Storagearea1-18,

finalpaintingarea-Cuttingarea-39,  
finalpaintingarea-Sandblastingroom-39,  
finalpaintingarea-Preconstructarea-32,  
finalpaintingarea-Firstlayerarea-35,  
finalpaintingarea-weldingarea-27,  
finalpaintingarea-Cleaninginspect-22,  
finalpaintingarea-internalpainting-18,  
finalpaintingarea-curingarea-13,  
finalpaintingarea-Finalweldingarea-8,  
finalpaintingarea-Storagearea2-18,  
finalpaintingarea-Storagearea1-9,

storagearea1-Cuttingarea-36,  
storagearea1-Sandblastingroom-36,  
storagearea1-Preconstructarea-27,  
storagearea1-Firstlayerarea-32,  
storagearea1-weldingarea-22,  
storagearea1-Cleaninginspect-18,  
storagearea1-internalpainting-13,  
storagearea1-curingarea-8,  
storagearea1-Finalweldingarea-9,  
storagearea1-Storagearea2-20,  
storagearea1-Finalpaintingarea-18,

storagearea2-Cuttingarea-47,  
storagearea2-Sandblastingroom-47,  
storagearea2-Preconstructarea-35,  
storagearea2-Firstlayerarea-43,  
storagearea2-weldingarea-32,  
storagearea2-Cleaninginspect-27,  
storagearea2-internalpainting-22,  
storagearea2-curingarea-18,  
storagearea2-Finalweldingarea-17,  
storagearea2-Storagearea1-20,  
storagearea2-Finalpaintingarea-9;

dstats:           nr(machine1),machine1utilization:  
                  nr(machine3),machine3utilization:  
                  nr(machine5),machine5utilization:  
                  nr(machine8),machine8utilization:  
                  nr(machine9),machine9utilization:  
                  nr(machine11),machine11utilization:  
                  nr(machine12),machine12utilization:

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nr(machine13),machine13utilization:
nr(machine14),machine14utilization:
nr(machine16),machine16utilization:
nr(machine18),machine18utilization:
nr(machine22),machine22utilization:
nr(machine24),machine24utilization:
nr(machine26),machine26utilization:
nr(machine28),machine28utilization:
nt(crane),craneutilization;

```

Counters:jobdone;

Replicate,1,0,20856;

end;

Model  
Begin;

create,batchsize;

queue,scanq0:mark(timescanq0);  
scan:cuttingpart<8;

tally:idletimescanq0,int(timescanq0);

station,cuttingarea;  
assign:cuttingpart=cuttingpart+1;

queue,processqueue1:mark(timeq1);  
seize:machine1:mark(timein);

tally:idletimeq1,int(timeq1);  
tally:overallidletime,int(timeq1);

Delay:processtime1;  
Release:machine1;

queue,scanq1:mark(timescanq1);  
scan:sandblastingpart<3.AND.NT(crane)<=1.AND.craneuse1<=0;

tally:idletimescanq1,int(timescanq1);  
tally:overallidletime,int(timescanq1);

assign:craneuse1=1;

queue,craneq1:mark(timecrane1);  
request:crane(sds);

tally:idletimecrane1,int(timecrane1);  
tally:overallidletime,int(timecrane1);

assign:cuttingpart=cuttingpart-1;

transport:crane,sandblastingroom;

station,sandblastingroom;  
free:crane;

assign:craneuse1=0;  
assign:sandblastingpart=sandblastingpart+1;

queue,processqueue3:mark(timeq3);  
seize:machine3;  
tally:idletimeq3,int(timeq3);  
tally:overallidletime,int(timeq3);

```

Delay:processtime3;
Release:machine3;

queue,scanq2:mark(timescanq2);
scan:Firstlayerpart<8.AND.NT(crane)<=1.AND.craneuse3<=0;

tally:idletimescanq2,int(timescanq2);
tally:overallidletime,int(timescanq2);

assign:craneuse3=1;

queue,craneq3:mark(timecrane3);
request:crane(sds);

tally:idletimecrane3,int(timecrane3);
tally:overallidletime,int(timecrane3);

assign:sandblastingpart=sandblastingpart-1;

transport:crane,Firstlayerarea;

station,firstlayerarea;
free:crane;

assign:craneuse3=0;
assign:firstlayerpart=Firstlayerpart+1;

queue,processqueue5:mark(timeq5);
seize:machine5;

tally:idletimeq5,int(timeq5);
tally:overallidletime,int(timeq5);

delay:processtime5;
release:machine5;

delay:paintwaiting6;

queue,scanq6:mark(timescanq6);
scan:Preconpart<8.AND.NT(crane)<=1.AND.craneuse6<=0;

tally:idletimescanq6,int(timescanq6);
tally:overallidletime,int(timescanq6);

assign:craneuse6=1;

queue,craneq6:mark(Timecrane6);
request:crane(sds);

tally:idletimecrane6,int(timecrane6);
tally:overallidletime,int(timecrane6);

assign:firstlayerpart=Firstlayerpart-1;

transport:crane,Preconstructarea;

station,Preconstructarea;

free:crane;
assign:craneuse6=0;
assign:Preconpart=Preconpart+1;

queue,processqueue8:mark(timeq8);
seize:machine8;

```

```

tally:idletimeq8,int(timeq8);
tally:overallidletime,int(timeq8);

delay:processtime8;
release:machine8;

queue,processqueue9:mark(timeq9);
seize:machine9;

tally:idletimeq9,int(timeq9);
tally:overallidletime,int(timeq9);

delay:processtime9;
release:machine9;

queue,scanq9:mark(timescanq9);
scan:Weldingpart<8.AND.NT(crane)<=1.AND.craneuse9<=0;
tally:idletimescanq9,int(timescanq9);
tally:overallidletime,int(timescanq9);

assign:craneuse9=1;

queue,craneq9:mark(timecrane9);
request:crane(sds);

tally:idletimecrane9,int(timecrane9);
tally:overallidletime,int(timecrane9);

assign:Preconpart=Preconpart-1;

transport:crane,weldingarea;

station,weldingarea;
free:crane;

assign:craneuse9=0;
assign:Weldingpart=Weldingpart+1;

queue,processqueue11:mark(timeq11);
seize:machine11;

tally:idletimeq11,int(timeq11);
tally:overallidletime,int(timeq11);

Delay:processtime11;
Release:machine11;

queue,processqueue12:mark(timeq12);
seize:machine12;

tally:idletimeq12,int(timeq12);
tally:overallidletime,int(timeq12);

Delay:processtime12;
Release:machine12;

queue,processqueue13:mark(timeq13);
seize:machine13;
tally:idletimeq13,int(timeq13);
tally:overallidletime,int(timeq13);

Delay:processtime13;
Release:machine13;

queue,processqueue14:mark(timeq14);
seize:machine14;
tally:idletimeq14,int(timeq14);

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```

tally:overallidletime,int(timeq14);

Delay:processtime14;
Release:machine14;

queue,scanq14:mark(timescanq14);
scan:Cleaningpart<8.AND.NT(crane)<=1.AND.craneuse14<=0;

tally:idletimescanq14,int(timescanq14);
tally:overallidletime,int(timescanq14);

assign:craneuse14=1;

queue,craneq14:mark(timecrane14);
request:crane(sds);

tally:idletimecrane14,int(timecrane14);
tally:overallidletime,int(timecrane14);

assign:Weldingpart=Weldingpart-1;
transport:crane,Cleaninginspect;

station,Cleaninginspect;

free:crane;
assign:craneuse14=0;
assign:Cleaningpart=Cleaningpart+1;

queue,processqueue16:mark(timeq16);
seize:machine16;
tally:idletimeq16,int(timeq16);
tally:overallidletime,int(timeq16);

Delay:processtime16;
Release:machine16;

queue,scanq16:mark(timescanq16);
scan:Internalpart<8.AND.NT(crane)<=1.AND.craneuse16<=0;

tally:idletimescanq16,int(timescanq16);
tally:overallidletime,int(timescanq16);

assign:craneuse16=1;

queue,craneq16:mark(timecrane16);
request:crane(sds);
tally:idletimecrane16,int(timecrane16);
tally:overallidletime,int(timecrane16);

assign:Cleaningpart=Cleaningpart-1;
transport:crane,Internalpainting;

station,Internalpainting;

free:crane;
assign:craneuse16=0;
assign:Internalpart=Internalpart+1;

queue,processqueue18:mark(timeq18);
seize:machine18;
tally:idletimeq18,int(timeq18);
tally:overallidletime,int(timeq18);

Delay:processtime18;
Release:machine18;

queue,scanq18:mark(timescanq18);

```

```

scan:Curingpart<8.AND.NT(crane)<=1.AND.craneuse18<=0;

tally:idletimescanq18,int(timescanq18);
tally:overallidletime,int(timescanq18);

assign:craneuse18=1;

queue,craneq18:mark(timecrane18);
request:crane(sds);
tally:idletimecrane18,int(timecrane18);
tally:overallidletime,int(timecrane18);

assign:Internalpart=Internalpart-1;
transport:crane,Curingarea;

station,Curingarea;

free:crane;
assign:craneuse18=0;
assign:Curingpart=Curingpart+1;

delay:paintwaiting20;

queue,scanq20:mark(timescanq20);
scan:Finalweldingpart<8.AND.NT(crane)<=1.AND.craneuse20<=0;

tally:idletimescanq20,int(timescanq20);
tally:overallidletime,int(timescanq20);

assign:craneuse20=1;

queue,craneq20:mark(timecrane20);
request:crane(sds);
tally:idletimecrane20,int(timecrane20);
tally:overallidletime,int(timecrane20);

assign:Curingpart=Curingpart-1;
transport:crane,Finalweldingarea;

station,Finalweldingarea;

free:crane;
assign:craneuse20=0;
assign:Finalweldingpart=Finalweldingpart+1;

queue,processqueue22:mark(timeq22);
seize:machine22;

tally:idletimeq22,int(timeq22);
tally:overallidletime,int(timeq22);

Delay:processtime22;
Release:machine22;

queue,scanq22:mark(timescanq22);
scan:Storagepart1<16.AND.NT(crane)<=1.AND.craneuse22<=0;

tally:idletimescanq22,int(timescanq22);
tally:overallidletime,int(timescanq22);

assign:craneuse22=1;

queue,craneq22:mark(timecrane22);
request:crane(sds);

tally:idletimecrane22,int(timecrane22);
tally:overallidletime,int(timecrane22);

assign:Finalweldingpart=Finalweldingpart-1;
transport:crane,Storagearea1;

```

```

station,Storagearea1;

free:crane;
assign:craneuse22=0;
assign:Storagepart1=Storagepart1+1;

queue,processqueue24:mark(timeq24);
seize:machine24;

tally:idletimeq24,int(timeq24);
tally:overallidletime,int(timeq24);

Delay:processtime24;
Release:machine24;

queue,scanq24:mark(timescanq24);
scan:Finalpaintingpart<8.AND.NT(crane)<=1.AND.craneuse24<=0;
tally:idletimescanq24,int(timescanq24);
tally:overallidletime,int(timescanq24);

assign:craneuse24=1;

queue,craneq24:mark(timecrane24);
request:crane(sds);
tally:idletimecrane24,int(timecrane24);
tally:overallidletime,int(timecrane24);

assign:Storagepart1=Storagepart1-1;
transport:crane,Finalpaintingarea;

station,Finalpaintingarea;

free:crane;
assign:craneuse24=0;
assign:Finalpaintingpart=Finalpaintingpart+1;

queue,processqueue26:mark(timeq26);
seize:machine26;
tally:idletimeq26,int(timeq26);
tally:overallidletime,int(timeq26);

Delay:processtime26;
Release:machine26;

delay:paintwaiting27;

queue,processqueue28:mark(timeq28);
seize:machine28;
tally:idletimeq28,int(timeq28);
tally:overallidletime,int(timeq28);

Delay:processtime28;
Release:machine28;

queue,scanq28:mark(timescanq28);
scan:Storagepart2<16.AND.NT(crane)<=1.AND.craneuse28<=0;
tally:idletimescanq28,int(timescanq28);
tally:overallidletime,int(timescanq28);

assign:craneuse28=1;

queue,craneq28:mark(timecrane28);
request:crane(sds);
tally:idletimecrane28,int(timecrane28);
tally:overallidletime,int(timecrane28);

assign:Finalpaintingpart=Finalpaintingpart-1;
transport:crane,storagearea2;

```



```

station,storagearea2;

free:crane;
assign:craneuse28=0;
assign:Storagepart2=Storagepart2+1;

delay:paintwaiting30;
delay:transferring31;

assign:storagepart2=storagepart2-1;

tally:avgflowtime,int(timein);
tally:cycletime,BET;
count:jobdone;
dispose;

create,1;

fail1 Delay:workingminutes;
      queue,preemptq1;
      preempt:machine1;
      Delay:idleminutes;
      Release:machine1:next(fail1);

      create,1;
fail3 Delay:workingminutes;
      queue,preemptq3;
      preempt:machine3;
      Delay:idleminutes;
      Release:machine3:next(fail3);

      create,1;
fail5 Delay:workingminutes;
      queue,preemptq5;
      preempt:machine5;
      Delay:idleminutes;
      Release:machine5:next(fail5);

      create,1;
fail8 Delay:workingminutes;
      queue,preemptq8;
      preempt:machine8;
      Delay:idleminutes;
      Release:machine8:next(fail8);

      create,1;
fail9 Delay:workingminutes;
      queue,preemptq9;
      preempt:machine9;
      Delay:idleminutes;
      Release:machine9:next(fail9);

      create,1;
fail11 Delay:workingminutes;
       queue,preemptq11;
       preempt:machine11;
       Delay:idleminutes;
       Release:machine11:next(fail11);

      create,1;
fail12 Delay:workingminutes;
       queue,preemptq12;
       preempt:machine12;
       Delay:idleminutes;
       Release:machine12:next(fail12);

      create,1;
fail13 Delay:workingminutes;
       queue,preemptq13;
       preempt:machine13;
       Delay:idleminutes;

```

```
        Release:machine13:next(fail13);

        create,1;
fail14 Delay:workingminutes;
        queue,preemptq14;
        preempt:machine14;
        Delay:idleminutes;
        Release:machine14:next(fail14);

        create,1;
fail16 Delay:workingminutes;
        queue,preemptq16;
        preempt:machine16;
        Delay:idleminutes;
        Release:machine16:next(fail16);

        create,1;
fail18 Delay:workingminutes;
        queue,preemptq18;
        preempt:machine18;
        Delay:idleminutes;
        Release:machine18:next(fail18);

        create,1;
fail22 Delay:workingminutes;
        queue,preemptq22;
        preempt:machine22;
        Delay:idleminutes;
        Release:machine22:next(fail22);

        create,1;
fail24 Delay:workingminutes;
        queue,preemptq24;
        preempt:machine24;
        Delay:idleminutes;
        Release:machine24:next(fail24);

        create,1;
fail26 Delay:workingminutes;
        queue,preemptq26;
        preempt:machine26;
        Delay:idleminutes;
        Release:machine26:next(fail26);

        create,1;
fail28 Delay:workingminutes;
        queue,preemptq28;
        preempt:machine28;
        Delay:idleminutes;
        Release:machine28:next(fail28);

end;
```



## **Biography**

Mr. Vorapol Mauthorn was born on April 17, 1978. He graduated a Bachelor's Degree in Industrial Engineering from Thammasat University in 2000.

He has been working at Sahawattana Corp. as an Assistant Enigeer since 2003.