A KNOWLEDGE BASED MODELLING SYSTEM FOR THE DESIGN AND EVALUATION OF FLEXIBLE MANUFACTURING FACILITIES

Volume II

by

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Table of Contents

Appendix I
COMPUTER CODE OF THE MULTI-PALLET QUEUEING MODEL

The following lists the computer code of the multi-pallet queueing model described in Chapter 5. The program was written in PASCAL on the departmental PRIME mini-computer.

```
PROGRAM MVAQ(INPUT, OUTPUT);
CONST  max_parts = 20;
       max_mach_groups = 20;
TYPE   vtarray = ARRAY[1..max_parts,1..max_mach_groups] OF real ;
       p_array = ARRAY[1..max_parts] OF real ;
       m_array = ARRAY[1..max_mach_groups] OF real;

VAR  i, m, p,
     no_part_types,
     no_mach_groups : integer;
     aver_proce_time, no_visits : vtarray ;
     calcul_preci, calcul_coeffic : real;
     no_pallets_fixtures,
     production_rate,
     aver_time_in_system : p_array;
     no_machs_one_group,
     station_utilisation,
     no_parts_in_process,
     no_parts_waiting : m_array;
{----------------------------------------------------------------------}
{***** PROCEDURE READFILE *****}
PROCEDURE READ_FILE ;
CONST  max_routes = 4;
       max_machs_one_group = 8;
       max_operns = 10;
VAR  r, o, i, m, p,
     part_type_no,
     mach_group_no,
     no_routes,
     route_no,
     no_operns,
     opern_no : integer;
     proce_time : ARRAY [1..max_parts, 1..max_routes,
                         1..max_operns] OF real;
     route_propn : ARRAY [1..max_parts, 1..max_routes,
                          1..max_operns] OF real;
    total_time : ARRAY[1..max_parts, 1..max_mach_groups] OF real ;
    datafile : text;
BEGIN
  reset (datafile, 'benchmark-input');
  FOR i := 1 to 7 DO
  readln(datafile);
  readln(datafile, no_part_types, no_mach_groups);
  FOR i := 1 to 4 DO
  readln(datafile);
  readln(datafile, calcul_preci, calcul_coeffic);
  FOR i := 1 to 4 DO
  readln(datafile);
  FOR m := 1 to (no_mach_groups-1) DO
  readln(datafile, mach_group_no, no_machs_one_group[m]);
  FOR i := 1 to 4 DO
  readln(datafile);
  readln(datafile, mach_group_no, no_machs_one_group[no_mach_groups]);
  FOR i := 1 to 4 DO
  readln(datafile);
  FOR p := 1 to no_part_types DO
  readln(datafile, part_type_no, no_pallets_fixtures[p]);
  FOR i := 1 to 5 DO
  readln(datafile);
  FOR p := 1 to no_part_types DO
  begin
    FOR m := 1 to no_mach_groups DO
    begin
      total_time[p, m] := 0;
      no_visits[p, m] := 0
    end;{for m}
```

```
  end; {for p}
  WHILE (NOT EOF(datafile)) AND (NOT EOLN(datafile)) DO
  begin
    read(datafile, part_type_no);
    read(datafile, no_routes);
    FOR r := 1 to no_routes DO
   begin
      read(datafile, route_no);
      read(datafile, no_operns);
      FOR o := 1 to no_operns DO
      begin
        readln(datafile, opern_no, mach_group_no,
                                         proce_time [part_type_no,
                                         route_no, opern_no],
                                         route_propn [part_type_no,
                                         route_no, opern_no]) ;
        total_time[part_type_no, mach_group_no] :=
                                     total_time[part_type_no, mach_group_no]
                                     + proce_time[part_type_no, route_no,opern_no];
        no_visits[part_type_no, mach_group_no] :=
                                     no_visits[part_type_no, mach_group_no]
                                     +route_propn[part_type_no, route_no, opern_no]
      end {FOR o}
    end {FOR r}
  end; {WHILE}
  FOR p := 1 to no_part_types DO
  begin
    FOR m := 1 to no_mach_groups DO
    IF no_visits[p, m] = 0 THEN aver_proce_time[p, m] := 0
    ELSE IF no_visits[p, m] < 1.00 THEN aver_proce_time[p, m]:=total_time[p,m]
             ELSE aver_proce_time[p, m] := total_time[p, m]/no_visits[p, m]
  end {FOR p}
END; {PROCEDURE READ_FILE}
--------------------------------------------------------------------}
{***** PROCEDURE MVAQ_C *****}
PROCEDURE MVAQ_C(p1, m1 : integer;
                yb, ar : real ;VAR t,v : vtarray ;VAR n, x, y : p_array;
                VAR n1, u1, b1, w1 : m_array);
VAR r1,j,l,k,i,m,p : integer;
    sum1: ARRAY[1..max_parts] OF real;
    q1 : ARRAY[1..max_mach_groups] OF real;
    q,u,w ,b,r, qnew,  sum : vtarray ;
BEGIN
  FOR p := 1 to p1 DO
  begin
    FOR m := 1 to m1 DO
      q[p, m] := n[p] / m1
  end; {FOR p}
  FOR p := 1 to p1 DO
  begin
    REPEAT
    FOR m := 1 to m1 DO
    begin
      sum1[p] := 0;
      FOR i :=1 to m1 DO
      begin
        sum [p, i] := 0;
        FOR r1 := 1 to p1 DO
        IF r1 <> p THEN
        sum [p, i] := sum[p, i] + q[r1, i] * t[r1, i] ;
        r[p, i] := t[p, i] + ar /n1[i] *((n[p] -1)/n[p]*q[p, i]*t[p, i]
                 + sum[p, i] );
        sum1[p] := sum1[p] + v[p, i] * r[p, i]
      end; {FOR i}
      IF sum1[p] > 0.001 THEN x[p] := n[p] / sum1[p]
                         ELSE x[p] := 0.0 ;
```

```
      qnew[p, m] := v[p, m] *r[p, m] * x[p]
    end; {FOR m}
    k := 0;
    FOR l:= 1 to ml DO
    begin
      IF abs(qnew[p, l] - q[p, l]) < yb THEN
      k:= k +1;
      q[p, l] := qnew[p, l]
    end;
  UNTIL k = ml;
  y[p] := 1/x[p] * no_pallets_fixtures[p]
  end; {FOR p}
  FOR m := 1 to ml Do
  begin
    ql[m] := 0.0;
    ul[m] := 0.0;
    wl[m] := 0;
    bl[m] := 0;
    FOR p := 1 to pl DO
    begin
      u[p, m] := v[p, m]* t[p, m] * x[p];
      w[p, m] := (r[p, m] - t[p, m])/r[p, m] * qnew[p, m];
      b[p, m] := t[p, m]/r[p, m]* qnew[p, m];
      ql[m] := ql[m] + qnew[p, m];
      ul[m] := ul[m] + u[p, m]/no_machs_one_group[m];
      wl[m] := wl[m] + w[p, m];
      bl[m] := bl[m] + b[p, m]
    end {FOR p}
  end  {FOR m}
END; {PROCEDURE MVAQ_C}
{-------------------------------------------------------------------}
PROCEDURE WRITE_FILE;
VAR p, m : integer;
    total_parts : real;
    output_type : string;
    datafile : text;
begin
  rewrite(datafile,'benchmark-output');
  writeln(datafile, '                ','SYSTEM PERFORMANCE MEASURES');
  writeln(datafile);
  writeln(datafile, '                    ', '*** PRODUCTION RATE ***');
  writeln(datafile);
  write(datafile, '     ', 'Part No', '                  ');
  writeln(datafile, 'Parts per shift(8 Hours)');
  writeln(datafile);
  total_parts := 0;
  FOR p := 1 to no_part_types DO
  begin
    writeln(datafile, '     ', p:2, '                              ',
                          production_rate[p]*480:7:2);
    total_parts := total_parts + production_rate[p]*480
  end;
  writeln(datafile);
  writeln(datafile, '     ', 'Total Parts/Shift = ',total_parts:7:2);
  writeln(datafile);
  writeln(datafile, '                ', '***AVERAGE TIME IN SYSTEM***');
  writeln(datafile);
  writeln(datafile, '     ', 'Part No', '                  ', 'Time(Minutes)');
  writeln(datafile);
  FOR p := 1 to no_part_types DO
  writeln(datafile, '     ', p:2, '                   ',
                          aver_time_in_system[p]:7:2);
  writeln(datafile);
  writeln(datafile, '                    ', '******UTILIZATION******');
  writeln(datafile);
  write(datafile, '     ', 'Machine Group');
```

```
  writeln(datafile,'                    ', 'Machine Util.');
  writeln(datafile);
  FOR m := 1 to no_mach_groups DO
    writeln(datafile, '      ', m:2, '                        ',
                      station_utilisation[m]:7:2);
  writeln(datafile);
  write(datafile,'       ');
  writeln(datafile, '***AVERAGE QUEUE LENGTH (AT MACHINE GROUP)***');
  writeln(datafile);
  write(datafile, '       ', 'Mchine', '       ','No of Parts', '          ');
  writeln(datafile, 'No of Parts');
  write(datafile, '       ', 'Group No', '        ','in Process');
  writeln(datafile,'           ','Waiting');
  writeln(datafile);
  FOR m := 1 to no_mach_groups DO
    writeln(datafile, '        ', m:4, '         ',
                      no_parts_in_process[m]:7:2, '            ',
                      no_parts_waiting[m]:7:2)
end; {PROCEDURE WRITE_FILE}
{-----------------------------------------------------------------------}
{***** MAIN PROGRAM ***** }
BEGIN
  read_file ;
  mvaq_c (no_part_types, no_mach_groups,
        calcul_preci, calcul_coeffic,no_visits,aver_proce_time,
        no_pallets_fixtures,production_rate,aver_time_in_system,
        no_machs_one_group,station_utilisation,no_parts_in_process,
        no_parts_waiting);
 write_file
END. {MAIN PROGRAM}
```

Appendix II
DEFINITION OF CLASSES

This appendix summarizs the main classes defined in this modelling system. The classes to be covered include the inference engine, the working memory, the decision centre, the conflict sets and the major manufacturing cell elements. Each class is described by only showing those variables and methods which are defined locally.

Table II.1: Definition of Class
— InferenceEngine

Class Variables	Instance Variables	Methods
None	ModellingLevel MasterClock BlockTime DisplayFlg StartTime FinishTime RunTime	BlockModelling ComputeRunTime DisplayNextGoal EndActions EndPalletsActions1 EndPalletsActions2 EndPalletsActions3 EndToolTransporterActions ExecuteObjects FilterObjects FindFreePallets NextGoal ReleaseParts ResolveReleaseConflicts ResolveStartActionConflicts ReturnStartableElements RunModel StartActions StartPalletsActions1 StartPalletsActions2 StartPalletsActions3 StartToolTransportersActions TerminateCondition TestReleaseOfParts TestStartOfActions TestStartOfPalletsActions1 TestStartOfPalletsActions2 TestStartOfPalletsActions3 UpdateDisplay UpdateStatesDisplay

Table II.2: Definition of Class
— ConflictSet

Class Variables	Instance Variables	Methods
None	ItemSelected RulesApplied UsedFlg	ApplyDecisionRule ConflictExists PutToDecisionCentre

Table II.3: Definition of Class — DecisionCentre

Class Variables	Instance Variables	Methods
None	DecisionTime AvailableResources ReleaseConflictSets OperationConflictSets LUStationConflictSets WorkTransporterConflictSets NextStationConflictSets ToolingConflictSets ToolTransporterConflictSets	ConstructSelectedPalletsList ConstructSelectedResourcesList DetectOperationConflicts DetectToolTransporterConflicts DetectToolingConflicts ExecuteObjects FindAFreeLUStationSet FindAFreeNextStationSet FindAFreeOperationSet FindAFreeReleaseSet FindAFreeToolTransporterSet FindAFreeToolingSet FindAFreeTransporterSet FindSelectedPart ResolveLUStationConflicts ResoveNextStationConflicts ResolveOperationConflicts ResolveReleaseConflicts ResolveToolTransporterConflicts ResolveToolingConflicts ResolveTransporterConflicts ReturnAllocatedPallets TryObjects

Table II.4: Definition of Class — LUStationConflictSet

Class Variables	Instance Variables	Methods
Type CondidateType RuleLibrary SpecifiedRule	Stations StationSelected	ClearConflictSet GetQueueLength GetWorkLoad LeastWorkLoad LowestUtilisation ResolveConflict ShortestQueueLength

Table II.5: Definition of Class
— NextStationConflictSet

Class Variables	Instance Variables	Methods
Type CondidateType RuleLibrary SpecifiedRule	NextStations NextStationSelected	ClearConflictSet GetQueueLength GetSpraeSpaces GetWorkLoad LeastWorkLoad LowestUtilisation MostSpraeSpaces ResolveConflict ShortestQueueLength

Table II.6: Definition of Class
— OperationConflictSet

Class Variables	Instance Variables	Methods
Type CondidateType RuleLibrary SpecifiedRule		CostOverTime EarliestDueDate FewestOperationsRemaining FewestTools FirstInFirstOut GetCostOverTime GetDueDate GetFinishTime GetOperationsRemanining GetProcessingTime GetRemainingProcessingTime GetTools LongestProcessingTime LongestRemainingProcessingTime MostTools ResolveConflict ShortestProcessingTime ShortestRemainingProcessingTime

Table II.7: Definition of Class
— PalletConflictSet

Class Variables	Instance Variables	Methods
	PalletSelected Pallets Resource	ClearConflictSet

Table II.8: Definition of Class — ReleaseConflictSet		
Class Variables	**Instance Variables**	**Methods**
Type CondidateType RuleLibrary SpecifiedRule	PartTypeSelected PartTypes FilteredPartTypes Pallet	CheckPartsAvailability ClearConflictSet EarliestDueDate FewestOperations FewestTools GetDueDate GetLongestTotalTime GetOperations GetShortestTotalTime GetTools LongestTotalProcessingTime MostOperations MostTools ResolveConflict ShortestTotalProcessingTime SpecifiedSequence

Table II.9: Definition of Class — ResourceConflictSet		
Class Variables	**Instance Variables**	**Methods**
	Pallet	GetUtilisation

Table II.10: Definition of Class — ToolTransporterConflictSet		
Class Variables	**Instance Variables**	**Methods**
Type CondidateType RuleLibrary SpecifiedRule	ToolTransporterSelected ToolTransporters	ClearConflictSet LowestUtilisation ResolveConflict ShortestTransferTime

Table II.11: Definition of Class – ToolingConflictSet		
Class Variables	Instance Variables	Methods
Type CondidateType RuleLibrary SpecifiedRule		FewestOperationsRemaining GetOperationsRemaining ResolveConflict FirstInFirstOut

Table II.12: Definition of Class – WorkTransporterConflictSet		
Class Variables	Instance Variables	Methods
Type CondidateType RuleLibrary SpecifiedRule	Transporters TransporterSelected	ClearConflictSet LowestUtilisation ResolveConflict ShortestTransferTime

Table II.13: Definition of Class – Entities		
Class Variables	Instance Variables	Methods
	Status StatusWindow TraceFlg	Display MonitorAVariable SetupMonitorMenu SetupVarsMenu TraceIt UntraceIt

Table II.14: Definition of Class — LoadUnloadStation		
Class Variables	Instance Variables	Methods
ResourceType AvailabilityRulesLibrary AvailabilityRule	FixturingTime	AllCommingPallets CheckPartsInBuffer CollectFixturingTime CollectLoadingUnloadingTime EndDepalletisation EndLoadingAndDepalletisation EndPalletisation LoadUnloadStationAvailable RequiredByAwaitingPallet StartDepalletisation StartLoadingAndDepalletisation StartPalletisation

Table II.15: Definition of Class — MachineStation		
Class Variables	Instance Variables	Methods
ResourceType AvailabilityRulesLibrary AvailabilityRule	ToolTimes ToolRequirement TotalToolTypes TotalToolsNumber ToolList ToolsInPTS UnusableTools ChangesOfWornTools ChangesOfUnusableTools ChangesOfTypeTools MachiningTime CuttingTime ToolChangingTime TimeWaitingForTools ToolLoadUnloadTime	AddSisterTool CollectCuttingTime CollectLoadingUnloadingTime CollectMachiningTime CollectToolChangingTime CollectToolLoadUnloadTime EndLoadingAndProcessing EndProcessing ExecuteToolsInPTS FindATool FindAToolType FindToolInPTS FindToolTypeList FindWornTools GetTotalToolTypes GetTotalToolsNumber InitialiseTestedToolStatus SparePositions StartLoadingAndProcessing StartProcessing ToolIsUnavailable?

Table II.16: Definition of Class – Part

Class Variables	Instance Variables	Methods
	Identity	CollectFixturingTime
	PartType	CollectLoadingUnloadingTime
	PalletAllocation	CollectMachiningTime
	CurrentLocation	CollectMachiningTime2
	CurrentOperation	CollectTimeAtBuffer
	OperationList	CollectTimeAtStation
	Schedule	CollectTimeInStorage
	EntryTime	CollectTimeWaitingForTools
	CompletionTime	CollectTransportTime
	FlowTime	GetCovert
	DueDate	GetRemainingTime
	MachiningTime	RateTransporters
	TransportTime	ReconstructInitialPartList
	WaitingTime	ScheduleOperation
	TimeInStorage	
	TimeAtBuffer	
	TimeAtStation	
	TimeWaitingForTools	
	LoadingUnloadingTime	
	FixturingTime	

Table II.17: Definition of Class PartType

Class Variables	Instance Variables	Methods
None	Throughput	GetOpTime
	LeadTime	
	Average	
	Maximum	
	Minimum	
	Mean	
	MachiningTime	
	Average	
	Maximum	
	Minimum	
	Mean	
	TransportTime	
	Average	
	Maximum	
	Minimum	
	Mean	
	WaitingTime	
	Average	
	Maximum	
	Minimum	
	Mean	
	FixturingTime	
	Average	
	Maximum	
	Minimum	
	Mean	

Table II.18: Definition of Class – ResourceMixin		
Class Variables	Instance Variables	Methods
	AvailableTime AvailablePallets BusyTime IdleTime Utilisation Breakdown Schedule BlockageFlg TimeBrokenDown SpareCapacity SelectedPallet	ComputeIdleTime ComputeSpareCapacity ComputeUtilisation FindOperationConflict GetAvailableTime MultiplePalletsRequireResource PutIdleTime PutToOperationConflictSet ResourceAvailable SinglePalletRequiresResource UpdateUtilisation

Table II.19: Definition of Class – SecondaryToolStore		
Class Variables	Instance Variables	Methods
ResourceType	AvailableTime BusyTime ToolLoadUnloadTime ToolsInStore IdelTime SpareCapacity StationaryTime Utilisation	CollectLoadingUnloadingTime ComputeIdleTime ComputeSpareCapacity ComputeUtilisation EndLoadingToolsOntoTransporter FindATool StartLoadingToolsOntoTransporter

Table II.20: Definition of Class – Station (to be continued)		
Class Variables	Instance Variables	Methods
AvailabilityRulesLibrary AvailabilityRule	PalletOnStation PalletsInBuffer PalletsInInputBuffer PalletsInOutputBuffer QueueLength MaxQueueLength StationaryTime LoadingUnloadingTime	BufferIsAvailable BufferSize CollectIdleTime CollectStationaryTime CommingPallets ComputeQueueLength EndUnloading FilterObjects GetWorkLoad HasNoBuffer InputBufferAvailable

Table II.20: Definition of Class — Station (continued)		
Class Variables	**Instance Variables**	**Methods**
		InputBufferEmpty InputBufferSize IsIdle NextStationAvailable1 NextStationAvailable2 OutputBufferAvailable OutputBufferSize PalletsInBuffer PalletsInInputBuffer PalletsInOutputBuffer PartBufferAvailable RequiredByTransferredPallet SchedulePalletOperation StartUnloading ToolRequirement

Table II.21: Definition of Class — Storage		
Class Variables	**Instance Variables**	**Methods**
ResourceType	PalletsInStore BusyTime LoadingUnloadinTime StationaryTime IdleTime Utilisation SpareCapacity AvailableTime	CollectIdleTime CollectLoadingUnloadingTime CollectStationaryTime CommingPallets ComputeIdleTime ComputeSpareCapacity ComputeUtilisation FilterObjects PalletsInStore RequiredByTransferredPallet StorageCapacity TempStorageAvailable UpdateUtilisation

Table II.22: Definition of Class
– Tool

Class Variables	Instance Variables	Methods
	Identity	InitialiseStatus
	MaxUse	InitialiseTestedStatus
	NumberOfUses	IsAvailable?
	PercentageToolLifeUsed	UpdateStatus
	Status	UpdateTestedStatus
	ToolLife	
	ToolLifeUsed	
	ToolType	
	CurrentLocation	
	TestedPercentageToolLifeUsed	
	TestedStatus	
	TestedToolLifeUsed	

Table II.23: Definition of Class
– ToolTransporter (to be continued)

Class Variables	Instance Variables	Methods
ResourceType	ToolsOnIt	ArrivesAtPTS
	FinishTime	ArrivesAtSTS
	GoalStatus	CollectIdleTime
	ArrivalTime	CollectLoadingUnloadingTime
		ComputeSpareCapacity
		EndAction
		ExchangeTools
		ExchangeWithUnusableTools
		ExchangeWithWornTools
		FillSparePositions
		FindANumberOfTools
		FindLoadingUnloadingTime
		FindTransferTime
		FindWornTools
		LeavingForSTS
		LoadTools
		MultiplePalletsAreAwaiting–ForToolTransporters
		PutSelectedPalletToList
		PutToApplicableToolTransportersList
		PutToStartableToolTransportersList
		PutToToolingConflictSets
		RemoveFromStartableToolTransportersList
		RequiedPositions
		RequiredTools

Table II.23: Definition of Class — ToolTransporter (continued)

Class Variables	Instance Variables	Methods
		SetNewGoal SetStatusToIdleOrReadyForSTS SinglePalletIsWaitingFor–ToolTransporters StartAction TestStartOfAction ThereAreToolsLeft UnloadTools

Table II.24: Definition of Class — ToolType

Class Variables	Instance Variables	Methods
	SisterTools	CheckUnavailableToolTime ComputeSisterTools

Table II.25: Definition of Class — Transporter

Class Variables	Instance Variables	Methods
	CurrentLocation EmptyRunningTime LoadRunningTime LoadingUnloadingTime	CollectEmptyRunningTime CollectLoadRunningTime

Table II.26: Definition of Class — WorkTransporter

Class Variables	Instance Variables	Methods
ResourceType AvailabilityRulesLibrary AvailabilityRule	PalletOnIt	CheckDetination CollectIdleTime CollectLoadingUnloadingTime EndLoadingOn EndTransferAndUnloading SchedulePalletOperation StartLoadingOn StartTransferAndUnloading TransporterAvailable

Table II.27: Definition of Class
– Pallet (to be continued)

Class Variables	Instance Variables	Methods
None	AvailablePartTypes	AddToBuffer
	SelectedPartType	AddToStation
	AllocatedParts	AllocatePalletToParts
	PartsOnPallet	AllocateParts
	TransporterArrivalTime	AlternativePartTypes
	SubOpsDuration	AlternativeResourcesExist
	FinishTime	AvailableTempStorage
	StartTimeForTools	CellToolRequirement
	GoalStatus	CheckBuffer
	CurrentLocation	CkeckLoadUnloadStation
	BusyTime	CheckNextStation1
	IdleTime	CheckNextStation2
	Utilisation	CheckStation
	NextOperation	CheckStation3
	OperationList	CheckTempStorage
	CurrentOperation	CheckToolsAvailability
	AvailableNextStations	CheckTransporter
	SelectedNextStation	CheckTransporterLocation
	AvailableResources	CollectPartsFixturingTime
	Selectedresource	CollectPartsFlowTime
	AvailableToolTransporters	CollectPartsLoadingUnloadingTime
	SelectedToolTransporter	CollectPartsMachiningTime
	TemporaryStorages	CollectPartsMachiningTime2
	UnavailableTools	CollectPartsTimeAtBuffer
		CollectPartsTimeAtStation
		CollectPartsTimeInStorage
		CollectPartsTimeWaitingForTools
		CollectPartsTransportTime
		CollectStationLoadingUnloadingTime
		CollectStationTimeWaitingForTools
		CollectStationaryTime
		ConstrudtUnavailableToolsList
		DetectOperationConflict
		DoPartsOnPallet
		EndAction1
		EndAction2
		EndAction3
		EndRemovingFromStation
		ExecutePartsOnPallet
		FindDepalletisationDuration
		FindOperationTime
		FindPalletExchangeTime
		FindPalletisationDuration
		FindProcessingDuration
		FindStationExchangeTime

Table II.27: Definition of Class
– Pallet (continued)

Class Variables	Instance Variables	Methods
		FindToolTransporterConflict FindTransferDuration FindTransferTime GetAlternativeNextStations GetAlternativeResources LoadOntoStation1 LoadOntoTransporter1 LoadToStation1 MultipleNextStationsAvailable1 MultipleNextStationsAvailable2 MultiplePartTypesLeft MultipleResourcesAvailable MultipleToolTransportersRequirepallet NextOpHasAlternativeStations NextStationRequired PalletFree PartType PutToLUStationConflictSets PutSelectedResourceToList PutToAllocatedPalletsList PutToApplicablePalletsList PutToAwaitingForToolTransporters–PalletsList PutToAwaitingForToolsArrival–PalletsList PutToNextStationConflictSets PutToreleaseConflictSets PutToStartablePalletsList PutToToolTransporterConflictSets PutToTransporterConflictSets ReconstructInitialPartList ReleaseParts RemoveFromAllocatedPalletsList RemoveFromAwaitingForTool–TransportersPalletsList RemoveFromBuffer RemoveFromStartablePalletsList ResourceRequired SchedulePartsOperation ScheduleSubops2 ScheduleSubops3 SetCurrentOperation SetLocation SetNewGoal SetNewGoal2 SetPalletOperations

Table II.27: Definition of Class — Pallet (continued)

Class Variables	Instance Variables	Methods
		SetPartsEntryTime
		SetStatusToAwaitProcOrDepall
		SetStatusToAwaitUnloadOrTransfer
		SingleNextStationAvailable1
		SingleNextStationAvailable2
		SinglePartTypeLeft
		SingleResourceAvailable
		SingleToolTransporterRequiresPallet
		StartAction1
		StartAction2
		StartAction3
		StartRemovingFromStation
		StationStartsPalletisation
		TestReleaseOfParts
		TestStartOfAction1
		TestStartOfAction2
		TestStartOfAction3
		TransporterArrives
		UnloadFromTransporter
		UnloadIntoStationBuffer1
		UpdateOperationStatus

Table II.28: Definition of Class — WorkingMemory (to be continued)

Class Variables	Instance Variables	Methods
	AvailablePallets	AddSisterTool
	AllocatedPallets	AddTool
	ApplicablePallets	ComputeAverageFlowTime
	ApplicableToolTransporters	ComputeAverageUtilisation
	SelectedResources	ComputeIdleTime
	SelectedPallets	ComputeLoadUnloadStationPerformance
	StartablePallets	ComputeLoadUnloadStationPerformance2
	AwaitingForTool–TransportersPallets	ComputeMakeSpan
	StartableToolTransporters	ComputeMinCellToolRequirement
	InitialPartList	ComputePTSToolRequirement
	LUStationList	ComputePartLeadTimes
	MachineList	ComputePartPerformance
	PalletList	ComputePartPerformance3
	PartList	ComputePartThroughputs
	PartTypeList	ComputeResourceSpareCapacity

Table II.28: Definition of Class — WorkingMemory (continued)		
Class Variables	Instance Variables	Methods
	ProcessList StationList ToolList TransporterList ToolTransporters SecondaryToolStore ResourceList StorageList SpecifiedSequence ToolTimes MinToolRequirement MaxToolRequirement MakeSpan MaxQueue TotalThroughput AverageFlowTime TotalLateness AverageUtilisation TotalToolTypes TotalToolNumber ToolsAdded	ComputeResourceUtilisation ComputeStationPerformance ComputeStationPerformance2 ComputeStationPerformance3 ComputeStatistics1 ComputeStatistics2 ComputeStatistics3 ComputeTempStoragePerformance ComputeToolTransporterPerformance ComputeTotalLateness ComputeTotalThroughput ComputeTransporterPerformance etc.

Appendix III
LIST OF RULES

This appendix lists the inference rules and the transformation rules employed in Chapter 7 and Chapter 8 respectively.

The inference rules are the rules developed around the class ***InferenceEngine***, which are used for the top-level control of the modelling.

The transformation rules are writen separately for the three levels of modelling. At level 1 and level 2, these rules are all built around the class ***Pallet***, since only work flow is considered at these two levels. In the level-3 modelling, there are transformation rules built around the class ***ToolTransporter*** to model tool flow as well as rules defined around the class ***Pallet*** to model work flow.

```
WorkSpace Class: Inference Engine;
Compiler Options: A;
Temporary Vars: ;
Control Structure: WHILEALL;
Iteration Condition: T;
Rule Class: MyRule;
********

IF .TerminationCondition
THEN (Stop T 'Done);

THEN .NextGoal;

THEN .EndActions;

IF .FindFreePallets
THEN .TestReleaseOfParts;

IF .ResolveReleaseConflicts
THEN .ReleaseParts;

THEN .TestStartOfActions;

IF .ResolveStartActionConflicts
THEN .StartActions;
```

Figure III.1	*InferenceEngine .RunModel*	**LUT-FMS Research Group**

```
WorkSpace Class:  InferenceEngine;
Compiler Option:  A;
Temporary Vars:
Control Structure:  DO1;
Rule Class: MyRule;
********

IF ~$InstWorkingMemory:InitialPartList
   ~$InstWorkingMemory:AllocatedPallets
THEN T;
```

Figure III.2	*InferenceEngine .TerminationCondition*	**LUT-FMS Research Group**

```
WorkSpace Class:     InferenceEngine;
Compiler Option:
Temporary Vars:
Control Structure:
Rule Class: MyRule;
********

IF :ModellingLevel='Level1
THEN .EndPalletsActions1;

IF :ModellingLevel='Level2
THEN .EndPalletsActions2;

IF :ModellingLevel='Level3
THEN .EndPalletsActions3
        .EndToolTransportersActions;
```

Figure III.3	*InferenceEngine .EndActions*	**LUT-FMS Research Group**

```
WorkSpace Class: InferenceEngine;
Compiler Option: A;
Temporary Vars: freepallets;
Control Structure: DO1;
Rule Class: MyRule;
********

IF ~$InstWorkingMemory:AllocatedPallets
THEN $InstWorkingMemory:AvailablePallets←
        $InstWorkingMemory:PalletList;

IF freepallets←(← self FilterObjects 'PalletFree
            $InstWorkingMemory:PalletList)
THEN $InstWorkingMemory:AvailablePallets
                        ←freepallets;
```

Figure III.4	*InferenceEngine .FindFreePallets*	**LUT-FMS Research Group**

```
WorkSpace Class: InferenceEngine;
Compiler Option: A;
Temporary Vars: pallets;
Control Structure: DOALL;
Rule Class: MyRule;
********

IF pallets←$InstWorkingMemory:AvailablePallets
THEN (← self ExecuteObjects
        'TestReleaseOfParts pallets);
```

Figure III.5	*InferenceEngine .TestReleaseOfParts*	**LUT-FMS Research Group**

```
WorkSpace Class: InferenceEngine;
Compiler Option: A;
Temporary Vars: DOALL;
Control Structure:
Rule Class: MyRule;
********

THEN $InstDecisionCentre.ResolveReleaseConflicts;
```

Figure III.6	*InferenceEngine .ResolveReleaseConflicts*	**LUT-FMS Research Group**

```
WorkSpace Class: InferenceEngine;
Compiler Option:  A;
Temporary Vars:
Control Structure:  DOALL;
Rule Class: MyRule;
********



THEN (— self ExecuteObjects 'ReleaseParts
        $InstWorkingMemory:AllocatedPallets);
```

Figure III.7	*InferenceEngine .ReleaseParts*	**LUT-FMS Research Group**

```
WorkSpace Class: InferenceEngine;
Compiler Option:  A;
Temporary Vars:
Control Structure:  DO1;
Rule Class: MyRule;
********


IF ::ModellingLevel='Level1
THEN .TestStartOfPalletsActions1;


IF ::ModellingLevel='Level2
THEN .TestStartOfPalletsActions2;


IF ::ModellingLevel='Level3
THEN .TestStartOfPalletsActions3
       .TestStartOgToolTransportersActions;
```

Figure III.8	*InferenceEngine .TestStartOfActions*	**LUT-FMS Research Group**

```
WorkSpace Class:    InferenceEngine;

Compiler Option:    A;

Temporary Vars:

Control Structure:    DO1;

Rule Class: MyRule;

********


IF :ModellingLevel='Level1

THEN $InstDecisionCentre.ResolveLUStationConflicts

       $InstDecisionCentre.ResolveNextStationConflicts

       $InstDecisionCentre.ResolveTransporterConflicts

       $InstDecisionCentre.DetectOperationConflicts

       $InstDecisionCentre.ResolveOperationConflicts

       .ReturnStartableElements;
```

Figure III.9	*InfenceEngine .ResolveStartActionConflicts - Rule 1*	LUT-FMS Research Group

```
WorkSpace Class:    InferenceEngine;

Compiler Option:    A;

Temporary Vars:

Control Structure:    DO1;

Rule Class: MyRule;

********


IF :ModellingLevel='Level2

THEN $InstDecisionCentre.ResolveLUStationConflicts

       $InstDecisionCentre.ResolveNextStationConflicts

       $InstDecisionCentre.ResolveTransporterConflicts

       $InstDecisionCentre.DetectOperationConflicts

       $InstDecisionCentre.ResolveOperationConflicts

       .ReturnStartableElements;
```

Figure III.10	*InfenceEngine .ResolveStartActionConflicts - Rule 2*	LUT-FMS Research Group

```
WorkSpace Class:    InferenceEngine;

Compiler Option:    A;

Temporary Vars:

Control Structure:    DO1;

Rule Class: MyRule;

********


IF :ModellingLevel='Level3

THEN $InstDecisionCentre.ResolveLUStationConflicts

       $InstDecisionCentre.ResolveNextStationConflicts

       $InstDecisionCentre.ResolveTransporterConflicts

       $InstDecisionCentre.DetectOperationConflicts

       $InstDecisionCentre.ResolveOperationConflicts

       $InstDecisionCentre.DetectToolingConflicts

       $InstDecisionCentre.ResolveToolingConflicts

       $InstDecisionCentre.DetectToolTransporterConflicts

       $InstDecisionCentre.ResolveToolTransporterConflicts

       .ReturnStartableElements;
```

Figure III.11	*InfenceEngine .ResolveStartActionConflicts - Rule 3*	LUT-FMS Research Group

```
WorkSpace Class:    InferenceEngine;
Compiler Option:    A;
Temporary Vars:
Control Structure:    DO1;
Rule Class: MyRule;
********


IF :ModellingLevel='Level1
THEN .StartPalletsActions1;

IF :ModellingLevel='Level2
THEN .StartPalletsActions2;

IF :ModellingLevel='Level3
THEN .StartPalletsActions3
        .StartToolTransportersActions;
```

Figure III.12	*InferenceEngine .StartActions*	LUT-FMS Research Group

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars: type candidatetypes;
Control Structure: DO1;
Rule Class: MyRule;
********

IF ~AlternativePartTypes
   type-.PartType
   type.FindParts
THEN :SelectedPartType-type
       .PutToAllocatedPalletsList;

IF .AlternativePartTypes
   type-.SinglePartTypeLeft
THEN :SelectedPartType-type
       .PutToAllocatedPalletsList

IF .AlternativePartTypes
   candidatetypes-.MultiplePartTypesLeft
THEN :AvailablePartTypes-candidatetypes
       .PutToReleaseConflictSets;

THEN :FinishTime-NIL;
```

Figure III.13	*Pallet .TestReleaseOfParts*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: canpts;
Control Structure: DOALL;
Rule Class: MyRule;
********

THEN .AllocatedParts
       :Status-'AwaitingForPalletisation
       .SetPalletOperations
       .ReconstructInitialPartList;
```

Figure III.14	*Pallet .ReleaseParts*	**LUT-FMS Research Group**

```
WorkSpace Class:  Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure:  DO1;
Rule Class: MyRule;
********


IF :Status='AwaitingForPalletisation
THEN .CheckLoadUnloadStation;

IF :Status='AwaitingForTransfer
   .CheckNextStation1
THEN .CheckTransporter;

IF :Status='AwaitingForProcessing
THEN .CheckStation;

IF :Status='AwaitingForDepalletisation
THEN .CheckStation;
```

Figure III.15	*Pallet .TestStartOfAction1*	**LUT-FMS Research Group**

```
WorkSpace Class:  Pallet;
Compiler Option:  A;
Temporary Vars:  station stations;
Control Structure:  DO1;
Rule Class: MyRule;
********

IF :CurrentLocation
   :CurrentLocation.
            LoadUnloadStationAvailable
THEN :SelectedResource-
            :CurrentLocation
        .PutToApplicablePalletsList;

IF ~:CurrentLocation
   ~.AlternativeResourcesExist
   station-.ResourceRequired
   station.LoadUnloadStationAvailable
THEN :SelectedResource-station
        .PutToApplicablePalletsList;
```

Figure III.16	*Pallet .CheckLoadUnloadStation - Rules 1 & 2*	**LUT-FMS Research Group**

```
WorkSpace Class:  Pallet;
Compiler Option:  A;
Temporary Vars:  station stations;
Control Structure:  DO1;
Rule Class: MyRule;
********

IF ~:CurrentLocation
   .AlternativeResourcesExist
   station-.SingleResourceAvailable
THEN :SelectedResource-station
        .PutToApplicablePalletsList;

IF ~:CurrentLocation
   .AlternativeResourcesExist
   stations-.MultipleResourcesAvailable
THEN :AvailableResources-stations
        .PutToLUStationConflictSets;
```

Figure III.17	*Pallet .CheckLoadUnloadStation - Rules 3 & 4*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: nextstation nextstations;
Control Structure: DO1;
Rule Class: MyRule;
********

IF ~.NextOpHasAlternativeStations
  nextstation←.NextStationRequired
  nextstation.NextStationAvailable1
THEN :SelectedNextStation←nextstation;

IF .NextOpHasAlternativeStations
  nextstation←.SingleNextStationAvailable1
THEN :SelectedNextStation←nextstation;

IF .NextOpHasAlternativeStations
  nextstations←.MultipleNextStationsAvailable1
THEN :AvailableNextStations←nextstations
     .PutToNextStationConflictSets
     nextstations;
```

Figure III.18	*Pallet .CheckNextStation1*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: transporter transporters;
Control Structure: DO1;
Rule Class: MyRule;
********

IF ~AlternativeResourcesExist
  transporter←.ResourceRequired
  transporter.TransporterAvailable
THEN :SelectedResource←transporter
     .PutToApplicablePalletsList;

IF .AlternativeResourcesExist
  transporter←.SingleResourceAvailable
THEN :SelectedResource←transporter
     .PutToApplicablePalletsList;

IF .AlternativeResourcesExist
  transporters←.MultipleResourcesAvailable
THEN :AvailableResources←transporters
     .PutToTransporterConflictSets;
```

Figure III.19	*Pallet .CheckTransporter*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :CurrentLocation.IsIdle
THEN :SelectedResource←:CurrentLocation
     .PutToApplicablePalletsList
     :CurrentLocation;
```

Figure III.20	*Pallet .CheckStation*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: location;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForPalletisation
THEN .RemoveFromStartablePalletsList
        .SetCurrentOperation
        .SetLocation
        :Status-'Palletisation
        .SetPartsEntryTime
        .SchedulePartsOperation
        .CollectPartsFixturingTime
        .SetNewGoal
        location-:CurrentLocation
        location:PalletOnStation-self
        location.SchedulePalletOperation
        location:Status-'Busy
        location.CollectIdleTime
        location.CollectFixturingTime
        location:AvailableTime-:FinishTime;
```

Figure III.21	*Pallet.StartAction1 - Rule 1*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: location;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForTransfer
THEN .RemoveFromStartablePalletsList
        .TransporterArrives
        .LoadOntoTransporter1
        :Status-'Transfer
        .CollectPartsTransportTime
        .SetNewGoal
        location-:CurrentLocation
        location:Status-'Busy
        location.CollectIdleTime
        location.CollectLoadRunningTime
        location:AvailableTime-:FinishTime;
```

Figure III.22	*Pallet.StartAction1 - Rule 2*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: location;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForProcessing
THEN .RemoveFromStartablePalletsList
        .SetCurrentOperation
        .LoadOntoStation1
        :Status-'Processing
        .SchedulePartsOperation
        .CollectPartsMachiningTime
        .SetNewGoal
        location-:CurrentLocation
        location.SchedulePalletOperation
        location:Status-'Busy
        location.CollectIdleTime
        location.CollectMachiningTime
        location:AvailableTime-:FinishTime;
```

Figure III.23	*Pallet.StartAction1 - Rule 3*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: location;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForDepalletisation
THEN .RemoveFromStartablePalletsList
        .SetCurrentOperation
        .LoadOntoStation1
        :Status-'Depalletisation
        .SchedulePartsOperation
        .CollectPartsFixturingTime
        .SetNewGoal
        location-:CurrentLocation
        location.SchedulePalletOperation
        location:Status-'Busy
        location.CollectIdleTime
        location.CollectFixturingTime
        location:AvailableTime-:FinishTime;
```

Figure III.24	*Pallet.StartAction1 - Rule 4*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: duration fintime;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Palletisation
THEN :GoalStatus-'Active
       duration-.FindPalletisationDuration
       fintime-$InstInferenceEngine:_
       MasterClock + duration
       :FinishTime-fintime;

IF :Status='Transfer
THEN :GoalStatus-'Active
       duration-:TransporterArrivalTime +
       .FindTransferDuration
       fintime-$InstInferenceEngine:_
       MasterClock + duration
       :FinishTime-fintime;
```

Figure III.25	*Pallet.SetNewGoal - Rules 1 & 2*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: duration fintime;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Processing
THEN :GoalStatus-'Active
       duration-.FindProcessingDuration
       fintime-$InstInferenceEngine:_
       MasterClock + duration
       :FinishTime-fintime;

IF :Status='Depalletisation
THEN :GoalStatus-'Active
       duration-.FindDepalletisation_
       Duration
       fintime-$InstInferenceEngine:_
       MasterClock + duration
       :FinishTime-fintime;
```

Figure III.26	*Pallet.SetNewGoal - Rules 3 & 4*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: station transporter;
Control Structure: DO1;
Rule Class: MyRule;
********


IF :Status='Palletisation
   $InstInferenceEngine:MasterClock>=:FinishTime
THEN :PartsOnPallet-:AllocatedParts
        .UnloadIntoStationBuffer1
        .CollectPartsLoadingUnloadingTime
        :Status-'AwaitingForTransfer
        :GoalStatus-NIL
        .UpdateOperationStatus
        station-:CurrentLocation
        station:Status-'Idle
        station.UpdateUtilisation;
```

Figure III.27	*Pallet.EndAction1 - Rule 1*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: station transporter;
Control Structure: DO1;
Rule Class: MyRule;
********


IF :Status='Processing
   $InstInferenceEngine:MasterClock>=:FinishTime
THEN .UnloadIntoStationBuffer1
        .CollectPartsLoadingUnloadingTime
        :Status-'AwaitingForTransfer
        :GoalStatus-NIL
        .UpdateOperationStatus
        station-:CurrentLocation
        station:Status-'Idle
        station.UpdateUtilisation;
```

Figure III.28	*Pallet.EndAction1 - Rule 2*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: station transporter;
Control Structure: DO1;
Rule Class: MyRule;
********


IF :Status='Transfer
   $InstInferenceEngine:MasterClock>=:FinishTime
THEN .UnloadFromTransporter
        .CollectsPartsLoadingUnloadingTime
        .LoadToStation1
        :GoalStatus-NIL;
```

Figure III.29	*Pallet.EndAction1 - Rule 3*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: station transporter;
Control Structure: DO1;
Rule Class: MyRule;
********


IF :Status='Depalletisation
   $InstInferenceEngine:MasterClock>=:FinishTime
THEN .CollectPartsFlowTime
        :PartsOnPallet-NIL
        .RemoveFromAllocatedPalletsList
        :Status-'Idle
        :GoalStatus-NIL
        station-:CurrentLocation
        station:Status-'Idle
        station:PalletOnStation-NIL
        station.UpdateUtilisation;
```

Figure III.30	*Pallet.EndAction1 - Rule 4*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********


IF :Status='AwaitingForPalletisation
THEN .CheckLoadUnloadStation;

IF :Status='AwaitingForTransfer
   .CheckNextStation2
THEN .CheckTransporter;

IF :Status='AwaitingForTransfer
   .CheckTempStorage
THEN .CheckTransporter;

IF :Status='ReadyForTransfer
THEN .PutToStartablePalletsList;

IF :Status='AwaitingForProcessing
THEN .CheckStation;
```

Figure III.31	*Pallet.TestStartOfAction2 - Rules 1, 2, 3, 4 & 5*	LUT-FMS Research Group

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********


IF :Status='ReadyForProcessing
THEN .PutToStartablePalletsList;

IF :Status='AwaitingForUnloading
THEN .CheckBuffer;

IF :Status='AwaitingForDepalletisation
THEN .CheckStation;

IF :Status='ReadyForDepalletisation
THEN .PutToStartablePalletsList;
```

Figure III.32	*Pallet.TestStartOfAction2 - Rules 6, 7, 8 & 9*	LUT-FMS Research Group

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: nextstation nextstations;
Control Structure: DO1;
Rule Class: MyRule;
********


IF ~.NextOpHasAlternativeStations
   nextstation–.NextStationRequired
   nextstation.NextStationAvailable2
THEN :SelectedNextStation–nextstation;
IF .NextOpHasAlternativeStations
   nextstation–.SingleNextStationAvailable2
THEN :SelectedNextStation–nextstation;
IF .NextOpHasAlternativeStations
   nextstations–.MultipleNextStationsAvailable2
THEN :AvailableNextStations–nextstations
       .PutToNextStationConflictSets
       nextstations;
```

Figure III.33	*Pallet .CheckNextStation2*	LUT-FMS **Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars: availablestorage;
Control Structure: DO1;
Rule Class: MyRule;
********

IF $InstWorkingMemory:TempStorageFlg
   availablestorage–.AvailableTempStorage
THEN :SelectedNextStation–availablestorage;
```

Figure III.34	*Pallet .CheckTempStorage*	LUT-FMS **Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :CurrentLocation.BufferIsAvailable
THEN .PutToStartablePalletsList;
```

Figure III.35	*Pallet .CheckBuffer*	LUT-FMS **Research Group**

```
WorkSpace Class:  Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForPalletisation
THEN .RemoveFromStartablePalletsList
     .SetCurrentOperation
     .SetLocation
     .SetPartsEntryTime
     .SchedulePartsOperation
     .CollectPartsFixturingTime
     :Status-'Palletisation
     .SetNewGoal2
     :CurrentLocation:PalletOnStation-self
     :CurrentLocation.StartPalletisation;
```

Figure III.36	*Pallet.StartAction2 - Rule 1*	LUT-FMS **Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForTransfer
THEN .RemoveFromStartablePalletsList
     .TransporterArrives
     .CollectPartsLoadingUnloadingTime
     :Status-'LoadingOntoTransporter
     .StartRemovingFromStation
     .SetNewGoal2
     :SelectedResource.StartLoadingOn;
```

Figure III.37	*Pallet.StartAction2 - Rule 2*	LUT-FMS **Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='ReadyForTransfer
THEN .RemoveFromStartablePalletsList
     .CollectPartsTransportTime
     :Status-'TransferAndUnloading
     .SetNewGoal2
     :SelectedResource.StartTransfer_
     AndUnloading;
```

Figure III.38	*Pallet.StartAction2 - Rule 3*	LUT-FMS **Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForProcessing
THEN .RemoveFromStartablePalletsList
     .CollectPartsTimeAtBuffer
     .CollectPartsLoadingUnloadingTime
     :Status-'LoadingAndProcessing
     .SetCurrentOperation
     .SchedulePartsOperation
     .ScheduleSubOps2
     .CellToolRequirement
     .SetNewGoal2
     :CurrentLocation:PalletOnStation-self
     :CurrentLocation.StartLoading_
     AndProcessing;
```

Figure III.39	*Pallet.StartAction2 - Rule 4*	LUT-FMS **Research Group**

```
WorkSpace Class:  Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='ReadyForProcessing
THEN .RemoveFromStartablePalletsList
        :Status-'Processing
        .SetCurrentOperation
        .SchedulePartsOperation
        .ScheduleSubOps2
        .CellToolRequirement
        .SetNewGoal2
        :CurrentLocation.StartProcessing;
```

Figure III.40	*Pallet.StartAction2 - Rule 5*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForUnloading
THEN .RemoveFromStartablePalletsList
        :Status-'UnloadingFromStation
        .CollectPartsTimeAtStation
        .CollectPartsLoadingUnloadingTime
        :CurrentLocation.CollectStationaryTime
        .SetNewGoal2
        :CurrentLocation.StartUnloading;
```

Figure III.41	*Pallet.StartAction2 - Rule 6*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForDepalletisation
THEN .RemoveFromStartablePalletsList
        .CollectPartsTimeAtBuffer
        .CollectPartsLoadingUnloadingTime
        :Status-'LoadingAndDepalletisation
        .SetCurrentOperation
        .SchedulePartsOperation
        .CollectPartsFixturingTime
        .SetNewGoal2
        :CurrentLocation:PalletOnStation-self
        :CurrentLocation.StartLoading_
        AndDepalletisation
```

Figure III.42	*Pallet.StartAction2 - Rule 7*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='ReadyForDepalletisation
THEN .RemoveFromStartablePalletsList
        :Status-'Depalletisation
        .SetCurrentOperation
        .SchedulePartsOperation
        .CollectPartsFixturingTime
        .SetNewGoal2
        :CurrentLocation.StartDepalletisation;
```

Figure III.43	*Pallet.StartAction2 - Rule 8*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:  duration fintime;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Palletisation
THEN :GoalStatus-'Active
        duration-.FindOperationTime
        fintime-$InstInferenceEngine:_
        MasterClock + duration
        :FinishTime-fintime;

IF :Status='LoadingOntoTransporter
THEN :GoalStatus-'Active
        duration-:TransporterArrivalTime +
        .FindPalletExchangeTime
        fintime-$InstInferenceEngine:_
        MasterClock + duration
        :FinishTime-fintime;
```

Figure III.44	*Pallet.SetNewGoal2 - Rules 1 & 2*	**LUT-FMS** **Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:  duration fintime;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='TransferAndUnloading
THEN :GoalStatus-'Active
        duration-.FindTransferTime +
        .FindPalletExchangeTime
        fintime-$InstInferenceEngine:_
        MasterClock + duration
        :FinishTime-fintime;

IF :Status='Processing
THEN :GoalStatus-'Active
        duration-:SubOpsDuration
        fintime-$InstInferenceEngine:_
        MasterClock + duration
        :FinishTime-fintime;
```

Figure III.45	*Pallet.SetNewGoal2 - Rules 3 & 4*	**LUT-FMS** **Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:  duration fintime;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='LoadingAndProcessing
THEN :GoalStatus-'Active
        duration-.FindStationExchange_
        Time + :SubOpsDuration
        fintime-$InstInferenceEngine:_
        MasterClock + duration
        :FinishTime-fintime;

IF :Status='UnloadingFromStation
THEN :GoalStatus-'Active
        duration-.FindStationExchangeTime
        fintime-$InstInferenceEngine:_
        MasterClock + duration
        :FinishTime-fintime;
```

Figure III.46	*Pallet.SetNewGoal2 - Rules 5 & 6*	**LUT-FMS** **Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:  duration fintime;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Depalletisation
THEN :GoalStatus-'Active
        duration-.FindOperationTime
        fintime-$InstInferenceEngine:_
        MasterClock + duration
        :FinishTime-fintime;

IF :Status='LoadingAndDepalletisation
THEN :GoalStatus-'Active
        duration-.FindStationExchange_
        Time + .FindOperationTime
        fintime-$InstInferenceEngine:_
        MasterClock + duration
        :FinishTime-fintime;
```

Figure III.47	*Pallet.SetNewGoal2 - Rules 7 & 8*	**LUT-FMS** **Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Palletisation
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN .SetStatusToAwaitUnloadOrTransfer
      :PartsOnPallet-:AllocatedParts
      .UpdateOperationStatus
      :GoalStatus-NIL
      :CurrentLocation.EndPalletisation;

IF :Status='LoadingOntoTransporter
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN :Status-'ReadyForTransfer
      :GoalStatus-NIL
      .EndRemovingFromStation
      :CurrentLocation-:SelectedResource
      :CurrentLocation.EndLoadingOn;
```

Figure III.48	*Pallet.EndAction2 - Rules 1 & 2*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='TransferAndUnloading
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN .SetStatusToAwaitProcOrDepall
      :GoalStatus-NIL
      :CurrentLocation.EndTransfer_
      AndUnloading
      .AddToStation;

IF :Status='LoadingAndProcessing
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN .SetStatusToAwaitUnloadOrTransfer
      .UpdateOperationStatus
      :GoalStatus-NIL
      :CurrentLocation.EndLoading_
      AndProcessing;
```

Figure III.49	*Pallet.EndAction2 - Rules 3 & 4*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Processing
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN :Status-'AwaitingForTransfer
      .UpdateOperationStatus
      :GoalStatus-NIL
      :CurrentLocation.EndProcessing;

IF :Status='UnloadingFromStation
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN :Status-'AwaitingForTransfer
      :GoalStatus-NIL
      :CurrentLocation.EndUnloading;
```

Figure III.50	*Pallet.EndAction2 - Rules 5 & 6*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********
IF :Status='LoadingAndDepalletisation
  $InstInferenceEngine:MasterClock>=
  :FinishTime
THEN :Status-'Idle
      .CollectPartsFlowTimes
      :PartsOnPallet-NIL
      .SetFinalLocation
      :GoalStatus-NIL
      .RemoveFromAllocatedPalletsList
      :CurrentLocation.EndLoading_
      AndDepalletisation;
```

Figure III.51	*Pallet.EndAction2 - Rule 7*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Depalletisation
  $InstInferenceEngine:MasterClock>=
  :FinishTime
THEN :Status-'Idle
      .CollectPartsFlowTimes
      :PartsOnPallet-NIL
      .SetFinalLocation
      :GoalStatus-NIL
      .RemoveFromAllocatedPalletsList
      :CurrentLocation.EndDepalletisation;
```

Figure III.52	*Pallet.EndAction2 - Rule 8*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********


IF :Status='AwaitingForPalletisation
THEN .CheckLoadUnloadStation;

IF :Status='AwaitingForTransfer
   .CheckNextStation2
THEN .CheckTransporter;

IF :Status='AwaitingForTransfer
   .CheckTempStorage
THEN .CheckTransporter;

IF :Status='ReadyForTransfer
THEN .PutToStartablePalletsList;

IF :Status='AwaitingForProcessing
THEN .CheckStation3;
```

Figure III.53	*Pallet.TestStartOfAction3 - Rules 1, 2, 3, 4 & 5*	LUT-FMS **Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********


IF :Status='ReadyForProcessing
THEN .PutToStartablePalletsList;

IF :Status='AwaitingForUnloading
THEN .CheckBuffer;

IF :Status='AwaitingForDepalletisation
THEN .CheckStation;

IF :Status='ReadyForDepalletisation
THEN .PutToStartablePalletsList;
```

Figure III.54	*Pallet.TestStartOfAction3 - Rules 6, 7, 8 & 9*	LUT-FMS **Research Group**

```
WorkSpace Class:  Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForPalletisation
THEN .RemoveFromStartablePalletsList
        .SetCurrentOperation
        .SetLocation
        .SetPartsEntryTime
        .SchedulePartsOperation
        .CollectPartsFixturingTime
        :Status-'Palletisation
        .SetNewGoal2
        :CurrentLocation:PalletOnStation-self
        :CurrentLocation.StartPalletisation;
```

Figure III.55	*Pallet.StartAction3 - Rule 1*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForTransfer
THEN .RemoveFromStartablePalletsList
        .TransporterArrives
        .CollectPartsLoadingUnloadingTime
        :Status-'LoadingOntoTransporter
        .StartRemovingFromStation
        .SetNewGoal2
        :SelectedResource.StartLoadingOn;
```

Figure III.56	*Pallet.StartAction3 - Rule 2*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='ReadyForTransfer
THEN .RemoveFromStartablePalletsList
      .CollectPartsTransportTime
      :Status-'TransferAndUnloading
      .SetNewGoal2
      :SelectedResource.StartTransfer_
      AndUnloading;
```

Figure III.57	*Pallet.StartAction3 - Rule 3*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForProcessing
THEN .RemoveFromStartablePalletsList
        .CollectPartsTimeAtBuffer
        .CollectPartsLoadingUnloadingTime
        :Status-'LoadingAndProcessing
        .SetCurrentOperation
        .SchedulePartsOperation
        .ScheduleSubOps3
        .SetNewGoal2
        :CurrentLocation:PalletOnStation-self
        :CurrentLocation.StartLoading_
        AndProcessing;
```

Figure III.58	*Pallet.StartAction3 - Rule 4*	**LUT-FMS Research Group**

```
WorkSpace Class:  Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='ReadyForProcessing
THEN .RemoveFromStartablePalletsList
      :Status—'Processing
      .SetCurrentOperation
      .SchedulePartsOperation
      .ScheduleSubOps3
      .SetNewGoal2
      :CurrentLocation.StartProcessing;
```

Figure III.59	*Pallet.StartAction3 - Rule 5*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForUnloading
THEN .RemoveFromStartablePalletsList
      :Status—'UnloadingFromStation
      .CollectPartsTimeAtStation
      .CollectPartsLoadingUnloadingTime
      :CurrentLocation.CollectStationaryTime
      .SetNewGoal2
      :CurrentLocation.StartUnloading;
```

Figure III.60	*Pallet.StartAction3 - Rule 6*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='AwaitingForDepalletisation
THEN .RemoveFromStartablePalletsList
      .CollectPartsTimeAtBuffer
      .CollectPartsLoadingUnloadingTime
      :Status—'LoadingAndDepalletisation
      .SetCurrentOperation
      .SchedulePartsOperation
      .CollectPartsFixturingTime
      .SetNewGoal2
      :CurrentLocation:PalletOnStation—self
      :CurrentLocation.StartLoading_
      AndDepalletisation
```

Figure III.61	*Pallet.StartAction3 - Rule 7*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option:  A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='ReadyForDepalletisation
THEN .RemoveFromStartablePalletsList
      :Status—'Depalletisation
      .SetCurrentOperation
      .SchedulePartsOperation
      .CollectPartsFixturingTime
      .SetNewGoal2
      :CurrentLocation.StartDepalletisation;
```

Figure III.62	*Pallet.StartAction3 - Rule 8*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Palletisation
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN .SetStatusToAwaitUnloadOrTransfer
        :PartsOnPallet-:AllocatedParts
        .UpdateOperationStatus
        :GoalStatus-NIL
        :CurrentLocation.EndPalletisation;

IF :Status='LoadingOntoTransporter
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN :Status-'ReadyForTransfer
        :GoalStatus-NIL
        .EndRemovingFromStation
        :CurrentLocation-:SelectedResource
        :CurrentLocation.EndLoadingOn;
```

Figure III.63	*Pallet.EndAction3 - Rules 1 & 2*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='TransferAndUnloading
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN .SetStatusToAwaitProcOrDepall
        :GoalStatus-NIL
        :CurrentLocation.EndTransfer_
        AndUnloading
        .AddToStation;

IF :Status='LoadingAndProcessing
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN .SetStatusToAwaitUnloadOrTransfer
        .UpdateOperationStatus
        :GoalStatus-NIL
        :CurrentLocation.EndLoading_
        AndProcessing;
```

Figure III.64	*Pallet.EndAction3 - Rules 3 & 4*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Processing
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN :Status-'AwaitingForTransfer
        .UpdateOperationStatus
        :GoalStatus-NIL
        :CurrentLocation.EndProcessing;

IF :Status='UnloadingFromStation
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN :Status-'AwaitingForTransfer
        :GoalStatus-NIL
        :CurrentLocation.EndUnloading;
```

Figure III.65	*Pallet.EndAction3 - Rules 5 & 6*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********
IF :Status='LoadingAndDepalletisation
  $InstInferenceEngine:MasterClock>=
  :FinishTime
THEN :Status-'Idle
       .CollectPartsFlowTimes
       :PartsOnPallet-NIL
       .SetFinalLocation
       :GoalStatus-NIL
       .RemoveFromAllocatedPalletsList
       :CurrentLocation.EndLoading_
       AndDepalletisation;
```

Figure III.66	*Pallet.EndAction3 - Rule 7*	**LUT-FMS Research Group**

```
WorkSpace Class: Pallet;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Depalletisation
  $InstInferenceEngine:MasterClock>=
  :FinishTime
THEN :Status-'Idle
       .CollectPartsFlowTimes
       :PartsOnPallet-NIL
       .SetFinalLocation
       :GoalStatus-NIL
       .RemoveFromAllocatedPalletsList
       :CurrentLocation.EndDepalletisation;
```

Figure III.67	*Pallet.EndAction3 - Rule 8*	**LUT-FMS Research Group**

```
WorkSpace Class: ToolTransporter;
Compiler Option: A;
Temporary Vars: pallet pallets;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='Idle
   pallet-.SinglePalletIsWaitingFor_
   ToolTransporters
THEN :SelectedPallet-pallet
       pallet.RemoveFromAwaitingFor_
       ToolTransportersPalletsList
       .PutToApplicableTool_
       TransportersList;

IF :Status='Idle
   pallets-.MultiplePalletsAreWaitingFor_
   ToolTransporters
THEN :AvailablePallets-pallets
       .PutToToolingConflictSets;
```

Figure III.68	*ToolTransporter .TestStartOfAction - Rules 1 & 2*	**LUT-FMS Research Group**

```
WorkSpace Class: ToolTransporter;
Compiler Option: A;
Temporary Vars: pallet pallets;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='ReadyForPTS
THEN .PutToStartableTool_
       TransportersList;

IF :Status='ReadyForSTS
THEN .PutToStartableTool_
       TransportersList;
```

Figure III.69	*ToolTransporter .TestStartOfAction - Rule 3 & 4*	**LUT-FMS Research Group**

```
WorkSpace Class: ToolTransporter;
Compiler Option:  A;
Temporary Vars:  sts;
Control Structure:  DO1;
Rule Class:  MyRule;
********

IF :Status='Idle
THEN .RemoveFromStartableTool_
       TransportersList
       .LeavingForSTS
       :Status-'ArrivingAndLoading
       .CollectLoadingUnloadingTime
       sts-$InstWorkingMemory:
       SecondaryToolStore
       sts.StartLoadingToolsOnto_
       Transporter
       .SetNewGoal;
```

Figure III.70	*ToolTransporter .StartAction - Rule 1*	**LUT-FMS Research Group**

```
WorkSpace Class: ToolTransporter;
Compiler Option:  A:
Temporary Vars:  sts;
Control Structure:  DO1;
Rule Class:  MyRule;
********

IF :Status='ReadyForPTS
THEN .RemoveFromStartableTool_
       TransportersList
       :Status-'TransferAndExchanging
       .CollectLoadRunningTime
       .CollectLoadingUnloadingTime
       .SetNewGoal;

IF :Status='ReadyForSTS
THEN .RemoveFromStartableTool_
       TransportersList
       :Status-'TransferAndUnloading
       .CollectLoadRunningTime
       .CollectLoadingUnloadingTime
       .SetNewGoal;
```

Figure III.71	*ToolTransporter .StartAction - Rules 2 & 3*	**LUT-FMS Research Group**

```
WorkSpace Class: ToolTransporter;
Compiler Option: A;
Temporary Vars: duration fintime;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='ArrivingAndLoading
THEN :GoalStatus-'Active
       duration-:ArrivalTime +
       .FindLoadingUnloadingTime
       fintime-$InstInferenceEngine:_
       MasterClock + duration
       :FinishTime-fintime;

IF :Status='TransferAndExchanging
THEN :GoalStatus-'Active
       duration-.FindTransferTime +
       .FindLoadingUnloadingTime
       fintime-$InstInferenceEngine:_
       MasterClock + duration
       :FinishTime-fintime;
```

Figure III.72	*ToolTransporter .SetNewGoal - Rules 1 & 2*	**LUT-FMS Research Group**

```
WorkSpace Class: ToolTransporter;
Compiler Option: A;
Temporary Vars: duration fintime;
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='TransferAndUnloading
THEN :GoalStatus-'Active
       duration-.FindTransferTime +
       .FindLoadingUnloadingTime
       fintime-$InstInferenceEngine:_
       MasterClock + duration
       :FinishTime-fintime;
```

Figure III.73	*ToolTransporter .SetNewGoal - Rule 3*	**LUT-FMS Research Group**

```
WorkSpace Class: ToolTransporter;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='ArrivingAndLoading
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN .ArrivesAtSTS
     .LoadTools
     $InstWorkingMemory:SecondaryTool_
     Store.EndLoadingToolsOntoTransporter
     :Status-'ReadyForPTS
     :GoalStatus-NIL;
```

Figure III.74	*ToolTransporter .EndAction - Rule 1*	**LUT-FMS Research Group**

```
WorkSpace Class: ToolTransporter;
Compiler Option: A:
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********
IF :Status='TransferAndExchanging
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN .ArrivesAtPTS
     .ExchangeTools
     .SetStatusToIdleOrReadyForSTS
     :GoalStatus-NIL
     :SelectedPallet.CollectPartsTime_
     WaitingForTools
     :SelectedPallet.CollectStationTime_
     WaitingForTools
     :CurrentLocation:Status-'ToolsAreArrived
     :SelectedPallet.PutToStartablePalletsList;
```

Figure III.75	*ToolTransporter .EndAction - Rule 2*	**LUT-FMS Research Group**

```
WorkSpace Class: ToolTransporter;
Compiler Option: A;
Temporary Vars:
Control Structure: DO1;
Rule Class: MyRule;
********

IF :Status='TransferAndUnloading
   $InstInferenceEngine:MasterClock>=
   :FinishTime
THEN .ArrivesAtSTS
     .UnloadTools
     :Status-'Idle
     :GoalStatus-NIL;
```

Figure III.76	*ToolTransporter .EndAction - Rule 3*	**LUT-FMS Research Group**

Appendix IV

XEROX 1186 WORKSTATION AND LOOPS

IV.1. The Hardware Structure

The Xerox 1186 Workstation is an artificial intelligence development workstation that combines Xerox hardware and software to provide a wide variety of user applications. It consists of a processor unit, a display screen, a keyboard, a three-button optical mouse, and a floppy disk drive as an optional feature.

The 1186 workstation has a total of 3712 Kilobytes of processor memory. Contained in the processor unit is a 80 Megabyte rigid disk which may be partitioned into up to ten regions called logical volumes. Logical volumes are like directories on the disk device: they may be used to hold Interlisp virtual memories, or Interlisp files.

The virtual memory is the working space on the local disk and is stored as a large file on a logical volume of the rigid disk, called the virtual memory file. Interlisp controls the swapping of pages between this file and the real memory. Therefore at any moment, the total state of the Interlisp virtual memory is stored partially in the virtual memory file, and partially in the real physical memory.

IV.2. The Interlisp-D Programming Environment

As a progarmming system, Interlisp-D consists of a programming language, a large number of predefined functions and an environment. The language and predefined functions of Interlisp-D are rich, but similar to those of other modern programming languages. The Interlisp-D programming environment, on the other hand, is very distinctive. In addition to some basic programming tools, it also provides an intergated set of programming support mechanisms:

- ***Structure editor.*** It allows the user to change the list structure of a function's definition directly.

- ***Pretty-printer.*** It is a function that prints lisp function definitions so that their syntactic structure is displayed by the indentation and fonts used.

- ***Break package.*** When errors occur, the break package is called, allowing the user to examine and modify the context at the point of the error. It automatically corrects the user's misspellings and errors in typing.

- ***DWIM.*** The package automatically corrects the user's misspellings and errors in typing.

- ***Programmer's assistant.*** Interlisp-D keeps track of the user's actions during a session and allows each one to be replayed, undone or altered.

- ***Masterscope.*** It is a program analysis and management tool which can analyse user's functions and build a data base of the results.

- ***Record/Datatype package.*** Interlisp-D allows a programmer to define new data structures.

- ***File package.*** Files in Interlisp-D are managed by the system, removing the problem of ensuring timely file updates from the user.

- ***Performance analysis.*** It allows statistics on progarm operations to be collected and analysed.

- ***Multiple processes.*** The multiple and independent processes allowed in Interlisp-D simplify problems which require logically separate pieces of code to operate in parallel.

- ***Windows.*** This ability allows many different processes or activities to be active on the screen at once.

- ***Inspector.*** It is a display tool for examining complex data structures encountered during debugging.

IV.3. The LOOPS Knowledge Engineering Language

LOOPS is an integrated knowledge programming system. Its intergation has two major themes: to allow various programming paradigms to be used together in building a knowledge system; and to provide a programming environment for creating and debugging knowledge systems.

An important principle of knowldge programming in that different paradigms are appropriate for different purposes. LOOPS integrates four programming paradigms:

- ***Procedure oriented programming.*** In this paradigm. large procedures are built up from small ones by use of subroutines. Data and programs are kept separate. Interlisp-D is the procedure oriented part of LOOPS.

- ***Object oriented programming.*** In this paradigm, information is organised in terms of objects, which combine both instructions and data, Large objects are built up from smaller objects. Objects communicate with each other by sending messages. This approach makes it convenient to define program interfaces in terms of message protocols.

- ***Access oriented programming.*** This paradigm is useful for programs that monitor other programs. Its basic mechanism is a structure called an active value, which has procedures that are involved when variables are accessed.

- ***Rule oriented programming.*** This paragigm is specialised for representing the decision making knowledge in a program. In LOOPS, rules are organised into rulesets which specify the rules, a control structure, and other descriptions of the rules. This makes it convenient for describing flexible responses to a wide range of events.

These different organizational methods determine the way that information is factored and shared. Each paradigm provides a vocabulary and a set of composition methods for organizing information in a paradigm.

- ***Procedure composition:*** The composition methods of Interlisp-D are forms of familiar control statements for iteration, recursion and procedure call.

- ***Object Composition:*** This paradigm provides several composition methods. The simplest is the specialization of methods and variables of a super-class. Special classes called Mixins are used to impart a specific set of behaviours to a number of subclasses. Mixins exploit the multiple inheritance lattice by allowing inheritance to be factored. Composite objects extend the notion of objects to be recursive in structure so that multiple objects can be instantiated and linked together. Finally, perspectives in LOOPS are groupings of objects into a higher level object, such that each component is a view (or perspective of the whole). Perspectives provide for the forwarding of messages to the appropriate view.

- *Access composition:* Composition in this paradigm is done by nesting of active values. Analogous to the use of multiple probes in measuring a circuit, this composition assumes that the 'probes' are for independent instruments and do not interfere with each other.

- *Rule composition:* The LOOPS rule-oriented paradigm provides for the sharing of rules among rulesets. It makes use of the other paradigms for organizing the interactions bwteen the rules. Thus rules can call rulesets directly (using the procedural orientation), or invoke rulesets by sending messages (using the object orientation), or invoke rulesets by changing data (using the access orientation).

Some examples illustrate the integration of paradigms in LOOPS: rules and rule sets are considered LOOPS objects and can communicate by object-oriented message passing or by standard subroutine calls, procedures can be either LISP functions or rule sets and can be used with active values to display gauges. The ring in the LOOPS logo reflects the fact that LOOPS not only contains the different paradigms, but integrates them. The paradigms are designed not only to complement each other, but also to be used together in combination.

The second theme of integration is the intergation with the programming environment. For example, LOOPS extends to other paradigms many of the facilities of Interlisp-D, such as the display-oriented break package, editors, and inspectors. In LOOPS, this integration has led to the same synergy that is exploited in using multiple paradigms for application programs.

Appendix V
USER INTERFACE

V.1 Introduction

In this appendix, the user interface is presented. First the global menus are illustrated. Then the model configurator is described, which allows the user to physically configure a manufacturing cell layout. After this, the menu driven software is presented for the manipulation of production requirements data and manufacturing cell data.

The interactive rule entry editor is then introduced, which allows the user, by means of selecting or expressing English-like rules, to enter decision or behaviour rules that govern the behaviour of the modelled system. Following this, the graphics and textual output facilities are described that aid the user in understanding the operation of a model and the relationship between the behaviour of the model and the computer code embedded in the model.

V.2 The Global Menus

The global menus are a suite of menus which act as the control centre for all the user's activities with the modelling system. They provide the user with options to state the modelling level entry, create or choose a model, edit a model, run a model and display the results.

The options the user needs in order to manipulate model layout configuration, model data specification and editing, decision and behaviour rules entry, and graphics and textual outputs, are available through the other menus.

The global menus are displayed when the user selects the *K B Modelling* option over the main system backgroud menu.

V.2.1 The Modelling Master Menu

The first menu in the global menus is the modelling master menu. It has eight options(Figure V.1).

The *Level 1, Level 2* and *Level 3* options allow the user to enter the modelling environment which models a manufacturing system at the first level, the second level and the third level respectively. Entry of a new level from an existing level will dump all the objects in the existing modelling environment. This is facilitated by a mouse confirm function.

The objectives and assumptions at each of the levels have been discussed in previous chapters. Selection of these options displays the modelling master menu for the corresponding level.

The *Level 1 Help, Level 2 Help*, and *Level 3 Help* options provide a description of the modelling at each of these levels in the summary window, which helps the user understand what the system does at a particular level and choose an appropriate level for the desired experiment.

The *Class Browser* option is provided for users who are adequately experienced with the LOOPS environment and desire to work with the system. Selection of this option displays the class inheritance lattice which contains all the classes and methods defined in the modelling system.

The *Exit* option closes all the windows currently open on the current modelling environment: including the global menus, the data base browser, the model layout map and any associated windows and menus. This option does not save the model that is currently displayed, but the model remains in the system.

To continue with the modelling system after the exit option is selected, select the *KBModelling* option of the system's background menu.

V.2.2 The Level-1 Modelling Master Menu

When the level 1 option in the modelling master menu is selected, this menu is displayed (Figure V.2). It lets the user to work with the level-1 modelling environment.

The *Edit Model* option displays the edit model menu, with its options to edit an existing model or to create a new model. The edit model menu is described below.

The ***Run Model*** option displays the run model menu for the existing model, which provides all the options for the running of a model. It is illustrated below.

The ***Output Results*** option displays the output results menu, with its options to output various categories of results for the user's subsequent analyses. The output results menu is further described below.

The ***Master Menu*** option lets the user to return to the modelling master menu.

The ***Class Browser*** and ***Exit*** options are the same as those in the modelling master menu. They are provided here simply for the ease of manipulation.

V.2.2.1 The Level-1 Edit Model Menu

This menu is displayed when the user selects the edit model option in the level-1 modelling master menu. It provides all the options for the design of a model, including manufacturing cell layout, cell data specification, control rules entry, storage and retrieving of models, and hardcopy of model input information (Figure V.3).

The ***Configure Model*** option lets the user to create a new model. First the user is confirmed to dump any existing objects in the modelling environment. Then he is prompted to enter the name of the new model, and to position and size the layout map. Menus associated with the model layout map (model configurator) are to be described in the next section. All the model configurator does is to allow the user to layout a manufacturing cell interactively on the map by means of icons which represent major cell elements, and to invoke the data base browser in oeder to specify or edit the manufacturing cell data.

The ***Save Model*** option saves the existing model currently in the environment as a lisp file in the connected directory. The name of the file is created automatically using the name of the model.

The ***Retrieve Model*** option retrieves an existing model from the connected directory and loads it into the current modelling environment. When this option is selected, the user is confirmed for dumping all the objects currently existing in the environment and is prompted for the name of the model, and the system automatically loads the model which has been created at the current modelling level.

The *Change Directory* option is provided for connecting to the desired directory when saving or retrieving a model.

The *Hardcopy Input* option lets the user to write the data information of an existing model on a text file which can then be printed out on the connected printer. It is provided because the lisp file which stores a model is not explicitly readable.

Following these options, there are options in this menu which are provided for the user to specify the top level system parameters and control strategies for a model.

The *Planning Horizon* option allows the user to specify the planning horizon for the production requirements specified in the data base browser.

The *Fixed/Unfixed Pallets* option allows the user to specify whether the model has a fixed or unfixed number of pallets. The modelling knowledge concerning either of the cases has been discussed in the previous chapter.

The next option, *Behavioural Rules*, displays the behaviour rules library, which provides all the options concerning the behaviour of the cell elements at this level of modelling. The behaviour rules library is to be described in section V.5.

The next five options are concerned with the entry of control or conflict-resolution rules. Selection of each of these options displays the corresponding rules library. Selection of existing rules from the library and entry of new rules into the library are also to be described in section V.5.

The *Previous Menu* option simplay allows the user to return to the previous menu, i.e. the level-1 modelling master menu.

V.2.2.2 The Level-1 Run Model Menu

The run model menu provides the options the user needs to run a model. There are options for creating a working memory, setting up graphics and textual output facilities, initialising and running the model. Other options are for handling blocking and stopping the run (Figure V.4). This menu is displayed by the selection of the run model option on the level-1 modelling master menu.

The ***Create W.M.*** option automatically create a working memory for an existing model in the current modelling environment. It involves creating dynamic instance objects for the corresponding static instance objects in the data base browser and establishing direct links among these dynamic objects. As mentioned in Chapter 7, these links are only represented indirectly in the data base browser. To run a model this option must be selected.

The inheritance of the information of the static objects to the dynamic objects is facilitated by using the access-oriented programming method. Therefore, any changes of the information within the data base browser are automatically transmitted to the working memory.

The ***Setup Display*** option displays the graphics output facilities for the running of the model. These facilities are to be described in detail in section V.6.

The ***Clock Gauge*** sets up a time display window for the run. when the model is running, it changes dynamically showing the advance of the time.

The ***Utilisation Gauge*** displays a bar chart window showing the utilisation of the major system elements at any time during a run.

The ***Trace/Untrace*** option has two slide-out options, i.e. ***Trace*** and ***Untrace***. The former sets up the trace window for the textual output of a run, and the latter closes this window. For a detailed description, see section V.6.

The ***Block On*** option lets the user specify the blocking intervals to be used during the model run. Blocking intervals are set in milliseconds.

The ***Initialise W.M.*** option prepares the working memory of the model for running. It involves setting up the initial values of the working memory elements.

The *Run Model* option begines the run of a model, which is a LISP process. The model runs until a termination condition is met or the run is suspended or aborted.

The *Suspend Modelling* option suspends a running model. A suspended model run can be continued using the *Resume Modelling* option on the menu.

The *Terminate Modelling* option stops a run by deleting the corresponding LISP process.

The *Close Windows* option closes all the wondows except the global menus window, the data base browser window and the model configurator window.

V.2.2.3 The Level-1 Output Results Menu

The output results menu is displayed when the *Output Results Menu* option on the level-1 modelling master menu is selected (Figure V.5). It provides the options for displaying the results after a run, which can then be subject to the user's further analysis.

There are ten options for outputing results at this level. The *Run Time* option provides an indication on the performance of a computational run.

The *Cell Performance*, *Part Throughput*, *Part Lead Times*, *Part Performance*, *Machine Performance*, *Transporter Performance*, *Load/Unload Station Performance*, *Station Operation Schedules* and *Part* **Operation Schedules** options all provide a summary of the performance of the modelled system.

For a more close discussion on the system outputs, refer to Chapter 10.

The *Hardcopy Output* option lets the user to print the results on a text file. There are also slide-out options for printing different categories of results on separate files.

The *Change Directory* option is provided to ease the managemnet of the output results files.

V.2.3 The Level-2 Modelling Master Menu

This menu is displayed when the *Level 2* option in the modelling master menu is selected (Figure V.6). It provides an environment for modelling a system at level 2.

The options on this menu are identical to those of the level-1 modelling master menu.

V.2.3.1 The Level-2 Edit Model Menu

The options on this menu are similar to those on the level-1 edit model menu, except that there is an additional option ***Temporary Storage Flg*** which lets the user set the flg indicating whether to use the temporary work storages or not (Figure V.7). In addition, the control rules in the rule libraries can be different from those in the level-1 modelling. Details of this aspect are to be described in section V.5.

V.2.3.2 The Level-2 Run Model Menu

The run model menu provides all the options the user needs to run a model at this level (Figure V.8).

This menu is exactly the same as the level-1 run model menu, except that it is displayed when the run model option on the level-2 modelling master menu is selected.

V.2.3.3 The Level-2 Output Results Menu

This menu provides all the options for displaying the output results after a run at this modelling level (Figure V.9).

In addtion to the options available on the level-1 output results menu, this menu also provides options for outputing the ***Temporary Storage Performance***, the ***Minimum Tool Requirements***, the ***PTS Tool Requirements*** and the ***Tool Performance***. Again these system outputs are to be closely discussed in the next chapter.

V.2.4 The Level-3 Modelling Master Menu

This menu is displayed when the *Level 3* option on the modelling master menu is selected (Figure V.10). It provides an environment for modelling a system at the third level.

The options on this menu are also identical to those of the level-3 modelling master menu.

V.2.4.1 The Level-3 Edit Model Menu

This menu provides all the options for designing a model at level 2 (Figure V.11). The options on this menu are also similar to those on the level-2 edit model menu, except that additional control rules have to be input, including the ***Pallet Tooling Rules*** and ***Tool Transporter Rules***. Besides, the control rules in the other rule libraries can be different from those in the previous two levels of modelling. This is discussed in detail in section V.5.

V.2.4.2 The Level-3 Run Model Menu

This menu contains all the options for running a model at this level (Figure V.12).

It is also the same as the level-1 or level-2 run model menu. It is displayed when the user selects the run model option on the level-3 modelling master menu.

V.2.4.3 The Level-3 Output Results Menu

This menu provides all the options for displaying model output results at this modelling level. In addition to the options available on the level-1 output results menu, this menu also provides options for outputing the ***Temporary Storage Performance***, the ***Cell Tool Requirement***, the ***PTS Performance***, the ***STS***

Performance, the ***Tool Transporter Performance*** and the ***Tool Performance*** (Figure V.13). Again these output results are to be discussed in the next chapter.

V.3 The Model Configurator

The model configurator is invoked when the user selects the ***Configure Model*** option on the edit model menu at any of the three modelling levels. It provides the user with all the facilities for physically configuring a manufacturing system layout.

The user configures a cell layout by interactively selecting icons of the major cell elements, placing them on the layout map, drawing the routes of the transporters and finally connecting the icons with the routes by adding pathes. Each of the graphics items on the screen is a LOOPS object which is also automatically placed into the data base browser. The data base browser is to be illustrated in the next section.

V.3.1 The Title Bar Menu

After the user has positioned and sized the layout map, left clicking over the title bar at the map displays the title bar menu. It is primarily concerned with creating objects on the map and assisting in positioning the objects. It also provides the option to display the data base browser (Figure 9.2).

The ***Create Object*** option allows new cell elements or transport routes of the available classes to be added to the map. When this option is selected, the select which class menu is displayed. On selecting the class required (there may be several sub-menus to select from), a message prompts for a name to be given to the new object. Then the user is prompted to enter a label for the created cell element (this can be ignored), which is printed on the image of the object. Finally the object requires positioning on the layout map.

The ***Select Which Class Menu*** lets the user choose which class of object the user wishes to create and position on the map. The main classes are displayed as options directly on this menu. Other classes are available as slide-out options. There can be several levels of slide-out options. This menu is displayed from the ***Create Object*** option of the title bar menu.

Since each level modelles a different cross section of manufacturing system elements, there are a different menu of classes available in each modelling level. For a introduction of the system elements included within eahc level, see Chapter 8 for details. Figures V.14, V.15 and V.16 summarize the graphic icons of the classes on the ***Select Which Class Menu.***

The ***Create New Class*** option lets the user to define a specialised class for an existing one. First the user is prompted to choose the class to specialize. Then the user is required to enter the name for the new class. And finally a LISP DEdit window is invoked, where the user can edit the Supers, ClassVariables and InstanceVariables of the defined class. Thiis is done with the assumption that the user has certain LOOPS experience.

The ***Toggle Grid (Grid On)*** option turns the grid display on. The grid is useful for positioning icons on the map. This option has several slide-out options which allow the user to further handle with the grid display if desired.

The ***Grid On*** option is the same as the main default option. The ***Smaller Grid*** option increases the granularity of the grid in 5 pixels in both axis. The ***Larger Grid*** option decreases the granularity of the grid in 5 pixels in both axis. The ***Grid Off*** option turns the grid display off.

The ***Measure (Distance)*** option has two slide-out options. The default is ***Distance*** which lets the user to measure the distance between two points in pixels. When this option is selected, the user is prompted for the position of the strating point and finishing point on the map. The distance is then automatically printed in the prompt window of the map.

The ***Angle*** slide-out option measures the angle between two lines. When this option is selected, the user is prompted to indicate the position of three points on the map. The first line is made up of the starting point and the middle point, whereas the second line is comprised of the middle point and the finishing point.

The ***Shift Contents*** option shifts all the items on the layout map. When it is selected, the user is first prompted to choose the direction for the shifting. Four options are available, i.e. left, right, up and down. After this, a small number pad is displayed and the user can specify the number of pixels to shift by clicking over the digits on the pad.

The ***Flash Regions*** option flashes the map region occupied by each object on the map in turn. This feature is useful in configuring complex layouts.

The ***Inspect Configurator*** option brings up a system inspector on the map, displaying the associated parameters.

The ***Browse Data Base*** option automatically displays the data base browser for the model. The menus associated with the data base browser is to be described in section V.4.

V.3.2 The Configurator Object Menu

The configurator object menu provides options for manipulating the objects on the layout map. Different options can be displayed for different objects, but they are mainly for moving, changing, deleting and examining objects. Some objects have the options for adding, moving and deleting paths which connect the object with the routes on the map. Thus the options described below may not all be displayed together (Figure 9.2).

The configurator object menu is displayed when the user left clicks over a selected object on the map. Objects are selected by clicking over them. Selected objects are marked by reversed corners of their images. Only one object on the map can be the selected object at any one time. Selecting an object de- selects any previously selected object.

The ***Move Object*** option lets the user to move the seleted object to another position on the map. When this option is selected, the user is prompted to indicate the new position of the object by clicking the cursor in the new position of bottom left-hand corner of the object.

The ***Copy Object*** option allows the user to produce a copy of the selected object. The user is required to position the copy.

The ***Delete Object*** option removes the selected object from the map. Any connected paths are also automatically deleted.

The ***Inspect Object*** option opens an Inspector on the selected object's variables. All variables and their associated values are shown.

The *Modify Paths (Add Path)* option has several slide-out options. The default is to add a path. When this option or the *Add Path* slide-out option is selected, a list of available gates are displayed at the selected object; just select the one the new path is to be connected to. Essentially an object can have two gates, i.e. ***Work*** and ***Tool*** which are used to connect to the work flow network and the tool flow network respectively. Having established one end of the path, the user must specify the route that this path is to be connected to. This is done by clicking near the line route, or the desired side of a loop or network route on the map, and finally a straight line from the object to the route is then added.

The *Delete Path* slide out option lets the user to remove one of the paths connected to the selected object. To identify the path the user must specify the gate it is connected to. This is done by selecting the gate from the displayed list. When the path has been identified, it is removed from the layout map.

The *Appearance (Change Label)* option has a range of slide- out options. The default is to change the label of the selected object. When this option or the *Change Label* slide-out option is selected, the user is prompted for a new label, and the new label is printed on the object. Carriage return enables no label on the object.

The *Change Image* slide-out option allows the user to change the bit image of the selected object on the map. When this option is selected, a list of all the available bit maps are displayed for the user to select. The *Other* option lets the user to create a new bit map. If an existing bit map is selected, the selected object's image is replaced with the new bit map. If the *Other* option is selected, the user is prompted for the name of the new image. After that the Bit Map Editor is opened so that the user can create the new image.

The *Align Buffer-Image* slide-out option automatically aligns the buffer image and the selected object's image along the horizontal axis. The ***Object to Top*** slide-out option puts the selected object to the top if it is partly buried under the other objects.

The *Examine Components* option opens a Browser window on the selected object, showing the components of that object.

The *Stretch Object* option lets the user to stretch the routes on the map. When it is selected, the user is prompted to left select a point on the route. Once it is selected, the route is graphically connected with the cursor. Moving the mouse while the left button is down stretches the shape of the route. Release the left button when a desired shape is achieved.

The *Set Line Width* lets the user to set the width of the line used to draw the selected path or route. When the new width is set, the path or route is re-drawn using the new width.

V.3.3 The Configurator Class Menu

The configurator class menu is displayed when the user middle clicks over a selected object on the map (Figure 9.2). It provides options for the user to edit and change the class of the selected object. Since these options change the definition of the class, the changes made may affect many other objects in the modelling environment and other models, not just the one the user selects on the map. For this reason, it is recommended that the user always specialises a class, and edit that specialisation rather than directly edit one of the existing classes.

The *Edit Class* option requirs a knowledge of LISP, LOOPS and the system *DEdit* package. When this option is selected, a *DEdit* window is displayed for the class.

The *Add a Method* option lets the user to add a lisp procedure to the selected object's class. When it is selected, the user is prompted for the name of the new method, and then a *DEdit* window for the new method is opened.

The *Add a RuleSet* option is similar to the *Add a Method* option, except that it lets the user to add a ruleset to the class; and when it is selected, a *RuleSet TEdit* window for the new ruleset is opened.

The *Edit a Method* option lets the user to edit the method of the selected object's class. When this option is selected, all the existing methods of the class are displayed for the user to select the one to be edited. A *DEdit* window or a *RuleSet TEdit* window is opened on the procedure or ruleset the user chooses.

The ***Change Default Image*** option allows the user to change the default bit image of the selected object's class. It is similar to the ***Change Image*** option of the configurator object menu, except that images of the existing objects on the map will not be changed, but the objects of the class created afterwards will use the new default image.

The ***Change Default Apperance*** option has a number of sub- options which are different for the different types of routes. The ***Change Default Length*** option changes the default length of the line-type route. The ***Change Default Angle*** option lets the user to change the default angle of the line when a line-type route is added on the map.

The ***Change Default Width*** and ***Change Default Height*** options allow the user to change the default width and height of the loop-type route. And the ***Change Default Dashing*** option changes the default dashing of the line which is used to draw the routes.

V.4 Data Browsing and Editing Facilities

The data base browser is invoked when the user selects the ***Browse Data Base*** option on the title bar menu of the model configurator. It provides the user with the options for browsing and editing the static data associated with the production requirements and the machining cell.

Each of the items in the browser has actions associated with the left and middle mouse buttons. When either button is clicked over an item, a menu of options is brought up, and the user can make a selection of them. These options are mainly concerned with the specification, editing and printing of the information of the objects, and the addition and deleting of objects and object stacks. In addition, there are options for manipulating the browser itself with the title bar menu.

V.4.1 The Title Bar Menu

After the data base browser is invoked, left clicking over the title bar at the browser displays the title bar menu (Figure 9.3). The options available on this menu depend on the modelling level in which the browser is created. In the following discussion, the data base browser for the third level is to be assumed.

The ***Create New Browser*** option dumps all the objects including the item stacks in the browser and creates a new browser for entering and defining objects. The mouse confirm function is used to confirm the user about the objects' dumping.

The other options, i.e. ***Browse Data Base***, ***Browse Parts***, ***Browse Pallets***, ***Browse Load/Unload Stations***, ***Browse Machines***, ***Browse Work Transporters***, ***Browse Temporary Storages***, ***Browse Tools***, ***Browse STS***, ***Browse Tool Transporters*** and ***Browse Processes***, automatically set up a browser for the data base, parts data, pallets data, load/unload stations data, machine stations data, work transporters data, temporary storages data, tools data, STS data, tool transporters data and processes data respectively. This does not dump any objects shown in the browser, but eases significantly the management of objects when the browser becomes considerably large. Thus the user can conveniently invoke the desired sub-browsers and work with them.

V.4.2 The Summary Menu

This menu is displayed when the user left clicks over an item in the browser (Figure 9.3). At the present time, only one option is provided on this menu, i.e. ***Print Summary***.

When this option is selected, a summary is printed in the summary window showing all the variables and their associated values. This helps the user to edit or change the values of these parameters.

V.4.3 The Edit Menu

This menu provides options for editing and changing each of the item in a browser (Figure 9.3). It is displayed when the user clicks over an item with middle button. There are different actions associated with the options on this menu when clicking over different items in the browser.

When the edit menu for the data base icon is displayed, the user can specify the variables of the root stack, edit, inspect, shade and box it. In particular, the user can define new item stakcs associated with the root stack. When the ***Edit Item*** option is selected from this menu, the user can add a new item stack where instance objects os the same class can be stored as a list, delete all the stacks, or just clear the entered instance objects in the browser without affecting the item stacks. Since these editings may change the structure of the defined three levels of modelling, these options are suggested only to the experienced users of the modelling system.

The edit menu for an item stack icon is used for the user to create or delete instance objects of the type designated by the stack. When the option ***Specify Item*** is selected, the user is required to enter the identities of all the instance objects, and these objects are added automatically into the browser.

The ***Edit Item*** option of the edit menu for a stack provides options for adding a new object, deleting an existing one, or clear all objects. The ***Object to Top*** option moves the item to the top of the item list of its super stack.

The edit menu for an instance object in the browser provides all the options for specifying, editing and inspecting the object. When the user selects the ***Specify Item*** option, he/she is prompted to enter all the required information for this object in the prompt window at a particular modelling level. See Chapter 8 for a detailed summary of this information. The ***Edit Item*** option lets the user to edit a particular piece of information associated with the object. When it is selected, another pop- up menu is displayed, which lists all the options for editing the object. The ***DEdit Item*** option is provided for experienced users, which opens a *DEdit* window for the selected object. The ***Object to Top*** option moves the object to the top of the objects list of the stack. This helps to manage the objects in the browser.

For the process stack, it is designed to contain the operations for all the part types. But an operation can also contain a list of sub-operations which may need to be defined in the level-2 or level-3 modelling. The options which are available on the edit menu are functionally similar to the above.

V.5 The Interactive Rule Entry Editor

Once the structure of a machining cell is specified, and the manufacturing requirements are input, behaviours of cell elements and interactions among them need to be defined in order to establish an operational model, with which the user can then carry out experiments.

As discussed in previours chapters, in this modelling system behaviours of each cell element are defined as English-like rules, the interactions among objects are modelled as message passing, and the conflicts among various actions of the cell elements are resolved by applying control rules or conflict- resolution rules which are also implemented using the LOOPS rule- oriented progrmming paradigm.

The interactive rule entry editor of this modelling system has been developed to allow users to enter behaviour rules of cell elements and control rules with regard to the operation of the cell. With this facility, the user can select a rule for the model to apply from a library of existing ones, modifying a particular rule, or express a new rule within the LOOPS rule language editor.

As shown in Figure 9.4, when entering rules by selecting, decision points with regard to the operation of a model have to be identified and rules concerning each of these points have to be established. In this modelling system, these decision points are designed as conflict sets and the user enters rules through the edit model menu at each of the modelling levels.

When selecting a rule option from the edit model menu at any of the three levels, a library (or menu) of existing rules with regard to the decision point are displayed beneath the global menus, and the command menu is attached to the right-bottom of the rule library menu. To select a control rule for a particular decision point, left click over an option in the rule library. When a rule is selected, it is shaded into black in the library, and this updates the command menu of the decision point.

The first option, ***Explain This Rule***, in the command menu is to explain the selected rule in terms of English. This explanation is printed in the summary window.

If the user wishes to modify an existing rule, this rule must be selected first from the library and the user can select the **Edit This Rule** option on the command menu.

This opens a ruleset TEdit window for the selected rule. To actually edit the selected rule within the window, the user needs to have certain knowledge about the editor. In addition, the user needs to inspect the class around which the edited rule is built. This is done because the user has to know the variables that are accessable within the rule. Besides, the user should have experience with the LOOPS rule langauge so that he/she can write statements using the variables of the class or any arguments in the rule editor window.

When entering rules by expressing, the user requires the rule language, decision points and data access methods as the supporting facilities (Figure 9.4). In other words, the user has to know the variables of the decision point class. This can be done by selecting the ***Inspect Decision Point*** or ***Edit Decision Point*** option of the command menu. After that, the user can select the ***Add New Decision Rule*** option. This results in the opening of the rule editor window and the user can use the LOOPS rule language to express his/her own decisions. After defined, the new control rule is placed into the rule library automatically. To define a rule which can be called within the new control rule, the user can select the ***Add Auxiliary Rule***.

The other options of the command-menu are for deleting a control rule or an auxiliary rule and stopping the entry of rules.

Another option, which is available on the edit model menu for each of the three levels, is ***Enter Behavioural Rules***. This option is suggested to be invoked only by the experienced users of the modelling system since it is concerned with all the methods which have been defined around each of the cell element at each level.

When the user selects this option, a library of classes which have been defined for a particular level are displayed as a menu. If the user selects one from this menu, a library of rules for this class are displayed beneath the class library, with the command menu being attached to the rule library. The options available on the command menu include inspecting or editing a class, explaining, editing or deleting a selected rule, and adding a new rule.

V.6 Graphics and Textual Output Facilities

When running a designed model, the user needs to be supported by the facilities which can demonstrate the operation of the model in order to understand the behaviour of the model. Additionally, the user needs facilities which can show the relationship between the behaviour of the model and the computer code behind this behaviour.

In this modelling system, software has been developed to allow the user to setup windows showing the status of each of the major cell element (Figure 9.5).

When the user selects the ***Setup Display*** option from the run model menu for each of the three levels, the status windows for pallets, load/unload stations, machine stations, work transporters, temporary storages, tool transporters and the secondary tool store. In addition, there are two windows showing the current time and the next event (or next goal in AI terminology).

Once the status windows are displayed, the values of the variables depicted in the window can change dynamically during the running of the model. To query about the state of a particular object, the user can suspend the modelling first by selecting the ***Suspend Modelling*** option. Notably this option can only be selected when a cycle is completed. Once the modelling process is suspended, the user can left or middle click over the status window of the selected object, and this displays a pop-up menu (Figure V.18). Selecting the ***Rule Executive*** option from this menu opens the rule executive window of the selected object. The user can then ask about the state of the object by typing ***Why*** followed by a particular variable in the window. This leads to the rule to be displayed, the application of which has caused the object to change to the current state as shown in the status window. This explanation facility helps the user to understand the relationship between the computer code and the immediate behaviour of the model and to debug or modify the model.

Another facility which aids the user to examine the operation of the model is the modelling trace option. Since the changes of the behaviour of objects are represented using rules, they can be traced during the running of the model. This is achieved by selecting the ***Trace Modelling*** option on the run model menu, and the user can trace all the behaviour rules for all instance objects of a given class, or a specific behaviour rule for all for a class, or even particular types of rules for specific instances of a class.

To trace the major behaviour rules of a particular instance object, select the ***Trace Item*** option from the pop-up menu of the status window of the desired object. Then the rules which are applied by the selected object during the modelling are displayed in the trace window.

In addition to the screen displays for a cell element, various gauges can be attached to the specific parameters of particular objects. This is done by selecting the ***Attach Monitor*** option from the pop-up menu of the desired object. After this the user is prompted to choose the type of monitor and the variable of the object to which the selected type of monitor is attached.

Global Menus of Knowledge Based Manufacturing System Modelling

Modelling Master Menu

Level 1	Level 1 Help			Class Browser
Level 2	Level 2 Help			
Level 3	Level 3 Help			
				Exit

Figure V.1	*The Modelling Master Menu*	**LUT - FMS** **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Modelling Master Menu - Level 1

Edit Model	Run Model	Output Results		Class Browser
			Master Menu	Exit

Figure V.2	*The Modelling Master Menu - Level 1*	**LUT - FMS** **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Edit Model Menu - Level 1

Config. Model	Save Model	Retrieve Model	Change Direct.	Hardcopy Input
Plann. Horizon	Fx./Unfx. Palts.	Behave. Rules		
Release Rules	LUStation Rules	Next Stn. Rules	Transp. Rules	Part Rules
			Previous Menu	Exit

Figure V.3	*The Edit Model Menu - Level 1*	**LUT - FMS** **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Run Model Menu - Level 1				
Create W.M.	Setup Display	Clock Gauge	Utilis. Gauge	Trace/Untrace ▶
Block On	Initialise W.M.	Run Model	Suspend Model.	Resume Model.
Termin. Model.				Close Windows
			Previous Menu	Exit

Figure V.4 — *The Run Model Menu - Level 1* — LUT - FMS **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Output Results Menu - Level 1				
Run Time	Cell Perform.	Part Through.	Part Ld. Tm.	Part Perform.
Mach. Perform.	Transp. Perf.	LUStn. Perf.	Stn. Op. Sches.	Pt. Op. Sches.
			Change Direct.	Hdcop. Outp. ▶
			Previous Menu	Exit

Figure V.5 — *The Output Results Menu - Level 1* — LUT - FMS **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Modelling Master Menu - Level 2				
Edit Model	Run Model	Output Results		Class Browser
			Master Menu	Exit

Figure V.6 — *The Modelling Master Menu - Level 2* — LUT - FMS **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Edit Model Menu - Level 2				
Config. Model	Save Model	Retrieve Model	Change Direct.	Hardcopy Input
Plann. Horizon	Fx./Unfx. Palts.	Temp. Stor. Flg	Behave. Rules	
Release Rules	LUStation Rules	Next Stn. Rules	Transp. Rules	Part Rules
			Previous Menu	Exit

Figure V.7 — *The Edit Model Menu - Level 2* — LUT - FMS **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Run Model Menu - Level 2				
Create W.M.	Setup Display	Clock Gauge	Utilis. Gauge	Trace/Untrace
Block On	Initialise W.M.	Run Model	Suspend Model.	Resume Model.
Termin. Model.				Close Windows
			Previous Menu	Exit

Figure V.8 — *The Run Model Menu - Level 2* — LUT - FMS **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Output Results Menu - Level 2				
Run Time	Cell Perform.	Part Through.	Part Ld. Tm.	Part Perform.
Mach. Perform.	Transp. Perf.	LUStn. Perf.	Temp. Str. Perf.	Min. Tl. Require.
PTS Tl. Require.	Tool Perform.	Stn. Op. Sches.	Pt. Op. Sches.	Hdcop. Outp.
Change Direct.			Previous Menu	Exit

Figure V.9 — *The Output Results Menu - Level 2* — LUT - FMS **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Modelling Master Menu - Level 3				
Edit Model	Run Model	Output Results		Class Browser
			Master Menu	Exit

Figure V.10 *The Modelling Master Menu - Level 3* LUT - FMS **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Edit Model Menu - Level 3				
Config. Model	Save Model	Retrieve Model	Change Direct.	Hardcopy Input
Plann. Horizon	Fx./Unfx. Palts.	Temp. Stor. Flg	Behave. Rules	
Release Rules	LUStation Rules	Next Stn. Rules	Wk. Transp. Rls.	Part Rules
Plt. Tooling Rls.	Tl. Transp. Rls.		Previous Menu	Exit

Figure V.11 *The Edit Model Menu - Level 3* LUT - FMS **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Run Model Menu - Level 3				
Create W.M.	Setup Display	Clock Gauge	Utilis. Gauge	Trace/Untrace ▶
Block On	Initialise W.M.	Run Model	Suspend Model.	Resume Model.
Termin. Model.				Close Windows
			Previous Menu	Exit

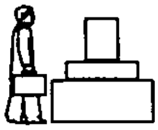
Figure V.12	*The Run Model Menu - Level 3*	**LUT - FMS** **Research Group**

Global Menus of Knowledge Based Manufacturing System Modelling

Output Results Menu - Level 3				
Run Time	Cell Perform.	Part Through.	Part Ld. Tm.	Part Perform.
Mach. Perform.	Wk. Tranp. Perf.	LUStn. Perf.	Temp. Str. Perf.	Cell Tl. Require.
PTS Perform.	STS Perform.	Tl. Tranp. Perf.	Tool Perform.	Hdcop. Outp. ▶
Stn. Op. Sches.	Pt. Op. Sches.	Change Direct.	Previous Menu	Exit

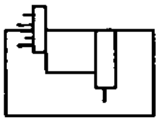
Figure V.13	*The Output Results Menu - Level 3*	**LUT - FMS** **Research Group**

DLoadUnloadStation



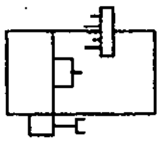
A manual load/unload station

DMachineStation



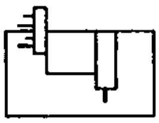
A machine station

DLathe



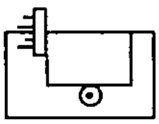
A CNC lathe with a robot as a work loading device

DHMachiningCentre



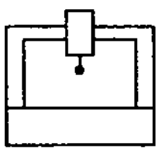
A horizontal machining centre

DVMachiningCentre



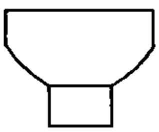
A vertical machining centre

DInspectionStation



An inspection machine

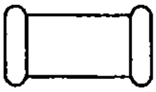
DWashingStation



A washing machine

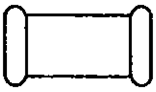
Figure V.14	*Graphic Icons of the Model Configurator (1)*	LUT-FMS Research Group

DWorkTransporter



An AGV–type work transporter

DToolTransporter



An AGV–type Tool Transporter

DSecondaryToolStore

A Chain–type secondary tool store

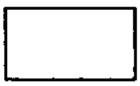
DStorage

A pallet–stand type temporary storage

LineType

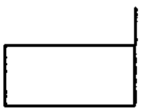
A line–type transport route

LoopType



A loop–type transport route

NetworkType



A network–type transport route

Figure V.15	*Graphic Icons of the Model Configurator (2)*	LUT–FMS Research Group

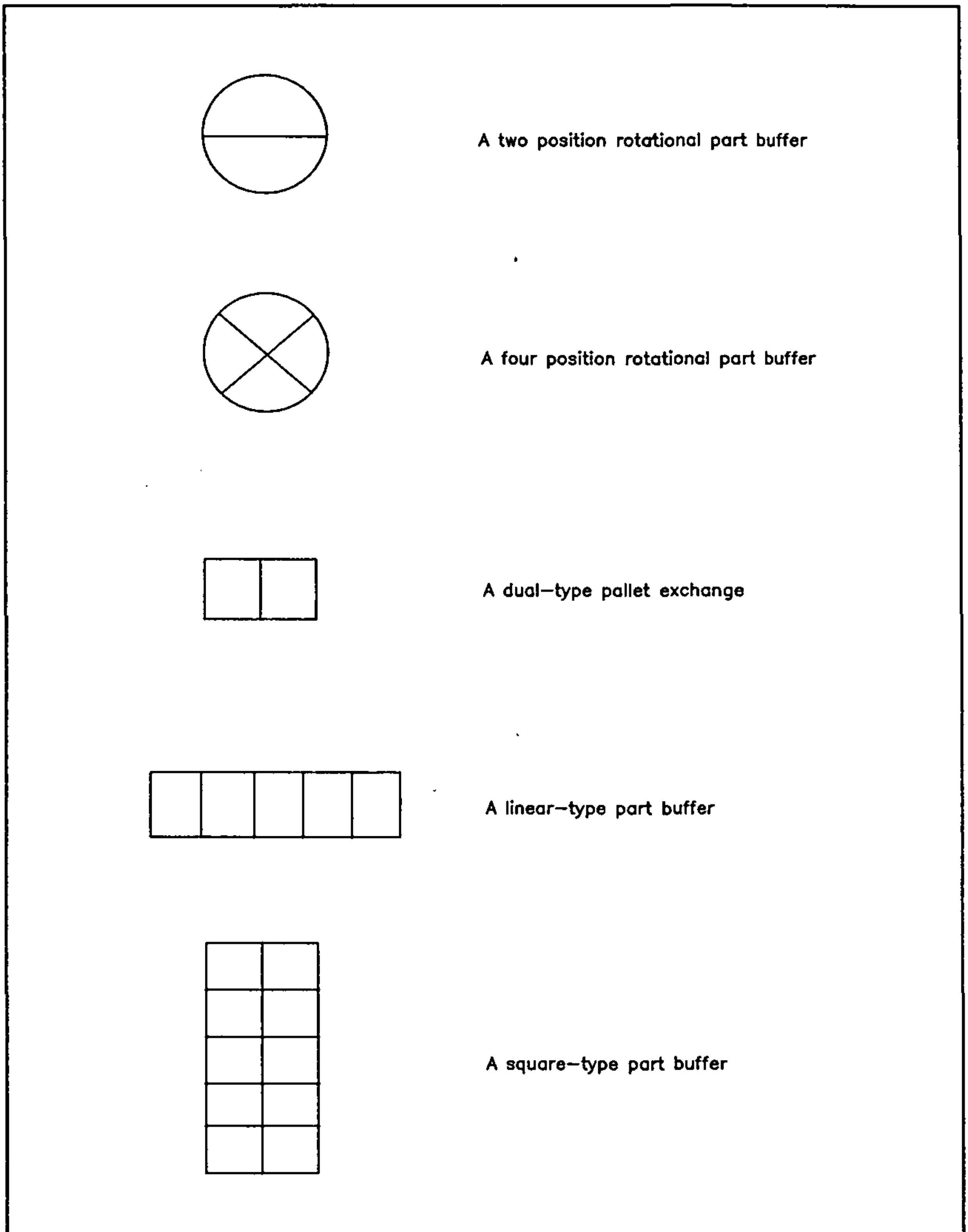


Figure V.16

Graphic Icons of the Model Configurator (3)

LUT–FMS Research Group

Appendix VI

STUDY OF THE THREE MACHINE CELL

Appendix VI.1

PART PROCESS INFORMATION AND TOOL DETAILS

Table VI.1: Process Details for Part No. 1

Part Description: F.Gear.Hsg		Part I.D.: 3177545	
Op. No.	Op. Time	Op. Description	Tool I.D.
1	5.00	rough&fin	0002
2	4.00	spot.dr	0003
3	1.00	dr1hol	0059
4	3.00	finmill	0060
5	10.50	dr42hol	0004
6	0.40	dr1hol	0055
7	0.30	re1hol	0056
8	1.10	dr2hol	0006
9	0.40	dr1hol	0012
10	4.50	dr14hol	0007
11	1.20	ta14hol	0008
12	4.00	bore1hol	0063
13	2.00	bore1hol	0062
14	0.50	dr2hol	0019
15	0.80	bore2hol	0020
16	0.45	re1hol	0021
17	0.45	re1hol	0022
18	1.00	probe	0200
Total cutting time: 40.60			

Table VI.2: Process Details for Part No. 2

Part Description: F.Gear.Hsg		Part I.D.: 3176918	
Op. No.	Op. Time	Op. Description	Tool I.D.
1	5.00	rough&fin	0002
2	4.00	spot.dr	0003
3	1.00	dr1hol	0059
4	3.00	finmill	0060
5	10.50	dr42hol	0004
6	0.40	dr1hol	0055
7	0.30	re1hol	0056
8	1.10	dr2hol	0006
9	0.40	dr1hol	0012
10	4.50	dr14hol	0007
11	1.20	ta14hol	0008
12	4.00	bore1hol	0063
13	2.00	bore1hol	0062
14	0.50	dr2hol	0019
15	0.80	bore2hol	0020
16	0.45	re1hol	0021
17	0.45	re1hol	0022
18	1.00	probe	0200
19	1.00	c'bore1hol	0057
20	3.40	bore1hol	0061
21	0.90	c'bore1	0099
22	0.85	dr1hol	0006
Total cutting time: 46.75			

Table VI.3: Process Details for Part No. 3

Part Description: F.Gear.Cov Part I.D.: 3177536

Op. No.	Op. Time	Op. Description	Tool I.D.
1	15.40	rough&fin	0001
2	5.80	millbosses	0002
3	2.70	sdr13hol	0003
4	1.50	dr2hol	0004
5	0.75	re2hol	0005
6	0.90	dr4hol	0006
7	4.27	dr14hol	0007
8	3.43	tap14hol	0008
9	0.50	dr1hol	0043
10	0.58	dr1hol	0012
11	13.15	r&fbosses	0001
12	0.75	c'bore2	0009
13	2.10	rboreHH	0030
14	2.07	rboreEE	0031
15	2.23	rough&fin	0032
16	2.17	finishHH	0033
17	2.53	finishEE	0034
18	2.42	roughturn	0035
19	2.00	finishturn	0036
20	1.70	sdr12hol	0003
21	11.83	dr24hol	0010
22	1.33	dr4hol	0007
23	1.00	ta4hol	0008
24	0.50	dr1hol	0011
25	0.37	ta1hol	0015
26	0.55	dr1hol	0013
27	0.42	ta1hol	0014
28	0.58	dr1hol	0016
29	0.48	re1hol	0017
30	0.50	ta1hol	0018
31	1.32	dr2hol	0019
32	1.93	bore2	0020
33	0.88	re1hol	0021
34	0.85	re1hol	0022
35	3.42	dr4hol	0023

Total cutting time: 93.91

Table VI.4: Process Details for Part No. 4

Part Description: F.Gear.Hsg Part I.D.: 3177537

Op. No.	Op. Time	Op. Description	Tool I.D.
1	4.20	r&fpanra	0001
2	0.92	sdr5hol	0003
3	1.42	dr5hol	0007
4	1.20	tap5hol	0008
5	3.42	mill6point	0102
6	1.95	dr6hol	0024
7	2.23	c'bore6	0025
8	1.70	re6hol	0027
9	14.53	dr6rifle	0026
10	1.28	dr2hol	0028
11	1.00	ta2hol	0029
12	1.10	dr4hol	0103

Total cutting time: 34.95

Table VI.5: Process Details for Part No. 5

Part Description: Lub.Filt.H   Part I.D.: 3176302

Op. No.	Op. Time	Op. Description	Tool I.D.
1	1.80	sdr4hol	0107
2	1.80	dr4hol	0080
3	6.50	dr2hol	0076
4	4.70	mill3spots	0101
5	3.10	dr1hol	0080
6	1.80	bore2hol	0064
7	1.20	re2hol	0084
8	2.10	dr2hol	0088
9	1.40	bore1hol	0072
10	0.75	re1hol	0081
11	2.10	dr1rifle	0087
12	1.60	dr1hol	0071
13	0.60	ta1hol	0085
14	4.00	re1hol	0079
15	0.80	rough&fin	0001
16	3.00	dr1hol	0082
17	1.20	mill1face	0083
18	4.70	dr2hol	0076
19	2.00	dr2hol	0028
20	0.60	c'bore1	0106
21	1.50	bore1hol	0105
22	1.20	ta2hol	0029
23	1.30	dr1hol	0043
24	0.90	ta1hol	0044
25	2.30	bore1hol	0065
26	2.20	sdr1hol	0067
27	3.00	bore1hol	0066
28	4.00	rough&fin	0100
29	4.70	dr4hol	0078
30	5.00	dr4hol	0077
31	2.10	ta4hol	0086
32	7.00	dr9hol	0075
33	2.00	millslot	0069
34	1.20	dr1hol	0068
35	2.00	fdr1hol	0074
36	2.30	c'bore1	0073
37	1.60	dr1hol	0071
38	0.60	ta1hol	0085
39	2.20	re1hol	0070

Total cutting time: 92.85

Table VI.6: Process Details for Part No. 6			
Part Description: Lub.Filt.H		Part I.D.: 3176398	
Op. No.	Op. Time	Op. Description	Tool I.D.
1	2.20	sdr5hol	0107
2	6.50	dr4hol	0080
3	4.70	dr2hol	0076
4	3.10	mill3spots	0101
5	1.80	dr1hol	0080
6	1.20	bore2hol	0064
7	2.10	re2hol	0084
8	14.50	dr2hol	0088
9	1.40	bore1hol	0072
10	0.75	re1hol	0081
11	2.75	dr1rifle	0087
12	1.60	dr1hol	0071
13	0.60	ta1hol	0085
14	4.00	re1hol	0079
15	0.80	rough&fin	0001
16	3.00	dr1hol	0082
17	1.20	mill1face	0083
18	4.70	dr2hol	0076
19	2.00	dr2hol	0028
20	0.60	c'bore1	0106
21	1.50	bore1hol	0105
22	1.20	ta2hol	0029
23	1.30	dr1hol	0043
24	0.90	ta1hol	0044
25	2.30	bore1hol	0065
26	2.20	sdr1hol	0067
27	3.00	bore1hol	0066
28	4.50	rough&fin	0100
29	5.70	dr5hol	0078
30	6.30	dr5hol	0077
31	2.80	ta5hol	0086
32	9.30	dr12hol	0075
33	2.00	millslot	0069
34	1.20	dr1hol	0068
35	2.00	fdr1hol	0074
36	2.30	c'bore1	0073
37	1.60	dr1hol	0071
38	0.60	ta1hol	0085
39	2.20	re1hol	0070
Total cutting time: 112.40			

Table VI.7: Process Details for Part No. 7

Part Description: Thermo.Hsg		Part I.D.: 3035844	
Op. No.	Op. Time	Op. Description	Tool I.D.
1	16.00	rough&fin	0001
2	3.00	9.5drill	0012
3	7.00	roughbore	0053
4	8.00	finbore	0054
5	13.00	29/64dr	0049
6	3.00	3/4dr	0046
7	2.00	3/4taperR	0047
8	1.00	3/4taperT	0048
Total cutting time: 53.00			

Table VI.8: Process Details for Part No. 8

Part Description: Thm.Hsg.Su		Part I.D.: 3178276	
Op. No.	Op. Time	Op. Description	Tool I.D.
1	27.00	rough&fin	0001
2	5.00	sdr44hol	0003
3	10.00	dr44hol	0043
4	10.00	ta44hol	0044
5	7.00	dr12hol	0042
6	3.00	bore4hol	0051
7	4.00	bore4hol	0050
8	1.00	chamfer2	0052
9	1.00	dr4hol	0012
10	2.00	dr4hol	0028
11	1.00	ta4hol	0029
12	6.00	dr8hol	0046
13	3.00	re8hol	0047
14	2.00	ta8hol	0048
15	6.00	dr14hol	0045
16	5.00	re14hol	0017
17	4.00	ta14hol	0018
Total cutting time: 97.00			

Table VI.9: Tool Details of the Three Machine Cell							
TOOL I.D.	TOOL DESC.	TOOL LIFE	MAX.% USE	TOOL I.D.	TOOL DESC.	TOOL LIFE	MAX.% USE
0001	FM	120	90	0052	BB	30	90
0002	FM	60	90	0053	BB	30	90
0003	CD	60	90	0054	BB	30	90
0004	DR	60	90	0055	DR	30	90
0005	RE	60	90	0056	RE	30	90
0006	DR	60	90	0057	SD	30	90
0007	DR	60	90	0058	DR	30	90
0008	TA	30	90	0059	DR	30	90
0009	EM	30	90	0060	EM	60	90
0010	DR	60	90	0061	BB	30	90
0011	DR	30	90	0062	BB	30	90
0012	DR	60	90	0063	BB	30	90
0013	FD	30	90	0064	BB	30	90
0014	TA	30	90	0065	BB	30	90
0015	TA	30	90	0066	BB	30	90
0016	FD	30	90	0067	SD	30	90
0017	RE	30	90	0068	SD	30	90
0018	TA	30	90	0069	SD	30	90
0019	DR	30	90	0070	RE	30	90
0020	BB	30	90	0071	FD	30	90
0021	RE	30	90	0072	BB	30	90
0022	RE	30	90	0073	BB	30	90
0023	DR	60	90	0074	FD	30	90
0024	DR	60	90	0075	DR	30	90
0025	SD	30	90	0076	DR	30	90
0026	GD	60	90	0077	FD	30	90
0027	RE	60	90	0078	DR	30	90
0028	FD	60	90	0079	RE	30	90
0029	TA	30	90	0080	DR	30	90
0030	BB	30	90	0081	RE	30	90
0031	BB	60	90	0082	DR	30	90
0032	BB	60	90	0083	SD	30	90
0033	BB	60	90	0084	RE	30	90
0034	BB	60	90	0085	TA	30	90
0035	BB	60	90	0086	TA	30	90
0036	BB	60	90	0087	GD	30	90
0042	DR	30	90	0088	GD	30	90
0043	DR	30	90	0099	SD	30	90
0044	TA	30	90	0100	FM	30	90
0045	FD	30	90	0101	SD	30	90
0046	FD	30	90	0102	EM	60	90
0047	RE	30	90	0103	DR	60	90
0048	TA	30	90	0105	DR	30	90
0049	DR	30	90	0106	FB	30	90
0050	BB	30	90	0107	CD	30	90
0051	BB	30	90	0200	PR	999	90
Total number of tools: 93							

Appendix VI.2

DATA INPUT OF THE THREE MACHINE CELL MODEL

Specification and Data Requirements for

Knowledge Based Modelling of the 3 Machine Cell

- Modelling Level 1

Introduction

The following lists the parameters for the study of the three machine cell at level 1.

Parts and Processes

No. of part types: 8

Part I.D.	Part No.	Part Desc.	Daily Requir.
part1	3176545	F-Gear-Hsg	4
part2	3177918	F-Gear-Hsg	4
part3	3177536	F-Gear-Cover	8
part4	3177537	F-Gear-Cover	8
part5	3176302	Lub-F-Head	5
part6	3176398	Lub-F-Head	3
part7	3035844	Thermo-Hsg	4
part8	3178276	Thermo-Hsg-Suppt	4

Part I.D.	No. of Ops	Op. No	Op. Time(mins)	Stations
part1	3	1	0	lu1 lu2
		2	54.28	mc3 mc2
		3	30	lu1 lu2
part2	3	1	0	lu1 lu2
		2	63.47	mc3 mc2
		3	30	lu1 lu2

part3	3	1	0	lu1 lu2
		2	120.51	mc2 mc1
		3	25	lu1 lu2
part4	3	1	0	lu1 lu2
		2	44.07	mc2 mc1
		3	25	lu1 lu2
part5	3	1	0	lu1 lu2
		2	122.49	mc1 mc3
		3	30	lu1 lu2
part6	3	1	0	lu1 lu2
		2	142.04	mc1 mc3
		3	30	lu1 lu2
part7	3	1	0	lu1 lu2
		2	59.08	mc1 mc3
		3	20	lu1 lu2
part8	3	1	0	lu1 lu2
		2	109.92	mc1 mc3
		3	20	lu1 lu2

Machines

No. of Machines: 3

Machine Type: Makino Horizontal Machining Centre

No. of Spindles: 1

Machine #1 I.D.: mc1

Machine #2 I.D.: mc2

Machine #3 I.D.: mc3

Machine Exchange Time: 1 min.

Buffer Exchange Time: 16 sec.(0.27 mins)

Load/Unload Stations

No. of Load/Unload Stations: 2

Load/Unload Station #1 I.D.: lu1

Load/Unload Station #2 I.D.: lu2

Station Exchange Time: 0.0

Transporters

No. of Transporters: 1

Transporter Type: AGV

Transporter I.D.: agv

Average Part Transfer Time: 0.8 mins

Transporter Pallet Capacity: 1

Pallet Exchange Time: 16 sec (0.27 mins).

Pallets/Fixtures

No. of Pallets/Fixtures: 6

Pallet No.	Pallet I.D.	Part Types	Parts Capacity
1	pallet1	part1	1
		part2	1
2	pallet2	part3	1
3	pallet3	part4	1
4	pallet4	part5	1
		part6	1
5	pallet5	part7	1
6	pallet6	part8	1

Specification and Data Requirements for Knowledge Based Modelling of the 3 Machine Cell

- Modelling Level 2

Introduction

The following lists the parameters for the study of the three machine cell at level 2.

Parts and Processes

No. of part types: 8

Part I.D.	Part No.	Part Desc.	Daily Requir.
part1	3176545	F-Gear-Hsg	4
part2	3177918	F-Gear-Hsg	4
part3	3177536	F-Gear-Cover	8
part4	3177537	F-Gear-Cover	8
part5	3176302	Lub-F-Head	5
part6	3176398	Lub-F-Head	3
part7	3035844	Thermo-Hsg	4
part8	3178276	Thermo-Hsg-Suppt	4

Part I.D.	No. Ops	Op. No	Stations	No. Sub-Ops	Tl Activs.
part1	3	1	lu1 lu2	0	0
		2	mc3 mc2	18	18
		3	lu1 lu2	0	0
part2	3	1	lu1 lu2	0	0
		2	mc3 mc2	22	22

		3	lu1 lu2	0	0
part3	3	1	lu1 lu2	0	0
		2	mc2 mc1	35	35
		3	lu1 lu2	0	0
part4	3	1	lu1 lu2	0	0
		2	mc2 mc1	12	12
		3	lu1 lu2	0	0
part5	3	1	lu1 lu2	0	0
		2	mc1 mc3	39	39
		3	lu1 lu2	0	0
part6	3	1	lu1 lu2	0	0
		2	mc1 mc3	39	39
		3	lu1 lu2	0	0
part7	3	1	lu1 lu2	0	0
		2	mc1 mc3	8	8
		3	lu1 lu2	0	0
part8	3	1	lu1 lu2	0	0
		2	mc1 mc3	17	17
		3	lu1 lu2	0	0

Machines

No. of Machines: 3

Machine Type: Makino Horizontal Machining Centre

No. of Spindles: 1

Machine #1 I.D.: mc1

Machine #2 I.D.: mc2

Machine #3 I.D.: mc3

Tool Exchange Time (magazine to spindle): 0.26 mins.

Tool Index Time: 0.5 mins.

Buffer Type: Pallet exchange store

No. of Input Buffer Spaces: 1

No. of Output Buffer Spaces: 1

Machine Exchange Time: 1 min.

Buffer Exchange Time: 16 sec.(0.27 mins)

Load/Unload Stations

No. of Load/Unload Stations: 2

No. of Buffer Spaces: 0

Load/Unload Station #1 I.D.: lu1

Load/Unload Station #2 I.D.: lu2

Station Exchange Time : 0

Transporters

No. of Transporters: 1

Transporter Type: AGV

Transporter I.D.: agv

Average Part Transfer Time: 0.8 mins

Transporter Pallet Capacity: 1

Pallet Exchange Time: 16 sec (0.27 mins).

Pallets/Fixtures

No. of Pallets/Fixtures: 6

Pallet No.	Pallet I.D.	Part Types	Parts Capacity	Store
1	pallet1	part1	1	ps14
		part2	1	

2	pallet2	part3	1	ps8
3	pallet3	part4	1	ps7
4	pallet4	part5	1	ps11
		part6	1	
5	pallet5	part7	1	ps4
6	pallet6	part8	1	ps6

Temporary Storages

No. of Pallet Stands: 22

Pallet Stand Identities: ps1 - ps22

Pallet Stand Capacity: 1

Pallet Exchange Time: 16 sec.(0.27 mins).

Tools

No. of Tool Types: 92

Max. Percent Tool Life Utilisation for Tools: 90%

Specification and Data Requirements for Knowledge Based Modelling of the 3 Machine Cell

- Modelling Level 3

Introduction

The following lists the parameters for the study of the three machine cell at level 3.

Parts and Processes

No. of part types: 8

Part I.D.	Part No.	Part Desc.	Daily Requir.
part1	3176545	F-Gear-Hsg	4
part2	3177918	F-Gear-Hsg	4
part3	3177536	F-Gear-Cover	8
part4	3177537	F-Gear-Cover	8
part5	3176302	Lub-F-Head	5
part6	3176398	Lub-F-Head	3
part7	3035844	Thermo-Hsg	4
part8	3178276	Thermo-Hsg-Suppt	4

Part I.D.	No. Ops	Op. No	Stations	No. Sub-Ops	Tl Activs.
part1	3	1	lu1 lu2	0	0
		2	mc3 mc2	18	18
		3	lu1 lu2	0	0
part2	3	1	lu1 lu2	0	0
		2	mc3 mc2	22	22

		3	lu1 lu2	0	0
part3	3	1	lu1 lu2	0	0
		2	mc2 mc1	35	35
		3	lu1 lu2	0	0
part4	3	1	lu1 lu2	0	0
		2	mc2 mc1	12	12
		3	lu1 lu2	0	0
part5	3	1	lu1 lu2	0	0
		2	mc1 mc3	39	39
		3	lu1 lu2	0	0
part6	3	1	lu1 lu2	0	0
		2	mc1 mc3	39	39
		3	lu1 lu2	0	0
part7	3	1	lu1 lu2	0	0
		2	mc1 mc3	8	8
		3	lu1 lu2	0	0
part8	3	1	lu1 lu2	0	0
		2	mc1 mc3	17	17
		3	lu1 lu2	0	0

Machines

No. of Machines: 3

Machine Type: Makino Horizontal Machining Centre

No. of Spindles: 1

Machine #1 I.D.: mc1

Machine #2 I.D.: mc2

Machine #3 I.D.: mc3

Magazine Capacity: 120

Tool Exchange Time (magazine to spindle): 0.27 mins.

Tool Index Time: 0.5 mins.

Buffer Type: Pallet exchange store

No. of Input Buffer Spaces: 1

No. of Output Buffer Spaces: 1

Machine Exchange Time: 1 min.

Buffer Exchange Time: 16 sec.(0.27 mins)

Load/Unload Stations

No. of Load/Unload Stations: 2

No. of Buffer Spaces: 0

Load/Unload Station #1 I.D.: lu1

Load/Unload Station #2 I.D.: lu2

Station Exchange Time: 0

Transporters

No. of Transporters: 1

Transporter Type: AGV

Transporter I.D.: agv

Average Part Transfer Time: 0.8 mins

Transporter Pallet Capacity: 1

Pallet Exchange Time: 16 sec (0.27 mins).

Pallets/Fixtures

No. of Pallets/Fixtures: 6

Pallet No.	Pallet I.D.	Part Types	Parts Capacity	Store
1	pallet1	part1	1	ps14

		part2	1	
2	pallet2	part3	1	ps8
3	pallet3	part4	1	ps7
4	pallet4	part5	1	ps11
		part6	1	
5	pallet5	part7	4	ps4
6	pallet6	part8	2	ps6

Temporary Storages

No. of Pallet Stands: 22

Pallet Stand Identities: ps1 - ps22

Pallet Stand Capacity: 1

Pallet Exchange Time: 16 sec.(0.27 mins).

Tools

No. of Tools: 92

Max. Percent Tool Life Utilisation for Tools: 90%

Tool Transporters

No. of Tool Transporters: 3

Transporter #1 I.D.: man1

Transporter #2 I.D.: man2

Transporter #3 I.D.: man3

Average Transfer Time: 0.8 mins.

Transporter Tool Capacity: 120

Tool Exchange Time: 0.26 mins/tool

Secondary Tool Store

STS I.D.: stoolstore

Tool Exchange Time: 0.26 mins/tool

Tool Capacity: infinite

Appendix VI.3

RESULTS OF THE KNOWLEDGE BASED MODELLING

********* Outputs of Knowledge Based Modelling - Level 1 ********

Model: 3MachineCell

****

Computer run time(mins): 12

****

Overall Cell Performance
==========

Make Span(mins) : 1447.35
Total Throughput(parts/shift) : 13
Total Lateness(mins) : 7.35
Average Flow Time(mins) : 154.33
Average Utilisation(%) : 63.59

****

Primary Outputs
===========

Part Throughputs

Part	Throughput(parts/shift)
part1	3.03
part2	1.70
part3	2.72
part4	4.05
part5	2.63
part6	.99
part7	3.18
part8	2.67

Part Lead Times

Part	Activity	Ave.(mins)	Max.(mins)	Min.(mins)	Mean(mins)
part1	Lead Time	158.63	206.76	98.45	152.61
	Machining	54.28	54.28	54.28	54.28

	Transport	1.60	1.60	1.60	1.60
	Waiting	69.67	117.80	9.49	63.65
	Fixturing	30	30	30	30
part2	Lead Time	123.71	186.07	98.95	142.51
	Machining	63.47	63.47	63.47	63.47
	Transport	1.60	1.60	1.60	1.60
	Waiting	25.55	87.92	.80	44.36
	Fixturing	30	30	30	30
part3	Lead Time	165.46	197.86	150.99	174.42
	Machining	120.51	120.51	120.51	120.51
	Transport	1.60	1.60	1.60	1.60
	Waiting	15.27	47.67	.80	24.23
	Fixturing	25	25	25	25
part4	Lead Time	118.59	181.79	70.35	126.07
	Machining	44.07	44.07	44.07	44.07
	Transport	1.60	1.60	1.60	1.60
	Waiting	49.84	113.04	1.60	57.32
	Fixturing	20	20	20	20
part5	Lead Time	182.37	227.86	157.97	192.92
	Machining	122.49	122.49	122.49	122.49
	Transport	1.60	1.60	1.60	1.60
	Waiting	25.20	70.69	.80	35.75
	Fixturing	30	30	30	30
part6	Lead Time	178.50	178.87	178.32	178.60
	Machining	142.04	142.04	142.04	142.04
	Transport	1.60	1.60	1.60	1.60
	Waiting	1.78	2.15	1.60	1.88
	Fixturing	30	30	30	30
part7	Lead Time	151.02	174.02	87.50	130.76
	Machining	59.08	59.08	59.08	59.08
	Transport	1.60	1.60	1.60	1.60
	Waiting	67.25	90.26	3.74	47.00
	Fixturing	20	20	20	20
part8	Lead Time	180.05	219.07	144.68	181.88
	Machining	109.92	109.92	109.92	109.92
	Transport	1.60	1.60	1.60	1.60
	Waiting	40.45	79.47	5.08	42.28
	Fixturing	25	25	25	25

****

Secondary Outputs
===========

Part Performance

(Unit: mins)

Part	InStorage	AtBuffer	AtStation	LoadUnload	Fixturing
part10001	0	117.80	54.28	3.08	30
part10002	0	9.49	54.28	3.08	30
part10003	0	58.55	54.28	3.08	30
part10004	0	92.83	54.28	3.08	30
part20001	0	87.92	63.47	3.08	30
part20002	0	1.60	63.47	3.08	30
part20003	0	11.90	63.47	3.08	30
part20004	0	.80	63.47	3.08	30
part30001	0	47.67	120.51	3.08	25
part30002	0	44.67	120.51	3.08	25
part30003	0	1.60	120.51	3.08	25
part30004	0	1.60	120.51	3.08	25
part30005	0	23.42	120.51	3.08	25
part30006	0	.80	120.51	3.08	25
part30007	0	.80	120.51	3.08	25
part30008	0	1.60	120.51	3.08	25
part40001	0	1.60	44.07	3.08	20
part40002	0	99.03	44.07	3.08	20
part40003	0	62.30	44.07	3.08	20
part40004	0	25.86	44.07	3.08	20
part40005	0	113.04	44.07	3.08	20
part40006	0	47.72	44.07	3.08	20
part40007	0	1.60	44.07	3.08	20
part40008	0	47.56	44.07	3.08	20
part50001	0	70.69	122.49	3.08	30
part50002	0	7.30	122.49	3.08	30
part50003	0	23.60	122.49	3.08	30
part50004	0	23.60	122.49	3.08	30
part50005	0	.80	122.49	3.08	30
part60001	0	1.60	142.04	3.08	30
part60002	0	2.15	142.04	3.08	30
part60003	0	1.60	142.04	3.08	30
part70001	0	3.74	59.08	3.08	20
part70002	0	85.78	59.08	3.08	20
part70003	0	90.26	59.08	3.08	20
part70004	0	89.24	59.08	3.08	20
part80001	0	5.08	109.92	3.08	25
part80002	0	44.63	109.92	3.08	25
part80003	0	79.47	109.92	3.08	25
part80004	0	32.60	109.92	3.08	25

Machine Station Performance

Machine: mc1

	Time(mins)	%
Machining	1125.21	77.74
LoadUnload	26	1.80
SpareCapa.	211.80	14.63
Idle	296.14	20.46

Max. Queue: 3

Machine: mc2

	Time(mins)	%
Machining	1124.63	77.70
LoadUnload	28	1.93
SpareCapa.	60.81	4.20
Idle	294.72	20.36

Max. Queue: 2

Machine: mc3

	Time(mins)	%
Machining	1252.37	86.53
LoadUnload	26	1.80
SpareCapa.	32.14	2.22
Idle	168.98	11.68

Max. Queue: 3

Transporter Performance

Transporter: agv

	Time(mins)	%
LoadRun	64.00	4.42
EmptyRun	56.00	3.87

LoadUnload	43.20	2.98
Idle	1284.15	88.72

Load/Unload Station Performance

Station: lu1

	Time(mins)	%
Fixturing	525	36.27
LoadUnload	0	0.00
SpareCapa.	0.00	0.00
Idle	922.35	63.73

Max. Queue: 2

Station: lu2

	Time(mins)	%
Fixturing	495	34.20
LoadUnload	0	0.00
SpareCapa.	33.67	2.33
Idle	952.35	65.80

Max. Queue: 3

****

Station Operation Schedules

Station	Pallet	Operation	Start Time(mins)
lu1			
	pallet3	op4-1	0
	pallet6	op8-1	0
	pallet1	op1-1	0
	pallet3	op4-3	50.35
	pallet3	op4-1	70.35
	pallet6	op8-3	119.68
	pallet6	op8-1	144.68
	pallet1	op1-3	176.76
	pallet1	op1-1	206.76

pallet3	op4-3	218.13
pallet3	op4-1	238.13
pallet1	op1-3	275.21
pallet1	op1-1	305.21
pallet4	op5-3	362.33
pallet4	op5-1	392.33
pallet5	op7-3	411.06
pallet5	op7-1	431.06
pallet3	op4-3	443.79
pallet3	op4-1	463.79
pallet6	op8-3	522.98
pallet6	op8-1	547.98
pallet2	op3-3	579.51
pallet1	op1-3	604.51
pallet2	op3-1	634.51
pallet1	op2-1	634.51
pallet4	op5-3	723.87
pallet4	op5-1	753.87
pallet2	op3-3	761.30
pallet2	op3-1	786.30
pallet3	op4-3	812.40
pallet3	op4-1	832.40
pallet1	op2-3	890.33
pallet1	op2-1	920.33
pallet2	op3-3	934.91
pallet2	op3-1	959.91
pallet4	op6-3	1060.16
pallet4	op6-1	1090.16
pallet1	op2-3	1099.33
pallet4	op6-3	1239.03
pallet4	op6-1	1269.03
pallet4	op6-3	1417.35

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lu2

pallet5	op7-1	0
pallet2	op3-1	0
pallet4	op5-1	0
pallet5	op7-3	67.50
pallet5	op7-1	87.50
pallet2	op3-3	172.86
pallet4	op5-3	197.86
pallet2	op3-1	227.86
pallet4	op5-1	227.86
pallet5	op7-3	237.04
pallet5	op7-1	257.04
pallet6	op8-3	303.91
pallet6	op8-1	328.91
pallet3	op4-3	349.18
pallet3	op4-1	369.18
pallet2	op3-3	397.72
pallet1	op1-3	422.72
pallet2	op3-1	452.72
pallet1	op1-1	452.72
pallet4	op5-3	543.10

pallet4	op5-1	573.10
pallet5	op7-3	584.06
pallet3	op4-3	625.58
pallet3	op4-1	645.58
pallet6	op8-3	695.18
pallet3	op4-3	742.05
pallet3	op4-1	762.05
pallet1	op2-3	790.58
pallet1	op2-1	820.58
pallet4	op5-3	881.84
pallet4	op6-1	911.84
pallet3	op4-3	928.71
pallet1	op2-3	1000.38
pallet1	op2-1	1030.38
pallet2	op3-3	1085.90
pallet2	op3-1	1110.90
pallet2	op3-3	1236.89
pallet2	op3-1	1261.89
pallet2	op3-3	1388.68

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mc1

pallet5	op7-2	4.28
pallet4	op5-2	65.36
pallet6	op8-2	189.85
pallet3	op4-2	301.77
pallet5	op7-2	347.84
pallet6	op8-2	408.92
pallet5	op7-2	520.84
pallet6	op8-2	581.92
pallet3	op4-2	693.84
pallet4	op5-2	756.01
pallet3	op4-2	880.50
pallet2	op3-2	961.25
pallet2	op3-2	1113.04

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mc2

pallet3	op4-2	2.14
pallet2	op3-2	48.21
pallet3	op4-2	170.72
pallet1	op1-2	216.79
pallet2	op3-2	273.07
pallet3	op4-2	395.58
pallet2	op3-2	454.86
pallet3	op4-2	577.37
pallet2	op3-2	636.65
pallet3	op4-2	764.19
pallet2	op3-2	810.26
pallet1	op2-2	932.77
pallet1	op2-2	1031.72
pallet2	op3-2	1264.03

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mc3

pallet6	op8-2	6.42
pallet1	op1-2	118.34
pallet5	op7-2	174.62
pallet4	op5-2	235.70
pallet1	op1-2	360.19
pallet4	op5-2	416.47
pallet1	op1-2	540.96
pallet4	op5-2	597.24
pallet1	op2-2	721.73
pallet1	op2-2	822.72
pallet4	op6-2	913.98
pallet4	op6-2	1092.30
pallet4	op6-2	1271.17

Part Operation Schedules

Part	Operation	Start Time	Station
part10001			
	op1-1	0	lu1
	op1-2	118.34	mc3
	op1-3	176.76	lu1
part10002			
	op1-1	206.76	lu1
	op1-2	216.79	mc2
	op1-3	275.21	lu1
part10003			
	op1-1	305.21	lu1
	op1-2	360.19	mc3
	op1-3	422.72	lu2
part10004			
	op1-1	452.72	lu2
	op1-2	540.96	mc3
	op1-3	604.51	lu1

part20001			
	op2-1	634.51	lu1
	op2-2	721.73	mc3
	op2-3	790.58	lu2
part20002			
	op2-1	820.58	lu2
	op2-2	822.72	mc3
	op2-3	890.33	lu1
part20003			
	op2-1	920.33	lu1
	op2-2	932.77	mc2
	op2-3	1000.38	lu2

part20004			
	op2-1	1030.38	lu2
	op2-2	1031.72	mc2
	op2-3	1099.33	lu1

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part30001			
	op3-1	0	lu2
	op3-2	48.21	mc2
	op3-3	172.86	lu2
part30002			
	op3-1	227.86	lu2
	op3-2	273.07	mc2
	op3-3	397.72	lu2
part30003			
	op3-1	452.72	lu2
	op3-2	454.86	mc2
	op3-3	579.51	lu1
part30004			
	op3-1	634.51	lu1
	op3-2	636.65	mc2
	op3-3	761.30	lu1
part30005			
	op3-1	786.30	lu1
	op3-2	810.26	mc2
	op3-3	934.91	lu1
part30006			
	op3-1	959.91	lu1
	op3-2	961.25	mc1
	op3-3	1085.90	lu2
part30007			
	op3-1	1110.90	lu2
	op3-2	1113.04	mc1
	op3-3	1236.89	lu2
part30008			
	op3-1	1261.89	lu2
	op3-2	1264.03	mc2
	op3-3	1388.68	lu2

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part40001			
	op4-1	0	lu1
	op4-2	2.14	mc2
	op4-3	50.35	lu1
part40002			
	op4-1	70.35	lu1
	op4-2	170.72	mc2
	op4-3	218.13	lu1
part40003			
	op4-1	238.13	lu1
	op4-2	301.77	mc1

	op4-3	349.18	lu2
part40004			
	op4-1	369.18	lu2
	op4-2	395.58	mc2
	op4-3	443.79	lu1
part40005			
	op4-1	463.79	lu1
	op4-2	577.37	mc2
	op4-3	625.58	lu2
part40006			
	op4-1	645.58	lu2
	op4-2	693.84	mc1
	op4-3	742.05	lu2
part40007			
	op4-1	762.05	lu2
	op4-2	764.19	mc2
	op4-3	812.40	lu1
part40008			
	op4-1	832.40	lu1
	op4-2	880.50	mc1
	op4-3	928.71	lu2

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part50001			
	op5-1	0	lu2
	op5-2	65.36	mc1
	op5-3	197.86	lu2
part50002			
	op5-1	227.86	lu2
	op5-2	235.70	mc3
	op5-3	362.33	lu1
part50003			
	op5-1	392.33	lu1
	op5-2	416.47	mc3
	op5-3	543.10	lu2
part50004			
	op5-1	573.10	lu2
	op5-2	597.24	mc3
	op5-3	723.87	lu1
part50005			
	op5-1	753.87	lu1
	op5-2	756.01	mc1
	op5-3	881.84	lu2

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part60001			
	op6-1	911.84	lu2
	op6-2	913.98	mc3
	op6-3	1060.16	lu1
part60002			
	op6-1	1090.16	lu1

	op6-2	1092.30	mc3
	op6-3	1239.03	lu1
part60003			
	op6-1	1269.03	lu1
	op6-2	1271.17	mc3
	op6-3	1417.35	lu1

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part70001			
	op7-1	0	lu2
	op7-2	4.28	mc1
	op7-3	67.50	lu2
part70002			
	op7-1	87.50	lu2
	op7-2	174.62	mc3
	op7-3	237.04	lu2
part70003			
	op7-1	257.04	lu2
	op7-2	347.84	mc1
	op7-3	411.06	lu1
part70004			
	op7-1	431.06	lu1
	op7-2	520.84	mc1
	op7-3	584.06	lu2

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part80001			
	op8-1	0	lu1
	op8-2	6.42	mc3
	op8-3	119.68	lu1
part80002			
	op8-1	144.68	lu1
	op8-2	189.85	mc1
	op8-3	303.91	lu2
part80003			
	op8-1	328.91	lu2
	op8-2	408.92	mc1
	op8-3	522.98	lu1
part80004			
	op8-1	547.98	lu1
	op8-2	581.92	mc1
	op8-3	695.18	lu2

********* Outputs of Knowledge Based Modelling - Level 2 ********

Model: 3MachineCell

****
Computer run time(mins): 43

****

Overall Cell Performance
==========

Make Span(mins) : 1522.09
Total Throughput(parts/shift) : 12
Total Lateness(mins) : 82.09
Average Flow Time(mins) : 161.21
Average Utilisation(%) : 61.31

****

Primary Outputs
===========

Part Throughputs

Part	Throughput(parts/shift)
part1	2.91
part2	1.53
part3	2.63
part4	4.32
part5	2.43
part6	.95
part7	3.23
part8	2.58

Part Lead Times

Part	Activity	Ave.(mins)	Max.(mins)	Min.(mins)	Mean(mins)
part1	Lead Time	163.79	201.41	117.36	159.39
	Machining	54.28	54.28	54.28	54.28

	Transport	1.60	1.60	1.60	1.60
	Waiting	72.43	107.64	26.80	67.22
	Fixturing	30	30	30	30
part2	Lead Time	147.99	202.92	98.95	150.93
	Machining	63.47	63.47	63.47	63.47
	Transport	1.60	1.60	1.60	1.60
	Waiting	48.25	103.17	0.00	51.58
	Fixturing	30	30	30	30
part3	Lead Time	182.36	280.08	152.43	216.25
	Machining	120.51	120.51	120.51	120.51
	Transport	1.60	1.60	1.60	1.60
	Waiting	30.39	128.29	0.00	64.14
	Fixturing	25	25	25	25
part4	Lead Time	111.16	168.58	69.55	119.07
	Machining	44.07	44.07	44.07	44.07
	Transport	1.70	2.40	1.60	2.00
	Waiting	40.74	98.23	0.00	49.12
	Fixturing	20	20	20	20
part5	Lead Time	196.09	229.96	158.77	194.36
	Machining	122.49	122.49	122.49	122.49
	Transport	1.92	2.40	1.60	2.00
	Waiting	35.82	69.05	0.00	34.52
	Fixturing	30	30	30	30
part6	Lead Time	178.05	178.32	177.52	177.92
	Machining	142.04	142.04	142.04	142.04
	Transport	1.60	1.60	1.60	1.60
	Waiting	0.00	0.00	0.00	0.00
	Fixturing	30	30	30	30
part7	Lead Time	148.56	185.57	87.50	136.54
	Machining	59.08	59.08	59.08	59.08
	Transport	1.60	1.60	1.60	1.60
	Waiting	62.87	101.01	0.00	50.50
	Fixturing	20	20	20	20
part8	Lead Time	186.06	263.44	144.41	203.92
	Machining	109.92	109.92	109.92	109.92
	Transport	1.80	2.40	1.60	2.00
	Waiting	44.12	120.90	0.00	60.45
	Fixturing	25	25	25	25

****

Secondary Outputs
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Part Performance

(Unit: mins)

Part	InStorage	AtBuffer	AtStation	LoadUnload	Fixturing
part10001	0	107.64	57.49	3.08	30
part10002	0	77.64	54.28	3.08	30
part10003	0	77.64	54.28	3.08	30
part10004	0	26.80	54.28	3.08	30
part20001	0	103.17	63.47	3.08	30
part20002	0	0.00	65.02	3.08	30
part20003	0	0.00	63.47	3.08	30
part20004	0	89.83	63.47	3.08	30
part30001	0	39.65	123.72	3.08	25
part30002	0	16.79	120.51	3.08	25
part30003	0	17.21	120.51	3.08	25
part30004	0	17.59	120.51	3.08	25
part30005	0	13.62	120.51	3.08	25
part30006	0	0.00	121.15	3.08	25
part30007	0	9.95	120.51	3.08	25
part30008	0	128.29	120.51	3.08	25
part40001	0	0.00	44.07	3.08	20
part40002	0	98.23	44.07	3.08	20
part40003	0	98.23	44.07	3.08	20
part40004	0	29.10	44.07	3.08	20
part40005	0	0.00	44.07	3.08	20
part40006	0	98.23	44.07	3.08	20
part40007	0	0.00	44.07	3.08	20
part40008	2.14	0.00	44.07	3.62	20
part50001	8.01	52.52	125.70	3.62	30
part50002	0	18.33	122.49	3.08	30
part50003	27.26	41.79	122.49	3.62	30
part50004	0	0.00	122.49	3.08	30
part50005	0	31.19	122.49	3.08	30
part60001	0	0.00	142.04	3.08	30
part60002	0	0.00	142.04	3.08	30
part60003	0	0.00	142.04	3.08	30
part70001	0	0.00	61.22	3.08	20
part70002	0	100.21	59.08	3.08	20
part70003	0	101.01	59.08	3.08	20
part70004	0	50.24	59.08	3.08	20
part80001	0	0.00	113.13	3.08	25
part80002	0	27.80	109.92	3.08	25
part80003	0	27.80	109.92	3.08	25
part80004	2.14	118.76	109.92	3.62	25

Machine Station Performance

Machine: mc1

	Time(mins)	%
Cutting	963.63	63.31
ToolChange	238.64	15.68
LoadUnload	24	1.58
Stationary	5.99	0.39
SpareCapa.	87.15	5.73
Idle	289.83	19.04

Machine: mc2

	Time(mins)	%
Cutting	854.45	56.14
ToolChange	247.00	16.23
LoadUnload	30	1.97
Stationary	4.76	0.31
SpareCapa.	301.76	19.83
Idle	385.88	25.35

Machine: mc3

	Time(mins)	%
Cutting	963.65	63.31
ToolChange	234.84	15.43
LoadUnload	26	1.71
Stationary	5.42	0.36
SpareCapa.	32.14	2.11
Idle	292.18	19.19

Transporter Performance

Transporter: agv1

	Time(mins)	%
LoadRun	67.20	4.41
EmptyRun	57.60	3.78

LoadUnload	45.36	2.98
Idle	1351.93	88.82

Load/Unload Station Performance

Station: lu1

	Time(mins)	%
Fixturing	525	34.49
LoadUnload	10.53	.69
StationaryTime	19.17	1.26
SpareCapa.	0.00	0.00
Idle	967.39	63.56

Station: lu2

	Time(mins)	%
Fixturing	495	32.52
LoadUnload	11.07	.73
StationaryTime	22.80	1.50
SpareCapa.	60.01	3.94
Idle	993.22	65.25

Temporary Storage Performance

Stand: ps1

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps2

	Time(mins)	%
Stationary	0	0.00

LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps3

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps4

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps5

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps6

	Time(mins)	%
Stationary	2.14	.14
LoadUnload	.54	.04
SpareCapa.	1034.86	67.99
Idle		
	1519.41	99.82

Stand: ps7

	Time(mins)	%
Stationary	2.14	.14
LoadUnload	.54	.04
SpareCapa.	653.89	42.96
Idle		
	1519.41	99.82

Stand: ps8

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps9

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps10

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps11

	Time(mins)	%
Stationary	35.71	2.35
LoadUnload	1.08	.08
SpareCapa.	1082.38	71.11
Idle		
	1485.30	97.57

Stand: ps12

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps13

	Time(mins)	%
Stationary	0	0.00

LoadUnload	0	0.00
SpareCapa. Idle	1522.09	100.00
	1522.09	100.00

Stand: ps14

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa. Idle	1522.09	100.00
	1522.09	100.00

Stand: ps15

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa. Idle	1522.09	100.00
	1522.09	100.00

Stand: ps16

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa. Idle	1522.09	100.00
	1522.09	100.00

Stand: ps17

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa. Idle	1522.09	100.00
	1522.09	100.00

Stand: ps18

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa. Idle	1522.09	100.00
	1522.09	100.00

Stand: ps19

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps20

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps21

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Stand: ps22

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1522.09	100.00
Idle		
	1522.09	100.00

Minimum Cell Tool Requirement

Tool Type	Tool Time(mins)	No. of Tools
t0001	440.40	4
t0002	86.40	2
t0003	94.56	2
t0004	96.00	2
t0005	6.00	1
t0006	19.40	1

t0007	92.16	2
t0008	54.64	2
t0009	6.00	1
t0010	94.64	2
t0011	4.00	1
t0012	23.84	1
t0013	4.40	1
t0014	3.36	1
t0015	2.96	1
t0016	4.64	1
t0017	23.84	1
t0018	20.00	1
t0019	14.56	1
t0020	21.84	1
t0021	10.64	1
t0022	10.40	1
t0023	27.36	1
t0024	15.60	1
t0025	17.84	1
t0026	116.24	2
t0027	13.60	1
t0028	34.24	1
t0029	21.60	1
t0030	16.80	1
t0031	16.56	1
t0032	25.84	1
t0033	17.36	1
t0034	20.24	1
t0035	19.36	1
t0036	16.00	1
t0042	28.00	1
t0043	54.40	2
t0044	47.20	2
t0045	24.00	1
t0046	36.00	2
t0047	20.00	1
t0048	12.00	1
t0049	52.00	2
t0050	16.00	1
t0051	12.00	1
t0052	4.00	1
t0053	28.00	1
t0054	32.00	2
t0055	3.20	1
t0056	2.40	1
t0057	4.00	1
t0059	8.00	1
t0060	24	1
t0061	13.60	1
t0062	16.00	1
t0063	32.00	2
t0064	12.60	1
t0065	18.40	1
t0066	24.00	1
t0067	17.60	1

t0068	9.60	1
t0069	16.00	1
t0070	17.60	1
t0071	25.60	1
t0072	11.20	1
t0073	18.40	1
t0074	16.00	1
t0075	62.90	3
t0076	84.20	3
t0077	43.90	2
t0078	40.60	2
t0079	32.00	2
t0080	49.40	2
t0081	6.00	1
t0082	24.00	1
t0083	9.60	1
t0084	12.30	1
t0085	9.60	1
t0086	18.90	1
t0087	18.75	1
t0088	54.00	2
t0099	3.60	1
t0100	33.50	2
t0101	32.80	2
t0102	27.36	1
t0103	8.80	1
t0105	12.00	1
t0106	4.80	1
t0107	15.60	1
t0200	8.00	1
Total: 91		118

PTS Tool Requirement

Machine	Tool Type	No. of Tools
mc1	t0001	2
	t0002	1
	t0003	1
	t0004	1
	t0005	1
	t0006	1
	t0007	1
	t0008	1
	t0009	1
	t0010	1
	t0011	1
	t0012	1
	t0013	1
	t0014	1
	t0015	1
	t0016	1

t0017	1
t0018	1
t0019	1
t0020	1
t0021	1
t0022	1
t0023	1
t0024	1
t0025	1
t0026	1
t0027	1
t0028	1
t0029	1
t0030	1
t0031	1
t0032	1
t0033	1
t0034	1
t0035	1
t0036	1
t0042	1
t0043	1
t0044	1
t0045	1
t0046	1
t0047	1
t0048	1
t0049	2
t0050	1
t0051	1
t0052	1
t0053	1
t0054	1
t0064	1
t0065	1
t0066	1
t0067	1
t0068	1
t0069	1
t0070	1
t0071	1
t0072	1
t0073	1
t0074	1
t0075	2
t0076	2
t0077	1
t0078	1
t0079	1
t0080	1
t0081	1
t0082	1
t0083	1
t0084	1
t0085	1

	t0086	1
	t0087	1
	t0088	1
	t0100	1
	t0101	1
	t0102	1
	t0103	1
	t0105	1
	t0106	1
	t0107	1
Total:	81	85
mc2	t0001	2
	t0002	1
	t0003	1
	t0004	1
	t0005	1
	t0006	1
	t0007	1
	t0008	2
	t0009	1
	t0010	2
	t0011	1
	t0012	1
	t0013	1
	t0014	1
	t0015	1
	t0016	1
	t0017	1
	t0018	1
	t0019	1
	t0020	1
	t0021	1
	t0022	1
	t0023	1
	t0024	1
	t0025	1
	t0026	3
	t0027	1
	t0028	1
	t0029	1
	t0030	1
	t0031	1
	t0032	1
	t0033	1
	t0034	1
	t0035	1
	t0036	1
	t0043	1
	t0055	1
	t0056	1
	t0057	1
	t0059	1
	t0060	1

	t0061	1
	t0062	1
	t0063	1
	t0099	1
	t0102	1
	t0103	1
	t0200	1
Total:	49	54
mc3	t0001	1
	t0002	1
	t0003	1
	t0004	1
	t0006	1
	t0007	1
	t0008	1
	t0012	1
	t0017	1
	t0018	1
	t0019	1
	t0020	1
	t0021	1
	t0022	1
	t0028	1
	t0029	1
	t0042	1
	t0043	2
	t0044	2
	t0045	1
	t0046	1
	t0047	1
	t0048	1
	t0049	1
	t0050	1
	t0051	1
	t0052	1
	t0053	1
	t0054	1
	t0055	1
	t0056	1
	t0057	1
	t0059	1
	t0060	1
	t0061	1
	t0062	1
	t0063	1
	t0064	1
	t0065	1
	t0066	1
	t0067	1
	t0068	1
	t0069	1
	t0070	1
	t0071	1

t0072	1
t0073	1
t0074	1
t0075	2
t0076	2
t0077	1
t0078	1
t0079	1
t0080	1
t0081	1
t0082	1
t0083	1
t0084	1
t0085	1
t0086	1
t0087	1
t0088	2
t0099	1
t0100	1
t0101	1
t0105	1
t0106	1
t0107	1
t0200	1

Total: 69 74

Tool Performance

I.D.	Type	Uses	Init.(mins)	Permis.(mins)	Used(mins)	Locat.
1	t0001	11	120	108	106.65	mc2
2	t0003	20	60	54	40.44	mc2
3	t0007	20	60	54	51.44	mc2
4	t0008	15	30	27	26.12	mc2
5	t0102	7	60	54	23.94	mc2
6	t0024	7	60	54	13.65	mc2
7	t0025	7	30	27	15.61	mc2
8	t0027	7	60	54	11.90	mc2
9	t0026	3	60	54	43.59	mc2
10	t0028	7	60	54	8.96	mc2
11	t0029	7	30	27	7	mc2
12	t0103	7	60	54	7.70	mc2
13	t0001	10	120	108	97.80	mc1
14	t0012	7	60	54	11.74	mc1
15	t0053	3	30	27	21.00	mc1
16	t0054	3	30	27	24.00	mc1
17	t0049	2	30	27	26.00	mc1
18	t0046	4	30	27	15.00	mc1
19	t0047	4	30	27	9.00	mc1

20	t0048	4	30	27	5.00	mc1
21	t0001	8	120	108	100.20	mc3
22	t0003	8	60	54	35.00	mc3
23	t0043	6	30	27	25.20	mc3
24	t0044	6	30	27	23.60	mc3
25	t0042	3	30	27	21.00	mc3
26	t0051	3	30	27	9.00	mc3
27	t0050	3	30	27	12.00	mc3
28	t0052	3	30	27	3.00	mc3
29	t0012	9	60	54	8.00	mc3
30	t0028	7	60	54	14.00	mc3
31	t0029	7	30	27	7.80	mc3
32	t0046	4	30	27	21.00	mc3
33	t0047	4	30	27	11.00	mc3
34	t0048	4	30	27	7.00	mc3
35	t0045	3	30	27	18.00	mc3
36	t0017	3	30	27	15.00	mc3
37	t0018	3	30	27	12.00	mc3
38	t0002	8	60	54	44.00	mc2
39	t0004	8	60	54	39.00	mc2
40	t0005	5	60	54	3.75	mc2
41	t0006	11	60	54	10.35	mc2
42	t0043	5	30	27	2.50	mc2
43	t0012	8	60	54	4.10	mc2
44	t0009	5	30	27	3.75	mc2
45	t0030	5	30	27	10.50	mc2
46	t0031	5	60	54	10.35	mc2
47	t0032	5	60	54	16.15	mc2
48	t0033	5	60	54	10.85	mc2
49	t0034	5	60	54	12.65	mc2
50	t0035	5	60	54	12.10	mc2
51	t0036	5	60	54	10.00	mc2
52	t0010	4	60	54	47.32	mc2
53	t0011	5	30	27	2.50	mc2
54	t0015	5	30	27	1.85	mc2
55	t0013	5	30	27	2.75	mc2
56	t0014	5	30	27	2.10	mc2
57	t0016	5	30	27	2.90	mc2
58	t0017	5	30	27	2.40	mc2
59	t0018	5	30	27	2.50	mc2
60	t0019	8	30	27	8.10	mc2
61	t0020	8	30	27	12.05	mc2
62	t0021	8	30	27	5.75	mc2
63	t0022	8	30	27	5.60	mc2
64	t0023	5	60	54	17.10	mc2
65	t0107	4	30	27	7.60	mc1
66	t0080	8	30	27	23.00	mc1
67	t0076	4	30	27	22.40	mc1
68	t0101	4	30	27	17.20	mc1
69	t0064	4	30	27	6.60	mc1
70	t0084	4	30	27	5.70	mc1
71	t0088	4	30	27	20.80	mc1
72	t0072	4	30	27	5.60	mc1
73	t0081	4	30	27	3.00	mc1
74	t0087	4	30	27	9.05	mc1

75	t0071	8	30	27	12.80	mc1
76	t0085	8	30	27	4.80	mc1
77	t0079	4	30	27	16.00	mc1
78	t0082	4	30	27	12.00	mc1
79	t0083	4	30	27	4.80	mc1
80	t0028	6	60	54	11.28	mc1
81	t0106	4	30	27	2.40	mc1
82	t0105	4	30	27	6.00	mc1
83	t0029	6	30	27	6.80	mc1
84	t0043	8	30	27	16.70	mc1
85	t0044	5	30	27	13.60	mc1
86	t0065	4	30	27	9.20	mc1
87	t0067	4	30	27	8.80	mc1
88	t0066	4	30	27	12.00	mc1
89	t0100	4	30	27	16.50	mc1
90	t0078	4	30	27	19.80	mc1
91	t0077	4	30	27	21.30	mc1
92	t0086	4	30	27	9.10	mc1
93	t0075	3	30	27	21.00	mc1
94	t0069	4	30	27	8.00	mc1
95	t0068	4	30	27	4.80	mc1
96	t0074	4	30	27	8.00	mc1
97	t0073	4	30	27	9.20	mc1
98	t0070	4	30	27	8.80	mc1
99	t0002	5	60	54	25.00	mc3
100	t0059	5	30	27	5.00	mc3
101	t0060	5	60	54	15	mc3
102	t0004	5	60	54	52.50	mc3
103	t0055	5	30	27	2.00	mc3
104	t0056	5	30	27	1.50	mc3
105	t0006	6	60	54	6.35	mc3
106	t0007	5	60	54	22.50	mc3
107	t0008	5	30	27	6.00	mc3
108	t0063	5	30	27	20.00	mc3
109	t0062	5	30	27	10.00	mc3
110	t0019	5	30	27	2.50	mc3
111	t0020	5	30	27	4.00	mc3
112	t0021	5	30	27	2.25	mc3
113	t0022	5	30	27	2.25	mc3
114	t0200	5	999	899	5.00	mc3
115	t0043	1	30	27	10.00	mc3
116	t0044	1	30	27	10.00	mc3
117	t0049	1	30	27	13.00	mc1
118	t0003	8	60	54	19.12	mc1
119	t0007	7	60	54	18.22	mc1
120	t0008	7	30	27	14.49	mc1
121	t0102	1	60	54	3.42	mc1
122	t0024	1	60	54	1.95	mc1
123	t0025	1	30	27	2.23	mc1
124	t0027	1	60	54	1.70	mc1
125	t0026	1	60	54	14.53	mc1
126	t0103	1	60	54	1.10	mc1
127	t0076	4	30	27	20.60	mc1
128	t0026	3	60	54	43.59	mc2
129	t0053	1	30	27	7.00	mc3

130	t0054	1	30	27	8.00	mc3
131	t0049	1	30	27	13.00	mc3
132	t0001	6	120	108	65.50	mc2
133	t0042	1	30	27	7.00	mc1
134	t0051	1	30	27	3.00	mc1
135	t0050	1	30	27	4.00	mc1
136	t0052	1	30	27	1.00	mc1
137	t0045	1	30	27	6.00	mc1
138	t0017	4	30	27	6.44	mc1
139	t0018	4	30	27	5.50	mc1
140	t0107	4	30	27	8.00	mc3
141	t0080	8	30	27	26.40	mc3
142	t0076	4	30	27	22.40	mc3
143	t0101	4	30	27	15.60	mc3
144	t0064	4	30	27	6.00	mc3
145	t0084	4	30	27	6.60	mc3
146	t0088	3	30	27	18.70	mc3
147	t0072	4	30	27	5.60	mc3
148	t0081	4	30	27	3.00	mc3
149	t0087	4	30	27	9.70	mc3
150	t0071	8	30	27	12.80	mc3
151	t0085	8	30	27	4.80	mc3
152	t0079	4	30	27	16.00	mc3
153	t0082	4	30	27	12.00	mc3
154	t0083	4	30	27	4.80	mc3
155	t0106	4	30	27	2.40	mc3
156	t0105	4	30	27	6.00	mc3
157	t0065	4	30	27	9.20	mc3
158	t0067	4	30	27	8.80	mc3
159	t0066	4	30	27	12.00	mc3
160	t0100	4	30	27	17.00	mc3
161	t0078	4	30	27	20.80	mc3
162	t0077	4	30	27	22.60	mc3
163	t0086	4	30	27	9.80	mc3
164	t0075	3	30	27	23.30	mc3
165	t0069	4	30	27	8.00	mc3
166	t0068	4	30	27	4.80	mc3
167	t0074	4	30	27	8.00	mc3
168	t0073	4	30	27	9.20	mc3
169	t0070	4	30	27	8.80	mc3
170	t0002	3	60	54	17.40	mc1
171	t0004	3	60	54	4.50	mc1
172	t0005	3	60	54	2.25	mc1
173	t0006	3	60	54	2.70	mc1
174	t0001	5	120	108	70.25	mc1
175	t0009	3	30	27	2.25	mc1
176	t0030	3	30	27	6.30	mc1
177	t0031	3	60	54	6.21	mc1
178	t0032	3	60	54	9.69	mc1
179	t0033	3	60	54	6.51	mc1
180	t0034	3	60	54	7.59	mc1
181	t0035	3	60	54	7.26	mc1
182	t0036	3	60	54	6.00	mc1
183	t0010	3	60	54	35.49	mc1
184	t0011	3	30	27	1.50	mc1

185	t0015	3	30	27	1.11	mc1
186	t0013	3	30	27	1.65	mc1
187	t0014	3	30	27	1.26	mc1
188	t0016	3	30	27	1.74	mc1
189	t0019	3	30	27	3.96	mc1
190	t0020	3	30	27	5.79	mc1
191	t0021	3	30	27	2.64	mc1
192	t0022	3	30	27	2.55	mc1
193	t0023	3	60	54	10.26	mc1
194	t0057	1	30	27	1.00	mc3
195	t0061	1	30	27	3.40	mc3
196	t0099	1	30	27	.90	mc3
197	t0026	1	60	54	14.53	mc2
198	t0059	3	30	27	3.00	mc2
199	t0060	3	60	54	9	mc2
200	t0055	3	30	27	1.20	mc2
201	t0056	3	30	27	.90	mc2
202	t0008	5	30	27	8.03	mc2
203	t0063	3	30	27	12.00	mc2
204	t0062	3	30	27	6.00	mc2
205	t0200	3	999	899	3.00	mc2
206	t0057	3	30	27	3.00	mc2
207	t0061	3	30	27	10.20	mc2
208	t0099	3	30	27	2.70	mc2
209	t0076	4	30	27	18.80	mc3
210	t0010	1	60	54	11.83	mc2
211	t0075	1	30	27	9.30	mc1
212	t0088	1	30	27	14.50	mc3
213	t0075	1	30	27	9.30	mc3

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Station Operation Schedules

Station	Pallet	Operation	Start Time(mins)
lu1			
	pallet3	op10	0
	pallet6	op24	1.07
	pallet1	op1	5.35
	pallet3	op12	50.35
	pallet3	op10	70.35
	pallet6	op23	120.48
	pallet6	op24	145.48
	pallet1	op3	176.76
	pallet1	op1	206.76
	pallet3	op12	218.93
	pallet3	op10	238.93
	pallet6	op23	288.68
	pallet6	op24	313.68
	pallet1	op3	344.96
	pallet1	op1	374.96
	pallet3	op12	387.51

pallet3	op10	407.51
pallet6	op23	456.88
pallet6	op24	481.88
pallet1	op3	513.16
pallet1	op1	543.16
pallet5	op20	574.24
pallet1	op3	630.52
pallet1	op4	660.52
pallet6	op23	720.32
pallet4	op15	767.97
pallet4	op14	797.97
pallet1	op6	833.44
pallet1	op4	863.44
pallet3	op12	869.27
pallet4	op15	957.93
pallet4	op18	987.93
pallet1	op6	1033.69
pallet1	op4	1063.69
pallet2	op9	1157.00
pallet2	op7	1182.00
pallet4	op17	1314.57
pallet4	op18	1344.57
pallet4	op17	1492.09

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lu2

pallet5	op21	0
pallet2	op7	3.21
pallet4	op14	7.49
pallet5	op20	67.50
pallet5	op21	87.50
pallet2	op9	172.86
pallet2	op7	197.86
pallet4	op15	202.14
pallet4	op14	232.14
pallet5	op20	253.07
pallet5	op21	273.07
pallet2	op9	341.44
pallet2	op7	366.44
pallet4	op15	379.24
pallet4	op14	409.24
pallet5	op20	438.64
pallet5	op21	458.64
pallet3	op12	486.16
pallet3	op10	506.16
pallet2	op9	509.64
pallet2	op7	534.64
pallet3	op12	556.51
pallet3	op10	576.51
pallet4	op15	609.20
pallet4	op14	639.20
pallet2	op9	679.02
pallet2	op7	704.02
pallet3	op12	725.09
pallet3	op10	745.09

pallet3	op12	794.64
pallet3	op10	814.64
pallet2	op9	843.63
pallet2	op7	868.63
pallet1	op6	934.74
pallet1	op4	964.74
pallet2	op9	996.06
pallet2	op7	1021.06
pallet4	op17	1136.25
pallet4	op18	1166.25
pallet1	op6	1222.47
pallet2	op9	1437.08

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mc1

pallet5	op19	4.28
pallet4	op13	65.36
pallet5	op19	189.85
pallet4	op13	250.93
pallet5	op19	375.42
pallet3	op11	436.50
pallet4	op13	482.57
pallet6	op22	607.06
pallet2	op8	718.98
pallet2	op8	871.41
pallet4	op16	1168.39
pallet2	op8	1312.43

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mc2

pallet3	op11	2.14
pallet2	op8	48.21
pallet3	op11	170.72
pallet2	op8	216.79
pallet3	op11	339.30
pallet2	op8	385.37
pallet3	op11	508.30
pallet2	op8	554.37
pallet3	op11	676.88
pallet3	op11	746.43
pallet3	op11	816.78
pallet1	op5	867.13
pallet1	op5	966.88
pallet2	op8	1032.35
pallet1	op5	1154.86

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mc3

pallet6	op22	6.42
pallet1	op2	118.34
pallet6	op22	174.62
pallet1	op2	286.54
pallet6	op22	342.82
pallet1	op2	454.74
pallet5	op19	511.02

pallet1	op2	572.10
pallet4	op13	641.34
pallet1	op5	765.83
pallet4	op13	831.30
pallet4	op16	990.07
pallet4	op16	1345.91

Part Operation Schedules

Part	Operation	Start Time	Station
part10001			
	op1	5.35	lu1
	op2	118.34	mc3
	op3	176.76	lu1
part10002			
	op1	206.76	lu1
	op2	286.54	mc3
	op3	344.96	lu1
part10003			
	op1	374.96	lu1
	op2	454.74	mc3
	op3	513.16	lu1
part10004			
	op1	543.16	lu1
	op2	572.10	mc3
	op3	630.52	lu1

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part20001			
	op4	660.52	lu1
	op5	765.83	mc3
	op6	833.44	lu1
part20002			
	op4	863.44	lu1
	op5	867.13	mc2
	op6	934.74	lu2
part20003			
	op4	964.74	lu2
	op5	966.88	mc2
	op6	1033.69	lu1
part20004			
	op4	1063.69	lu1
	op5	1154.86	mc2
	op6	1222.47	lu2

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part30001			
	op7	3.21	lu2
	op8	48.21	mc2
	op9	172.86	lu2
part30002			
	op7	197.86	lu2
	op8	216.79	mc2
	op9	341.44	lu2
part30003			
	op7	366.44	lu2
	op8	385.37	mc2
	op9	509.64	lu2
part30004			
	op7	534.64	lu2
	op8	554.37	mc2
	op9	679.02	lu2
part30005			
	op7	704.02	lu2
	op8	718.98	mc1
	op9	843.63	lu2
part30006			
	op7	868.63	lu2
	op8	871.41	mc1
	op9	996.06	lu2
part30007			
	op7	1021.06	lu2
	op8	1032.35	mc2
	op9	1157.00	lu1
part30008			
	op7	1182.00	lu1
	op8	1312.43	mc1
	op9	1437.08	lu2

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part40001			
	op10	0	lu1
	op11	2.14	mc2
	op12	50.35	lu1
part40002			
	op10	70.35	lu1
	op11	170.72	mc2
	op12	218.93	lu1
part40003			
	op10	238.93	lu1
	op11	339.30	mc2
	op12	387.51	lu1
part40004			
	op10	407.51	lu1
	op11	436.50	mc1
	op12	486.16	lu2
part40005			
	op10	506.16	lu2

	op11	508.30	mc2
	op12	556.51	lu2
part40006			
	op10	576.51	lu2
	op11	676.88	mc2
	op12	725.09	lu2
part40007			
	op10	745.09	lu2
	op11	746.43	mc2
	op12	794.64	lu2
part40008			
	op10	814.64	lu2
	op11	816.78	mc2
	op12	869.27	lu1

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part50001			
	op14	7.49	lu2
	op13	65.36	mc1
	op15	202.14	lu2
part50002			
	op14	232.14	lu2
	op13	250.93	mc1
	op15	379.24	lu2
part50003			
	op14	409.24	lu2
	op13	482.57	mc1
	op15	609.20	lu2
part50004			
	op14	639.20	lu2
	op13	641.34	mc3
	op15	767.97	lu1
part50005			
	op14	797.97	lu1
	op13	831.30	mc3
	op15	957.93	lu1

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part60001			
	op18	987.93	lu1
	op16	990.07	mc3
	op17	1136.25	lu2
part60002			
	op18	1166.25	lu2
	op16	1168.39	mc1
	op17	1314.57	lu1
part60003			
	op18	1344.57	lu1
	op16	1345.91	mc3
	op17	1492.09	lu1

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part70001			
	op21	0	lu2
	op19	4.28	mc1
	op20	67.50	lu2
part70002			
	op21	87.50	lu2
	op19	189.85	mc1
	op20	253.07	lu2
part70003			
	op21	273.07	lu2
	op19	375.42	mc1
	op20	438.64	lu2
part70004			
	op21	458.64	lu2
	op19	511.02	mc3
	op20	574.24	lu1

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part80001			
	op24	1.07	lu1
	op22	6.42	mc3
	op23	120.48	lu1
part80002			
	op24	145.48	lu1
	op22	174.62	mc3
	op23	288.68	lu1
part80003			
	op24	313.68	lu1
	op22	342.82	mc3
	op23	456.88	lu1
part80004			
	op24	481.88	lu1
	op22	607.06	mc1
	op23	720.32	lu1

********* Outputs of Knowledge Based Modelling - Level 3 ********

Model: 3MachineCell

****
Computer run time(mins): 53

****
Overall Cell Performance
==========

Make Span(mins) : 1737.62
Total Throughput(parts/shift) : 11
Total Lateness(mins) : 297.62
Average Flow Time(mins) : 171.19
Average Utilisation(%) : 57.98

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Primary Outputs
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Part Throughputs

Part	Throughput(parts/shift)
part1	2.68
part2	1.57
part3	2.69
part4	4.11
part5	2.01
part6	.83
part7	2.69
part8	2.32

Part Lead Times

Part	Activity	Ave.(mins)	Max.(mins)	Min.(mins)	Mean(mins)
part1	Lead Time	177.61	260.51	102.35	181.43
	Machining	54.28	54.28	54.28	54.28

	Transport	2.00	2.40	1.60	2.00
	Waiting	85.37	167.81	11.79	89.80
	Fixturing	30	30	30	30
part2	Lead Time	126.30	188.99	99.75	144.37
	Machining	63.47	63.47	63.47	63.47
	Transport	1.60	1.60	1.60	1.60
	Waiting	26.75	89.24	0.00	44.62
	Fixturing	30	30	30	30
part3	Lead Time	178.27	271.24	150.99	211.12
	Machining	120.51	120.51	120.51	120.51
	Transport	1.80	2.40	1.60	2.00
	Waiting	25.74	114.10	0.00	57.05
	Fixturing	25	25	25	25
part4	Lead Time	116.80	171.70	72.67	122.19
	Machining	44.07	44.07	44.07	44.07
	Transport	1.70	2.40	1.60	2.00
	Waiting	45.91	101.35	3.12	52.23
	Fixturing	20	20	20	20
part5	Lead Time	236.73	348.54	161.89	255.22
	Machining	122.49	122.49	122.49	122.49
	Transport	2.24	3.20	1.60	2.40
	Waiting	75.05	182.28	3.12	92.70
	Fixturing	30	30	30	30
part6	Lead Time	182.16	184.40	180.64	182.52
	Machining	142.04	142.04	142.04	142.04
	Transport	1.60	1.60	1.60	1.60
	Waiting	4.64	7.68	3.12	5.40
	Fixturing	30	30	30	30
part7	Lead Time	178.58	244.27	101.26	172.76
	Machining	59.08	59.08	59.08	59.08
	Transport	2.40	3.20	1.60	2.40
	Waiting	90.95	154.63	13.76	84.19
	Fixturing	20	20	20	20
part8	Lead Time	206.77	283.27	148.44	215.86
	Machining	109.92	109.92	109.92	109.92
	Transport	2.00	2.40	1.60	2.00
	Waiting	63.69	139.93	7.24	73.58
	Fixturing	25	25	25	25

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Secondary Outputs
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Part Performance

(Unit: mins)

Part	InStore	AtBuf.	AtStn.	Ld/Unld	Fixtur.	ForTools
part10001	11.58	68.03	57.49	3.62	30	24.40
part10002	0	11.79	54.28	3.08	30	0
part10003	34.25	133.56	54.28	3.62	30	25.92
part10004	0	82.28	54.28	3.08	30	0
part20001	0	89.24	63.47	3.08	30	6.16
part20002	0	13.14	63.47	3.08	30	6.16
part20003	0	0.00	63.47	3.08	30	0
part20004	0	4.64	63.47	3.08	30	4.64
part30001	11.58	102.52	123.72	3.62	25	45.68
part30002	6.39	51.04	120.51	3.62	25	30.48
part30003	0	12.81	120.51	3.08	25	0
part30004	0	15.36	120.51	3.08	25	0
part30005	0	3.12	120.51	3.08	25	3.12
part30006	0	0.00	120.51	3.08	25	0
part30007	0	0.00	120.51	3.08	25	0
part30008	0	3.12	120.51	3.08	25	3.12
part40001	0	20.98	44.07	3.08	20	19.84
part40002	0.00	55.06	44.07	3.62	20	0
part40003	0	31.66	44.07	3.08	20	0
part40004	0	13.76	46.53	3.08	20	13.76
part40005	0	44.26	46.21	3.08	20	3.12
part40006	0	97.09	44.07	3.08	20	0
part40007	0	101.35	44.07	3.08	20	3.12
part40008	0	3.12	44.07	3.08	20	3.12
part50001	58.49	123.79	125.70	4.16	30	47.20
part50002	46.35	88.64	123.83	3.62	30	48.72
part50003	6.22	30.02	123.91	3.62	30	0
part50004	0	18.64	122.49	3.08	30	0
part50005	0	3.12	122.49	3.08	30	3.12
part60001	0	3.12	142.04	3.08	30	3.12
part60002	0	3.12	142.04	3.08	30	3.12
part60003	0	7.68	142.04	3.08	30	7.68
part70001	0	13.76	61.22	3.08	20	13.76
part70002	41.38	101.19	59.08	3.62	20	0
part70003	23.36	29.47	59.08	3.62	20	3.12
part70004	29.33	125.30	59.08	4.16	20	4.64
part80001	0	27.78	113.13	3.08	25	27.44
part80002	18.40	121.53	109.92	3.62	25	0
part80003	22.26	57.56	109.92	3.62	25	4.64
part80004	0	7.24	109.92	3.08	25	4.64

Machine Station Performance

Machine: mc1

	Time(mins)	%
Cutting	920.69	52.99
ToolChange	228.76	13.17
LoadUnload	24	1.38
Stationary	10.57	0.61
ForTools	135.92	7.82
SpareCapa.	216.54	12.46
Idle	417.68	24.04

Machine: mc2

	Time(mins)	%
Cutting	841.74	48.44
ToolChange	247.76	14.26
LoadUnload	32	1.84
Stationary	5.35	0.31
ForTools	98.00	5.64
SpareCapa.	335.40	19.30
Idle	512.77	29.51

Machine: mc3

	Time(mins)	%
Cutting	1019.30	58.66
ToolChange	243.96	14.04
LoadUnload	24	1.38
Stationary	6.42	0.37
ForTools	129.92	7.48
SpareCapa.	31.34	1.80
Idle	314.02	18.07

Transporter Performance

Transporter: agv

	Time(mins)	%

LoadRun	76.00	4.37
EmptyRun	66.40	3.82
LoadUnload	51.30	2.95
Idle	1543.92	88.85

Load/Unload Station Performance

Station: lu1

	Time(mins)	%
Fixturing	520	29.93
LoadUnload	11.07	.64
StationaryTime	23.58	1.36
SpareCapa.	0.00	0.00
Idle	1182.97	68.08

Station: lu2

	Time(mins)	%
Fixturing	500	28.77
LoadUnload	10.53	.61
StationaryTime	25.96	1.49
SpareCapa.	184.13	10.60
Idle	1201.13	69.13

Temporary Storage Performance

Stand: ps1

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps2

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps3

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps4

	Time(mins)	%
Stationary	93.27	5.37
LoadUnload	2.16	.12
SpareCapa.	1044.36	60.10
Idle		
	1642.19	94.51

Stand: ps5

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps6

	Time(mins)	%
Stationary	40.66	2.34
LoadUnload	1.08	.06
SpareCapa.	1084.00	62.38
Idle		
	1695.88	97.60

Stand: ps7

	Time(mins)	%
Stationary	0.00	0.00
LoadUnload	.54	.04
SpareCapa.	1643.88	94.61

Idle		
	1737.08	99.96

Stand: ps8

	Time(mins)	%
Stationary	17.97	1.03
LoadUnload	1.08	.06
SpareCapa.	1277.88	73.54
Idle		
	1718.57	98.90

Stand: ps9

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps10

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps11

	Time(mins)	%
Stationary	111.86	6.44
LoadUnload	2.16	.12
SpareCapa.	916.85	52.76
Idle		
	1623.60	93.44

Stand: ps12

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps13

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps14

	Time(mins)	%
Stationary	45.83	2.64
LoadUnload	1.08	.06
SpareCapa.	1416.94	81.54
Idle		
	1690.71	97.30

Stand: ps15

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps16

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps17

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps18

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00

Idle		
	1737.62	100.00

Stand: ps19

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps20

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps21

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Stand: ps22

	Time(mins)	%
Stationary	0	0.00
LoadUnload	0	0.00
SpareCapa.	1737.62	100.00
Idle		
	1737.62	100.00

Cell Tool Requirement

Tool Type	No. of Tools
t0001	6
t0002	3
t0003	3

t0004	4
t0005	2
t0006	3
t0007	4
t0008	4
t0009	2
t0010	2
t0011	2
t0012	3
t0013	2
t0014	2
t0015	2
t0016	2
t0017	3
t0018	3
t0019	3
t0020	3
t0021	3
t0022	3
t0023	2
t0024	2
t0025	2
t0026	4
t0027	2
t0028	3
t0029	3
t0030	2
t0031	2
t0032	2
t0033	2
t0034	2
t0035	2
t0036	2
t0042	2
t0043	4
t0044	3
t0045	1
t0046	2
t0047	2
t0048	2
t0049	2
t0050	1
t0051	1
t0052	1
t0053	2
t0054	2
t0055	2
t0056	2
t0057	2
t0058	0
t0059	2
t0060	2
t0061	2
t0062	2
t0063	2

	t0064	2
	t0065	2
	t0066	2
	t0067	2
	t0068	2
	t0069	2
	t0070	2
	t0071	2
	t0072	2
	t0073	2
	t0074	2
	t0075	3
	t0076	5
	t0077	3
	t0078	2
	t0079	2
	t0080	3
	t0081	2
	t0082	2
	t0083	2
	t0084	2
	t0085	2
	t0086	2
	t0087	2
	t0088	3
	t0099	2
	t0100	2
	t0101	2
	t0102	2
	t0103	2
	t0105	2
	t0106	2
	t0107	2
	t0200	2
Total:	92	212

Machine PTS Performance

Machine: mc1

LoadUnload(mins)	61.56
InitialContents	0
FinalContents	81
ChangesOfWornTools	0
ChangesOfPositionTools	0

Machine: mc2

LoadUnload(mins)	41.80
InitialContents	0
FinalContents	55
ChangesOfWornTools	0

ChangesOfPositionTools	0

Machine: mc3

LoadUnload(mins)	57.76
InitialContents	0
FinalContents	76
ChangesOfWornTools	0
ChangesOfPositionTools	0

Cell STS Performance

Secondary Tool Store: sts

LoadUnload(mins)	161.12
InitialContents	0
FinalContents	0

Tool Transporter Performance

Tool Transporter: man1

	Time(mins)	%
LoadRun	16.00	.92
EmptyRun	16.00	.92
LoadUnload	179.36	10.32
Idle	1526.26	87.84

Tool Transporter: man2

	Time(mins)	%
LoadRun	3.20	.18
EmptyRun	3.20	.18
LoadUnload	115.52	6.65
Idle	1615.70	92.98

Tool Transporter: man3

	Time(mins)	%

LoadRun	1.60	.09
EmptyRun	1.60	.09
LoadUnload	27.36	1.57
Idle	1707.06	98.24

Tool Performance

I.D.	Type	Uses	Init.(mins)	Permis.(mins)	Used(mins)	Locat.
1	t0048	4	30	27	4.00	mc1
2	t0047	4	30	27	8.00	mc1
3	t0046	4	30	27	12.00	mc1
4	t0049	2	30	27	26.00	mc1
5	t0054	3	30	27	24.00	mc1
6	t0053	3	30	27	21.00	mc1
7	t0012	8	60	54	14.32	mc1
8	t0001	9	120	108	98.35	mc1
9	t0103	7	60	54	7.70	mc2
10	t0029	7	30	27	7	mc2
11	t0028	7	60	54	8.96	mc2
12	t0026	3	60	54	43.59	mc2
13	t0027	7	60	54	11.90	mc2
14	t0025	7	30	27	15.61	mc2
15	t0024	7	60	54	13.65	mc2
16	t0102	7	60	54	23.94	mc2
17	t0008	17	30	27	26.49	mc2
18	t0007	18	60	54	49.24	mc2
19	t0003	20	60	54	44.04	mc2
20	t0001	11	120	108	106.65	mc2
21	t0018	4	30	27	16.00	mc3
22	t0017	4	30	27	20.00	mc3
23	t0045	4	30	27	24.00	mc3
24	t0048	4	30	27	8.00	mc3
25	t0047	4	30	27	12.00	mc3
26	t0046	4	30	27	24.00	mc3
27	t0029	9	30	27	10.00	mc3
28	t0028	9	60	54	18.00	mc3
29	t0012	7	60	54	5.20	mc3
30	t0052	4	30	27	4.00	mc3
31	t0050	4	30	27	16.00	mc3
32	t0051	4	30	27	12.00	mc3
33	t0042	3	30	27	21.00	mc3
34	t0044	3	30	27	20.90	mc3
35	t0043	3	30	27	21.30	mc3
36	t0003	7	60	54	32.00	mc3
37	t0001	4	120	108	81.80	mc3
38	t0200	5	999	899	5.00	mc2
39	t0022	9	30	27	5.65	mc2
40	t0021	9	30	27	5.77	mc2

41	t0020	9	30	27	11.72	mc2
42	t0019	9	30	27	7.78	mc2
43	t0062	5	30	27	10.00	mc2
44	t0063	5	30	27	20.00	mc2
45	t0012	9	60	54	4.32	mc2
46	t0006	12	60	54	11.65	mc2
47	t0056	5	30	27	1.50	mc2
48	t0055	5	30	27	2.00	mc2
49	t0004	7	60	54	46.50	mc2
50	t0060	5	60	54	15	mc2
51	t0059	5	30	27	5.00	mc2
52	t0002	9	60	54	48.20	mc2
53	t0023	4	60	54	13.68	mc1
54	t0022	4	30	27	3.40	mc1
55	t0021	4	30	27	3.52	mc1
56	t0020	4	30	27	7.72	mc1
57	t0019	4	30	27	5.28	mc1
58	t0018	4	30	27	2.00	mc1
59	t0017	4	30	27	1.92	mc1
60	t0016	4	30	27	2.32	mc1
61	t0014	4	30	27	1.68	mc1
62	t0013	4	30	27	2.20	mc1
63	t0015	4	30	27	1.48	mc1
64	t0011	4	30	27	2.00	mc1
65	t0010	4	60	54	47.32	mc1
66	t0036	4	60	54	8.00	mc1
67	t0035	4	60	54	9.68	mc1
68	t0034	4	60	54	10.12	mc1
69	t0033	4	60	54	8.68	mc1
70	t0032	4	60	54	12.92	mc1
71	t0031	4	60	54	8.28	mc1
72	t0030	4	30	27	8.40	mc1
73	t0009	4	30	27	3.00	mc1
74	t0043	7	30	27	5.90	mc1
75	t0008	9	30	27	18.92	mc1
76	t0007	9	60	54	23.82	mc1
77	t0006	4	60	54	3.60	mc1
78	t0005	4	60	54	3.00	mc1
79	t0004	4	60	54	6.00	mc1
80	t0003	9	60	54	18.52	mc1
81	t0002	4	60	54	23.20	mc1
82	t0070	5	30	27	11.00	mc3
83	t0073	5	30	27	11.50	mc3
84	t0074	5	30	27	10.00	mc3
85	t0068	5	30	27	6.00	mc3
86	t0069	5	30	27	10.00	mc3
87	t0075	3	30	27	21.00	mc3
88	t0086	5	30	27	11.90	mc3
89	t0077	4	30	27	21.30	mc3
90	t0078	5	30	27	25.50	mc3
91	t0100	5	30	27	21.00	mc3
92	t0066	5	30	27	15.00	mc3
93	t0067	5	30	27	11.00	mc3
94	t0065	5	30	27	11.50	mc3
95	t0105	5	30	27	7.50	mc3

96	t0106	5	30	27	3.00	mc3
97	t0083	5	30	27	6.00	mc3
98	t0082	5	30	27	15.00	mc3
99	t0079	5	30	27	20.00	mc3
100	t0085	10	30	27	6.00	mc3
101	t0071	10	30	27	16.00	mc3
102	t0087	5	30	27	11.80	mc3
103	t0081	5	30	27	3.75	mc3
104	t0072	5	30	27	7.00	mc3
105	t0088	4	30	27	20.80	mc3
106	t0084	5	30	27	7.80	mc3
107	t0064	5	30	27	7.80	mc3
108	t0101	5	30	27	20.30	mc3
109	t0076	4	30	27	22.40	mc3
110	t0080	8	30	27	23.00	mc3
111	t0107	5	30	27	9.80	mc3
112	t0023	4	60	54	13.68	mc2
113	t0018	4	30	27	2.00	mc2
114	t0017	4	30	27	1.92	mc2
115	t0016	4	30	27	2.32	mc2
116	t0014	4	30	27	1.68	mc2
117	t0013	4	30	27	2.20	mc2
118	t0015	4	30	27	1.48	mc2
119	t0011	4	30	27	2.00	mc2
120	t0010	4	60	54	47.32	mc2
121	t0036	4	60	54	8.00	mc2
122	t0035	4	60	54	9.68	mc2
123	t0034	4	60	54	10.12	mc2
124	t0033	4	60	54	8.68	mc2
125	t0032	4	60	54	12.92	mc2
126	t0031	4	60	54	8.28	mc2
127	t0030	4	30	27	8.40	mc2
128	t0009	4	30	27	3.00	mc2
129	t0043	4	30	27	2.00	mc2
130	t0005	4	60	54	3.00	mc2
131	t0103	1	60	54	1.10	mc1
132	t0029	4	30	27	4.60	mc1
133	t0028	4	60	54	7.28	mc1
134	t0026	1	60	54	14.53	mc1
135	t0027	1	60	54	1.70	mc1
136	t0025	1	30	27	2.23	mc1
137	t0024	1	60	54	1.95	mc1
138	t0102	1	60	54	3.42	mc1
139	t0049	2	30	27	26.00	mc1
140	t0200	3	999	899	3.00	mc3
141	t0022	3	30	27	1.35	mc3
142	t0021	3	30	27	1.35	mc3
143	t0020	3	30	27	2.40	mc3
144	t0019	3	30	27	1.50	mc3
145	t0062	3	30	27	6.00	mc3
146	t0063	3	30	27	12.00	mc3
147	t0008	3	30	27	3.60	mc3
148	t0007	3	60	54	13.50	mc3
149	t0006	4	60	54	4.15	mc3
150	t0056	3	30	27	.90	mc3

151	t0055	3	30	27	1.20	mc3
152	t0004	3	60	54	31.50	mc3
153	t0060	3	60	54	9	mc3
154	t0059	3	30	27	3.00	mc3
155	t0002	3	60	54	15.00	mc3
156	t0026	3	60	54	43.59	mc2
157	t0070	3	30	27	6.60	mc1
158	t0073	3	30	27	6.90	mc1
159	t0074	3	30	27	6.00	mc1
160	t0068	3	30	27	3.60	mc1
161	t0069	3	30	27	6.00	mc1
162	t0075	3	30	27	23.30	mc1
163	t0086	3	30	27	7.00	mc1
164	t0077	3	30	27	16.30	mc1
165	t0078	3	30	27	15.10	mc1
166	t0100	3	30	27	12.50	mc1
167	t0066	3	30	27	9.00	mc1
168	t0067	3	30	27	6.60	mc1
169	t0065	3	30	27	6.90	mc1
170	t0044	3	30	27	2.70	mc1
171	t0105	3	30	27	4.50	mc1
172	t0106	3	30	27	1.80	mc1
173	t0083	3	30	27	3.60	mc1
174	t0082	3	30	27	9.00	mc1
175	t0079	3	30	27	12.00	mc1
176	t0085	6	30	27	3.60	mc1
177	t0071	6	30	27	9.60	mc1
178	t0087	3	30	27	6.95	mc1
179	t0081	3	30	27	2.25	mc1
180	t0072	3	30	27	4.20	mc1
181	t0088	3	30	27	18.70	mc1
182	t0084	3	30	27	4.50	mc1
183	t0064	3	30	27	4.80	mc1
184	t0101	3	30	27	12.50	mc1
185	t0076	4	30	27	22.40	mc1
186	t0080	6	30	27	18.10	mc1
187	t0107	3	30	27	5.80	mc1
188	t0044	6	30	27	23.60	mc3
189	t0043	6	30	27	25.20	mc3
190	t0054	1	30	27	8.00	mc1
191	t0053	1	30	27	7.00	mc1
192	t0042	1	30	27	7.00	mc3
193	t0001	5	120	108	30.20	mc3
194	t0001	4	120	108	36.95	mc2
195	t0099	1	30	27	.90	mc3
196	t0061	1	30	27	3.40	mc3
197	t0057	1	30	27	1.00	mc3
198	t0001	7	120	108	86.45	mc1
199	t0026	1	60	54	14.53	mc2
200	t0099	3	30	27	2.70	mc2
201	t0061	3	30	27	10.20	mc2
202	t0057	3	30	27	3.00	mc2
203	t0076	4	30	27	20.60	mc3
204	t0008	3	30	27	5.63	mc2
205	t0004	2	60	54	12.00	mc2

206	t0075	2	30	27	18.60	mc3
207	t0007	2	60	54	5.60	mc2
208	t0076	2	30	27	9.40	mc1
209	t0077	1	30	27	6.30	mc3
210	t0076	2	30	27	9.40	mc3
211	t0088	1	30	27	14.50	mc3
212	t0080	2	30	27	8.30	mc3

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Station Operation Schedules

Station	Pallet	Operation	Start Time(mins)
lu1			
	pallet3	op10	0
	pallet6	op24	1.07
	pallet1	op1	5.35
	pallet3	op12	71.33
	pallet3	op10	91.33
	pallet6	op23	148.26
	pallet6	op24	173.26
	pallet3	op12	198.08
	pallet3	op10	218.08
	pallet1	op3	253.22
	pallet1	op1	283.22
	pallet5	op20	310.53
	pallet5	op21	330.53
	pallet3	op12	385.86
	pallet3	op10	405.86
	pallet5	op20	450.06
	pallet5	op21	470.06
	pallet3	op12	502.61
	pallet3	op10	522.61
	pallet4	op15	623.27
	pallet4	op14	653.27
	pallet3	op12	670.05
	pallet3	op10	690.05
	pallet5	op20	694.33
	pallet2	op9	792.56
	pallet2	op7	817.56
	pallet4	op15	821.84
	pallet4	op14	851.84
	pallet1	op6	874.76
	pallet1	op4	904.76
	pallet3	op12	914.42
	pallet1	op6	986.85
	pallet1	op4	1016.85
	pallet1	op6	1086.60
	pallet1	op4	1116.60
	pallet4	op15	1161.14
	pallet4	op18	1191.14
	pallet2	op9	1250.25

pallet2	op7	1275.25
pallet2	op9	1404.36
pallet4	op17	1707.62

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lu2

pallet5	op21	0
pallet2	op7	3.21
pallet4	op14	7.49
pallet5	op20	81.26
pallet5	op21	101.26
pallet1	op3	150.87
pallet1	op1	180.87
pallet2	op9	249.45
pallet2	op7	274.45
pallet3	op12	299.29
pallet3	op10	319.29
pallet4	op15	326.03
pallet4	op14	356.03
pallet6	op23	431.53
pallet6	op24	456.53
pallet2	op9	460.81
pallet2	op7	485.81
pallet1	op3	513.73
pallet1	op1	543.73
pallet2	op9	625.41
pallet2	op7	650.41
pallet6	op23	654.69
pallet6	op24	679.69
pallet1	op3	685.77
pallet1	op4	715.77
pallet6	op23	803.13
pallet3	op12	841.75
pallet3	op10	861.75
pallet2	op9	947.47
pallet2	op7	972.47
pallet4	op15	999.25
pallet4	op14	1029.25
pallet2	op9	1098.46
pallet2	op7	1123.46
pallet1	op6	1190.99
pallet4	op17	1342.58
pallet4	op18	1372.58
pallet4	op17	1523.22
pallet4	op18	1553.22

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mc1

pallet5	op19	18.04
pallet2	op8	124.80
pallet5	op19	247.31
pallet3	op11	337.65
pallet5	op19	386.84
pallet4	op13	496.64
pallet5	op19	625.77

pallet4	op13	686.85
pallet2	op8	822.82
pallet2	op8	973.81
pallet2	op8	1125.60
pallet4	op16	1377.04

mc2

pallet3	op11	21.98
pallet1	op2	92.45
pallet3	op11	148.73
pallet1	op2	194.80
pallet3	op11	251.08
pallet2	op8	327.63
pallet3	op11	453.26
pallet2	op8	499.33
pallet3	op11	621.84
pallet2	op8	667.91
pallet3	op11	793.54
pallet3	op11	867.01
pallet1	op5	919.24
pallet1	op5	1018.99
pallet1	op5	1123.38
pallet2	op8	1279.71

mc3

pallet6	op22	33.86
pallet4	op13	192.98
pallet6	op22	317.47
pallet1	op2	455.31
pallet6	op22	516.23
pallet1	op2	628.15
pallet6	op22	689.07
pallet1	op5	807.15
pallet4	op13	872.62
pallet4	op13	1034.51
pallet4	op16	1196.40
pallet4	op16	1562.24

Part Operation Schedules

Part	Operation	Start Time	Station
part10001			
	op1	5.35	lu1
	op2	92.45	mc2
	op3	150.87	lu2
part10002			
	op1	180.87	lu2

	op2	194.80	mc2
	op3	253.22	lu1
part10003			
	op1	283.22	lu1
	op2	455.31	mc3
	op3	513.73	lu2
part10004			
	op1	543.73	lu2
	op2	628.15	mc3
	op3	685.77	lu2

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part20001			
	op4	715.77	lu2
	op5	807.15	mc3
	op6	874.76	lu1
part20002			
	op4	904.76	lu1
	op5	919.24	mc2
	op6	986.85	lu1
part20003			
	op4	1016.85	lu1
	op5	1018.99	mc2
	op6	1086.60	lu1
part20004			
	op4	1116.60	lu1
	op5	1123.38	mc2
	op6	1190.99	lu2

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part30001			
	op7	3.21	lu2
	op8	124.80	mc1
	op9	249.45	lu2
part30002			
	op7	274.45	lu2
	op8	327.63	mc2
	op9	460.81	lu2
part30003			
	op7	485.81	lu2
	op8	499.33	mc2
	op9	625.41	lu2
part30004			
	op7	650.41	lu2
	op8	667.91	mc2
	op9	792.56	lu1
part30005			
	op7	817.56	lu1
	op8	822.82	mc1
	op9	947.47	lu2
part30006			

	op7	972.47	lu2
	op8	973.81	mc1
	op9	1098.46	lu2
part30007			
	op7	1123.46	lu2
	op8	1125.60	mc1
	op9	1250.25	lu1
part30008			
	op7	1275.25	lu1
	op8	1279.71	mc2
	op9	1404.36	lu1

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part40001			
	op10	0	lu1
	op11	21.98	mc2
	op12	71.33	lu1
part40002			
	op10	91.33	lu1
	op11	148.73	mc2
	op12	198.08	lu1
part40003			
	op10	218.08	lu1
	op11	251.08	mc2
	op12	299.29	lu2
part40004			
	op10	319.29	lu2
	op11	337.65	mc1
	op12	385.86	lu1
part40005			
	op10	405.86	lu1
	op11	453.26	mc2
	op12	502.61	lu1
part40006			
	op10	522.61	lu1
	op11	621.84	mc2
	op12	670.05	lu1
part40007			
	op10	690.05	lu1
	op11	793.54	mc2
	op12	841.75	lu2
part40008			
	op10	861.75	lu2
	op11	867.01	mc2
	op12	914.42	lu1

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part50001			
	op14	7.49	lu2
	op13	192.98	mc3
	op15	326.03	lu2

part50002			
	op14	356.03	lu2
	op13	496.64	mc1
	op15	623.27	lu1
part50003			
	op14	653.27	lu1
	op13	686.85	mc1
	op15	821.84	lu1
part50004			
	op14	851.84	lu1
	op13	872.62	mc3
	op15	999.25	lu2
part50005			
	op14	1029.25	lu2
	op13	1034.51	mc3
	op15	1161.14	lu1

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part60001			
	op18	1191.14	lu1
	op16	1196.40	mc3
	op17	1342.58	lu2
part60002			
	op18	1372.58	lu2
	op16	1377.04	mc1
	op17	1523.22	lu2
part60003			
	op18	1553.22	lu2
	op16	1562.24	mc3
	op17	1707.62	lu1

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part70001			
	op21	0	lu2
	op19	18.04	mc1
	op20	81.26	lu2
part70002			
	op21	101.26	lu2
	op19	247.31	mc1
	op20	310.53	lu1
part70003			
	op21	330.53	lu1
	op19	386.84	mc1
	op20	450.06	lu1
part70004			
	op21	470.06	lu1
	op19	625.77	mc1
	op20	694.33	lu1

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part80001			
	op24	1.07	lu1
	op22	33.86	mc3
	op23	148.26	lu1
part80002			
	op24	173.26	lu1
	op22	317.47	mc3
	op23	431.53	lu2
part80003			
	op24	456.53	lu2
	op22	516.23	mc3
	op23	654.69	lu2
part80004			
	op24	679.69	lu2
	op22	689.07	mc3
	op23	803.13	lu2

Appendix VI.4

STUDY OF THE PTS CAPACITY

VI.4.1 Introduction

The purpose of this appendix is to investigate the capacity of the PTS in the three machine cell. Influence of this parameter on the major cell performance figures is discussed. The approriate capacities for the cell are suggested against different tool management strategies.

VI.4.2 Planned Experiments

The level 3 of the knowledge based modelling system is chosen to carry out the experiments. All the data and operational rule inputs for the level 3 modelling of the three machine cell as described in Chapters 13 and 14 are used here again, except that the machine tool magazine capacity is to be specified as 40, 60, 90 and 120 respectively.

VI.4.3 Influence on Total Throughput Time

As shown in Figure VI.4.1, the total throughput time varies with the PTS capacity of the machines. The best results were produced when the capacity was 40, whereas the worst was obtained when a 60-tool magazine was used. Since the throughput time dropped down when the magazine capacity became 90, the influence of this parameter on the total throughput time can be considered as arbitrary.

VI.4.4 Influence on Cell Tool Requirements

From Figure VI.4.2 it can be seen that the magazine capacity has a considerable influence on the cell tool requirements generated. When a small magazine is used, more tools need to be transferred between tool stores, and this increases the chance that tools are shared across several machines. Therefore tools are more fully utilised when the magazine is small, and the corresponding cell tool requirement can then be minimised.

VI.4.5 Influence on Tool Changes

Obviously, the smaller the magazine, the more frequent tool changes occur between the PTS and the STS. This is clearly shown in Figure VI.4.3. Notably, for all the three machines, the number of position tool changes approached zero when the magazine capacity was 90. Therefore if all the required tools are initially assigned to the specific magazines of 90-tool capacity, there will be no need for tools to be provided from the STS.

VI.4.6 Influence on PTS Performance

A more detailed summary of the performance figures of each PTS with regard to the varying capacity is shown in Figure VI.4.4. It is apparent that when the magazine capacity was 90, there were 3 tools changed at machine 1, but the final contents of the PTS on the other two machines are well below the capacity. Thus if the tool changes between the PTS and the STS are to be reduced, some of the components processed on machine 1 can be re-scheduled to the other two machines.

VI.4.7 Influence on Tool Wait Times

As shown in Figure VI.4.5, with smaller magazines, each machine spends a longer time on waiting for tools to be provided before the machining process can start. For large magazines, since tools transferred can reside for a longer time in the magazine, there is little need to transfer tools from the STS on changing of a new component.

VI.4.8 Influence on Tool Transporter Performance

It is apparent that the smaller the magazines, the more frequent the tool transporters are required and utilised for tool transfer (Figure VI.4.6). This can be shown through the load running time and the load/unload time of the three men. However, the empty running time became longer with the increase of the magazine capacity. This is because of that when large magazines are used, there are rarely tools for the transporters to transfer back to the STS on completion of tool transfer from the STS to the PTS. Therefore, when a tool transporter is required, it has to travel back to the STS from its current location.

VI.4.9 Conclusions

It can be concluded, based on the above discussion, that the tool magazine capacity has a considerable influence on the cell performance. In particular, this parameter is vitally important for determine the cell tool requirements and the capacity of the tool provision system. For the three machine cell, if tool transporters are widely available, then a small magazine capacity like 40 can be adopted. However, if the tool transfer between the tool stores is performed manually, and the manning level is intended to be reduced, it is more feasible to use large magazines, such as 90-tool magazines. In addition, unless new components are to be specified, the use of the 120-tool magazines in the cell is, to some extent, a waste.

Mach. / Capacity	MC1 Final Conten.	MC1 Worn Tool Change	MC1 Position Tool Change	MC2 Final Conten.	MC2 Worn Tool Change	MC2 Position Tool Change	MC3 Final Conten.	MC3 Worn Tool Change	MC3 Position Tool Change
40	40	0	78	40	0	27	40	0	42
60	60	1	64	51	0	0	60	0	12
90	90	0	3	51	0	0	71	0	0
120	93	0	0	51	0	0	71	0	0

Figure VI.4.1	*Influence of PTS Capacity on PTS Performance*	**LUT - FMS Research Group**

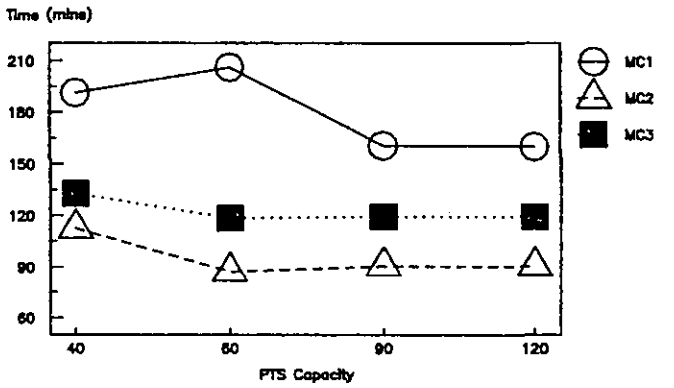

Figure VI.4.2	*Influence of PTS Capacity on Tool Wait Time*	**LUT - FMS Research Group**

Man / Capacity	MAN1 Load Run (mins)	MAN1 Empty Run (mins)	MAN1 Load/Unload (mins)	MAN2 Load Run (mins)	MAN2 Empty Run (mins)	MAN2 Load/Unload (mins)	MAN3 Load Run (mins)	MAN3 Empty Run (mins)	MAN3 Load/Unload (mins)
40	30.40	2.40	337.44	9.60	2.40	133.76	4.00	1.60	46.36
60	26.40	8.00	279.68	4.00	3.20	128.44	1.60	1.60	27.36
90	17.60	16.80	186.20	3.20	3.20	115.52	1.60	1.60	27.36
120	16.80	16.80	183.92	3.20	3.20	115.52	1.60	1.60	27.36

Figure VI.4.3	*Influence of PTS Capacity on Tool Transp. Perform.*	**LUT - FMS Research Group**

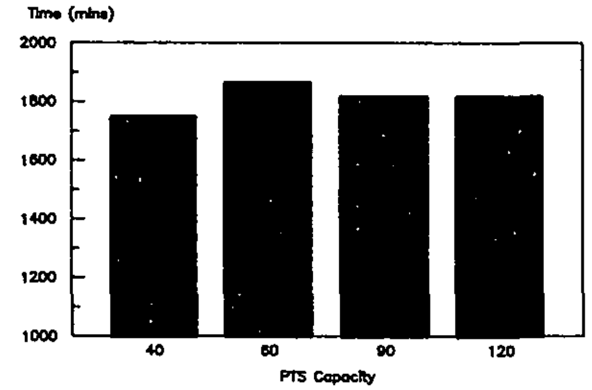

Figure VI.4.4 | *Influence of PTS Capacity on Total Throughput Time* | **LUT - FMS Research Group**

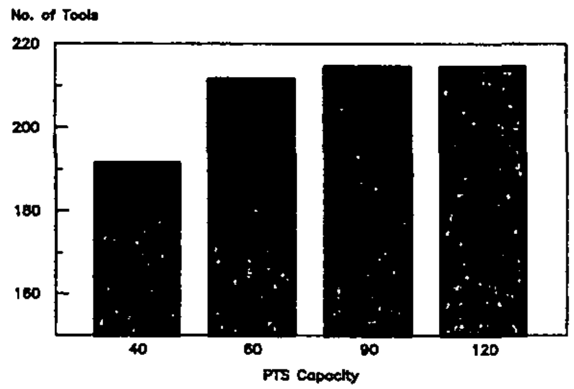

Figure VI.4.5 | *Influence of PTS Capacity on Cell Tool Requirements* | **LUT - FMS Research Group**

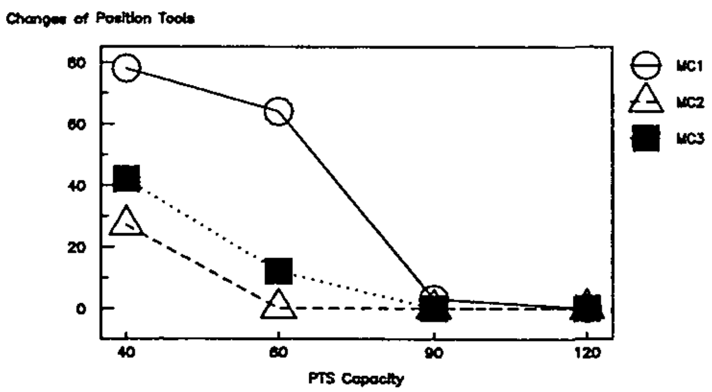

Figure VI.4.6 | *Influence of PTS Capacity on Tool Changes* | **LUT - FMS Research Group**

Appendix VII

STUDY OF THE EXTENDED CELL

Appendix VII.1

PRODUCTION REQUIREMENTS, PART PROCESS INFORMATION AND TOOL DETAILS

Table VII.1: Batching Machining List			
Batch Order	Part Type	Number Required	Machining Time
1	1	6	314.88
2	2	6	332.46
3	3	4	211.86
4	4	3	131.07
5	5	1	107.01
6	6	6	733.20
7	7	1	60.32
8	8	1	107.60
9	9	4	225.40
10	10	3	139.20
11	11	1	111.54
12	12	5	531.25
13	13	19	2181.20
14	14	8	293.84
15	15	3	154.68
16	16	5	351.35
17	17	3	129.93
18	18	5	259.35
19	19	6	270.00
20	20	11	480.37
Total machining time: 7136.49			

Table VII.2: Parts Kits				
Kit No.	No. of Parts	Part No.	Part Machining Time (mins)	Total Kit Machining Time (mins)
1	6	1 6 13 19 20 2	52.48 122.20 114.80 45.00 43.67 55.41	433.56
2	5	5 11 20 13 8 7	107.01 111.54 43.67 114.80 107.60 60.32	544.94
3	4	3 9 13 20	52.96 56.35 114.80 43.67	267.78
4	5	13 14 18 12 16	114.80 36.73 53.87 106.25 70.27	381.92
5	6	13 14 4 10 15 17	114.80 36.73 43.69 46.40 51.56 43.31	336.49
Remarks: Parts 13 and 20 – Common in kits 1, 2, 3 Parts 13 and 14 – Common in kits 4, 5				

Table VII.3: Kit Production	
Kits Number	Number Off
1	6
2	1
3	4
4	5
5	3
Total number of parts: 101	

Table VII.4: Kit Machining List	
Order Number	Kit Number
1	1
2	3
3	4
4	2
5	5
6	1
7	3
8	1
9	4
10	5
11	4
12	1
13	3
14	5
15	4
16	1
17	3
18	4
19	1

Table VII.5: Process Details for Part No. 1			
Part Description: Job 1		Part I.D.: P1	
Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	5.00	rough&fin	0002
2	5.00	spotdr	0003
3	13.50	dr42hol	0004
4	0.40	dr1hol	0055
5	0.30	re1hol	0056
6	1.10	dr2hol	0006
7	0.40	dr1hol	0012
8	4.50	dr14hol	0007
9	5.20	ta14hol	0008
10	2.50	dr2hol	0019
11	0.80	bore2hol	0020
12	0.45	re1hol	0021
13	1.45	re1hol	0022
Total cutting time: 40.60 Tool Change: 9.88 Load/Unload: 2.00		Total Time: 52.48	

Table VII.6: Process Details for Part No. 2

Part Description: Job 2 — Part I.D.: P2

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	5.00	rough&fin	0002
2	7.00	spotdr	0003
3	10.50	dr42hol	0004
4	1.10	dr2hol	0006
5	0.40	dr1hol	0012
6	4.50	dr14hol	0007
7	5.20	ta14hol	0008
8	2.50	dr2hol	0019
9	0.80	bore2hol	0020
10	1.45	re1hol	0021
11	6.60	re1hol	0022

Total cutting time: 45.05
Tool Change: 8.36
Load/Unload: 2.00
Total Time: 55.41

Table VII.7: Process Details for Part No. 3

Part Description: Job 3 — Part I.D.: P3

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	5.40	rough&fin	0001
2	10.75	r32hol	0005
3	13.15	bore2	0009
4	11.83	dr2hol	0010
5	2.33	dr4hol	0007
6	0.50	dr1hol	0011
7	0.37	ta1hol	0015
8	0.55	dr1hol	0013

Total cutting time: 44.88
Tool Change: 6.08
Load/Unload: 2.00
Total Time: 52.96

Table VII.8: Process Details for Part No. 4

Part Description: Job 4 — Part I.D.: P4

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	4.20	r&fpanro	0001
2	6.96	mill6pant	0038
3	1.95	dr6hol	0024
4	2.23	bore6	0025
5	1.70	re6hol	0027
6	14.53	dr6rifle	0026
7	1.28	dr2hol	0028
8	1.00	ta2hol	0029
9	1.00	dr4hol	0039

Total cutting time: 34.85
Tool Change: 6.84
Load/Unload: 2.00
Total Time: 43.69

Table VII.9: Process Details for Part No. 5			
Part Description: Job 5		Part I.D.: P5	
Op. No.	**Op. Time (mins)**	**Op. Description**	**Tool I.D.**
1	3.60	dr4hol	0080
2	9.60	dr2hol	0076
3	5.90	mill8spots	0037
4	1.80	bore2hol	0064
5	4.25	re1hol	0081
6	8.30	re1hol	0079
7	9.70	dr2hol	0076
8	2.60	c'bore1	0041
9	4.00	bore1hol	0040
10	0.90	ta1hol	0044
11	2.30	bore1hol	0065
12	9.20	sdr1hol	0067
13	6.80	dr4hol	0078
14	12.00	dr4hol	0077
15	7.90	millslot	0069
16	4.00	dr1hol	0068
Total cutting time: 92.85 Tool Change: 12.16 Load/Unload: 2.00		Total Time: 107.01	

Table VII.10: Process Details for Part No. 6			
Part Description: Job 5		Part I.D.: P5	
Op. No.	**Op. Time (mins)**	**Op. Description**	**Tool I.D.**
1	9.00	dr4hol	0080
2	6.00	dr2hol	0076
3	3.10	mill3spots	0037
4	3.30	bore2hol	0064
5	12.00	re1hol	0081
6	12.10	re1hol	0079
7	9.70	dr2hol	0076
8	2.60	c'bore1	0041
9	4.00	bore1hol	0040
10	8.40	ta1hol	0044
11	11.60	bore1hol	0065
12	2.20	sdr1hol	0067
13	5.70	dr5hol	0078
14	9.10	dr5hol	0077
15	10.00	millslot	0069
Total cutting time: 108.80 Tool Change: 11.40 Load/Unload: 2.00		Total Time: 122.20	

Table VII.11: Process Details for Part No. 7

Part Description: Job 7 — Part I.D.: P7

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	16.00	rough&fin	0001
2	7.00	roughbore	0053
3	8.00	finbore	0054
4	13.00	29/64dr	0049
5	3.00	3/4dr	0046
6	2.00	3/4taperR	0047
7	4.00	3/4taperT	0048

Total cutting time: 53.00
Tool Change: 5.32
Load/Unload: 2.00
Total Time: 60.32

Table VII.12: Process Details for Part No. 8

Part Description: Job 8 — Part I.D.: P8

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	10.00	dr44hol	0043
2	10.00	ta44hol	0044
3	12.00	dr12hol	0042
4	7.00	bore4hol	0051
5	9.00	bore4hol	0050
6	10.00	chamfer2	0052
7	6.00	dr8hol	0046
8	8.00	re8hol	0047
9	11.00	ta8hol	0048
10	15.00	dr14hol	0045

Total cutting time: 98.00
Tool Change: 7.6
Load/Unload: 2.00
Total Time: 107.60

Table VII.13: Process Details for Part No. 9

Part Description: Job 9 — Part I.D.: P9

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	10.00	dr1hol	0059
2	13.50	finmill	0060
3	1.50	dr1hol	0055
4	6.40	re1hol	0056
5	4.00	bore1hol	0063
6	4.20	bore1hol	0068
7	1.00	probe	0090
8	1.00	c'bore1hol	0057
9	3.40	bore1hol	0061
10	1.75	c'bore1	0091

Total cutting time: 46.75
Tool Change: 7.60
Load/Unload: 2.00
Total Time: 56.35

Table VII.14: Process Details for Part No. 10

Part Description: Job 7 | Part I.D.: P7

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	10.00	dr1hol	0059
2	13.50	finmill	0060
3	11.90	bore1hol	0063
4	3.30	bore1hol	0062
5	1.90	probe	0090

Total cutting time: 40.60
Tool Change: 3.80
Load/Unload: 2.00

Total Time: 46.40

Table VII.15: Process Details for Part No. 11

Part Description: Job 11 | Part I.D.: P11

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	10.80	millbosses	0002
2	13.10	sdr18hol	0003
3	12.25	dr2hol	0004
4	11.40	dr4hol	0006
5	4.27	dr14hol	0007
6	13.43	tap14hol	0008
7	2.58	dr1hol	0012
8	12.85	dr2hol	0019
9	8.77	bore2	0020
10	5.88	re1hol	0021
11	5.85	re1hol	0022

Total cutting time: 101.18
Tool Change: 8.36
Load/Unload: 2.00

Total Time: 111.54

Table VII.16: Process Details for Part No. 12

Part Description: Job 12 | Part I.D.: P12

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	4.70	sdr4hol	0089
2	7.90	re2hol	0084
3	2.10	dr2hol	0088
4	7.90	bore1hol	0072
5	5.10	dr1firle	0087
6	8.95	dr1hol	0071
7	3.60	ta1hol	0085
8	6.00	millface	0083
9	8.70	rough&fin	0092
10	10.00	dr9hol	0075
11	4.70	frd1hol	0074
12	7.70	c'bore1	0073
13	7.80	dr1hol	0071
14	5.50	ta1hol	0085
15	2.20	re1hol	0070

Total cutting time: 92.85
Tool Change: 11.40
Load/Unload: 2.00

Total Time: 106.25

Table VII.17: Process Details for Part No. 13			
Part Description: Job 13		Part I.D.: P13	
Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	11.00	sdr5hol	0089
2	7.90	bore2hol	0064
3	13.50	dr2hol	0088
4	2.15	bore1hol	0072
5	2.75	dr1rifle	0087
6	1.60	dr1hol	0071
7	8.40	ta1hol	0085
8	6.90	mill1face	0088
9	10.60	ta5hol	0086
10	9.30	dr12hol	0075
11	10.40	fdr1hol	0074
12	2.30	c'bore1	0073
13	7.30	dr1hol	0071
14	5.10	ta1hol	0085
15	2.20	re1hol	0070
Total cutting time: 101.40 Tool Change: 11.40 Load/Unload: 2.00		Total Time: 114.80	

Table VII.18: Process Details for Part No. 14			
Part Description: Job 14		Part I.D.: P14	
Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	9.10	dr1hol	0043
2	3.43	bore1hol	0030
3	2.07	boreEE	0031
4	3.23	rough&fin	0032
5	2.17	finishHH	0033
6	2.53	finishEE	0034
7	2.42	roughturn	0035
8	3.70	finishturn	0036
Total cutting time: 28.65 Tool Change: 6.08 Load/Unload: 2.00		Total Time: 36.73	

Table VII.19: Process Details for Part No. 15			
Part Description: Job 15		Part I.D.: P15	
Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	7.92	dr1hol	0014
2	9.01	tap1hol	0016
3	10.71	roughturn	0017
4	6.39	roughfin	0018
5	11.73	bore1hol	0023
Total cutting time: 45.76 Tool Change: 3.80 Load/Unload: 2.00		Total Time: 51.56	

Table VII.20: Process Details for Part No. 16

Part Description: Job 16 | Part I.D.: P16

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	8.08	MillRF	0052
2	8.54	MillLF	0040
3	11.41	dr1hol	0064
4	10.64	bore1hol	0067
5	2.36	dr1hol	0076
6	8.03	ta1hol	0077
7	8.84	grdRF	0079
8	4.29	grdLF	0081

Total cutting time: 62.19
Tool Change: 6.08
Load/Unload: 2.00

Total Time: 70.27

Table VII.21: Process Details for Part No. 17

Part Description: Job 17 | Part I.D.: P17

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	5.17	dr1hol	0092
2	1.60	ta1hol	0058
3	9.10	millRF	0082
4	3.15	grdRF	0094
5	8.57	dr1hol	0096
6	9.16	millFF	0099

Total cutting time: 36.75
Tool Change: 4.56
Load/Unload: 2.00

Total Time: 43.31

Table VII.22: Process Details for Part No. 18

Part Description: Job 18 | Part I.D.: P18

Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	6.11	dr1hol	0092
2	8.42	ta1hol	0066
3	4.63	millFF	0093
4	9.79	millRF	0095
5	9.81	grdRF	0097
6	4.61	dr1hol	0098
7	3.18	bore1	0100

Total cutting time: 46.55
Tool Change: 5.32
Load/Unload: 2.00

Total Time: 53.87

Table VII.23: Process Details for Part No. 19			
Part Description: Job 19		Part I.D.: P19	
Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	6.99	rough	0068
2	8.90	dr1hol	0090
3	5.05	bore1	0024
4	7.90	mill	0026
5	10.36	grind	0027
Total cutting time: 39.20 Tool Change: 3.80 Load/Unload: 2.00		Total Time: 45.00	

Table VII.24: Process Details for Part No. 20			
Part Description: Job 20		Part I.D.: P20	
Op. No.	Op. Time (mins)	Op. Description	Tool I.D.
1	8.96	dr1hol	0053
2	10.31	bore1hol	0054
3	12.00	millFF	0042
4	7.36	grdFF	0044
Total cutting time: 38.63 Tool Change: 3.04 Load/Unload: 2.00		Total Time: 43.67	

Table VII.25: Tool Details of the Extended Cell							
TOOL I.D.	TOOL DESC.	TOOL LIFE (mins)	MAX.% USE	TOOL I.D.	TOOL DESC.	TOOL LIFE (mins)	MAX.% USE
0001	FM	120	90	0052	BB	30	90
0002	FM	60	90	0053	BB	30	90
0003	CD	60	90	0054	BB	30	90
0004	DR	60	90	0055	DR	30	90
0005	RE	60	90	0056	RE	30	90
0006	DR	60	90	0057	SD	30	90
0007	DR	60	90	0058	DR	30	90
0008	TA	30	90	0059	DR	30	90
0009	EM	30	90	0060	EM	60	90
0010	DR	60	90	0061	BB	30	90
0011	DR	30	90	0062	BB	30	90
0012	DR	60	90	0063	BB	30	90
0013	FD	30	90	0064	BB	30	90
0014	TA	30	90	0065	BB	30	90
0015	TA	30	90	0066	BB	30	90
0016	FD	30	90	0067	SD	30	90
0017	RE	30	90	0068	SD	30	90
0018	TA	30	90	0069	SD	30	90
0019	DR	30	90	0070	RE	30	90
0020	BB	30	90	0071	FD	30	90
0021	RE	30	90	0072	BB	30	90
0022	RE	30	90	0073	BB	30	90
0023	DR	60	90	0074	FD	30	90
0024	DR	60	90	0075	DR	30	90
0025	SD	30	90	0076	DR	30	90
0026	GD	60	90	0077	FD	30	90
0027	RE	60	90	0078	DR	30	90
0028	FD	60	90	0079	RE	30	90
0029	TA	30	90	0080	DR	30	90
0030	BB	30	90	0081	RE	30	90
0031	BB	60	90	0082	DR	30	90
0032	BB	60	90	0083	SD	30	90
0033	BB	60	90	0084	RE	30	90
0034	BB	60	90	0085	TA	30	90
0035	BB	60	90	0086	TA	30	90
0036	BB	60	90	0087	GD	30	90
0042	DR	30	90	0088	GD	30	90
0043	DR	30	90	0091	SD	30	90
0044	TA	30	90	0092	FM	30	90
0045	FD	30	90	0037	SD	30	90
0046	FD	30	90	0038	EM	60	90
0047	RE	30	90	0039	DR	60	90
0048	TA	30	90	0040	DR	30	90
0049	DR	30	90	0041	FB	30	90
0050	BB	30	90	0089	CD	30	90
0051	BB	30	90	0090	PR	999	90
0093	TA	30	90	0097	DR	30	90
0094	DR	30	90	0098	FB	30	90
0095	BB	30	90	0099	CD	30	90
0096	BB	30	90	0100	BB	30	90
Total number of tools: 100							

Appendix VII.2

DATA INPUT OF THE EXTENDED CELL MODEL

Specification and Data Requirements for Knowledge Based Modelling of the Extended Cell

- Modelling Level 1

Introduction

The following lists the parameters for the study of the extended machine cell at level 1.

Parts and Processes

No. of part types: 20

Part I.D.	Part No.	Part Desc.	Daily Requir.
part1	1	job 1	6
part2	2	job 2	6
part3	3	job 3	4
part4	4	job 4	3
part5	5	job 5	1
part6	6	job 6	6
part7	7	job 7	1
part8	8	job 8	1
part9	9	job 9	4
part10	10	job 10	3
part11	11	job 11	1
part12	12	job 12	5
part13	13	job 13	19
part14	14	job 14	8
part15	15	job 15	3
part16	16	job 16	5

part17	17	job 17	3
part18	18	job 18	5
part19	19	job 19	6
part20	20	job 20	11

Part I.D.	No. of Ops	Op. No	Op. Time(mins)	Stations
part1	3	1	0	lu1 lu2
		2	50.48	mc1 - mc5
		3	20	lu1 lu2
part2	3	1	0	lu1 lu2
		2	53.41	mc1 - mc5
		3	20	lu1 lu2
part3	3	1	0	lu1 lu2
		2	50.96	mc1 - mc5
		3	20	lu1 lu2
part4	3	1	0	lu1 lu2
		2	41.69	mc1 - mc5
		3	20	lu1 lu2
part5	3	1	0	lu1 lu2
		2	105.01	mc1 - mc5
		3	20	lu1 lu2
part6	3	1	0	lu1 lu2
		2	120.20	mc1 - mc5
		3	20	lu1 lu2
part7	3	1	0	lu1 lu2
		2	58.32	mc1 - mc5
		3	20	lu1 lu2

part8	3	1	0	lu1 lu2
		2	105.60	mc1 - mc5
		3	20	lu1 lu2
part9	3	1	0	lu1 lu2
		2	54.35	mc1 - mc5
		3	20	lu1 lu2
part10	3	1	0	lu1 lu2
		2	44.40	mc1 - mc5
		3	20	lu1 lu2
part11	3	1	0	lu1 lu2
		2	109.54	mc1 - mc5
		3	20	lu1 lu2
part12	3	1	0	lu1 lu2
		2	104.25	mc1 - mc5
		3	20	lu1 lu2
part13	3	1	0	lu1 lu2
		2	112.80	mc1 - mc5
		3	20	lu1 lu2
part14	3	1	0	lu1 lu2
		2	34.73	mc1 - mc5
		3	20	lu1 lu2
part15	3	1	0	lu1 lu2
		2	49.56	mc1 - mc5
		3	20	lu1 lu2
part16	3	1	0	lu1 lu2
		2	68.27	mc1 - mc5
		3	20	lu1 lu2
part17	3	1	0	lu1 lu2

		2	41.31	mc1 - mc5
		3	20	lu1 lu2
part18	3	1	0	lu1 lu2
		2	51.87	mc1 - mc5
		3	20	lu1 lu2
part19	3	1	0	lu1 lu2
		2	43.00	mc1 - mc5
		3	20	lu1 lu2
part20	3	1	0	lu1 lu2
		2	41.67	mc1 - mc5
		3	20	lu1 lu2

Machines

No. of Machines: 5

Machine Type: Makino Horizontal Machining Centre

No. of Spindles: 1

Machine #1 I.D.: mc1

Machine #2 I.D.: mc2

Machine #3 I.D.: mc3

Machine #4 I.D.: mc4

Machine #5 I.D.: mc5

Machine Exchange Time: 1 min.

Buffer Exchange Time: 16 sec.(0.27 mins)

Load/Unload Stations

No. of Load/Unload Stations: 2

Load/Unload Station #1 I.D.: lu1

Load/Unload Station #2 I.D.: lu2

Station Exchange Time: 0.0

Transporters

No. of Transporters: 1

Transporter Type: AGV

Transporter I.D.: agv

Average Part Transfer Time: 0.8 mins

Transporter Pallet Capacity: 1

Pallet Exchange Time: 16 sec (0.27 mins).

Pallets/Fixtures

No. of Pallets/Fixtures: 6

Pallet No.	Pallet I.D.	Part Types	Parts Capacity
1	pallet1	part1 - part20	1
2	pallet2	part1 - part20	1
3	pallet3	part1 - part20	1
4	pallet4	part1 - part20	1
5	pallet5	part1 - part20	1
6	pallet6	part1 - part20	1
7	pallet7	part1 - part20	1
8	pallet8	part1 - part20	1
9	pallet9	part1 - part20	1
10	pallet10	part1 - part20	1

Specification and Data Requirements for Knowledge Based Modelling of the Extended Cell

- Modelling Level 2

Introduction

The following lists the parameters for the study of the extended machine cell at level 2.

Parts and Processes

No. of part types: 8

Part I.D.	Part No.	Part Desc.	Daily Requir.
part1	1	job 1	6
part2	2	job 2	6
part3	3	job 3	4
part4	4	job 4	3
part5	5	job 5	1
part6	6	job 6	6
part7	7	job 7	1
part8	8	job 8	1
part9	9	job 9	4
part10	10	job 10	3
part11	11	job 11	1
part12	12	job 12	5
part13	13	job 13	19
part14	14	job 14	8
part15	15	job 15	3

part16	16	job 16	5
part17	17	job 17	3
part18	18	job 18	5
part19	19	job 19	6
part20	20	job 20	11

Part I.D.	No. Ops	Op. No	Stations	No. Sub-Ops	Tl Activs.
part1	3	1	lu1 lu2	0	0
		2	mc1 - mc5	13	13
		3	lu1 lu2	0	0
part2	3	1	lu1 lu2	0	0
		2	mc1 - mc5	11	11
		3	lu1 lu2	0	0
part3	3	1	lu1 lu2	0	0
		2	mc1 - mc5	8	8
		3	lu1 lu2	0	0
part4	3	1	lu1 lu2	0	0
		2	mc1 - mc5	9	9
		3	lu1 lu2	0	0
part5	3	1	lu1 lu2	0	0
		2	mc1 - mc5	16	16
		3	lu1 lu2	0	0
part6	3	1	lu1 lu2	0	0
		2	mc1 - mc5	15	15
		3	lu1 lu2	0	0
part7	3	1	lu1 lu2	0	0
		2	mc1 - mc5	7	7
		3	lu1 lu2	0	0

part8	3	1	lu1 lu2	0	0
		2	mc1 - mc5	10	10
		3	lu1 lu2	0	0
part9	3	1	lu1 lu2	0	0
		2	mc1 - mc5	10	10
		3	lu1 lu2	0	0
part10	3	1	lu1 lu2	0	0
		2	mc1 - mc5	5	5
		3	lu1 lu2	0	0
part11	3	1	lu1 lu2	0	0
		2	mc1 - mc5	11	11
		3	lu1 lu2	0	0
part12	3	1	lu1 lu2	0	0
		2	mc1 - mc5	15	15
		3	lu1 lu2	0	0
part13	3	1	lu1 lu2	0	0
		2	mc1 - mc5	15	15
		3	lu1 lu2	0	0
part14	3	1	lu1 lu2	0	0
		2	mc1 - mc5	8	8
		3	lu1 lu2	0	0
part15	3	1	lu1 lu2	0	0
		2	mc1 - mc5	5	5
		3	lu1 lu2	0	0
part16	3	1	lu1 lu2	0	0
		2	mc1 - mc5	8	8
		3	lu1 lu2	0	0

part17	3	1	lu1 lu2	0	0
		2	mc1 - mc5	6	6
		3	lu1 lu2	0	0
part18	3	1	lu1 lu2	0	0
		2	mc1 - mc5	7	7
		3	lu1 lu2	0	0
part19	3	1	lu1 lu2	0	0
		2	mc1 - mc5	5	5
		3	lu1 lu2	0	0
part20	3	1	lu1 lu2	0	0
		2	mc1 - mc5	4	4
		3	lu1 lu2	0	0

<u>Machines</u>

No. of Machines: 5

Machine Type: Makino Horizontal Machining Centre

No. of Spindles: 1

Machine #1 I.D.: mc1

Machine #2 I.D.: mc2

Machine #3 I.D.: mc3

Machine #4 I.D.: mc4

Machine #5 I.D.: mc5

Tool Exchange Time (magazine to spindle): 0.26 mins.

Tool Index Time: 0.5 mins.

Buffer Type: Pallet exchange store

No. of Input Buffer Spaces: 1

No. of Output Buffer Spaces: 1

Machine Exchange Time: 1 min.

Buffer Exchange Time: 16 sec.(0.27 mins)

Load/Unload Stations

No. of Load/Unload Stations: 2

No. of Buffer Spaces: 0

Load/Unload Station #1 I.D.: lu1

Load/Unload Station #2 I.D.: lu2

Station Exchange Time : 0

Transporters

No. of Transporters: 1

Transporter Type: AGV

Transporter I.D.: agv

Average Part Transfer Time: 0.8 mins

Transporter Pallet Capacity: 1

Pallet Exchange Time: 16 sec (0.27 mins).

Pallets/Fixtures

No. of Pallets/Fixtures: 6

Pallet No.	Pallet I.D.	Part Types	Parts Capacity	Store
1	pallet1	part1 - part20	1	ps1-ps18
2	pallet2	part1 - part20	1	ps1-ps18
3	pallet3	part1 - part20	1	ps1-ps18
4	pallet4	part1 - part20	1	ps1-ps18
5	pallet5	part1 - part20	1	ps1-ps18
6	pallet6	part1 - part20	1	ps1-ps18
7	pallet7	part1 - part20	1	ps1-ps18

8	pallet8	part1 - part20	1	ps1-ps18
9	pallet9	part1 - part20	1	ps1-ps18
10	pallet10	part1 - part20	1	ps1-ps18

Temporary Storages

No. of Pallet Stands: 18

Pallet Stand Identities: ps1 - ps18

Pallet Stand Capacity: 1

Pallet Exchange Time: 16 sec.(0.27 mins).

Tools

No. of Tool Types: 100

Max. Percent Tool Life Utilisation for Tools: 90%

Specification and Data Requirements for Knowledge Based Modelling of the Extended Cell

- Modelling Level 3

Introduction

The following lists the parameters for the study of the extended machine cell at level 3.

Parts and Processes

No. of part types: 8

Part I.D.	Part No.	Part Desc.	Daily Requir.
part1	1	job 1	6
part2	2	job 2	6
part3	3	job 3	4
part4	4	job 4	3
part5	5	job 5	1
part6	6	job 6	6
part7	7	job 7	1
part8	8	job 8	1
part9	9	job 9	4
part10	10	job 10	3
part11	11	job 11	1
part12	12	job 12	5
part13	13	job 13	19
part14	14	job 14	8
part15	15	job 15	3

part16	16	job 16	5
part17	17	job 17	3
part18	18	job 18	5
part19	19	job 19	6
part20	20	job 20	11

Part I.D.	No. Ops	Op. No	Stations	No. Sub-Ops	T1 Activs.
part1	3	1	lu1 lu2	0	0
		2	mc1 - mc5	13	13
		3	lu1 lu2	0	0
part2	3	1	lu1 lu2	0	0
		2	mc1 - mc5	11	11
		3	lu1 lu2	0	0
part3	3	1	lu1 lu2	0	0
		2	mc1 - mc5	8	8
		3	lu1 lu2	0	0
part4	3	1	lu1 lu2	0	0
		2	mc1 - mc5	9	9
		3	lu1 lu2	0	0
part5	3	1	lu1 lu2	0	0
		2	mc1 - mc5	16	16
		3	lu1 lu2	0	0
part6	3	1	lu1 lu2	0	0
		2	mc1 - mc5	15	15
		3	lu1 lu2	0	0
part7	3	1	lu1 lu2	0	0
		2	mc1 - mc5	7	7
		3	lu1 lu2	0	0

part8	3	1	lu1 lu2	0	0
		2	mc1 - mc5	10	10
		3	lu1 lu2	0	0
part9	3	1	lu1 lu2	0	0
		2	mc1 - mc5	10	10
		3	lu1 lu2	0	0
part10	3	1	lu1 lu2	0	0
		2	mc1 - mc5	5	5
		3	lu1 lu2	0	0
part11	3	1	lu1 lu2	0	0
		2	mc1 - mc5	11	11
		3	lu1 lu2	0	0
part12	3	1	lu1 lu2	0	0
		2	mc1 - mc5	15	15
		3	lu1 lu2	0	0
part13	3	1	lu1 lu2	0	0
		2	mc1 - mc5	15	15
		3	lu1 lu2	0	0
part14	3	1	lu1 lu2	0	0
		2	mc1 - mc5	8	8
		3	lu1 lu2	0	0
part15	3	1	lu1 lu2	0	0
		2	mc1 - mc5	5	5
		3	lu1 lu2	0	0
part16	3	1	lu1 lu2	0	0
		2	mc1 - mc5	8	8
		3	lu1 lu2	0	0

part17	3	1	lu1 lu2	0	0
		2	mc1 - mc5	6	6
		3	lu1 lu2	0	0
part18	3	1	lu1 lu2	0	0
		2	mc1 - mc5	7	7
		3	lu1 lu2	0	0
part19	3	1	lu1 lu2	0	0
		2	mc1 - mc5	5	5
		3	lu1 lu2	0	0
part20	3	1	lu1 lu2	0	0
		2	mc1 - mc5	4	4
		3	lu1 lu2	0	0

Machines

No. of Machines: 5

Machine Type: Makino Horizontal Machining Centre

No. of Spindles: 1

Machine #1 I.D.: mc1

Machine #2 I.D.: mc2

Machine #3 I.D.: mc3

Machine #4 I.D.: mc4

Machine #5 I.D.: mc5

Magazine Capacity: 40

Tool Exchange Time (magazine to spindle): 0.27 mins.

Tool Index Time: 0.5 mins.

Buffer Type: Pallet exchange store

No. of Input Buffer Spaces: 1

No. of Output Buffer Spaces: 1

Machine Exchange Time: 1 min.

Buffer Exchange Time: 16 sec.(0.27 mins)

Load/Unload Stations

No. of Load/Unload Stations: 2

No. of Buffer Spaces: 0

Load/Unload Station #1 I.D.: lu1

Load/Unload Station #2 I.D.: lu2

Station Exchange Time: 0

Transporters

No. of Transporters: 1

Transporter Type: AGV

Transporter I.D.: agv

Average Part Transfer Time: 0.8 mins

Transporter Pallet Capacity: 1

Pallet Exchange Time: 16 sec (0.27 mins).

Pallets/Fixtures

No. of Pallets/Fixtures: 6

Pallet No.	Pallet I.D.	Part Types	Parts Capacity	Store
1	pallet1	part1 - part20	1	ps1-ps18
2	pallet2	part1 - part20	1	ps1-ps18
3	pallet3	part1 - part20	1	ps1-ps18
4	pallet4	part1 - part20	1	ps1-ps18
5	pallet5	part1 - part20	1	ps1-ps18
6	pallet6	part1 - part20	1	ps1-ps18

7	pallet7	part1 - part20	1	ps1-ps18
8	pallet8	part1 - part20	1	ps1-ps18
9	pallet9	part1 - part20	1	ps1-ps18
10	pallet10	part1 - part20	1	ps1-ps18

Temporary Storages

No. of Pallet Stands: 18

Pallet Stand Identities: ps1 - ps18

Pallet Stand Capacity: 1

Pallet Exchange Time: 16 sec.(0.27 mins).

Tools

No. of Tools: 100

Max. Percent Tool Life Utilisation for Tools: 90%

Tool Transporters

No. of Tool Transporters: 3

Transporter #1 I.D.: man1

Transporter #2 I.D.: man2

Transporter #3 I.D.: man3

Average Transfer Time: 0.8 mins.

Transporter Tool Capacity: 40

Tool Exchange Time: 0.26 mins/tool

Secondary Tool Store

STS I.D.: stoolstore

Tool Exchange Time: 0.26 mins/tool

Tool Capacity: infinite

Appendix VII.3

STUDY OF THE NUMBER OF PALLETS

VII.3.1 Introduction

This appendix focuses on the investegation of the number of pallets in the extended cell. Influence of the pallets on the work flow performance is discussed. Finally an appropriate number of pallets is suggested for the cell.

VII.3.2 Planned Experiments

The level 1 of the knowledge based modelling system is chosen to carry out the experiments. Major operational rules include the Shortest Total Processing Time release rule, the FIFO scheduling rule and the Least Workload station selection rule. The data input is the same as what was described in Chapter16, except that 6, 8, 10, 12, 14, 16 or 18 pallets are to be used in the cell respectively.

VII.3.3 Influence on Overall Cell Performance

As shown in Figure VII.3.1 to VI.3.3, with more pallets in the cell, the total throughput time dropped down and the throughput rate increased. However, the average part lead time became increasingly longer. The reason for this should be that few pallets tend to keep the major cell elements, such as machines, to wait for components, and thus the overall utilisation of the cell is very poor, leading to the decrease in the throughput rate. Notably, when 14 or more pallets were used, the throughput becomes nearly steady. Thus to achieve the best throughput performance, 14 pallets is adequate for the cell.

VII.3.4 Influence on Part Lead Times

A detailed summary of the part lead times in all seven runs is given in Figure VII.3.4. For every part, the laed time is increasing with more pallets introduced into the cell. This is because when more pallets are circulating in the cell, the components on pallets have to spend more time on queueing or waiting for transferring and processing.

VII.3.5 Influence on Machine Performance

It can be expected that when more pallets are in the cell, each machine should have a longer queue and therefore, the utilisation of the machines should be higher. This can be seen in Figure VII.3.5, where the machine idle time drops siginificantly with more pallets are used in the cell. For the same reason, the queue length of the machine became longer (Figure VII.3.6).

VII.3.6 Conclusions

It can be concluded, based on the above discussion, that the number of pallets used in a cell can significantly affect the work flow performance. Generally speaking, the more the pallets, the longer the part lead times but the higher the machine utilisation. For the extended cell, 14 pallets seem to be the best with regard to the overall cell performance.

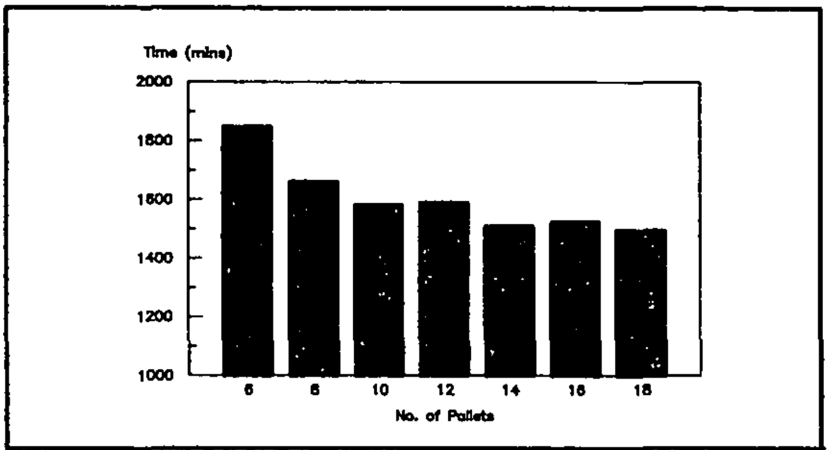

Figure VII.3.1 | *Influence of Pallets on Total Throughput Time* | **LUT - FMS Research Group**

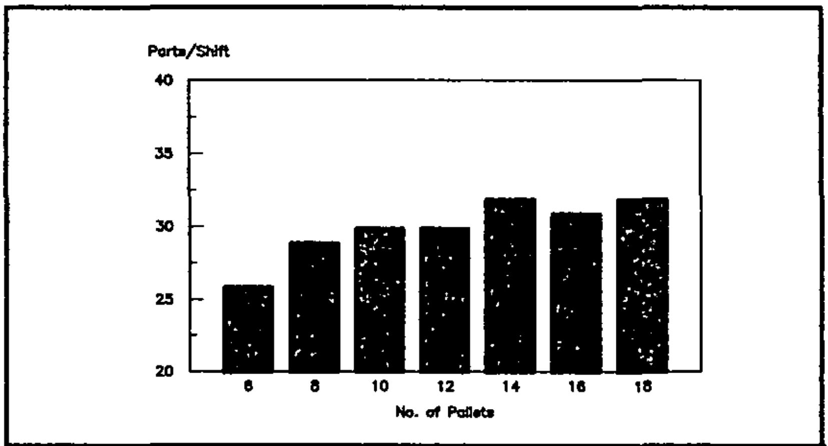

Figure VII.3.2 | *Influence of Pallets on Total Throughput Rate* | **LUT - FMS Research Group**

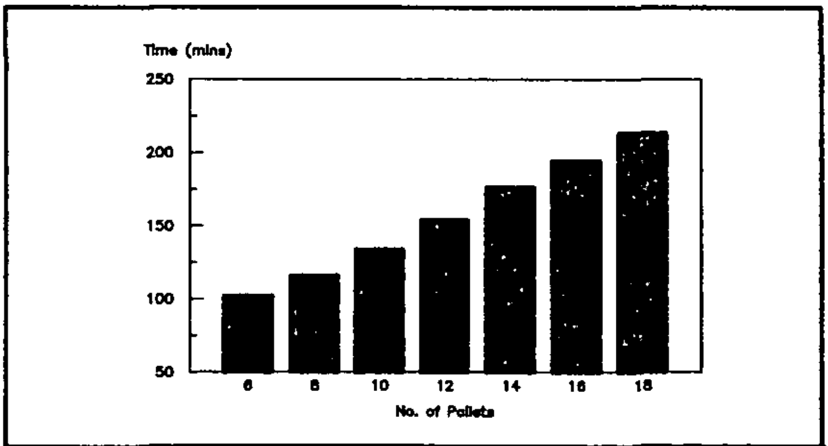

Figure VII.3.3 | *Influence of Pallets on Average Part Lead Time* | **LUT - FMS Research Group**

Part Type \ Pallets	6	8	10	12	14	16	18
1	84.52	85.37	88.56	93.33	106.67	103.33	133.33
2	87.40	91.27	89.88	111.14	116.06	127.74	136.06
3	86.27	92.32	91.42	109.43	105.92	125.00	145.00
4	74.19	71.01	94.27	92.11	112.11	120.00	138.78
5	133.43	133.43	163.36	251.47	249.61	165.55	252.53
6	151.72	187.93	236.49	274.93	320.63	364.01	416.63
7.	84.60	145.23	166.57	137.13	203.77	260.36	252.65
8	141.01	178.12	222.40	272.99	317.20	371.10	408.32
9	86.76	106.71	163.28	179.23	195.66	215.87	178.43
10	72.71	78.67	85.71	102.45	107.89	126.67	149.11
11	143.83	209.20	226.34	337.20	334.59	369.08	425.12
12	133.45	161.72	165.32	191.72	200.60	201.78	213.21
13	147.31	174.17	214.64	247.97	287.28	325.82	358.55
14	74.76	69.88	83.65	92.04	102.96	115.56	146.58
15	87.50	90.43	110.81	106.67	127.18	152.36	167.69
16	100.01	103.66	105.55	130.64	135.09	149.17	138.69
17	69.07	88.60	89.32	86.67	125.95	153.84	258.06
18	82.25	95.83	92.71	94.57	104.00	108.00	120.73
19	82.26	74.13	81.84	118.67	210.69	208.53	199.78
20	85.00	98.91	106.84	114.79	114.79	114.36	114.79

Figure VII.3.4	*Influence of Pallets on Part Lead Times*	LUT-FMS Research Group

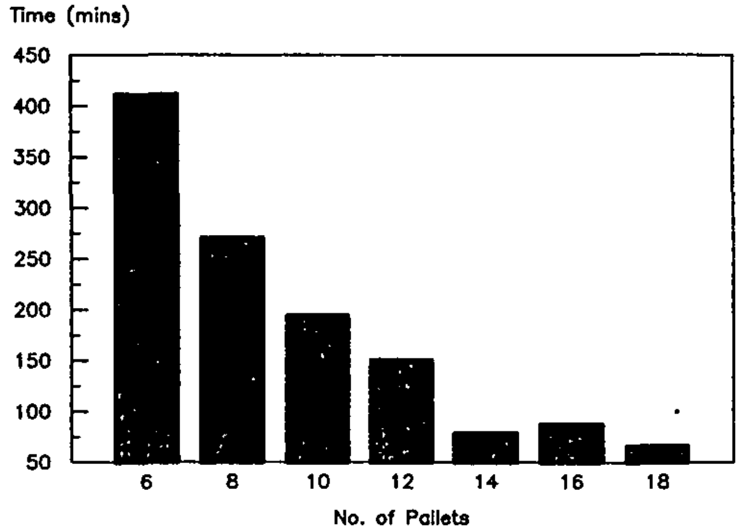

Figure VII.3.5	*Influence of Pallets on Machine Idle Time (machine #1)*	LUT - FMS Research Group

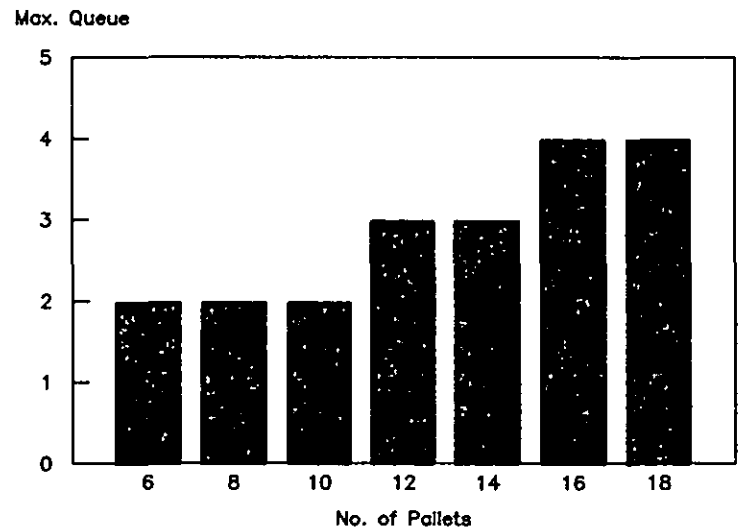

Figure VII.3.6	*Influence of Pallets on Machine Queue Length (machine #1)*	LUT - FMS Research Group

Appendix VII.4

RESULTS OF THE EMULATOR BASED STUDY

***EMULATION OUTPUT ***

EMULATION START TIME= 0.000 mins.

EMULATION RUN TIME = 1580.980 mins.

PART THROUGHPUT

PART	NUMBER COMPLETED
1	6
2	6
3	4
4	3
5	1
6	6
7	1
8	1
9	4
10	3
11	1
12	5
13	19
14	8
15	3
16	5
17	3
18	5
19	6
20	11

PART LEAD TIMES

PART 1	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	98.41	122.48	75.28
MACHINING TIME	50.48	50.48	50.48
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.29	2.70	0.28
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	23.56	48.64	1.42

PART 2	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	138.29	160.14	116.85

MACHINING TIME	53.41	53.41	53.41
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.39	2.68	0.30
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	60.41	80.97	40.06

PART 3	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	117.62	118.25	115.74
MACHINING TIME	50.96	50.96	50.96
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.64	2.70	0.28
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	41.94	42.71	41.42

PART 4	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	116.08	116.25	115.74
MACHINING TIME	41.69	41.69	41.69
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.49	2.10	0.90
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	49.82	50.58	49.38

PART 5	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	164.33	164.33	164.33
MACHINING TIME	105.01	105.01	105.01
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	0.89	0.89	0.89
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	35.35	35.35	35.35

PART 6	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	180.37	241.37	147.90
MACHINING TIME	120.20	120.20	120.20
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.29	2.69	0.29
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	35.80	97.80	3.13

PART 7	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	160.20	160.20	160.20

MACHINING TIME	58.32	58.32	58.32
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.50	1.50	1.50
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	77.30	77.30	77.30

PART 8	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	211.26	211.26	211.26
MACHINING TIME	105.60	105.60	105.60
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	2.09	2.09	2.09
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	80.49	80.49	80.49

PART 9	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	159.01	205.43	109.78
MACHINING TIME	54.35	54.35	54.35
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.34	2.69	0.30
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	80.23	127.70	29.66

PART10	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	115.32	164.94	70.81
MACHINING TIME	44.40	44.40	44.40
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	2.49	2.70	2.08
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	45.35	95.38	0.63

PART11	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	167.61	167.61	167.61
MACHINING TIME	109.54	109.54	109.54
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.50	1.50	1.50
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	33.49	33.49	33.49

PART12	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	189.25	228.80	141.08

MACHINING TIME	104.25	104.25	104.25
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.13	2.09	0.29
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	60.79	100.57	12.86

PART13	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	224.29	249.60	145.38
MACHINING TIME	112.80	112.80	112.80
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.59	2.69	0.29
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	86.83	113.42	6.82

PART14	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	148.63	179.96	107.09
MACHINING TIME	34.73	34.73	34.73
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.42	2.68	0.30
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	89.40	121.85	47.79

PART15	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	115.82	133.37	98.23
MACHINING TIME	49.56	49.56	49.56
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.89	2.69	0.90
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	41.28	58.64	22.90

PART16	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	120.22	138.90	96.81
MACHINING TIME	68.27	68.27	68.27
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.25	2.09	0.29
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	27.62	46.07	3.75

PART17	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	108.03	116.05	93.40

MACHINING TIME	41.31	41.31	41.31
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.29	2.68	0.30
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	42.35	50.76	26.33

PART18	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	115.95	133.87	98.33
MACHINING TIME	51.87	51.87	51.87
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.37	2.69	0.29
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	39.63	58.63	21.07

PART19	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	114.90	138.02	92.20
MACHINING TIME	47.33	69.00	43.00
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.69	2.69	0.88
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	42.80	69.84	21.79

PART20	AVERAGE (mins)	MAXIMUM (mins)	MINIMUM (mins)
LEAD TIME	114.03	132.81	93.08
MACHINING TIME	42.26	48.16	41.67
REFIXTURE TIME	0.00	0.00	0.00
REPALLET TIME	20.00	20.00	20.00
TRANSPORT TIME	1.27	2.70	0.29
L/UNLOAD TIME	3.08	3.08	3.08
WAITING TIME	47.42	67.18	26.23

****

STATION PERFORMANCE FIGURES

MACHINE NO: 1	TIME (mins.)	Percentage(%)
SET UP & CUTTING	1435.08	90.8
LOAD AND UNLOAD	40.00	2.5
BREAKDOWN	0.00	0.0
IDLE	105.90	6.7

FIRST TIME USED	0.82
LAST TIME USED	1490.39
TIME SINCE LAST USED	90.59

MACHINE NO: 2	TIME (mins.)	Percentage(%)
SET UP & CUTTING	1465.06	92.7
LOAD AND UNLOAD	44.00	2.8
BREAKDOWN	0.00	0.0
IDLE	71.92	4.5

FIRST TIME USED	2.07	
LAST TIME USED	1511.33	
TIME SINCE LAST USED	69.65	

MACHINE NO: 3	TIME (mins.)	Percentage(%)
SET UP & CUTTING	1400.54	88.6
LOAD AND UNLOAD	42.00	2.7
BREAKDOWN	0.00	0.0
IDLE	138.44	8.8

FIRST TIME USED	3.94	
LAST TIME USED	1494.56	
TIME SINCE LAST USED	86.42	

MACHINE NO: 4	TIME (mins.)	Percentage(%)
SET UP & CUTTING	1380.29	87.3
LOAD AND UNLOAD	38.00	2.4
BREAKDOWN	0.00	0.0
IDLE	162.69	10.3

FIRST TIME USED	6.39	
LAST TIME USED	1488.12	
TIME SINCE LAST USED	92.86	

MACHINE NO: 5	TIME (mins.)	Percentage(%)
SET UP & CUTTING	1286.01	81.3
LOAD AND UNLOAD	38.00	2.4
BREAKDOWN	0.00	0.0
IDLE	256.97	16.3

FIRST TIME USED	9.46	
LAST TIME USED	1511.79	
TIME SINCE LAST USED	69.19	

TRANSPORTER PERFORMANCE FIGURES

AGV. NO : 1	TIME (mins.)	Percentage(%)
TRAVELLING	214.52	13.6
LOAD AND UNLOAD	113.12	7.2
BREAKDOWN	0.00	0.0
IDLE	1253.34	79.3

****

LOAD/UNLOAD PERFORMANCE FIGURES

NUMBER IN USE	TIME (mins.)	Percentage(%)
0	270.96	17.14
1	501.81	31.74
2	808.21	51.12

LOAD/UNLOAD NO: 1	TIME (mins.)	Percentage(%)
REPALLETISING	1100.00	69.6
REFIXTURING	0.00	0.0
LOAD AND UNLOAD	29.70	1.9
WAITING	19.40	1.2
IDLE	431.88	27.3

FIRST TIME USED	0.01
LAST TIME USED	1580.96
TIME SINCE LAST USED	0.02

LOAD/UNLOAD NO: 2	TIME (mins.)	Percentage(%)
REPALLETISING	920.00	58.2
REFIXTURING	0.00	0.0
LOAD AND UNLOAD	24.84	1.6
WAITING	24.29	1.5
IDLE	611.85	38.7

FIRST TIME USED	0.01
LAST TIME USED	1559.15
TIME SINCE LAST USED	21.83

****

MAN PERFORMANCE FIGURES

NUMBER IN USE	TIME (mins.)	Percentage(%)
0	306.03	19.36
1	529.90	33.52
2	745.05	47.13
3	0.00	0.00

MAN No. : 1	TIME (mins.)	Percentage(%)
REPALLETISING	1100.00	69.6
LOAD AND UNLOAD	0.00	0.0
MANUAL VEHICLE	0.00	0.0
MACHINE SET UP	0.00	0.0
MACHINING OPERATION	0.00	0.0
PTS TOOL LD/UNLOAD	0.00	0.0
STS TOOL LD/UNLOAD	0.00	0.0
IDLE	480.99	30.4

UNAVAILABLE	0.00	0.0

FIRST TIME USED	55.29
LAST TIME USED	1580.96
TIME SINCE LAST USED	0.02

MAN No. : 2	TIME (mins.)	Percentage(%)
REPALLETISING	920.00	58.2
LOAD AND UNLOAD	0.00	0.0
MANUAL VEHICLE	0.00	0.0
MACHINE SET UP	0.00	0.0
MACHINING OPERATION	0.00	0.0
PTS TOOL LD/UNLOAD	0.00	0.0
STS TOOL LD/UNLOAD	0.00	0.0
IDLE	660.99	41.8
UNAVAILABLE	0.00	0.0

FIRST TIME USED	56.65
LAST TIME USED	1559.15
TIME SINCE LAST USED	21.83

MAN No. : 3	TIME (mins.)	Percentage(%)
REPALLETISING	0.00	0.0
LOAD AND UNLOAD	0.00	0.0
MANUAL VEHICLE	0.00	0.0
MACHINE SET UP	0.00	0.0
MACHINING OPERATION	0.00	0.0
PTS TOOL LD/UNLOAD	0.00	0.0
STS TOOL LD/UNLOAD	0.00	0.0
IDLE	0.00	0.0
UNAVAILABLE	1580.99	0.0

FIRST TIME USED	0.00
LAST TIME USED	0.00
TIME SINCE LAST USED	1580.98

****

MACHINE WORK LISTS

MACHINE NO: 1

pallet	part type	processing start time
1	1	1.82
6	1	54.31
1	2	106.80
6	3	162.22
2	6	215.19
5	6	337.40
10	9	459.61
6	12	515.97
2	13	622.23
5	13	737.04
2	13	851.85
5	13	966.66

2	14	1081.47
1	16	1127.00
6	17	1197.28
9	18	1240.60
10	18	1294.48
9	20	1353.88
10	20	1397.56
8	20	1447.73

MACHINE NO: 2

pallet	part type	processing start time
2	1	3.07
7	2	55.56
2	2	110.98
7	4	166.40
10	5	210.10
6	6	317.12
2	9	439.33
5	12	495.69
1	12	601.95
6	13	708.21
1	13	823.02
6	13	937.83
1	14	1052.64
6	14	1089.38
4	15	1126.12
7	16	1177.69
4	17	1247.97
7	19	1291.29
3	19	1336.30
1	20	1381.31
3	20	1424.99
4	20	1468.67

MACHINE NO: 3

pallet	part type	processing start time
3	1	4.94
8	2	57.43
3	3	112.85
8	4	165.82
3	6	218.53
7	7	340.74
1	9	401.07
7	11	457.43
8	12	568.98
7	13	675.24
8	13	790.05
7	13	904.86
8	14	1019.67
7	14	1056.41
8	14	1093.15
10	16	1146.35
3	16	1216.63
2	18	1286.91
8	19	1340.79

2	20	1385.80
5	20	1451.90

MACHINE NO: 4

pallet	part type	processing start time
4	1	7.39
9	2	59.88
4	3	115.30
9	4	171.49
4	6	222.57
8	8	344.78
3	10	452.39
4	12	498.80
10	13	605.06
4	13	719.87
10	13	834.68
4	13	949.49
10	14	1064.30
5	15	1104.55
2	16	1169.42
5	18	1239.70
6	19	1307.44
5	19	1352.45
6	20	1445.46

MACHINE NO: 5

pallet	part type	processing start time
5	1	10.46
10	2	62.95
5	3	124.65
1	6	195.16
9	9	317.37
4	10	385.86
9	10	432.27
9	13	508.01
3	13	622.82
9	13	737.63
3	13	852.44
9	13	967.25
3	14	1082.06
9	15	1122.98
8	17	1197.25
1	18	1261.60
4	19	1331.11
7	20	1398.62
9	20	1469.13

MACHINE 1

Tool No.	Count	Tool Life	Total Tool Machining
1	1	108.00	5.40
2	1	54.00	15.00
3	1	54.00	17.00
4	1	54.00	37.50
5	1	54.00	10.75
6	1	54.00	3.30
7	1	54.00	15.83
8	1	27.00	15.60
9	1	27.00	13.15
10	1	54.00	11.83
11	1	27.00	0.50
12	1	54.00	1.20
13	1	27.00	0.55
15	1	27.00	0.37
19	1	27.00	7.50
20	1	27.00	2.40
21	1	27.00	2.35
22	1	27.00	9.50
30	1	27.00	3.43
31	1	54.00	2.07
32	1	54.00	3.23
33	1	54.00	2.17
34	1	54.00	2.53
35	1	54.00	2.42
36	1	54.00	3.70
37	1	27.00	6.20
40	1	27.00	16.54
41	1	27.00	5.20
42	2	27.00	36.00
43	1	27.00	9.10
44	2	27.00	38.88
52	1	27.00	8.08
53	1	27.00	26.88
54	2	27.00	30.93
55	1	27.00	2.30
56	1	27.00	7.00
57	1	27.00	1.00
58	1	27.00	1.60
59	1	27.00	10.00
60	1	54.00	13.50
61	1	27.00	3.40
63	1	27.00	4.00
64	2	27.00	49.61
65	1	27.00	23.20
66	1	27.00	16.84
67	1	27.00	15.04
68	1	27.00	4.20
69	1	27.00	20.00
70	1	27.00	11.00
71	2	27.00	52.35

72	1	27.00	16.50
73	1	27.00	16.90
74	2	27.00	46.30
75	2	27.00	47.20
76	2	27.00	33.76
77	1	27.00	26.23
78	1	27.00	11.40
79	2	27.00	33.04
80	1	27.00	18.00
81	2	27.00	28.29
82	1	27.00	9.10
83	1	27.00	6.00
84	1	27.00	7.90
85	3	27.00	65.10
86	2	27.00	42.40
87	1	27.00	14.10
88	4	27.00	83.70
89	2	27.00	48.70
90	1	27.00	1.00
91	1	27.00	1.75
92	1	27.00	26.09
93	1	27.00	9.26
94	1	27.00	3.15
95	1	27.00	19.58
96	1	27.00	8.57
97	1	27.00	19.62
98	1	27.00	9.22
99	1	27.00	9.16
100	1	27.00	6.36

NUMBER OF TOOLS USED ON MACHINE 1 IS 96
TOOL STORE CAPACITY ON MACHINE 1 IS 40

MACHINE 2
============

Tool No.	Count	Tool Life	Total Tool Machining
1	1	108.00	4.20
2	1	54.00	15.00
3	1	54.00	19.00
4	1	54.00	34.50
6	1	54.00	3.30
7	1	54.00	13.50
8	1	27.00	15.60
12	1	54.00	1.20
14	1	27.00	7.92
16	1	27.00	9.01
17	1	27.00	10.71
18	1	27.00	6.39
19	1	27.00	7.50
20	1	27.00	2.40
21	1	27.00	3.35

22	1	27.00	14.65
23	1	54.00	11.73
24	1	54.00	12.05
25	1	27.00	2.23
26	1	54.00	30.33
27	1	54.00	22.42
28	1	54.00	1.28
29	1	27.00	1.00
30	1	27.00	6.86
31	1	54.00	4.14
32	1	54.00	6.46
33	1	54.00	4.34
34	1	54.00	5.06
35	1	54.00	4.84
36	1	54.00	7.40
37	1	27.00	9.00
38	1	27.00	6.96
39	1	27.00	1.00
40	1	27.00	16.54
41	1	27.00	5.20
42	2	27.00	36.00
43	1	27.00	18.20
44	2	27.00	31.38
52	1	27.00	8.08
53	1	27.00	26.88
54	2	27.00	30.93
55	1	27.00	1.90
56	1	27.00	6.70
57	1	27.00	1.00
58	1	27.00	1.60
59	1	27.00	10.00
60	1	54.00	13.50
61	1	27.00	3.40
63	1	27.00	4.00
64	2	27.00	40.21
65	1	27.00	13.90
67	1	27.00	22.04
68	1	27.00	22.18
69	1	27.00	17.90
70	1	27.00	11.00
71	3	27.00	60.20
72	1	27.00	22.25
73	1	27.00	22.30
74	2	27.00	40.60
75	2	27.00	47.90
76	2	27.00	37.36
77	2	27.00	29.13
78	1	27.00	12.50
79	2	27.00	29.24
80	1	27.00	12.60
81	1	27.00	20.54
82	1	27.00	9.10
83	1	27.00	12.00
84	1	27.00	15.80
85	3	27.00	62.70

86	2	27.00	31.80
87	1	27.00	14.45
88	3	27.00	65.40
89	2	27.00	42.40
90	1	27.00	18.80
91	1	27.00	1.75
92	1	27.00	22.57
94	1	27.00	3.15
96	1	27.00	8.57
99	1	27.00	9.16

NUMBER OF TOOLS USED ON MACHINE 2 IS 97
TOOL STORE CAPACITY ON MACHINE 2 IS 40

MACHINE 3
============

Tool No.	Count	Tool Life	Total Tool Machining
1	1	108.00	25.60
2	1	54.00	20.80
3	1	54.00	25.10
4	1	54.00	36.25
5	1	54.00	10.75
6	1	54.00	13.60
7	1	54.00	15.60
8	1	27.00	23.83
9	1	27.00	13.15
10	1	54.00	11.83
11	1	27.00	0.50
12	1	54.00	3.38
13	1	27.00	0.55
15	1	27.00	0.37
19	1	27.00	17.85
20	1	27.00	10.37
21	1	27.00	7.78
22	1	27.00	13.90
24	1	54.00	7.00
25	1	27.00	2.23
26	1	54.00	22.43
27	1	54.00	12.06
28	1	54.00	1.28
29	1	27.00	1.00
30	1	27.00	10.29
31	1	54.00	6.21
32	1	54.00	9.69
33	1	54.00	6.51
34	1	54.00	7.59
35	1	54.00	7.26
36	1	54.00	11.10
37	1	27.00	3.10
38	1	27.00	6.96
39	1	27.00	1.00

40	1	27.00	21.08
41	1	27.00	2.60
42	1	27.00	24.00
43	2	27.00	27.30
44	1	27.00	23.12
46	1	27.00	3.00
47	1	27.00	2.00
48	1	27.00	4.00
49	1	27.00	13.00
52	1	27.00	16.16
53	1	27.00	24.92
54	2	27.00	28.62
55	1	27.00	1.90
56	1	27.00	6.70
57	1	27.00	1.00
59	1	27.00	10.00
60	1	54.00	13.50
61	1	27.00	3.40
63	1	27.00	4.00
64	2	27.00	49.82
65	1	27.00	11.60
66	1	27.00	8.42
67	1	27.00	23.48
68	1	27.00	11.19
69	1	27.00	10.00
70	1	27.00	8.80
71	2	27.00	43.45
72	1	27.00	14.35
73	1	27.00	14.60
74	2	27.00	35.90
75	2	27.00	37.90
76	1	27.00	20.42
77	1	27.00	25.16
78	1	27.00	5.70
79	2	27.00	29.78
80	1	27.00	9.00
81	1	27.00	20.58
83	1	27.00	6.00
84	1	27.00	7.90
85	2	27.00	51.60
86	2	27.00	31.80
87	1	27.00	11.35
88	3	27.00	63.30
89	2	27.00	37.70
90	1	27.00	9.90
91	1	27.00	1.75
92	1	27.00	14.81
93	1	27.00	4.63
95	1	27.00	9.79
97	1	27.00	9.81
98	1	27.00	4.61
100	1	27.00	3.18

NUMBER OF TOOLS USED ON MACHINE 3 IS 98

TOOL STORE CAPACITY ON MACHINE 3 IS 40

MACHINE 4
===========

Tool No.	Count	Tool Life	Total Tool Machining
1	1	108.00	9.60
2	1	54.00	10.00
3	1	54.00	12.00
4	1	54.00	24.00
5	1	54.00	10.75
6	1	54.00	2.20
7	1	54.00	11.33
8	1	27.00	10.40
9	1	27.00	13.15
10	1	54.00	11.83
11	1	27.00	0.50
12	1	54.00	0.80
13	1	27.00	0.55
14	1	27.00	7.92
15	1	27.00	0.37
16	1	27.00	9.01
17	1	27.00	10.71
18	1	27.00	6.39
19	1	27.00	5.00
20	1	27.00	1.60
21	1	27.00	1.90
22	1	27.00	8.05
23	1	54.00	11.73
24	1	54.00	12.05
25	1	27.00	2.23
26	1	54.00	30.33
27	1	54.00	22.42
28	1	54.00	1.28
29	1	27.00	1.00
30	1	27.00	3.43
31	1	54.00	2.07
32	1	54.00	3.23
33	1	54.00	2.17
34	1	54.00	2.53
35	1	54.00	2.42
36	1	54.00	3.70
37	1	27.00	3.10
38	1	27.00	6.96
39	1	27.00	1.00
40	1	27.00	12.54
41	1	27.00	2.60
42	1	27.00	24.00
43	1	27.00	19.10
44	1	27.00	25.76
45	1	27.00	15.00
46	1	27.00	6.00
47	1	27.00	8.00

48	1	27.00	11.00
50	1	27.00	9.00
51	1	27.00	7.00
52	1	27.00	18.08
53	1	27.00	8.96
54	1	27.00	10.31
55	1	27.00	0.40
56	1	27.00	0.30
59	1	27.00	10.00
60	1	54.00	13.50
62	1	27.00	3.30
63	1	27.00	11.90
64	2	27.00	46.31
65	1	27.00	11.60
66	1	27.00	8.42
67	1	27.00	12.84
68	1	27.00	13.98
69	1	27.00	10.00
70	1	27.00	11.00
71	2	27.00	52.35
72	1	27.00	16.50
73	1	27.00	16.90
74	2	27.00	46.30
75	2	27.00	47.20
76	1	27.00	18.06
77	1	27.00	17.13
78	1	27.00	5.70
79	1	27.00	20.94
80	1	27.00	9.00
81	1	27.00	16.29
83	1	27.00	6.00
84	1	27.00	7.90
85	3	27.00	65.10
86	2	27.00	42.40
87	1	27.00	14.10
88	4	27.00	83.70
89	2	27.00	48.70
90	1	27.00	19.70
92	1	27.00	14.81
93	1	27.00	4.63
95	1	27.00	9.79
97	1	27.00	9.81
98	1	27.00	4.61
100	1	27.00	3.18

NUMBER OF TOOLS USED ON MACHINE 4 IS 102
TOOL STORE CAPACITY ON MACHINE 4 IS 40

MACHINE 5
===========

Tool No.	Count	Tool Life	Total Tool Machining

1	1	108.00	5.40
2	1	54.00	10.00
3	1	54.00	12.00
4	1	54.00	24.00
5	1	54.00	10.75
6	1	54.00	2.20
7	1	54.00	11.33
8	1	27.00	10.40
9	1	27.00	13.15
10	1	54.00	11.83
11	1	27.00	0.50
12	1	54.00	0.80
13	1	27.00	0.55
14	1	27.00	7.92
15	1	27.00	0.37
16	1	27.00	9.01
17	1	27.00	10.71
18	1	27.00	6.39
19	1	27.00	5.00
20	1	27.00	1.60
21	1	27.00	1.90
22	1	27.00	8.05
23	1	54.00	11.73
24	1	54.00	5.05
26	1	54.00	7.90
27	1	54.00	10.36
30	1	27.00	3.43
31	1	54.00	2.07
32	1	54.00	3.23
33	1	54.00	2.17
34	1	54.00	2.53
35	1	54.00	2.42
36	1	54.00	3.70
37	1	27.00	3.10
40	1	27.00	4.00
41	1	27.00	2.60
42	1	27.00	24.00
43	1	27.00	9.10
44	1	27.00	23.12
53	1	27.00	17.92
54	1	27.00	20.62
55	1	27.00	1.90
56	1	27.00	6.70
57	1	27.00	1.00
58	1	27.00	1.60
59	2	27.00	30.00
60	1	54.00	40.50
61	1	27.00	3.40
62	1	27.00	6.60
63	2	27.00	27.80
64	2	27.00	42.80
65	1	27.00	11.60
66	1	27.00	8.42
67	1	27.00	2.20
68	1	27.00	11.19

69	1	27.00	10.00
70	1	27.00	11.00
71	2	27.00	44.50
72	1	27.00	10.75
73	1	27.00	11.50
74	2	27.00	52.00
75	2	27.00	46.50
76	1	27.00	15.70
77	1	27.00	9.10
78	1	27.00	5.70
79	1	27.00	12.10
80	1	27.00	9.00
81	1	27.00	12.00
82	1	27.00	9.10
85	3	27.00	67.50
86	2	27.00	53.00
87	1	27.00	13.75
88	4	27.00	102.00
89	3	27.00	55.00
90	1	27.00	13.70
91	1	27.00	1.75
92	1	27.00	11.28
93	1	27.00	4.63
94	1	27.00	3.15
95	1	27.00	9.79
96	1	27.00	8.57
97	1	27.00	9.81
98	1	27.00	4.61
99	1	27.00	9.16
100	1	27.00	3.18

NUMBER OF TOOLS USED ON MACHINE 5 IS 99
TOOL STORE CAPACITY ON MACHINE 5 IS 40

Appendix VII.5

RESULTS OF THE TOOL FLOW MODELLING

SELECT OUTPUT REQUIRED BY NUMBER :

1) Final Primary Tool Store Contents.
2) Final Tooling Details + Status.
3) Machining History and Cell Performance Measures
4) Machine Activities for Schedule.
5) Cell Tool-Transfer Activities.
6) List of Machines in Each Cell.
7) List of Scheduled Parts for Each Cell.
8) Tool Transporter Contents and Schedule.
9) Cell Tool Summary and Tool Status Report.

0) Quit.

Select Desired Output and press <Enter>

Output Number Selected ? : 1

Tool Store Contents

Tool Store : MC1 Desc. : primary Status : final
Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
1	1	39.00	F	11	11	24.60	F	21	21	14.40	F
2	2	37.00	F	12	12	24.65	F	22	22	1.70	F
3	3	16.50	F	13	13	17.50	F	23	24	18.00	F
4	4	24.70	F	14	14	102.60	F	24	25	6.10	F
5	5	20.00	F	15	15	43.25	F	25	28	6.46	F
6	6	50.70	F	16	16	13.85	F	26	29	6.60	F
7	7	52.80	F	17	17	42.17	F	27	31	21.80	F
8	8	38.17	F	18	18	26.50	F	28	32	10.46	F
9	9	11.40	F	19	19	26.63	F	29	33	2.98	F
10	10	19.50	F	20	20	26.87	F	30	35	13.10	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC1 Desc. : primary Status : final
Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
31	36	4.96	F	41	46	26.00	F	51	63	21.00	F
32	37	14.50	F	42	47	23.60	F	52	64	13.13	F
33	38	5.90	F	43	48	25.25	F	53	65	7.70	F
34	40	9.10	F	44	49	0.30	F	54	68	1.50	F
35	41	4.82	F	45	51	19.10	F	55	70	10.10	F
36	23	14.94	F	46	52	4.50	F	56	71	16.00	F
37	42	17.00	F	47	56	10.50	F	57	72	5.80	F
38	43	40.50	F	48	57	10.90	F	58	53	6.60	F
39	44	23.00	F	49	58	1.35	F	59	59	0.30	F
40	45	880.30	F	50	60	4.40	F	60	61	0.00	W

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC1 Desc. : primary Status : final
Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
61	66	8.40	F	71	75	20.14	F	81	85	20.61	F
62	50	5.00	F	72	76	49.86	F	82	86	42.27	F
63	26	11.20	F	73	77	47.54	F	83	87	18.92	F
64	54	6.60	F	74	78	49.66	F	84	27	15.59	F
65	73	5.80	F	75	79	48.94	F	85	39	18.97	F
66	69	6.20	F	76	80	49.16	F	86	30	18.16	F
67	55	6.60	F	77	81	46.60	F	87	88	25.40	F
68	62	13.50	F	78	82	19.08	F	88	89	17.90	F
69	67	17.70	F	79	83	17.99	F	89	90	23.85	F
70	74	8.80	F	80	84	16.29	F	90	91	18.43	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC1 Desc. : primary Status : final
Capacity : 120 Tools in Store : 100 Under [-] : -20

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
91	92	17.84	F	101	0	0	0	111	0	0	0
92	93	43.90	F	102	0	0	0	112	0	0	0
93	94	38.20	F	103	0	0	0	113	0	0	0
94	95	33.28	F	104	0	0	0	114	0	0	0
95	96	0.12	F	105	0	0	0	115	0	0	0
96	97	6.38	F	106	0	0	0	116	0	0	0
97	99	3.00	F	107	0	0	0	117	0	0	0
98	98	16.69	F	108	0	0	0	118	0	0	0
99	100	15.00	F	109	0	0	0	119	0	0	0
100	34	19.64	F	110	0	0	0	120	0	0	0

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC2 Desc. : primary Status : final

Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
1	101	39.00	F	11	111	24.60	F	21	121	18.00	F
2	102	35.00	F	12	112	23.65	F	22	122	6.58	F
3	103	19.50	F	13	113	12.35	F	23	123	23.90	F
4	104	25.10	F	14	114	86.60	F	24	124	7.90	F
5	105	20.30	F	15	115	43.25	F	25	127	6.42	F
6	106	50.70	F	16	116	13.85	F	26	128	6.06	F
7	107	52.80	F	17	117	42.17	F	27	130	24.40	F
8	108	38.17	F	18	118	26.50	F	28	131	5.92	F
9	109	11.40	F	19	119	26.63	F	29	132	3.88	F
10	110	19.50	F	20	120	26.87	F	30	133	15.40	F

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Tool Store Contents

Tool Store : MC2 Desc. : primary Status : final

Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
31	134	3.52	F	41	145	7.00	F	51	156	19.10	F
32	135	21.30	F	42	146	27.00	F	52	157	4.50	F
33	136	1.84	F	43	147	11.10	F	53	161	10.50	F
34	137	17.00	F	44	148	15.81	F	54	162	10.90	F
35	138	2.08	F	45	149	887.30	F	55	163	1.35	F
36	139	8.69	F	46	150	26.00	F	56	165	4.40	F
37	141	14.00	F	47	151	23.60	F	57	168	21.00	F
38	142	24.00	F	48	152	25.25	F	58	169	12.19	F
39	143	25.00	F	49	153	23.70	F	59	170	7.70	F
40	144	23.00	F	50	154	0.30	F	60	173	1.50	F

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Tool Store Contents

Tool Store : MC2 Desc. : primary Status : final
Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
61	175	10.10	F	71	178	5.80	F	81	184	48.94	F
62	176	16.00	F	72	174	6.20	F	82	185	49.16	F
63	177	5.80	F	73	160	6.60	F	83	186	46.60	F
64	158	6.60	F	74	167	13.50	F	84	187	10.84	F
65	164	0.30	F	75	172	17.70	F	85	126	4.18	F
66	166	0.00	W	76	179	8.80	F	86	129	18.16	F
67	171	8.40	F	77	180	20.14	F	87	188	18.58	F
68	155	5.00	F	78	181	49.86	F	88	189	22.37	F
69	125	11.20	F	79	182	47.54	F	89	190	17.21	F
70	159	6.60	F	80	183	49.66	F	90	191	17.19	F

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift ~ PrtSc	Selection ?	Previous Screen P

Tool Store Contents

Tool Store : MC2 Desc. : primary Status : final
Capacity : 120 Tools in Store : 97 Under [-] : -23

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
91	192	22.39	F	101	0	0	0	111	0	0	0
92	193	23.82	F	102	0	0	0	112	0	0	0
93	194	48.95	F	103	0	0	0	113	0	0	0
94	195	46.10	F	104	0	0	0	114	0	0	0
95	196	43.64	F	105	0	0	0	115	0	0	0
96	197	3.00	F	106	0	0	0	116	0	0	0
97	140	16.69	F	107	0	0	0	117	0	0	0
98	0	0	0	108	0	0	0	118	0	0	0
99	0	0	0	109	0	0	0	119	0	0	0
100	0	0	0	110	0	0	0	120	0	0	0

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Tool Store Contents

Tool Store : MC3 Desc. : primary Status : final

Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
1	198	44.00	F	11	208	25.40	F	21	218	47.04	F
2	199	42.00	F	12	209	25.10	F	22	219	41.95	F
3	200	30.00	F	13	210	18.95	F	23	220	24.77	F
4	201	26.60	F	14	211	98.40	F	24	221	31.58	F
5	202	26.70	F	15	212	43.25	F	25	222	23.67	F
6	203	51.80	F	16	213	13.85	F	26	223	52.72	F
7	204	53.20	F	17	214	42.17	F	27	224	26.00	F
8	205	42.67	F	18	215	26.50	F	28	225	53.00	F
9	206	16.60	F	19	216	26.63	F	29	226	18.00	F
10	207	22.00	F	20	217	26.87	F	30	227	8.94	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC3 Desc. : primary Status : final

Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
31	228	23.90	F	41	241	9.87	F	51	252	12.00	F
32	229	7.90	F	42	242	17.00	F	52	253	17.00	F
33	232	10.71	F	43	243	7.90	F	53	254	40.50	F
34	233	6.06	F	44	244	3.00	F	54	255	15.10	F
35	234	24.40	F	45	246	20.00	F	55	256	23.70	F
36	235	14.46	F	46	247	18.00	F	56	257	879.40	F
37	236	1.24	F	47	248	8.92	F	57	258	0.30	F
38	238	15.40	F	48	249	21.00	F	58	260	19.10	F
39	239	14.16	F	49	250	19.00	F	59	261	4.50	F
40	240	21.30	F	50	251	16.00	F	60	265	10.50	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC3 | Desc. : primary | Status : final
Capacity : 120 | Tools in Store : 0 | Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
61	266	10.90	F	71	262	6.60	F	81	271	13.50	F
62	267	1.35	F	72	268	0.30	F	82	276	17.70	F
63	269	4.40	F	73	270	0.00	W	83	283	23.57	F
64	272	21.00	F	74	275	8.40	F	84	284	51.93	F
65	273	13.13	F	75	259	5.00	F	85	285	50.77	F
66	274	7.70	F	76	230	11.20	F	86	286	51.83	F
67	277	1.50	F	77	263	6.60	F	87	287	51.47	F
68	279	10.10	F	78	282	5.80	F	88	288	51.58	F
69	280	16.00	F	79	278	6.20	F	89	289	50.30	F
70	281	5.80	F	80	264	6.60	F	90	290	19.08	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC3 | Desc. : primary | Status : final
Capacity : 120 | Tools in Store : 105 | Under [-] : -15

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
91	291	17.99	F	101	300	13.02	F	111	0	0	0
92	292	16.29	F	102	301	9.08	F	112	0	0	0
93	293	20.61	F	103	302	6.38	F	113	0	0	0
94	294	42.27	F	104	245	15.00	F	114	0	0	0
95	231	15.59	F	105	237	19.64	F	115	0	0	0
96	295	25.40	F	106	0	0	0	116	0	0	0
97	296	17.90	F	107	0	0	0	117	0	0	0
98	297	23.85	F	108	0	0	0	118	0	0	0
99	298	18.43	F	109	0	0	0	119	0	0	0
100	299	17.84	F	110	0	0	0	120	0	0	0

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC4 Desc. : primary Status : final

Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
1	303	33.20	F	11	313	16.63	F	21	323	47.04	F
2	304	28.90	F	12	314	19.22	F	22	324	47.00	F
3	305	17.75	F	13	315	13.10	F	23	325	24.77	F
4	306	25.10	F	14	316	98.40	F	24	326	41.94	F
5	307	20.30	F	15	317	43.25	F	25	327	31.57	F
6	308	40.40	F	16	318	13.85	F	26	328	52.72	F
7	309	50.62	F	17	319	42.17	F	27	329	26.00	F
8	310	38.40	F	18	320	26.50	F	28	330	53.00	F
9	311	3.17	F	19	321	26.63	F	29	331	18.00	F
10	312	9.15	F	20	322	26.87	F	30	332	8.94	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC4 Desc. : primary Status : final

Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
31	333	23.90	F	41	344	9.87	F	51	354	23.70	F
32	334	7.90	F	42	345	17.00	F	52	355	0.30	F
33	336	10.71	F	43	346	7.00	F	53	357	19.10	F
34	337	6.06	F	44	347	27.00	F	54	358	4.50	F
35	338	24.40	F	45	348	11.10	F	55	361	12.65	F
36	339	14.46	F	46	349	15.81	F	56	362	13.65	F
37	340	3.88	F	47	350	887.30	F	57	363	1.35	F
38	341	15.40	F	48	351	26.00	F	58	365	4.40	F
39	342	14.16	F	49	352	23.60	F	59	367	21.00	F
40	343	21.30	F	50	353	25.25	F	60	368	6.08	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC4 Desc. : primary Status : final

Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
61	369	7.70	F	71	335	7.69	F	81	383	49.16	F
62	371	1.50	F	72	360	6.60	F	82	384	46.60	F
63	373	12.40	F	73	376	16.40	F	83	385	18.92	F
64	374	18.20	F	74	372	16.60	F	84	386	10.16	F
65	375	5.80	F	75	377	8.80	F	85	387	17.74	F
66	359	6.60	F	76	378	20.14	F	86	388	7.42	F
67	364	9.20	F	77	379	49.86	F	87	389	7.38	F
68	366	0.00	W	78	380	47.54	F	88	390	17.78	F
69	370	8.40	F	79	381	49.66	F	89	391	20.64	F
70	356	16.00	F	80	382	48.94	F	90	392	9.08	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC4 Desc. : primary Status : final

Capacity : 120 Tools in Store : 92 Under [-] : -28

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
91	393	6.38	F	101	0	0	0	111	0	0	0
92	394	3.00	F	102	0	0	0	112	0	0	0
93	0	0	0	103	0	0	0	113	0	0	0
94	0	0	0	104	0	0	0	114	0	0	0
95	0	0	0	105	0	0	0	115	0	0	0
96	0	0	0	106	0	0	0	116	0	0	0
97	0	0	0	107	0	0	0	117	0	0	0
98	0	0	0	108	0	0	0	118	0	0	0
99	0	0	0	109	0	0	0	119	0	0	0
100	0	0	0	110	0	0	0	120	0	0	0

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC5 Desc. : primary Status : final

Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
1	395	44.00	F	11	405	25.40	F	21	415	26.00	F
2	396	42.00	F	12	406	25.10	F	22	416	53.00	F
3	397	30.00	F	13	407	18.95	F	23	417	9.00	F
4	398	25.10	F	14	408	103.80	F	24	418	5.30	F
5	399	20.30	F	15	409	47.04	F	25	420	20.80	F
6	400	51.80	F	16	410	52.05	F	26	421	4.60	F
7	401	53.20	F	17	411	24.77	F	27	423	3.00	F
8	402	45.00	F	18	412	52.30	F	28	424	2.80	F
9	403	16.60	F	19	413	39.47	F	29	425	21.80	F
10	404	22.00	F	20	414	52.72	F	30	426	19.00	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc	,	P

Tool Store Contents

Tool Store : MC5 Desc. : primary Status : final

Capacity : 120 Tools in Store : 0 Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
31	427	2.84	F	41	437	22.80	F	51	451	1.35	F
32	429	3.80	F	42	438	898.10	F	52	453	4.40	F
33	430	22.60	F	43	439	26.00	F	53	456	21.00	F
34	431	15.60	F	44	440	23.60	F	54	457	0.91	F
35	432	8.80	F	45	441	25.25	F	55	458	7.70	F
36	433	7.00	F	46	442	0.30	F	56	461	1.50	F
37	419	17.30	F	47	444	19.10	F	57	463	10.10	F
38	434	17.00	F	48	445	4.50	F	58	464	16.00	F
39	435	40.50	F	49	449	10.50	F	59	465	5.80	F
40	436	23.00	F	50	450	10.90	F	60	446	6.60	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC5   Desc. : primary   Status : final

Capacity : 120   Tools in Store : 0   Under [-] : 0

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
61	452	0.30	F	71	460	17.70	F	81	476	17.99	F
62	454	0.00	W	72	467	17.90	F	82	477	16.29	F
63	459	8.40	F	73	468	23.57	F	83	478	20.61	F
64	443	5.00	F	74	469	51.93	F	84	479	42.27	F
65	422	11.20	F	75	470	50.77	F	85	480	25.40	F
66	447	6.60	F	76	471	51.83	F	86	481	17.90	F
67	466	5.80	F	77	472	51.47	F	87	482	23.85	F
68	462	6.20	F	78	473	51.58	F	88	483	18.43	F
69	448	6.60	F	79	474	50.30	F	89	484	17.84	F
70	455	13.50	F	80	475	19.08	F	90	485	10.16	F

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Store Contents

Tool Store : MC5   Desc. : primary   Status : final

Capacity : 120   Tools in Store : 99   Under [-] : -21

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
91	486	17.74	F	101	0	0	0	111	0	0	0
92	487	7.42	F	102	0	0	0	112	0	0	0
93	488	7.38	F	103	0	0	0	113	0	0	0
94	489	17.78	F	104	0	0	0	114	0	0	0
95	490	20.64	F	105	0	0	0	115	0	0	0
96	491	9.08	F	106	0	0	0	116	0	0	0
97	492	6.38	F	107	0	0	0	117	0	0	0
98	493	3.00	F	108	0	0	0	118	0	0	0
99	428	19.64	F	109	0	0	0	119	0	0	0
100	0	0	0	110	0	0	0	120	0	0	0

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

SELECT OUTPUT REQUIRED BY NUMBER :

1) Final Primary Tool Store Contents.
2) Final Tooling Details + Status.
3) Machining History and Cell Performance Measures
4) Machine Activities for Schedule.
5) Cell Tool-Transfer Activities.
6) List of Machines in Each Cell.
7) List of Scheduled Parts for Each Cell.
8) Tool Transporter Contents and Schedule.
9) Cell Tool Summary and Tool Status Report.

0) Quit.

Select Desired Output and press <Enter>

Output Number Selected ? : 2

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
1	002	R	F	3	60.00	39.00	5	0	N
2	003	R	F	3	60.00	37.00	5	0	N
3	004	R	F	3	60.00	16.50	5	0	N
4	055	R	F	3	30.00	24.70	5	0	N
5	056	R	F	3	30.00	20.00	5	0	N
6	006	R	F	3	60.00	50.70	5	0	N
7	012	R	F	3	60.00	52.80	5	0	N
8	007	R	F	4	60.00	38.17	5	0	N
9	008	R	F	3	30.00	11.40	5	0	N
10	019	R	F	3	30.00	19.50	5	0	N
11	020	R	F	3	30.00	24.60	5	0	N
12	021	R	F	3	30.00	24.65	5	0	N
13	022	R	F	3	30.00	17.50	5	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
14	001	R	F	1	120.00	102.60	5	0	N
15	005	R	F	1	60.00	43.25	4	0	N
16	009	R	F	1	30.00	13.85	4	0	N
17	010	R	F	1	60.00	42.17	4	0	N
18	011	R	F	1	30.00	26.50	4	0	N
19	015	R	F	1	30.00	26.63	4	0	N
20	013	R	F	1	30.00	26.87	4	0	N
21	080	R	F	2	30.00	14.40	5	0	N
22	076	R	F	3	30.00	1.70	7	0	N
23	076	R	F	2	30.00	14.94	7	0	N
24	037	R	F	2	30.00	18.00	5	0	N
25	064	R	F	4	30.00	6.10	13	0	N
26	064	R	F	2	30.00	11.20	13	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
27	064	R	F	1	30.00	15.59	13	0	N
28	081	R	F	3	30.00	6.46	5	0	N
29	079	R	F	2	30.00	6.60	7	0	N
30	079	R	F	1	30.00	18.16	7	0	N
31	041	R	F	2	30.00	21.80	5	0	N
32	040	R	F	3	30.00	10.46	5	0	N
33	044	R	F	4	30.00	2.98	8	0	N
34	044	R	F	1	30.00	19.64	8	0	N
35	065	R	F	2	30.00	13.10	5	0	N
36	067	R	F	3	30.00	4.96	5	0	N
37	078	R	F	2	30.00	14.50	5	0	N
38	077	R	F	2	30.00	5.90	6	0	N
39	077	R	F	1	30.00	18.97	6	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
40	069	R	F	2	30.00	9.10	5	0	N
41	068	R	F	4	30.00	4.82	5	0	N
42	059	R	F	1	30.00	17.00	5	0	N
43	060	R	F	1	60.00	40.50	5	0	N
44	063	R	F	1	30.00	23.00	5	0	N
45	090	R	F	3	999.00	880.30	5	0	N
46	057	R	F	1	30.00	26.00	4	0	N
47	061	R	F	1	30.00	23.60	4	0	N
48	091	R	F	1	30.00	25.25	4	0	N
49	089	R	F	3	30.00	0.30	10	0	N
50	089	R	F	2	30.00	5.00	10	0	N
51	084	R	F	1	30.00	19.10	5	0	N
52	088	R	F	3	30.00	4.50	19	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
53	088	R	F	2	30.00	6.60	19	0	N
54	088	R	F	2	30.00	6.60	19	0	N
55	088	R	F	2	30.00	6.60	19	0	N
56	072	R	F	5	30.00	10.50	5	0	N
57	087	R	F	5	30.00	10.90	5	0	N
58	071	R	F	4	30.00	1.35	10	0	N
59	071	R	F	6	30.00	0.30	10	0	N
60	085	R	F	4	30.00	4.40	14	0	N
61	085	R		4	30.00	0.00	14	0	N
62	085	R	F	2	30.00	13.50	14	0	N
63	083	R	F	1	30.00	21.00	5	0	N
64	092	R	F	2	30.00	13.13	5	0	N
65	075	R	F	2	30.00	7.70	14	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
66	075	R	F	2	30.00	8.40	14	0	N
67	075	R	F	1	30.00	17.70	14	0	N
68	074	R	F	3	30.00	1.50	10	0	N
69	074	R	F	2	30.00	6.20	10	0	N
70	073	R	F	5	30.00	10.10	5	0	N
71	070	R	F	5	30.00	16.00	5	0	N
72	086	R	F	2	30.00	5.80	10	0	N
73	086	R	F	2	30.00	5.80	10	0	N
74	043	R	F	2	30.00	8.80	5	0	N
75	030	R	F	2	30.00	20.14	5	0	N
76	031	R	F	2	60.00	49.86	5	0	N
77	032	R	F	2	60.00	47.54	5	0	N
78	033	R	F	2	60.00	49.66	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
79	034	R	F	2	60.00	48.94	5	0	N
80	035	R	F	2	60.00	49.16	5	0	N
81	036	R	F	2	60.00	46.60	5	0	N
82	014	R	F	1	30.00	19.08	3	0	N
83	016	R	F	1	30.00	17.99	3	0	N
84	017	R	F	1	30.00	16.29	3	0	N
85	018	R	F	1	30.00	20.61	3	0	N
86	023	R	F	1	60.00	42.27	3	0	N
87	052	R	F	1	30.00	18.92	4	0	N
88	058	R	F	1	30.00	25.40	3	0	N
89	082	R	F	1	30.00	17.90	3	0	N
90	094	R	F	1	30.00	23.85	3	0	N
91	096	R	F	1	30.00	18.43	3	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
92	099	R	F	1	30.00	17.84	3	0	N
93	024	R	F	2	60.00	43.90	5	0	N
94	026	R	F	2	60.00	38.20	5	0	N
95	027	R	F	2	60.00	33.28	5	0	N
96	053	R	F	3	30.00	0.12	5	0	N
97	054	R	F	2	30.00	6.38	7	0	N
98	054	R	F	1	30.00	16.69	7	0	N
99	042	R	F	2	30.00	3.00	7	0	N
100	042	R	F	1	30.00	15.00	7	0	N
101	002	R	F	3	60.00	39.00	5	0	N
102	003	R	F	3	60.00	35.00	5	0	N
103	004	R	F	3	60.00	19.50	5	0	N
104	055	R	F	2	30.00	25.10	5	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
105	056	R	F	2	30.00	20.30	5	0	N
106	006	R	F	3	60.00	50.70	5	0	N
107	012	R	F	3	60.00	52.80	5	0	N
108	007	R	F	4	60.00	38.17	5	0	N
109	008	R	F	3	30.00	11.40	5	0	N
110	019	R	F	3	30.00	19.50	5	0	N
111	020	R	F	3	30.00	24.60	5	0	N
112	021	R	F	3	30.00	23.65	5	0	N
113	022	R	F	3	30.00	12.35	5	0	N
114	001	R	F	2	120.00	86.60	5	0	N
115	005	R	F	1	60.00	43.25	4	0	N
116	009	R	F	1	30.00	13.85	4	0	N
117	010	R	F	1	60.00	42.17	4	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
118	011	R	F	1	30.00	26.50	4	0	N
119	015	R	F	1	30.00	26.63	4	0	N
120	013	R	F	1	30.00	26.87	4	0	N
121	080	R	F	1	30.00	18.00	5	0	N
122	076	R	F	4	30.00	6.58	7	0	N
123	037	R	F	1	30.00	23.90	5	0	N
124	064	R	F	3	30.00	7.90	13	0	N
125	064	R	F	2	30.00	11.20	13	0	N
126	064	R	F	2	30.00	4.18	13	0	N
127	081	R	F	3	30.00	6.42	5	0	N
128	079	R	F	2	30.00	6.06	7	0	N
129	079	R	F	1	30.00	18.16	7	0	N
130	041	R	F	1	30.00	24.40	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
131	040	R	F	3	30.00	5.92	5	0	N
132	044	R	F	3	30.00	3.88	8	0	N
133	065	R	F	1	30.00	15.40	5	0	N
134	067	R	F	3	30.00	3.52	5	0	N
135	078	R	F	1	30.00	21.30	5	0	N
136	077	R	F	3	30.00	1.84	6	0	N
137	069	R	F	1	30.00	17.00	5	0	N
138	053	R	F	3	30.00	2.08	5	0	N
139	054	R	F	2	30.00	8.69	7	0	N
140	054	R	F	1	30.00	16.69	7	0	N
141	049	R	F	1	30.00	14.00	1	0	N
142	046	R	F	1	30.00	24.00	2	0	N
143	047	R	F	1	30.00	25.00	2	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
144	048	R	F	1	30.00	23.00	2	0	N
145	059	R	F	2	30.00	7.00	5	0	N
146	060	R	F	2	60.00	27.00	5	0	N
147	063	R	F	2	30.00	11.10	5	0	N
148	068	R	F	2	30.00	15.81	5	0	N
149	090	R	F	3	999.00	887.30	5	0	N
150	057	R	F	1	30.00	26.00	4	0	N
151	061	R	F	1	30.00	23.60	4	0	N
152	091	R	F	1	30.00	25.25	4	0	N
153	062	R	F	1	30.00	23.70	3	0	N
154	089	R	F	3	30.00	0.30	10	0	N
155	089	R	F	2	30.00	5.00	10	0	N
156	084	R	F	1	30.00	19.10	5	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
157	088	R	F	3	30.00	4.50	19	0	N
158	088	R	F	2	30.00	6.60	19	0	N
159	088	R	F	2	30.00	6.60	19	0	N
160	088	R	F	2	30.00	6.60	19	0	N
161	072	R	F	5	30.00	10.50	5	0	N
162	087	R	F	5	30.00	10.90	5	0	N
163	071	R	F	4	30.00	1.35	10	0	N
164	071	R	F	6	30.00	0.30	10	0	N
165	085	R	F	4	30.00	4.40	14	0	N
166	085	R		4	30.00	0.00	14	0	N
167	085	R	F	2	30.00	13.50	14	0	N
168	083	R	F	1	30.00	21.00	5	0	N
169	092	R	F	2	30.00	12.19	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
170	075	R	F	2	30.00	7.70	14	0	N
171	075	R	F	2	30.00	8.40	14	0	N
172	075	R	F	1	30.00	17.70	14	0	N
173	074	R	F	3	30.00	1.50	10	0	N
174	074	R	F	2	30.00	6.20	10	0	N
175	073	R	F	5	30.00	10.10	5	0	N
176	070	R	F	5	30.00	16.00	5	0	N
177	086	R	F	2	30.00	5.80	10	0	N
178	086	R	F	2	30.00	5.80	10	0	N
179	043	R	F	2	30.00	8.80	5	0	N
180	030	R	F	2	30.00	20.14	5	0	N
181	031	R	F	2	60.00	49.86	5	0	N
182	032	R	F	2	60.00	47.54	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
183	033	R	F	2	60.00	49.66	5	0	N
184	034	R	F	2	60.00	48.94	5	0	N
185	035	R	F	2	60.00	49.16	5	0	N
186	036	R	F	2	60.00	46.60	5	0	N
187	052	R	F	2	30.00	10.84	4	0	N
188	066	R	F	1	30.00	18.58	3	0	N
189	093	R	F	1	30.00	22.37	3	0	N
190	095	R	F	1	30.00	17.21	3	0	N
191	097	R	F	1	30.00	17.19	3	0	N
192	098	R	F	1	30.00	22.39	3	0	N
193	100	R	F	1	30.00	23.82	3	0	N
194	024	R	F	1	60.00	48.95	5	0	N
195	026	R	F	1	60.00	46.10	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
196	027	R	F	1	60.00	43.64	5	0	N
197	042	R	F	2	30.00	3.00	7	0	N
198	002	R	F	2	60.00	44.00	5	0	N
199	003	R	F	2	60.00	42.00	5	0	N
200	004	R	F	2	60.00	30.00	5	0	N
201	055	R	F	1	30.00	26.60	5	0	N
202	056	R	F	1	30.00	26.70	5	0	N
203	006	R	F	2	60.00	51.80	5	0	N
204	012	R	F	2	60.00	53.20	5	0	N
205	007	R	F	3	60.00	42.67	5	0	N
206	008	R	F	2	30.00	16.60	5	0	N
207	019	R	F	2	30.00	22.00	5	0	N
208	020	R	F	2	30.00	25.40	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy, Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
209	021	R	F	2	30.00	25.10	5	0	N
210	022	R	F	2	30.00	18.95	5	0	N
211	001	R	F	2	120.00	98.40	5	0	N
212	005	R	F	1	60.00	43.25	4	0	N
213	009	R	F	1	30.00	13.85	4	0	N
214	010	R	F	1	60.00	42.17	4	0	N
215	011	R	F	1	30.00	26.50	4	0	N
216	015	R	F	1	30.00	26.63	4	0	N
217	013	R	F	1	30.00	26.87	4	0	N
218	038	R	F	1	60.00	47.04	3	0	N
219	024	R	F	3	60.00	41.95	5	0	N
220	025	R	F	1	30.00	24.77	3	0	N
221	027	R	F	3	60.00	31.58	5	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
222	026	R	F	3	60.00	23.67	5	0	N
223	028	R	F	1	60.00	52.72	3	0	N
224	029	R	F	1	30.00	26.00	3	0	N
225	039	R	F	1	60.00	53.00	3	0	N
226	080	R	F	1	30.00	18.00	5	0	N
227	076	R	F	3	30.00	8.94	7	0	N
228	037	R	F	1	30.00	23.90	5	0	N
229	064	R	F	3	30.00	7.90	13	0	N
230	064	R	F	2	30.00	11.20	13	0	N
231	064	R	F	1	30.00	15.59	13	0	N
232	081	R	F	2	30.00	10.71	5	0	N
233	079	R	F	2	30.00	6.06	7	0	N
234	041	R	F	1	30.00	24.40	5	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
235	040	R	F	2	30.00	14.46	5	0	N
236	044	R	F	3	30.00	1.24	8	0	N
237	044	R	F	1	30.00	19.64	8	0	N
238	065	R	F	1	30.00	15.40	5	0	N
239	067	R	F	2	30.00	14.16	5	0	N
240	078	R	F	1	30.00	21.30	5	0	N
241	077	R	F	2	30.00	9.87	6	0	N
242	069	R	F	1	30.00	17.00	5	0	N
243	043	R	F	2	30.00	7.90	5	0	N
244	042	R	F	2	30.00	3.00	7	0	N
245	042	R	F	1	30.00	15.00	7	0	N
246	051	R	F	1	30.00	20.00	1	0	N
247	050	R	F	1	30.00	18.00	1	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
248	052	R	F	2	30.00	8.92	4	0	N
249	046	R	F	1	30.00	21.00	2	0	N
250	047	R	F	1	30.00	19.00	2	0	N
251	048	R	F	1	30.00	16.00	2	0	N
252	045	R	F	1	30.00	12.00	1	0	N
253	059	R	F	1	30.00	17.00	5	0	N
254	060	R	F	1	60.00	40.50	5	0	N
255	063	R	F	1	30.00	15.10	5	0	N
256	062	R	F	1	30.00	23.70	3	0	N
257	090	R	F	3	999.00	879.40	5	0	N
258	089	R	F	3	30.00	0.30	10	0	N
259	089	R	F	2	30.00	5.00	10	0	N
260	084	R	F	1	30.00	19.10	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
261	088	R	F	3	30.00	4.50	19	0	N
262	088	R	F	2	30.00	6.60	19	0	N
263	088	R	F	2	30.00	6.60	19	0	N
264	088	R	F	2	30.00	6.60	19	0	N
265	072	R	F	5	30.00	10.50	5	0	N
266	087	R	F	5	30.00	10.90	5	0	N
267	071	R	F	4	30.00	1.35	10	0	N
268	071	R	F	6	30.00	0.30	10	0	N
269	085	R	F	4	30.00	4.40	14	0	N
270	085	R		4	30.00	0.00	14	0	N
271	085	R	F	2	30.00	13.50	14	0	N
272	083	R	F	1	30.00	21.00	5	0	N
273	092	R	F	2	30.00	13.13	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
274	075	R	F	2	30.00	7.70	14	0	N
275	075	R	F	2	30.00	8.40	14	0	N
276	075	R	F	1	30.00	17.70	14	0	N
277	074	R	F	3	30.00	1.50	10	0	N
278	074	R	F	2	30.00	6.20	10	0	N
279	073	R	F	5	30.00	10.10	5	0	N
280	070	R	F	5	30.00	16.00	5	0	N
281	086	R	F	2	30.00	5.80	10	0	N
282	086	R	F	2	30.00	5.80	10	0	N
283	030	R	F	1	30.00	23.57	5	0	N
284	031	R	F	1	60.00	51.93	5	0	N
285	032	R	F	1	60.00	50.77	5	0	N
286	033	R	F	1	60.00	51.83	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
287	034	R	F	1	60.00	51.47	5	0	N
288	035	R	F	1	60.00	51.58	5	0	N
289	036	R	F	1	60.00	50.30	5	0	N
290	014	R	F	1	30.00	19.08	3	0	N
291	016	R	F	1	30.00	17.99	3	0	N
292	017	R	F	1	30.00	16.29	3	0	N
293	018	R	F	1	30.00	20.61	3	0	N
294	023	R	F	1	60.00	42.27	3	0	N
295	058	R	F	1	30.00	25.40	3	0	N
296	082	R	F	1	30.00	17.90	3	0	N
297	094	R	F	1	30.00	23.85	3	0	N
298	096	R	F	1	30.00	18.43	3	0	N
299	099	R	F	1	30.00	17.84	3	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
300	068	R	F	2	30.00	13.02	5	0	N
301	053	R	F	2	30.00	9.08	5	0	N
302	054	R	F	2	30.00	6.38	7	0	N
303	002	R	F	3	60.00	33.20	5	0	N
304	003	R	F	3	60.00	28.90	5	0	N
305	004	R	F	3	60.00	17.75	5	0	N
306	055	R	F	2	30.00	25.10	5	0	N
307	056	R	F	2	30.00	20.30	5	0	N
308	006	R	F	3	60.00	40.40	5	0	N
309	012	R	F	3	60.00	50.62	5	0	N
310	007	R	F	4	60.00	38.40	5	0	N
311	008	R	F	3	30.00	3.17	5	0	N
312	019	R	F	3	30.00	9.15	5	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
313	020	R	F	3	30.00	16.63	5	0	N
314	021	R	F	3	30.00	19.22	5	0	N
315	022	R	F	3	30.00	13.10	5	0	N
316	001	R	F	2	120.00	98.40	5	0	N
317	005	R	F	1	60.00	43.25	4	0	N
318	009	R	F	1	30.00	13.85	4	0	N
319	010	R	F	1	60.00	42.17	4	0	N
320	011	R	F	1	30.00	26.50	4	0	N
321	015	R	F	1	30.00	26.63	4	0	N
322	013	R	F	1	30.00	26.87	4	0	N
323	038	R	F	1	60.00	47.04	3	0	N
324	024	R	F	2	60.00	47.00	5	0	N
325	025	R	F	1	30.00	24.77	3	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
326	027	R	F	2	60.00	41.94	5	0	N
327	026	R	F	2	60.00	31.57	5	0	N
328	028	R	F	1	60.00	52.72	3	0	N
329	029	R	F	1	30.00	26.00	3	0	N
330	039	R	F	1	60.00	53.00	3	0	N
331	080	R	F	1	30.00	18.00	5	0	N
332	076	R	F	3	30.00	8.94	7	0	N
333	037	R	F	1	30.00	23.90	5	0	N
334	064	R	F	3	30.00	7.90	13	0	N
335	064	R	F	2	30.00	7.69	13	0	N
336	081	R	F	2	30.00	10.71	5	0	N
337	079	R	F	2	30.00	6.06	7	0	N
338	041	R	F	1	30.00	24.40	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
339	040	R	F	2	30.00	14.46	5	0	N
340	044	R	F	3	30.00	3.88	8	0	N
341	065	R	F	1	30.00	15.40	5	0	N
342	067	R	F	2	30.00	14.16	5	0	N
343	078	R	F	1	30.00	21.30	5	0	N
344	077	R	F	2	30.00	9.87	6	0	N
345	069	R	F	1	30.00	17.00	5	0	N
346	059	R	F	2	30.00	7.00	5	0	N
347	060	R	F	2	60.00	27.00	5	0	N
348	063	R	F	2	30.00	11.10	5	0	N
349	068	R	F	2	30.00	15.81	5	0	N
350	090	R	F	3	999.00	887.30	5	0	N
351	057	R	F	1	30.00	26.00	4	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
352	061	R	F	1	30.00	23.60	4	0	N
353	091	R	F	1	30.00	25.25	4	0	N
354	062	R	F	1	30.00	23.70	3	0	N
355	089	R	F	3	30.00	0.30	10	0	N
356	089	R	F	1	30.00	16.00	10	0	N
357	084	R	F	1	30.00	19.10	5	0	N
358	088	R	F	3	30.00	4.50	19	0	N
359	088	R	F	2	30.00	6.60	19	0	N
360	088	R	F	2	30.00	6.60	19	0	N
361	072	R	F	4	30.00	12.65	5	0	N
362	087	R	F	4	30.00	13.65	5	0	N
363	071	R	F	4	30.00	1.35	10	0	N
364	071	R	F	4	30.00	9.20	10	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
365	085	R	F	4	30.00	4.40	14	0	N
366	085	R		4	30.00	0.00	14	0	N
367	083	R	F	1	30.00	21.00	5	0	N
368	092	R	F	3	30.00	6.08	5	0	N
369	075	R	F	2	30.00	7.70	14	0	N
370	075	R	F	2	30.00	8.40	14	0	N
371	074	R	F	3	30.00	1.50	10	0	N
372	074	R	F	1	30.00	16.60	10	0	N
373	073	R	F	4	30.00	12.40	5	0	N
374	070	R	F	4	30.00	18.20	5	0	N
375	086	R	F	2	30.00	5.80	10	0	N
376	086	R	F	1	30.00	16.40	10	0	N
377	043	R	F	2	30.00	8.80	5	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
378	030	R	F	2	30.00	20.14	5	0	N
379	031	R	F	2	60.00	49.86	5	0	N
380	032	R	F	2	60.00	47.54	5	0	N
381	033	R	F	2	60.00	49.66	5	0	N
382	034	R	F	2	60.00	48.94	5	0	N
383	035	R	F	2	60.00	49.16	5	0	N
384	036	R	F	2	60.00	46.60	5	0	N
385	052	R	F	1	30.00	18.92	4	0	N
386	066	R	F	2	30.00	10.16	3	0	N
387	093	R	F	2	30.00	17.74	3	0	N
388	095	R	F	2	30.00	7.42	3	0	N
389	097	R	F	2	30.00	7.38	3	0	N
390	098	R	F	2	30.00	17.78	3	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
391	100	R	F	2	30.00	20.64	3	0	N
392	053	R	F	2	30.00	9.08	5	0	N
393	054	R	F	2	30.00	6.38	7	0	N
394	042	R	F	2	30.00	3.00	7	0	N
395	002	R	F	2	60.00	44.00	5	0	N
396	003	R	F	2	60.00	42.00	5	0	N
397	004	R	F	2	60.00	30.00	5	0	N
398	055	R	F	2	30.00	25.10	5	0	N
399	056	R	F	2	30.00	20.30	5	0	N
400	006	R	F	2	60.00	51.80	5	0	N
401	012	R	F	2	60.00	53.20	5	0	N
402	007	R	F	2	60.00	45.00	5	0	N
403	008	R	F	2	30.00	16.60	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
404	019	R	F	2	30.00	22.00	5	0	N
405	020	R	F	2	30.00	25.40	5	0	N
406	021	R	F	2	30.00	25.10	5	0	N
407	022	R	F	2	30.00	18.95	5	0	N
408	001	R	F	1	120.00	103.80	5	0	N
409	038	R	F	1	60.00	47.04	3	0	N
410	024	R	F	1	60.00	52.05	5	0	N
411	025	R	F	1	30.00	24.77	3	0	N
412	027	R	F	1	60.00	52.30	5	0	N
413	026	R	F	1	60.00	39.47	5	0	N
414	028	R	F	1	60.00	52.72	3	0	N
415	029	R	F	1	30.00	26.00	3	0	N
416	039	R	F	1	60.00	53.00	3	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
417	080	R	F	2	30.00	9.00	5	0	N
418	076	R	F	3	30.00	5.30	7	0	N
419	076	R	F	1	30.00	17.30	7	0	N
420	037	R	F	2	30.00	20.80	5	0	N
421	064	R	F	4	30.00	4.60	13	0	N
422	064	R	F	2	30.00	11.20	13	0	N
423	081	R	F	2	30.00	3.00	5	0	N
424	079	R	F	2	30.00	2.80	7	0	N
425	041	R	F	2	30.00	21.80	5	0	N
426	040	R	F	2	30.00	19.00	5	0	N
427	044	R	F	3	30.00	2.84	8	0	N
428	044	R	F	1	30.00	19.64	8	0	N
429	065	R	F	2	30.00	3.80	5	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
430	067	R	F	2	30.00	22.60	5	0	N
431	078	R	F	2	30.00	15.60	5	0	N
432	077	R	F	2	30.00	8.80	6	0	N
433	069	R	F	2	30.00	7.00	5	0	N
434	059	R	F	1	30.00	17.00	5	0	N
435	060	R	F	1	60.00	40.50	5	0	N
436	063	R	F	1	30.00	23.00	5	0	N
437	068	R	F	1	30.00	22.80	5	0	N
438	090	R	F	1	999.00	898.10	5	0	N
439	057	R	F	1	30.00	26.00	4	0	N
440	061	R	F	1	30.00	23.60	4	0	N
441	091	R	F	1	30.00	25.25	4	0	N
442	089	R	F	3	30.00	0.30	10	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
443	089	R	F	2	30.00	5.00	10	0	N
444	084	R	F	1	30.00	19.10	5	0	N
445	088	R	F	3	30.00	4.50	19	0	N
446	088	R	F	2	30.00	6.60	19	0	N
447	088	R	F	2	30.00	6.60	19	0	N
448	088	R	F	2	30.00	6.60	19	0	N
449	072	R	F	5	30.00	10.50	5	0	N
450	087	R	F	5	30.00	10.90	5	0	N
451	071	R	F	4	30.00	1.35	10	0	N
452	071	R	F	6	30.00	0.30	10	0	N
453	085	R	F	4	30.00	4.40	14	0	N
454	085	R		4	30.00	0.00	14	0	N
455	085	R	F	2	30.00	13.50	14	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
456	083	R	F	1	30.00	21.00	5	0	N
457	092	R	F	4	30.00	0.91	5	0	N
458	075	R	F	2	30.00	7.70	14	0	N
459	075	R	F	2	30.00	8.40	14	0	N
460	075	R	F	1	30.00	17.70	14	0	N
461	074	R	F	3	30.00	1.50	10	0	N
462	074	R	F	2	30.00	6.20	10	0	N
463	073	R	F	5	30.00	10.10	5	0	N
464	070	R	F	5	30.00	16.00	5	0	N
465	086	R	F	2	30.00	5.80	10	0	N
466	086	R	F	2	30.00	5.80	10	0	N
467	043	R	F	1	30.00	17.90	5	0	N
468	030	R	F	1	30.00	23.57	5	0	N

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
469	031	R	F	1	60.00	51.93	5	0	N
470	032	R	F	1	60.00	50.77	5	0	N
471	033	R	F	1	60.00	51.83	5	0	N
472	034	R	F	1	60.00	51.47	5	0	N
473	035	R	F	1	60.00	51.58	5	0	N
474	036	R	F	1	60.00	50.30	5	0	N
475	014	R	F	1	30.00	19.08	3	0	N
476	016	R	F	1	30.00	17.99	3	0	N
477	017	R	F	1	30.00	16.29	3	0	N
478	018	R	F	1	30.00	20.61	3	0	N
479	023	R	F	1	60.00	42.27	3	0	N
480	058	R	F	1	30.00	25.40	3	0	N
481	082	R	F	1	30.00	17.90	3	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Final Tool Details

#	Tool id	S1	S2	Uses	Life St.	Life Fin.	Sis.	Req.	R.
482	094	R	F	1	30.00	23.85	3	0	N
483	096	R	F	1	30.00	18.43	3	0	N
484	099	R	F	1	30.00	17.84	3	0	N
485	066	R	F	2	30.00	10.16	3	0	N
486	093	R	F	2	30.00	17.74	3	0	N
487	095	R	F	2	30.00	7.42	3	0	N
488	097	R	F	2	30.00	7.38	3	0	N
489	098	R	F	2	30.00	17.78	3	0	N
490	100	R	F	2	30.00	20.64	3	0	N
491	053	R	F	2	30.00	9.08	5	0	N
492	054	R	F	2	30.00	6.38	7	0	N
493	042	R	F	2	30.00	3.00	7	0	N

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

SELECT OUTPUT REQUIRED BY NUMBER :

1) Final Primary Tool Store Contents.
2) Final Tooling Details + Status.
3) Machining History and Cell Performance Measures
4) Machine Activities for Schedule.
5) Cell Tool-Transfer Activities.
6) List of Machines in Each Cell.
7) List of Scheduled Parts for Each Cell.
8) Tool Transporter Contents and Schedule.
9) Cell Tool Summary and Tool Status Report.

0) Quit.

Select Desired Output and press <Enter>

Output Number Selected ? : 3

Machining History

Pt #	Mc. ID	Mc	It	Op #	θ	Op min	Tl#1	Life1S	Life1F	Tl#2	Life2S	Life2F
1	MC1	1	1	1	1	5.00	1	54.0	49.0			
1	MC1	1	1	2	2	5.00	2	54.0	49.0			
1	MC1	1	1	3	3	13.50	3	54.0	40.5			
1	MC1	1	1	4	4	0.40	4	27.0	26.6			
1	MC1	1	1	5	5	0.30	5	27.0	26.7			
1	MC1	1	1	6	6	1.10	6	54.0	52.9			
1	MC1	1	1	7	7	0.40	7	54.0	53.6			
1	MC1	1	1	8	8	4.50	8	54.0	49.5			
1	MC1	1	1	9	9	5.20	9	27.0	21.8			
1	MC1	1	1	10	10	2.50	10	27.0	24.5			
1	MC1	1	1	11	11	0.80	11	27.0	26.2			
1	MC1	1	1	12	12	0.45	12	27.0	26.6			
1	MC1	1	1	13	13	1.45	13	27.0	25.6			

Edit Screen	Next	Hard Copy	Selection ?	Previous Screen
Ctrl - B	Enter	Shift - PrtSc		P

Machining History

Pt #	Mc. ID	Mc	It	Op #	θ	Op min	Tl#1	Life1S	Life1F	Tl#2	Life2S	Life2F
2	MC1	1	1	1	14	5.00	1	49.0	44.0			
2	MC1	1	1	2	15	5.00	2	49.0	44.0			
2	MC1	1	1	3	16	13.50	3	40.5	27.0			
2	MC1	1	1	4	17	0.40	4	26.6	26.2			
2	MC1	1	1	5	18	0.30	5	26.7	26.4			
2	MC1	1	1	6	19	1.10	6	52.9	51.8			
2	MC1	1	1	7	20	0.40	7	53.6	53.2			
2	MC1	1	1	8	21	4.50	8	49.5	45.0			
2	MC1	1	1	9	22	5.20	9	21.8	16.6			
2	MC1	1	1	10	23	2.50	10	24.5	22.0			
2	MC1	1	1	11	24	0.80	11	26.2	25.4			
2	MC1	1	1	12	25	0.45	12	26.6	26.1			
2	MC1	1	1	13	26	1.45	13	25.6	24.1			

Edit Screen	Next	Hard Copy	Selection ?	Previous Screen
Ctrl - B	Enter	Shift - PrtSc		P

Machining History

Pt #	Mc. ID	Mc	It	Op #	Q	Op min	Tl#1	Life1S	Life1F	Tl#2	Life2S	Life2F
3	MC1	1	1	1	27	5.00	1	44.0	39.0			
3	MC1	1	1	2	28	7.00	2	44.0	37.0			
3	MC1	1	1	3	29	10.50	3	27.0	16.5			
3	MC1	1	1	4	30	1.10	6	51.8	50.7			
3	MC1	1	1	5	31	0.40	7	53.2	52.8			
3	MC1	1	1	6	32	4.50	8	45.0	40.5			
3	MC1	1	1	7	33	5.20	9	16.6	11.4			
3	MC1	1	1	8	34	2.50	10	22.0	19.5			
3	MC1	1	1	9	35	0.80	11	25.4	24.6			
3	MC1	1	1	10	36	1.45	12	26.1	24.7			
3	MC1	1	1	11	37	6.60	13	24.1	17.5			
4	MC1	1	1	1	38	5.40	14	108.0	102.6			
4	MC1	1	1	2	39	10.75	15	54.0	43.3			

Edit Screen	Next	Hard Copy	Selection ?	Previous Screen
Ctrl - B	Enter	Shift - PrtSc		P

Machining History

Pt #	Mc. ID	Mc	It	Op #	Q	Op min	Tl#1	Life1S	Life1F	Tl#2	Life2S	Life2F
4	MC1	1	1	3	40	13.15	16	27.0	13.8			
4	MC1	1	1	4	41	11.83	17	54.0	42.2			
4	MC1	1	1	5	42	2.33	8	40.5	38.2			
4	MC1	1	1	6	43	0.50	18	27.0	26.5			
4	MC1	1	1	7	44	0.37	19	27.0	26.6			
4	MC1	1	1	8	45	0.13	20	27.0	26.9			
5	MC1	1	1	1	46	3.60	21	27.0	23.4			
5	MC1	1	1	2	47	9.60	22	27.0	17.4			
5	MC1	1	1	3	48	5.90	24	27.0	21.1			
5	MC1	1	1	4	49	1.80	25	27.0	25.2			
5	MC1	1	1	5	50	4.25	28	27.0	22.8			
5	MC1	1	1	6	51	8.30	29	27.0	18.7			
5	MC1	1	1	7	52	9.70	22	17.4	7.7			

Edit Screen	Next	Hard Copy	Selection ?	Previous Screen
Ctrl - B	Enter	Shift - PrtSc		P

Cell Performance Measures

Cell No. : 1 Planning Horizon : 1440.00

Cell Performance Time : 1881.94

Machine No. : 1	Used for :	1667.85	Utilisation :	115.82
Machine No. : 2	Used for :	1682.99	Utilisation :	116.87
Machine No. : 3	Used for :	1728.42	Utilisation :	120.03
Machine No. : 4	Used for :	1829.93	Utilisation :	127.08
Tool Cart # : 1	Used for :	338.04	Utilisation :	23.48
Tool Cart # : 2	Used for :	631.28	Utilisation :	43.84
Tool Cart # : 3	Used for :	618.48	Utilisation :	42.95
Tool Cart # : 0	Used for :	0.00	Utilisation :	0.00

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

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7) List of Scheduled Parts for Each Cell.
8) Tool Transporter Contents and Schedule.
9) Cell Tool Summary and Tool Status Report.

0) Quit.

Select Desired Output and press <Enter>

Output Number Selected ? : 4

Machine Activities

Pt #	It	Op#	Op min.	Mc.No	Q.Pos.	Mc.Avail.St.	Activity St.	Mc.Avail.End
1	1	1	5.00	1	1	0.1	161.0	167.8
1	1	2	5.00	1	2	167.8	167.8	173.5
1	1	3	13.50	1	3	173.5	173.5	187.8
1	1	4	0.40	1	4	187.8	187.8	189.0
1	1	5	0.30	1	5	189.0	189.0	190.0
1	1	6	1.10	1	6	190.0	190.0	191.9
1	1	7	0.40	1	7	191.9	191.9	193.0
1	1	8	4.50	1	8	193.0	193.0	198.3
1	1	9	5.20	1	9	198.3	198.3	204.3
1	1	10	2.50	1	10	204.3	204.3	207.5
1	1	11	0.80	1	11	207.5	207.5	209.1
1	1	12	0.45	1	12	209.1	209.1	210.3
1	1	13	1.45	1	13	210.3	210.3	213.7

Edit Screen Ctrl - B	Next Enter	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Machine Activities

Pt #	It	Op#	Op min.	Mc.No	Q.Pos.	Mc.Avail.St.	Activity St.	Mc.Avail.End
2	1	1	5.00	1	14	213.7	212.7	219.5
2	1	2	5.00	1	15	219.5	219.5	225.2
2	1	3	13.50	1	16	225.2	225.2	239.5
2	1	4	0.40	1	17	239.5	239.5	240.6
2	1	5	0.30	1	18	240.6	240.6	241.7
2	1	6	1.10	1	19	241.7	241.7	243.6
2	1	7	0.40	1	20	243.6	243.6	244.7
2	1	8	4.50	1	21	244.7	244.7	250.0
2	1	9	5.20	1	22	250.0	250.0	255.9
2	1	10	2.50	1	23	255.9	255.9	259.2
2	1	11	0.80	1	24	259.2	259.2	260.8
2	1	12	0.45	1	25	260.8	260.8	262.0
2	1	13	1.45	1	26	262.0	262.0	265.4

Edit Screen Ctrl - B	Next Enter	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Machine Activities

Pt #	It	Op#	Op min.	Mc.No	Q.Pos.	Mc.Avail.St.	Activity St.	Mc.Avail.End
3	1	1	5.00	1	27	265.4	264.4	271.1
3	1	2	7.00	1	28	271.1	271.1	278.9
3	1	3	10.50	1	29	278.9	278.9	290.2
3	1	4	1.10	1	30	290.2	290.2	292.0
3	1	5	0.40	1	31	292.0	292.0	293.2
3	1	6	4.50	1	32	293.2	293.2	298.4
3	1	7	5.20	1	33	298.4	298.4	304.4
3	1	8	2.50	1	34	304.4	304.4	307.7
3	1	9	0.80	1	35	307.7	307.7	309.2
3	1	10	1.45	1	36	309.2	309.2	311.4
3	1	11	6.60	1	37	311.4	311.4	320.0
4	1	1	5.40	1	38	320.0	319.0	326.1
4	1	2	10.75	1	39	326.1	326.1	337.7

Edit Screen Ctrl - B	Next Enter	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Machine Activities

Pt #	It	Op#	Op min.	Mc.No	Q.Pos.	Mc.Avail.St.	Activity St.	Mc.Avail.End
4	1	3	13.15	1	40	337.7	337.7	351.6
4	1	4	11.83	1	41	351.6	351.6	364.2
4	1	5	2.33	1	42	364.2	364.2	367.2
4	1	6	0.50	1	43	367.2	367.2	368.5
4	1	7	0.37	1	44	368.5	368.5	369.6
4	1	8	0.13	1	45	369.6	369.6	371.7
5	1	1	3.60	1	46	371.7	370.7	376.1
5	1	2	9.60	1	47	376.1	376.1	386.4
5	1	3	5.90	1	48	386.4	386.4	393.1
5	1	4	1.80	1	49	393.1	393.1	395.7
5	1	5	4.25	1	50	395.7	395.7	400.7
5	1	6	8.30	1	51	400.7	400.7	409.7
5	1	7	9.70	1	52	409.7	409.7	420.2

Edit Screen Ctrl - B	Next Enter	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

SELECT OUTPUT REQUIRED BY NUMBER :

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7) List of Scheduled Parts for Each Cell.
8) Tool Transporter Contents and Schedule.
9) Cell Tool Summary and Tool Status Report.

0) Quit.

Select Desired Output and press <Enter>

Output Number Selected ? : 5

Cell Tool Transportation

Cell	Trans.No.	Mc.	Q.Pos.	Trans.Av.	Load Tls	Unld.Tls	Rtn. STS	Trans.Av
1	3	1	1	0.000	0.0	160.8	321.3	322.0
1	2	2	1	76.0	76.0	232.0	387.7	388.4
1	1	3	1	149.7	149.7	318.5	487.0	487.8
1	3	4	1	322.0	322.0	470.0	617.7	618.5
1	2	5	1	392.0	392.0	551.1	710.0	710.8

Edit Screen Ctrl - B	Next Enter	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

SELECT OUTPUT REQUIRED BY NUMBER :

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4) Machine Activities for Schedule.
5) Cell Tool-Transfer Activities.
6) List of Machines in Each Cell.
7) List of Scheduled Parts for Each Cell.
8) Tool Transporter Contents and Schedule.
9) Cell Tool Summary and Tool Status Report.

0) Quit.

Select Desired Output and press <Enter>

Output Number Selected ? : 6

Machine Information

Cell	MachineID	Mc	Sp	MorF	P	Capac.	Cell	MachineID	Mc	Sp	MorF	P	Capac.
1	MC1	1	1	F	1	120							
1	MC2	2	1	F	2	120							
1	MC3	3	1	F	3	120							
1	MC4	4	1	F	4	120							
1	MC5	5	1	F	5	120							

Edit Screen	Next	Hard Copy	Selection ?	Previous Screen
Ctrl - B	Enter	Shift - PrtSc		P

SELECT OUTPUT REQUIRED BY NUMBER :

1) Final Primary Tool Store Contents.
2) Final Tooling Details + Status.
3) Machining History and Cell Performance Measures
4) Machine Activities for Schedule.
5) Cell Tool-Transfer Activities.
6) List of Machines in Each Cell.
7) List of Scheduled Parts for Each Cell.
8) Tool Transporter Contents and Schedule.
9) Cell Tool Summary and Tool Status Report.

0) Quit.

Select Desired Output and press <Enter>

Output Number Selected ? : 7

Part Information

Cell	Part ID	Ops.	Pt #	P	B.Size	Cell	Part ID	Ops.	Pt #	P	B.Size
1	Job1A	13	1	1	1	1	Job14G	8	14	9	1
1	Job1F	13	2	1	1	1	Job15A	5	15	10	1
1	Job2A	11	3	2	1	1	Job16A	8	16	11	1
1	Job3A	8	4	3	1	1	Job17A	6	17	12	1
1	Job5A	16	5	4	1	1	Job19A	5	18	13	1
1	Job6A	15	6	5	1	1	Job19E	5	19	13	1
1	Job9A	10	7	6	1	1	Job20A	4	20	14	1
1	Job12A	15	8	7	1	1	Job20F	4	21	14	1
1	Job13A	15	9	8	1	1	Job20G	4	22	14	1
1	Job13F	15	10	8	1	1	Job1B	13	23	15	1
1	Job13G	15	11	8	1	1	Job2B	11	24	16	1
1	Job13H	15	12	8	1	1	Job2F	11	25	16	1
1	Job14A	8	13	9	1	1	Job3B	8	26	17	1

Edit Screen	Next	Hard Copy	Selection ?	Previous Screen
Ctrl - B	Enter	Shift - PrtSc		P

Part Information

Cell	Part ID	Ops.	Pt #	P	B.Size	Cell	Part ID	Ops.	Pt #	P	B.Size
1	Job6B	15	27	18	1	1	Job18A	7	40	26	1
1	Job7A	7	28	19	1	1	Job19B	5	41	27	1
1	Job9B	10	29	20	1	1	Job20B	4	42	28	1
1	Job10A	5	30	21	1	1	Job20H	4	43	28	1
1	Job12B	15	31	22	1	1	Job1C	13	44	29	1
1	Job13B	15	32	23	1	1	Job2C	11	45	30	1
1	Job13I	15	33	23	1	1	Job3C	8	46	31	1
1	Job13J	15	34	23	1	1	Job4A	9	47	32	1
1	Job13K	15	35	23	1	1	Job6C	15	48	33	1
1	Job14B	8	36	24	1	1	Job8A	10	49	34	1
1	Job14F	8	37	24	1	1	Job10B	5	50	35	1
1	Job16B	8	38	25	1	1	Job12C	15	51	36	1
1	Job16E	8	39	25	1	1	Job13C	15	52	37	1

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Part Information

Cell	Part ID	Ops.	Pt #	P	B.Size	Cell	Part ID	Ops.	Pt #	P	B.Size
1	Job13L	15	53	37	1	1	Job3D	8	66	46	1
1	Job13M	15	54	37	1	1	Job4B	9	67	47	1
1	Job13N	15	55	37	1	1	Job6D	15	68	48	1
1	Job14C	8	56	38	1	1	Job9C	10	69	49	1
1	Job15B	5	57	39	1	1	Job10C	5	70	50	1
1	Job16C	8	58	40	1	1	Job11A	11	71	51	1
1	Job17B	6	59	41	1	1	Job12D	15	72	52	1
1	Job19C	5	60	42	1	1	Job13D	15	73	53	1
1	Job19F	5	61	42	1	1	Job13O	15	74	53	1
1	Job20C	4	62	43	1	1	Job13P	15	75	53	1
1	Job20I	4	63	43	1	1	Job14D	8	76	54	1
1	Job1D	13	64	44	1	1	Job14H	8	77	54	1
1	Job2D	11	65	45	1	1	Job16D	8	78	55	1

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Part Information

Cell	Part ID	Ops.	Pt #	P	B.Size	Cell	Part ID	Ops.	Pt #	P	B.Size
1	Job18B	7	79	56	1	1	Job13Q	15	92	65	1
1	Job18D	7	80	56	1	1	Job13R	15	93	65	1
1	Job19D	5	81	57	1	1	Job13S	15	94	65	1
1	Job20D	4	82	58	1	1	Job14E	8	95	66	1
1	Job20J	4	83	58	1	1	Job15C	5	96	67	1
1	Job1E	13	84	59	1	1	Job17C	6	97	68	1
1	Job2E	11	85	60	1	1	Job18C	7	98	69	1
1	Job4C	9	86	61	1	1	Job18E	7	99	69	1
1	Job6E	15	87	62	1	1	Job20E	4	100	70	1
1	Job6F	15	88	62	1	1	Job20K	4	101	70	1
1	Job9D	10	89	63	1						
1	Job12E	15	90	64	1						
1	Job13E	15	91	65	1						

Edit Screen	Next	Hard Copy	Selection ?	Previous Screen
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SELECT OUTPUT REQUIRED BY NUMBER :

1) Final Primary Tool Store Contents.
2) Final Tooling Details + Status.
3) Machining History and Cell Performance Measures
4) Machine Activities for Schedule.
5) Cell Tool-Transfer Activities.
6) List of Machines in Each Cell.
7) List of Scheduled Parts for Each Cell.
8) Tool Transporter Contents and Schedule.
9) Cell Tool Summary and Tool Status Report.

0) Quit.

Select Desired Output and press <Enter>

Output Number Selected ? : 8

Tool Transporter Contents

Cart Dest. : 1 Cart Origin : -1 Cart # : 3
Cap. : 12 Start : 0.00 Tools in Cart : Finish : 161.02

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
1	1	*	*	11	11	*	*	21	21	*	*
2	2	*	*	12	12	*	*	22	22	*	*
3	3	*	*	13	13	*	*	23	24	*	*
4	4	*	*	14	14	*	*	24	25	*	*
5	5	*	*	15	15	*	*	25	28	*	*
6	6	*	*	16	16	*	*	26	29	*	*
7	7	*	*	17	17	*	*	27	31	*	*
8	8	*	*	18	18	*	*	28	32	*	*
9	9	*	*	19	19	*	*	29	33	*	*
10	10	*	*	20	20	*	*	30	35	*	*

Next Enter	Edit Screen Ctrl - B	Hard Copy Shift - PrtSc	Selection ?	Previous Screen P

Tool Transporter Contents

Cart Dest. : 1 Cart Origin : -1 Cart # : 3

Cap. : 12 Start : 0.00 Tools in Cart : Finish : 161.02

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
31	36	*	*	41	46	*	*	51	63	*	*
32	37	*	*	42	47	*	*	52	64	*	*
33	38	*	*	43	48	*	*	53	65	*	*
34	40	*	*	44	49	*	*	54	68	*	*
35	41	*	*	45	51	*	*	55	70	*	*
36	23	*	*	46	52	*	*	56	71	*	*
37	42	*	*	47	56	*	*	57	72	*	*
38	43	*	*	48	57	*	*	58	53	*	*
39	44	*	*	49	58	*	*	59	59	*	*
40	45	*	*	50	60	*	*	60	61	*	*

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

Tool Transporter Contents

Cart Dest. : 1 Cart Origin : -1 Cart # : 3

Cap. : 12 Start : 0.00 Tools in Cart : Finish : 161.02

Pkt	Tl. No	Life	S	Pkt.	Tl. No	Life	S	Pkt.	Tl. No	Life	S
61	66	*	*	71	75	*	*	81	85	*	*
62	50	*	*	72	76	*	*	82	86	*	*
63	26	*	*	73	77	*	*	83	87	*	*
64	54	*	*	74	78	*	*	84	27	*	*
65	73	*	*	75	79	*	*	85	39	*	*
66	69	*	*	76	80	*	*	86	30	*	*
67	55	*	*	77	81	*	*	87	88	*	*
68	62	*	*	78	82	*	*	88	89	*	*
69	67	*	*	79	83	*	*	89	90	*	*
70	74	*	*	80	84	*	*	90	91	*	*

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
Enter	Ctrl - B	Shift - PrtSc		P

SELECT OUTPUT REQUIRED BY NUMBER :

1) Final Primary Tool Store Contents.
2) Final Tooling Details + Status.
3) Machining History and Cell Performance Measures
4) Machine Activities for Schedule.
5) Cell Tool-Transfer Activities.
6) List of Machines in Each Cell.
7) List of Scheduled Parts for Each Cell.
8) Tool Transporter Contents and Schedule.
9) Cell Tool Summary and Tool Status Report.

0) Quit.

Select Desired Output and press <Enter>

Output Number Selected ? : 9

Cell Details

Cell #	: 1		Run #	: 1	
Machines	: 5		Parts	: 101	
Tools	: 493		Transporters	: 3	

Tools on :	Mc #1: 99	Cap.: 120	Mc #2: 97	Cap.: 120
	Mc #3: 105	Cap.: 120	Mc #4: 92	Cap.: 120

Tools in STS : 0 Cap.: 1500 Spare cap.: 1500

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Enter	Ctrl - B	Shift - PrtSc		P

Cell Tool Status Report

Cell Tool Input : 493

Tools in Cell : 493

Worn Tools : 5

Refurbished Tools : 0

Added Tools : 0

for scheduled period

Next	Edit Screen	Hard Copy	Selection ?	Previous Screen
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Appendix VIII

PUBLISHED PAPER

"A knowledge based multi-level approach to the design of flexible machining facilities using artificial intelligence techniques",
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A Knowledge Based Multi-Level Approach to the Design of Flexible Machining Facilities Using Artificial Intelligence Techniques

by

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A Knowledge Based Multi-Level Approach to the Design of Flexible Machining Facilities Using Artificial Intelligence Techniques

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ABSTRACT

The design and implementation of flexible machining installations calls for a high investment in capital and manpower. A review of the state of the art of tools to design and evaluate such facilities is presented in order to establish the merits of different approaches. An Artificial Intelligence (A.I.) approach is described which is capable of modelling alternative facilities over multiple levels of detail. An industrial case study utilising the approach is presented with illustrations of typical results.

1. Introduction

A flexible machining facility has to be initially considered as part of the manufacturing in a computer integrated manufacturing (CIM) environment. Under this environment the issues of information flows and manufacturing flows are important CIM performance indicators. Unless their is balance between these flows bottlenecks will occur. One may consider flexible machining as a subset of the manufacturing area containing both single cell and multi- cell activities. This trend to cellular activities in the manufacturing area, depicted in Figure 1, highlights the manufacturing flows of parts and tools. Part flow is initiated from raw material stores into the machining cells and onward to assembly, finished warehousing and dispatch. With the tool flow at the machining cells being dictated by the part flow rules used. This paper concentrates on the flow of parts and tools in the design of such machining cells.

The nature of a flexible machining cell with its elements and structure is represented by Figure 2. The horizontal parameters represent the inputs and outputs, while vertical parameters constitute the major elements required for production within such a cell. A structured systematic approach must be adopted for the smooth design and implementation of a flexible machining facility.

An approach of this type requires a high investment in capital expenditure, with installation only following after extensive interactive dialogue between user and supplier. This interaction is encapsulated in Figure 3. Four major phases in the user/supplier relationship are identified as, the user definition of the production requirement and cell specification; the users evaluation of the suppliers initial design proposals; the interaction between the user and supplier in determining the final design; and the installation and implementation of the machining facility. The first step in the planning of a manufacturing facility is to define the production requirements to satisfy current and future needs. These production requirements together with detailed information on the processes of the parts constitute the major elements of the specification provided by the user. This specification represents the starting point for the design methodology presented in this paper.

2. State of the Art in Manufacturing System Modelling

Design tools used in the evaluation of manufacturing systems can be categorised into the following areas: physical models, graphical simulators, approximate models, and discrete event simulation models [1]. Physical models of manufacturing systems are usually built using modelling kits, which provide scale models of system elements to be used in the final design manufacturing system [2]. These types of models are used to test system software before final use on the actual system. Computer based graphical simulators are used for modelling and evaluation of industrial work cells and manufacturing systems. The main applications are in the design and layout of work cells, the simulation of robot movements and collision detection [3].

Approximate models are widely used because they have proven to be an effective tool for the initial sizing and balancing of manufacturing systems. Typical methods include capacity planning [4], queueing networks [5], mathematical programming [6], scheduling theory [7], operational analysis [8], perturbation analysis [9], semi-Markov process [10] and Petri-nets approach [11]. However most of these models make major assumptions, in the case of queueing networks models, such as exponentially distributed service rates, first in first out queues, infinite part buffers, etc., and only provide steady state outputs of station utilisation, transport utilisation, queue lengths and production throughput.

Discrete event simulators allow systems to be modelled at a greater level of detail compared to approximate modelling methods. A computer program is produced which describes a system in terms of the objects contained, which are called entities, and the states through which these objects pass as simulation proceeds. Four main approaches to program writing are available and are described in [1] and [12]. These are the event approach, the activity approach, the process-interaction approach and the three phase approach. Shires [13] reviews these approaches and their relative merits when applied to simulation of manufacturing systems.

Generalised manufacturing system simulators are a new form of simulation tool for the engineer. These may be defined as a class of simulators which can be rapidly be configured, and usually consist of a validated model which the user configures to his own particular requirements by his own input data. Typical examples of such simulators are MAST [4], WITNESS [14], SAME [15], and SIMFACTORY [16].

According to the requirements of modelling for the design of advanced manufacturing systems, modelling methods can be classified as (Figure 4):

- Abstraction Level: structural, approximate and detailed. Here modelling methods vary in terms of the logical details contained within the model which are compatible with the requirement of various stages in the design process.

- Modelling Objectives: evaluative, hybrid evaluative/prescriptive, and prescriptive. The distinction is conducted according to the way decisions are made with the use of the models.

- Modelling Formalisms: algorithm, graph, Markov chain, simulation techniques, and AI and expert systems. The categorisation is made based on the formalisms used to describe the models.

3. AI in System Modelling

Artificial Intelligence (AI) is the study of how to design and program computers to accomplish tasks that people accomplish using their intelligence [17]. In many areas, this methodology is increasingly coming to be seen as an alternative to conventional approaches.

The need to develop models within AI has led to the application of both AI methods and AI software tools to this development. These approaches to modelling include knowledge based simulation [18], planning [19], qualitative modelling [20], hierarchical abstraction [17], temporal reasoning [21], intelligent front-ends [22] and expert decision-makers [23], learning [22], and software tools [24].

The earliest use of AI approaches in modelling is to produce an intelligent front-end for an existing modelling package. This front-end usually sits between the modelling package and the user, and is capable of generating necessary instructions or code to use the package, or interpreting and explaining results from the package. An example of such a system used in flexible manufacturing modelling can be found in [25].

The most mature application of AI techniques in modelling may be the development of knowledge based simulation systems using AI programming paradigms. The simulation is constructed by using a knowledge based framework, with the simulated system being represented within a typical knowledge structure. Major software tools that have arisen from AI efforts in simulation are ROSS [26], KBS [27], SIM-KIT [28], STEM [29].

4. Scope of the Research

The objective of this work is to explore the use of AI techniques for modelling in flexible machining as a competition for conventional discrete event simulation systems [4]. With this end in view, it was decided to develop a knowledge based modelling system with the following features:

(1) Although there are many system variants in flexible manufacturing, it was choosen to develop the modelling system which is domain specific to the design of flexible machining cells. These type of cells usually consist of machine stations, load/unload stations, pallets, part buffer storages, tools, tool stores, work and tool transporters, and control functions for the management of both work flow and tool flow in the cell [30].

(2) Most conventonal manufacturing modelling systems are data driven, but it was decided that this AI based modelling system should be knowledge driven, i.e., both data and rules are required in the formulation of a model. The advantage of this method is that it allows the user to design alternative models easily by entering the data which define the physical structure of a manufacturing cell, and the operaional rules which govern the behaviour of the cell elements.

(3) As a result of the complexity of the design process and the need for a structured design approach, this modelling system is intended to be capable of modelling a cell over multiple levels of detail (Figure 5). Since rules can be hierarchically structured such that each higher level rule triggers hidden lower level rules, the lower the level the more detailed the modelling, and the less hidden the assumptions. Therefore, each level can be defined to have a set of self-contained primitive rules for the modelling system to apply, and this enables the modelling system to be used at different stages in the design of the cell.

(4) In order for the modelling system to be useful to industry, special attention is intended to be be given to making the system flexible and the user-interface friendly. Menu driven software have to be developed which enables the selection of desired level of modelling detail from defined options. Explanations also have to be provided with regard to the selection of each of these options. Machining cell data can be interactively input and manipulated using a menu driven data base browser.

The logic of the model is entered into the system by entering behavioural rules for the cell elements and decision rules for various decision points occuring within the model. This can be realised through two ways. One is to select the built-in rules from the rule libraries via an interactive menu driven editor. Another is to express the rules, using the LOOPS rule editor [31], by calling to the primitive rules which have been built around each of the objects or by building new primitive rules which access the data structures directly. Thus the designed model can behave as the user desires it to do.

(5) Since the design and analysis of flexible manufacturing systems has to take an integrated systematic approach, there is thus a clear need for models containing different levels of detail for the design process. At the early stages, modelling is required at an aggregate level, while for the subsequent implementation, detailed decisions have to be made by the model.

There can be many possibilities for abstracting a flexible machining facility with varying modelling methods. According to the decisions a manufacturing system designer has to make during the design process, it was decided to define three levels of modelling detail in this modelling system (Figure 6). At the first level, the primary objective is to provide a quick estimation of the performance of the designed system. This estimation should help identify the sufficient numbers of machines, transporters, load/unload stations and pallets. In addition, assessment is to be provided with regard to the work in progress at each station, and this helps to determine the size of the local buffer for each station.

Once these numbers have been accepted, the user is able to enter the next level. The major objective of level 2 is to study the flexible integration effects resulting from integrating the above system elements with buffers and temporary storages of specified capacities. Additionaly tool requirements planning can be conducted in order to give a preliminary indication on the strategies of tool management.

Since tool availability can have considerable influence on the performance of a system, the third modelling level is intended to assess this effect. This helps to determine the appropriate tool management strategies, the actual tool requirements, the size of major tool stores, and the number of tool transporters.

(6) Another feature that the modelling system has to take into account should be that the user be able to configure a model by manipulating user-friendly icons and other powerful graphics facilities. To allow structural choices, a library of icons representing standard and generic classes of cell elements and transport routes can be provided. The user is capable of interactively selecting icons from the library, placing them on the layout map and connecting them as needed. To help the selection of behavioural choices, each of the decision rules should be paraphased using English.

In addition to the graphics objects representing the images of the cell elements and transport routes, gauges can be used to show the results of statistical data collection. The status of each cell element can be displayed by using the 'split-screen' technique. The animation of the operation of the designed model will not be considered within the scope of this paper, but the future work will fully cover this aspect.

(7) Although most conventional modelling systems do not have explanation facilities with regard to the modelling process, it was decided that this knowledge based system should be capable of providing explanations about its inference process [17]. This can be achieved by tracing the rules which are applied during the running of the model. Therefore, the relationship

between the computer code and the immediate behaviour of the model can be made explicit, and this enables convenient and straight forward dubugging and modifications of the model.

(8) It should be able to provide with confidence rapid feedback of system performance parameters as desired by the user. In addition to the default output which can be provided by each level of the modelling system, the user can also specify the performance parameters he desires by entering rules which collect the required statistics of system elements.

(9) Since LOOPS has only reached the stage as a research system, the computational time for a run is considerable, but in this research priority is given to the support environment of the software and the Xerox Workstation rather than the run time.

5. System Overview

With the available Xerox Workstation [32] and LOOPS software [31], and AI techniques, decisions are made to develop the modelling system within a typical knowledge based system structure [17]. Figure 7 shows the user's requirements in flexible manufacturing modelling and the expertise to be embedded in the knowledge based modelling system. Four major areas have been identified as being pertinent to the application of AI/expert systems in solving the manufacturing modelling problem: model configuration and data specification, control rules formulation, model running and analysis of results.

For a modelling system specialised in flexible manufacturing, there is great demand for software to be constructed which provides a user-friendly method for the physical configuration of a model and a logical method for the definition and collection of the data needed to run the model. This can be achieved by developing the icon facilities and the data base browser, and applying the AI hierarchical abstraction concepts which enable models of different levels of details.

Once the data has been provided for a model, the next step is to describe how the manufacturing system is to operate. These include decisions of part scheduling, station selection, queue priorities, transporter selection, operation sequencing and traffic control. The facilities to be embedded in the knowledge based modelling system allow the users to review the default rule which has been selected, to change to another rule from a library of existing rules and to describe their own rules using the LOOPS rule language.

After an operational model is established, the user requires facilities to be provided to help understand the behaviour of the model and the computer code behind this behaviour during the running of the model. This can be met by developing graphics and textual output facilities using the Xerox graphics techniques and the LOOPS rule oriented programming method. Another feature which can be fruitful with regard to the running of a model is the application of the concept called rule composition. It uses an automatic learning mechanism to combine the rules which are executed sequentially during a run in order to speed up the run. Although this feature is not to be implemented within the scope of this research, it is to be considered in the further research.

In order for a modelling system to become an effective tool for solving manufacturing problems, it must provide expertise not only in the above mentioned three areas, but also in the evaluation and understanding of the results. This can be achieved by representing the knowledge of manufacturing evaluations as a set of rules. In addition, the perturbation analysis technique can be applied to develop a separate module to assist in the analysis of the relationship between the input parameters and the modelling results. Again this area is only to be considered in the future work.

Figure 8 shows the proposed operational structure of the prototype modelling system. On entering the modelling system, the user is required to choose the appropriate level of modelling detail first. As mentioned before, three levels are to be defined. At the first level, each machine station is assumed to have an infinite local buffer so that no blockage could occure. Temporary storages and tool availability are ignored.

Level 2 allows more system details to be modelled. Each machine station or load/unload station has a specified buffer type and size (it can also be zero). Part temporary storages, and tool requirements with regard to the whole cell or particular machine stations are considered. Rules with respect to the availability of buffers and allocation of parts or resources can also be modelled.

At level 3, in addition to the features considered at level 2, influence of tool availability on the performance of the cell is modelled. Primary tool stores (PTS), cell secondary tool stores (STS), tool transporters and tool flow strategies [33], are all considered in the modelling. In particular, control rules for work flow subject to tooling availability can be modelled.

6. Functional Structure of the Modelling System

Figure 9 shows the functional structure of the prototype knowledge based modelling system. It consists of two major parts: the man-machine interface and the logic elements. The man-machine interface acts as an intelligent front-end and back-end for entering date and rules, controlling the modelling process and displaying explanations and outputs. It is implemented using system-provided menu and window functions.

The logic elements part consists of four elements: a data base browser, a working memory, a knowledge base and an inference engine. They are all implemented within the class browser of LOOPS. It is evident that this structure provides the modelling system with the following advantages:

(1) The four modules of the system are distinct and and accessable by the user. The user can modify any of them without affecting the others. This is in contrast to conventional simulation techniques where the information and control functions are integrated.

(2) Since rules can be organised in various layers of increasing detail, the user can use the desired level of detail for the modelling.

(3) Different system configurations can easily be modelled by re-creating or editing the instance objects contained in the data base browser and re-running the model.

(4) Due to the separate and structured representation of the different kinds of knowledge and the reasoning power of the system, it can model very complicated decision mechanisms, and allows the user to enter and model the desired decision rules.

(5) The user can specify the output required for decision making or understanding of the designed system.

7. Operational Structure of the Modelling System

As shown previously in Figure 8, once the appropriate modelling level is chosen, the user is required to configure the cell layout by manipulating the built-in icons representing each of the major cell elements (Figure 10). Then the user can enter the cell data within the data base browser (Figure 11), which define the physical structure of the modelled system. After this, decision rules have to be entered to define the behaviour of the system. Next the user can determine the output results he desires to collect, and this will result in an operational model which is ready to run.

During the running of the model, two options are to be provided for understanding the behaviour of the model. One is to provide graphic outputs on the screen showing the dynamic updates of the status of each of the major cell elements (Figure 12). Another is to invoke the trace option by displaying the applying rules in order to follow the line of inference within the model.

When the running of the model is completed, the model can give the results specified by the user in the desired forms. If the results from the model are unsatisfactory, the user may want to initiate further runs, and this can be realised by re-configuring the cell layout, re-entering/editing the cell data, or re-selecting/editing the cell operational rules to produce a new specification, and re-run the established model. Once the outputs from the model are satisfactory, the user can exit from the selected modelling level.

If a detailed analysis is required, the user can choose a lower modelling level, enter the required data and operational rules in order to design a more detailed model. Once the new model is established, the user can run it and analyse the results obtained from it, and can repeat the analysis process as the previous level until the results are satisfactory.

The results from a run can be displayed on the screen by invoking the various options on the output results menus. Hardcopies can be made on the linked printer. Similar ways can be used for the presentation of the input information.

8. Industrial Case Study

A comparative case study using the knowledge based modelling system, the Emulator [34] and the Tool Flow Modelling System [33] has been carried out in order to assess the relative merits of the AI based modelling approach. However, consideration is only given below to the results obtained from level 3 of the knowledge based modelling. For a critical comparison of the three modelling methods, see [35].

The cell used in the case study is an extention of a three machine flexible machining cell installed in a British company. Major extentions include the addition of two more machining centers and the specification of a more complex parts spectrum. Configuration of the extended cell within the Model Configurator of the modelling system is shown in Figure 13, where the major cell elements, i.e. the load/unload stations, the machine stations, the temporary storages, the work transporter, the STS and the tool transporter, are represented by individual icons. The data input of the cell model for this level consists of the detailed information on the production requirements, the cell elements and the part processes, which is entered by the user within the data base browser. The main cell parameters and strategies necessary for the operation of the cell at level 3 are summarized in Figure 14.

For the entry of the operational rules of the cell, two steps are required in the process. In the first step, behavioural rules, which define the basic operation of the cell in the modelling system, are selected from the rule library. For the second step, decision rules have to be expressed by the user, which are used to model the interactions among the basic work and tool flow activities handled by the behavioural rules. For a detailed description of the operational rules of the cell, refer to the APPENDIX.

Three levels of outputs have been provided by the modelling system for the cell study corresponding to the three levels of modelling. At level 3, the output can be devided into three categories, i.e. the overall cell performance, the primary output, the secondary output and the tooling output. The overall cell performance is concerned with the make span of a production program, the total part throughput rate, the total lateness, the average part flow time and the average utilization of the major cell elements. The primary output is provided to assess the part flow within the cell, which includes part throughput rates and part lead times. The secondary output is provided to support the primary output and is mainly concerned with the performance of the cell elements. It includes performance figures on parts, machine stations, load/unload stations, work transporters and temporary part storages, and station and part operation schedules. The tooling output can be used to assess the influence of tool provision on the performance of the cell. It consists of the cell tool requirement, the machine PTS contents and performance, the cell STS contents and performance, the tool transporter performance, and the final tooling details.

Figure 15 shows a glimpse of the results obtained from the level 3 modelling. It is apparent that the five machining centres are well balanced with regard to the workload assigned, as a result of the use of the Least Workload rule for the station selection. Since the number of tools used on each machine is below the capacity of the magazine, no tools have been shared across the five machines and only worn tools have been taken back to the STS. As parts have to wait for tools before they can be loaded to machines, the lead times are longer, on the average, than those obtained from levels 1 and 2 (Figure 16).

9. Concluding Remarks

The main advantage of the knowledge based modelling system described in this paper is that the barrier between the user and the computer assisted modelling facility has been removed. It allows the user without programming skills to quickly design, modify and experiment with a model by manipulating icons and menus, and modifying structure parameters and the selection of operational strategies. In addition it provides the visibility into the structure, behaviour, and data collection for analysis through using enhanced graphics capabilities.

As a result of the structured organisation of the modelling knowledge extracted from the field of flexible machining, this modelling system is being further extended to include a more detailed modelling of complex behaviours; modelling of assembly operations; multi-cell system modelling; and learning within the modelling system.

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APPENDIX
Behavioural and Decision Rules of the Case Study Cell

1. Introduction

In this appendix, a description of the behavioural and decision rules of the case study cell model in general statement form is given. The corresponding exact rules which will be used in the modelling system for the cell study, however, are not described. The behavioural rules are obtained from the rule library of the modelling system, which define the basic operation of the case study cell in the modelling system. The decision rules, on the other hand, need to be entered by the user through the Workstation keyboard and are used to model the interactions among the basic work and tool flow activities which are handled by the behavioural rules.

As discussed in the text, each level models the cell at a different level of abstraction or detail which involves the use of varying behavioural and decision rules in the modelling system to represent the operation of the cell. However, only the rules which are used for the level-3 modelling are presented below.

2. Behavioural Rules of the Cell

The behavioural rules of the case study cell at this level for both work and tool flow are given as the follows:

Rule 1: The cell has a fixed number of pallets, i.e. as soon as a pallet takes a part out of the cell, a new part is loaded on the pallet unless all the parts for the pallet have been completed.

Rule 2: If there is an empty pallet/fixture at the load/unlod station, then a new part is palletised.

Rule 3: After the new part has been loaded onto the pallet, the control computer then checks to see if the input buffer of an assigned machine is available. If it is available, the AGV will move the pallet to the machine.

Rule 4: A loaded pallet/fixture can not be placed in the input buffer of the machine until the output buffer is cleared. An input buffer may be loaded while the machine is in cycle, provided the output buffer is empty.

Rule 5: If the input buffer is not available, the computer checks the assigned pallet stand. If the stand is available, the pallet is moved to the pallet stand by the AGV.

Rule 6: If no pallet stand is available for the first pallet in the queue, the computer will repeat the process for the part waiting in the next full pallet/fixture.

Rule 7: When a machine becomes available, a check is made of tools present in the PTS of the machine against the toolsd required by the part on a pallet waiting to be loaded in the input buffer of the machine. If some of the required tools are not available, then a tool requirement is generated for the part.

Rule 8: If all the required tools are available, the pallet is loaded and the machining process starts.

Rule 9: Following machining of the part on a pallet, the pallet/fixture is moved to the output buffer if it is free.

Rule 10: If either of the load/unload stations and the AGV are available, the pallet is moved back to the load/unload station on completion of the machining of the part on the pallet/fixture.

Rule 11: If no load/unload station is available but the assigned pallet stand is free, the machined part with the pallet is moved to the pallet stand.

Rule 12: If the required load/unload station or the assigned machine and the AGV become available, the pallet waiting at its assigned stand is moved to its destination.

Rule 13: After a pallet is moved back to the load/unload station, it is depalletised there immediately and the pallet becomes free.

Rule 14: If a part is waiting for tools and there is a free tool transporter, the transporter is sent back to the STS and loaded with tools required by the part.

Rule 15: A loaded tool transporter then moves the tools to the machine where the part is waiting for tools.

Rule 16: If there are any spare positions in the PTS, then the tools are loaded from the transporter to fill these positions.

Rule 17: If there are not enough spare positions in the magazine, worn tools or, if necessary, unrequired tools are taken out from the PTS and exchanged with the tools on the transporter.

Rule 18: The transporter then transfers the tools, if any, back to the STS.

3. Decision Rules of the Cell

The control of the cell at level 3 can be facilitated by the following decision rules:

(1) Part Release Rule:

If there are several parts that can be released when a pallet becomes available, the one which has the shortest total processing time is released first.

(2) Pallet Priority Rule for Allocation to Transporter:

If there are more than one pallets waiting to be transported, the one that has been waiting for the longest is selected and allocated the transporter first.

(3) Station Priority Rule for Assignment of Pallet:

If there are several stations which can be assigned to a pallet, the station which has the least workload is selected. The workload for a machine is computed by taking into account the cummulative busy time of the machine and the processing time of the part queueing in the input buffer of the machine. As for the load/unload stations, this is the cummulative busy time of the station.

(4) Tool Transporter Priority Rule for Assignment of Pallet:

If there are several tool transporters available, the one which has the lowest utilization, is selected and allocated to the pallet.

(5) Pallet Priority Rule for Allocation of Tool Transporter:

If there are a number of pallets waiting for transporters so that tools can be tranported for the part on the pallet, the one which has the longest waiting time is selected and allocated to the tool transporter.

LIST OF FIGURES

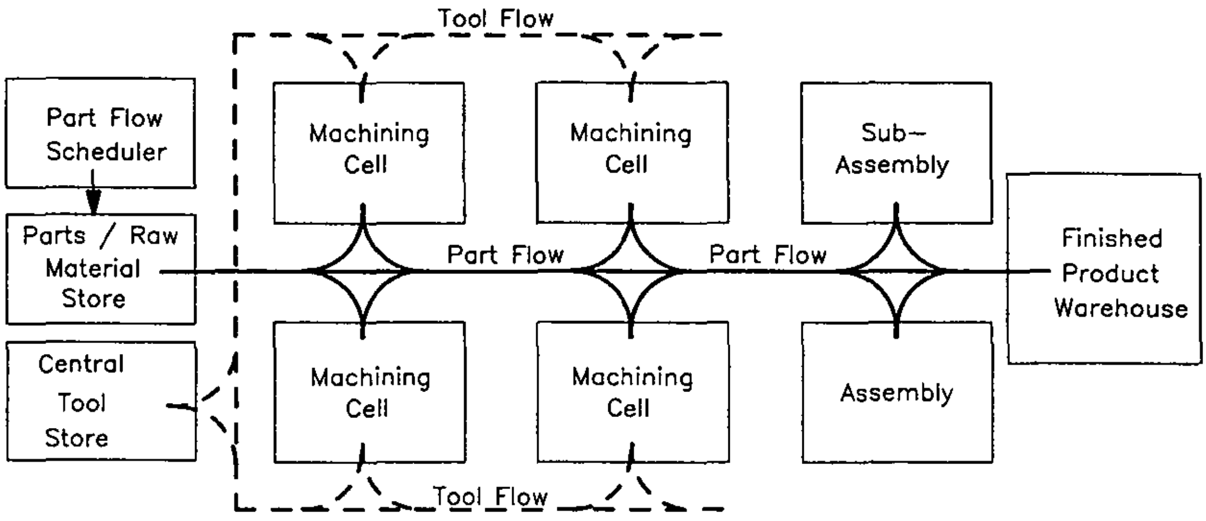

Figure 1	*Flexible Machining Within a Manufacturing Facility*	**LUT – FMS Research Group**

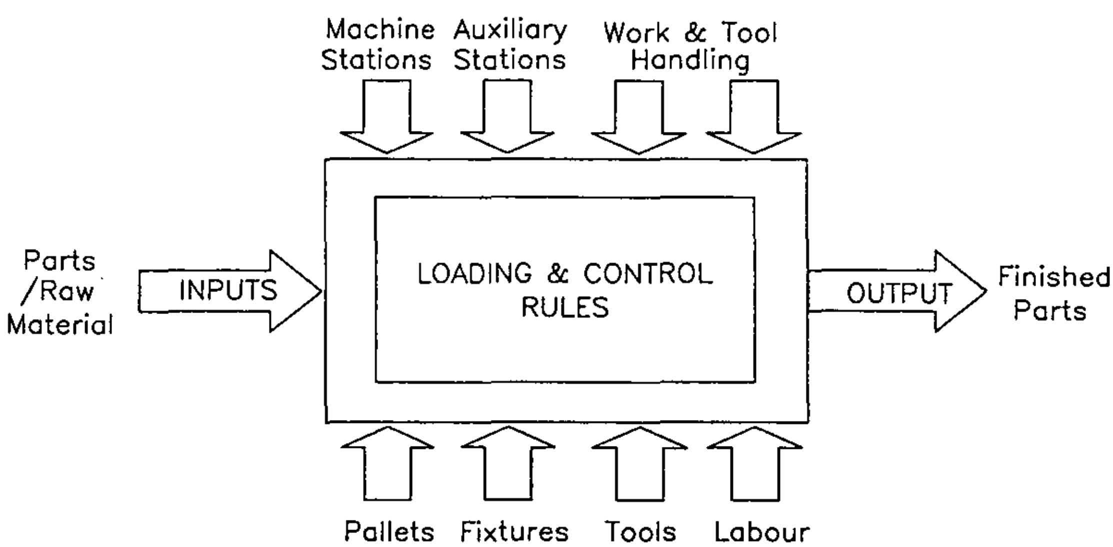

Figure 2	*An Overview of the Operations Within a Machining Cell*	**LUT – FMS Research Group**

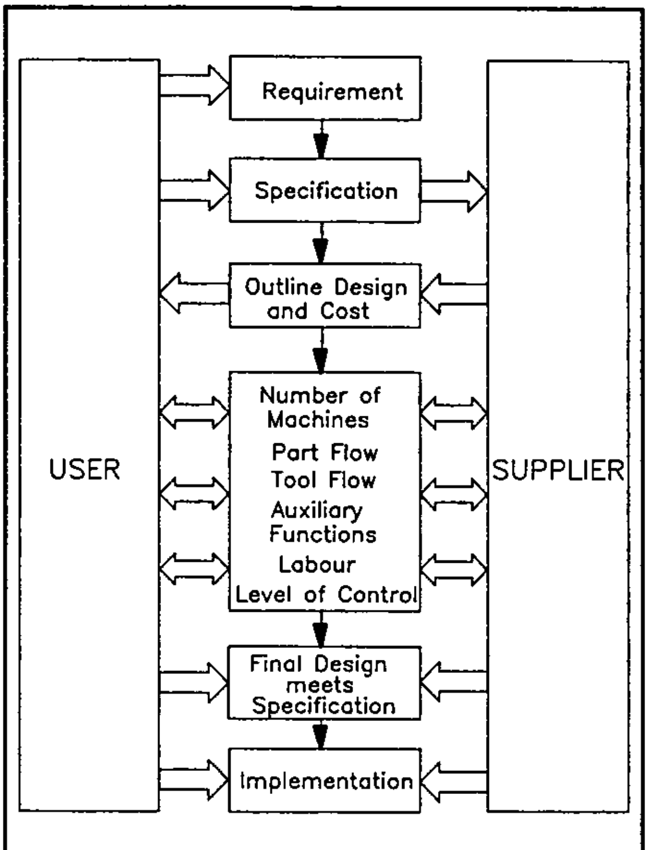

Figure 3 *User/Supplier Interactions in the Acquisition of a Manufacturing Facility* **LUT-FMS** Research Group

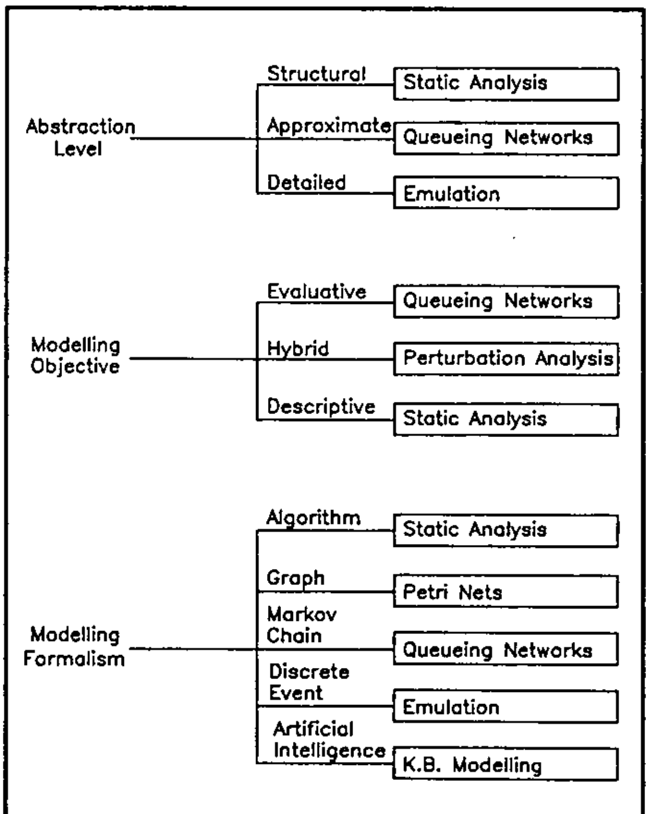

Figure 4 *Classification of Modelling Methods* **LUT-FMS Research Group**

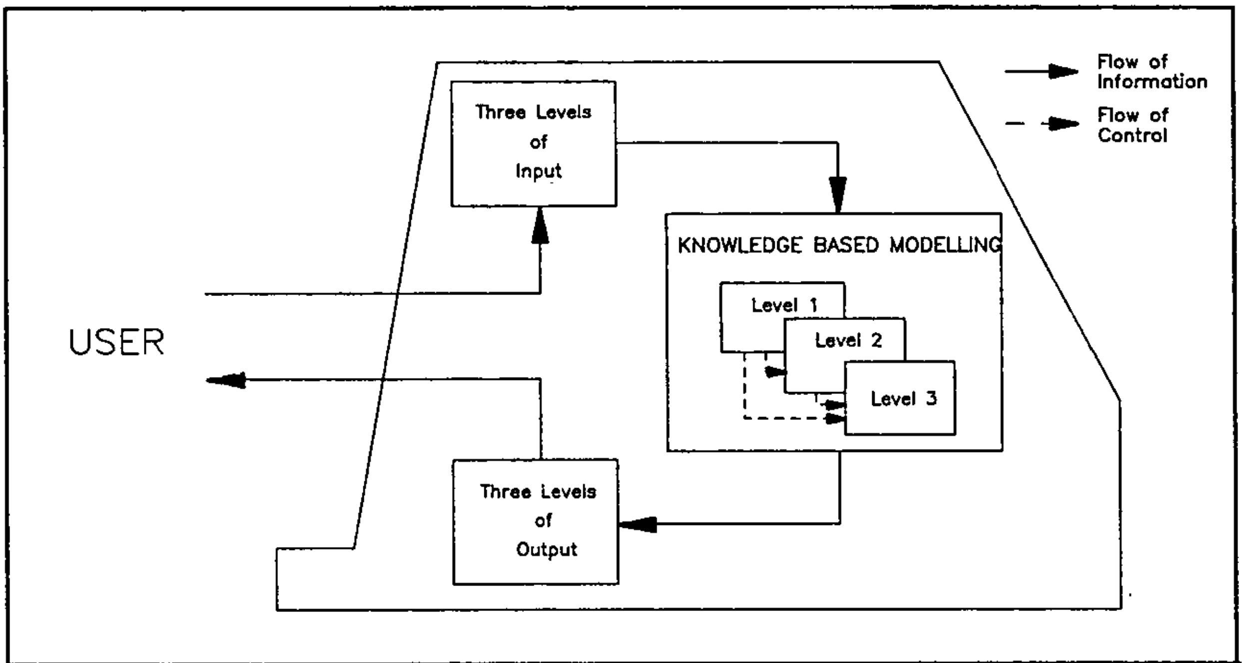

Figure 5	*Hierarchical Modelling Architecture*	LUT - FMS **Research Group**

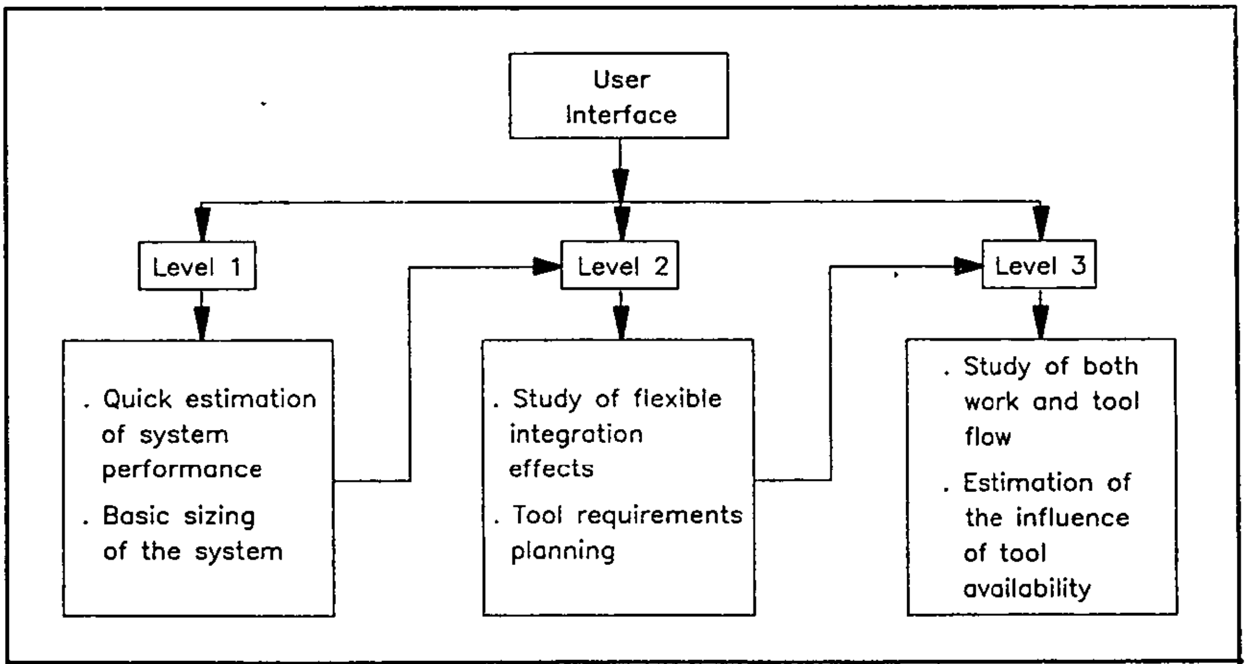

Figure 6	*Objectives of Three Levels of Modelling*	LUT - FMS **Research Group**

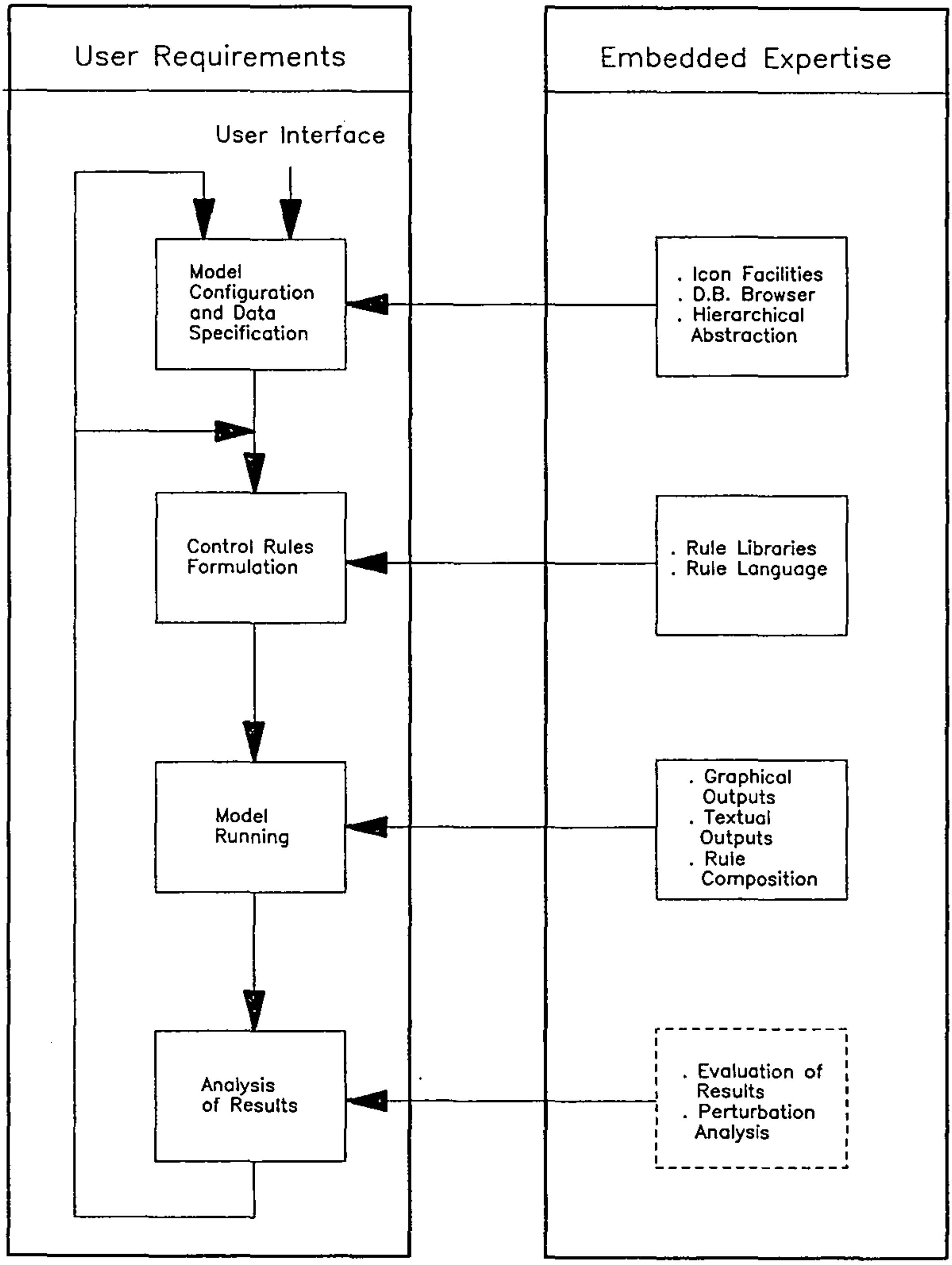

Figure 7	*Overview of the Modelling System*	LUT-FMS Research Group

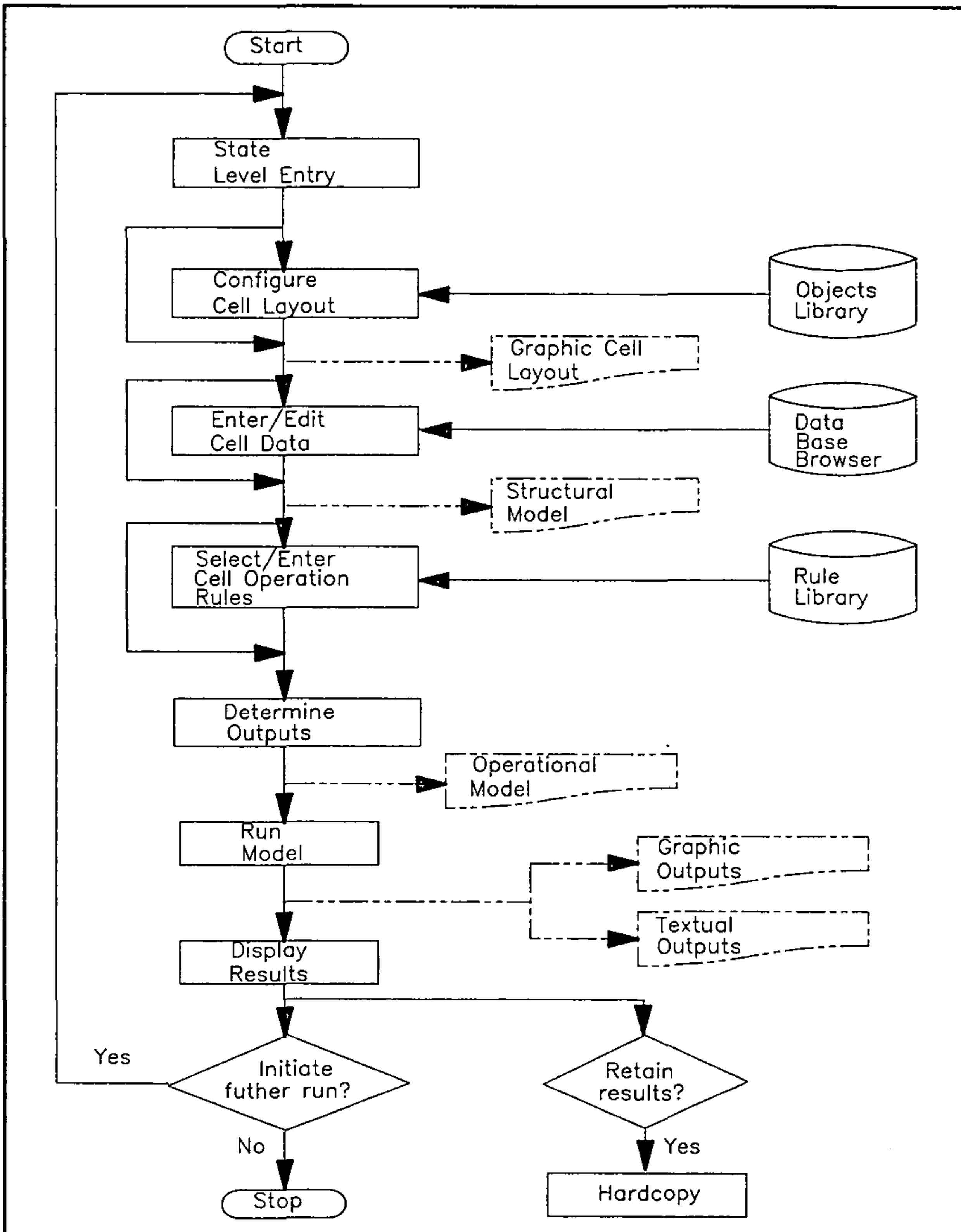

Figure 8

Operational Structure of the Knowledge Based Modelling System

LUT-FMS Research Group

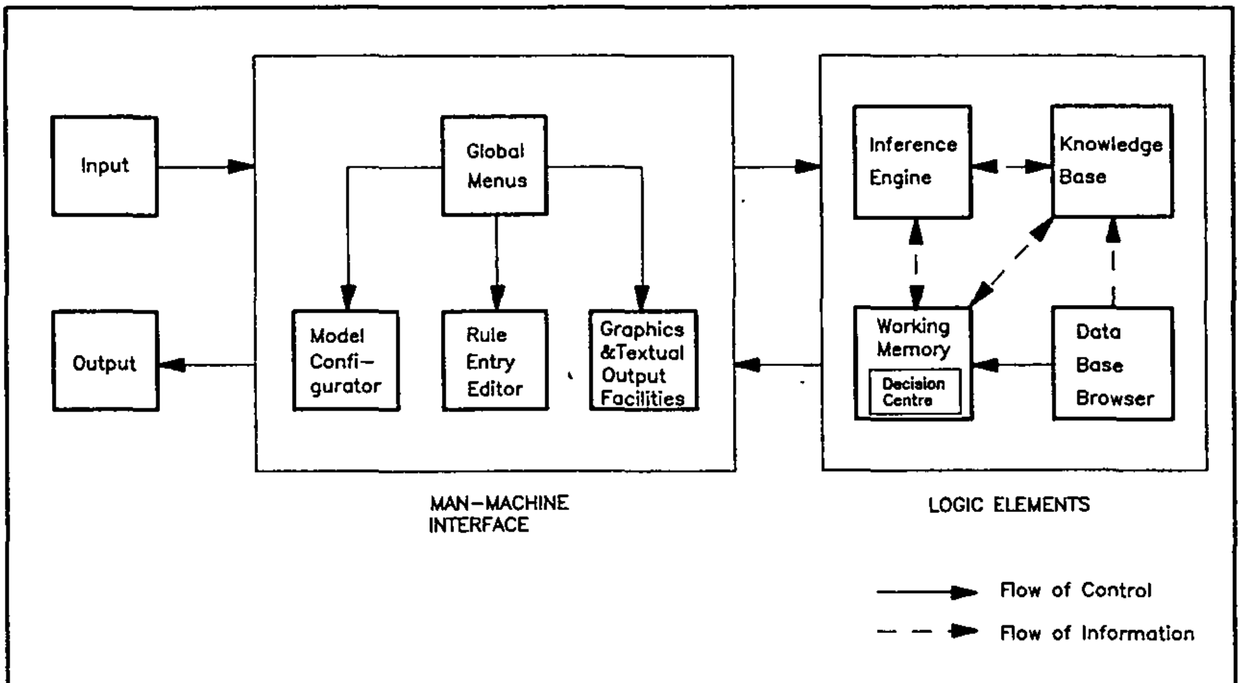

Figure 9

Functional Structure of the Knowledge Based Modelling System

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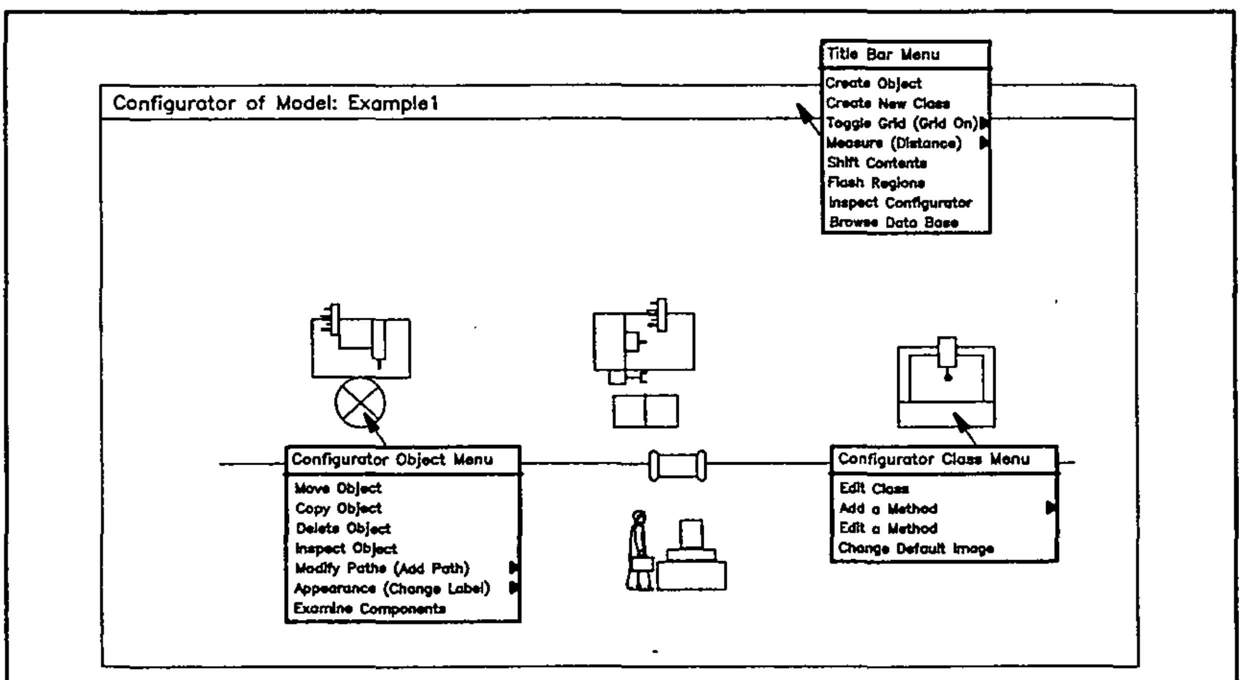

Figure 10

The Model Configurator

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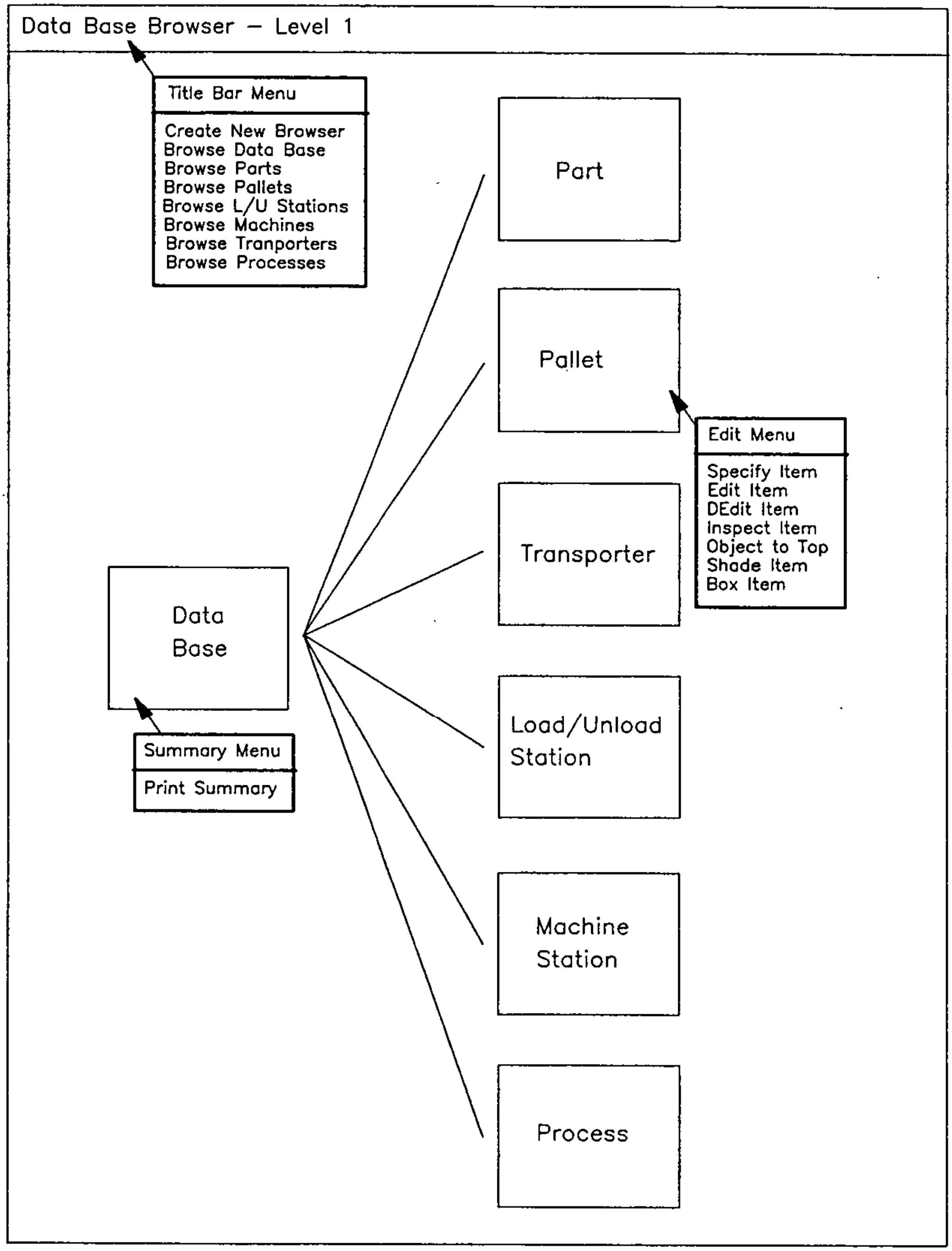

Figure 11	*The Data Base Browser*	LUT-FMS Research Group

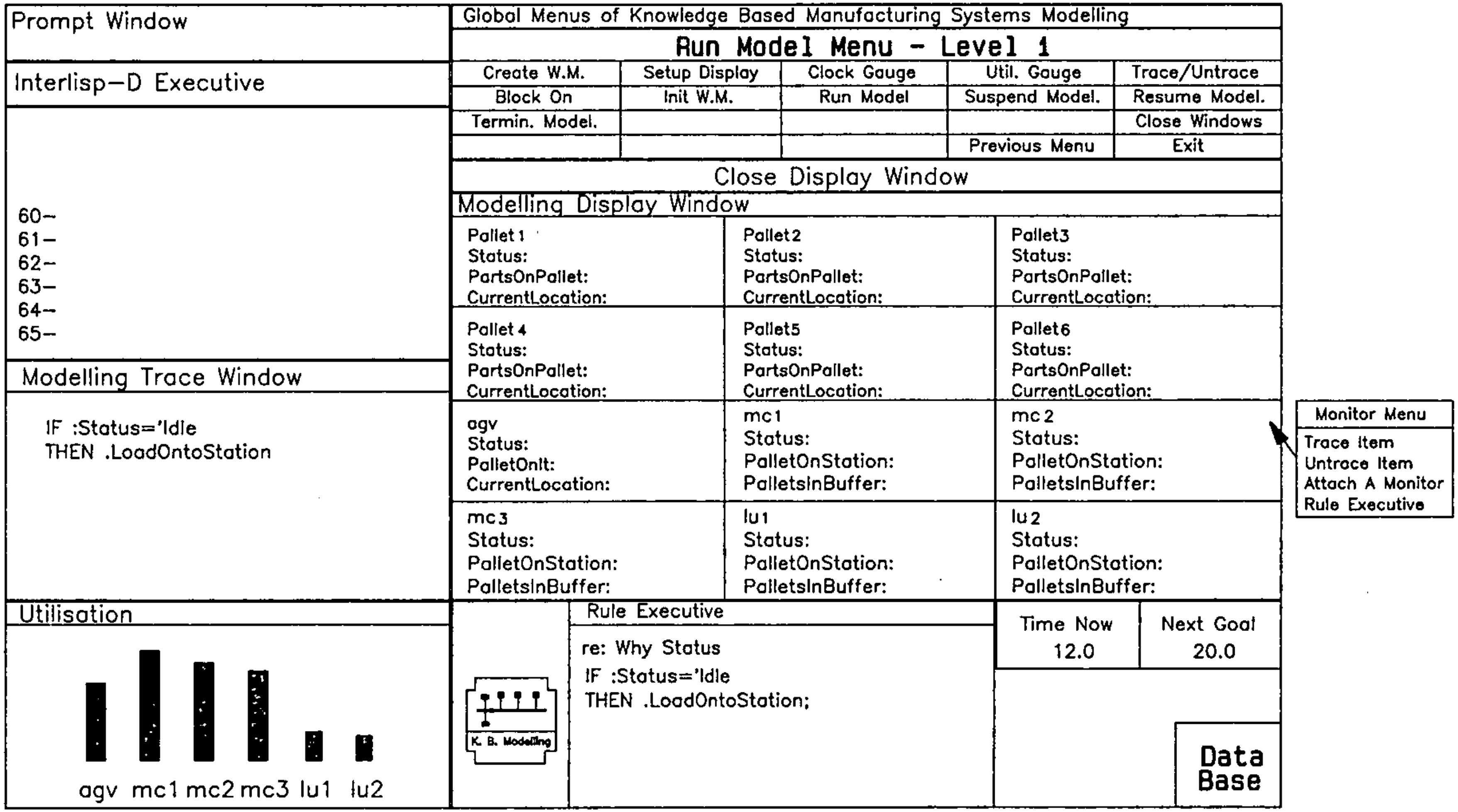

Figure 12

Graphics and Textual Output Facilities

LUT - FMS Research Group

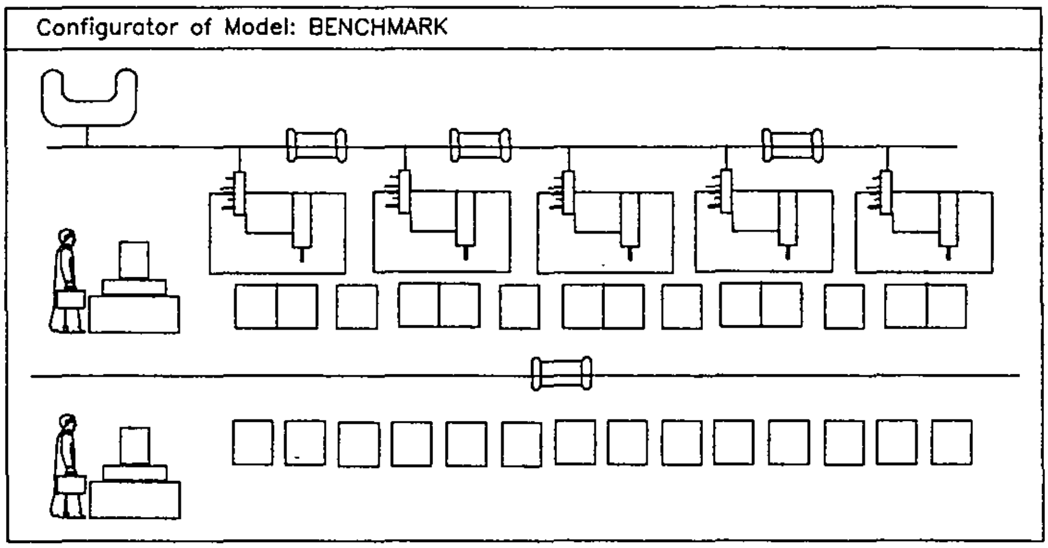

Figure 13	*Configuration of the Extended Cell at Level 3*	**LUT - FMS Research Group**

Planning Horizon: 24 Hours (1440 mins)

Tool Management: Workpiece-Oriented

Releasing: Shortest Total Processing Time

Station Selection: Least Workload

Scheduling: FIFO

Tool Issue: Differential Kitting

FMC:
- 5 machines with dual pallet exchange buffer & 120-tool PTS
- 1 rail guided vehicle
- 2 load/unload stations
- 10 pallets
- 101 parts
- mutually exclusive part & tool flow
- STS of unlimited capacity
- 3 tool transporters

Operation Assignment: part by part

Tool Life Management:
- permissible life 90%
- tool life as specified
- cell rationalisation

Tool Assignment: all required tools are available in STS

Figure 14	*K.B.Modelling Level 3 of the Extended Cell - System Strategies*	**LUT-FMS Research Group**

	Required	Actual
Total Part Throughput:	101	101
Time Horizon (mins):	1440.00	1751.84
Cell Tool Requirement:	505	

Station Performance

	Machine 1		Machine 2		Machine 3	
	Time	%	Time	%	Time	%
Cutting	1256.0	71.7	1211.0	69.1	1179.2	67.3
Tool Change	147.44	8.4	149.0	8.5	149.0	8.5
Load/Unload	40.0	2.3	40.0	2.3	40.0	2.3
For Tools	176.2	10.1	161.5	9.2	178.4	10.2
Idle	132.2	7.6	190.4	10.9	205.3	11.7
Tools Used	98		91		100	
Worn Tools	1		1		1	

Work Transp. Perfom.

	Transp. 1	
	Time	%
Load Run	220.0	12.6
Empty Run	219.2	12.5
Load/Unload	148.5	8.5
Idle	1164.1	66.5

Tool Transp. Perform.

	Transp. 1	
	Time	%
Load Run	44.8	2.6
Empty Run	37.6	2.2
Load/Unload	435.5	24.9
Idle	1234.0	70.4

Figure 15 *K. B. Modelling Level 3 of the Extended Cell - Summary of Outputs* **LUT-FMS Research Group**

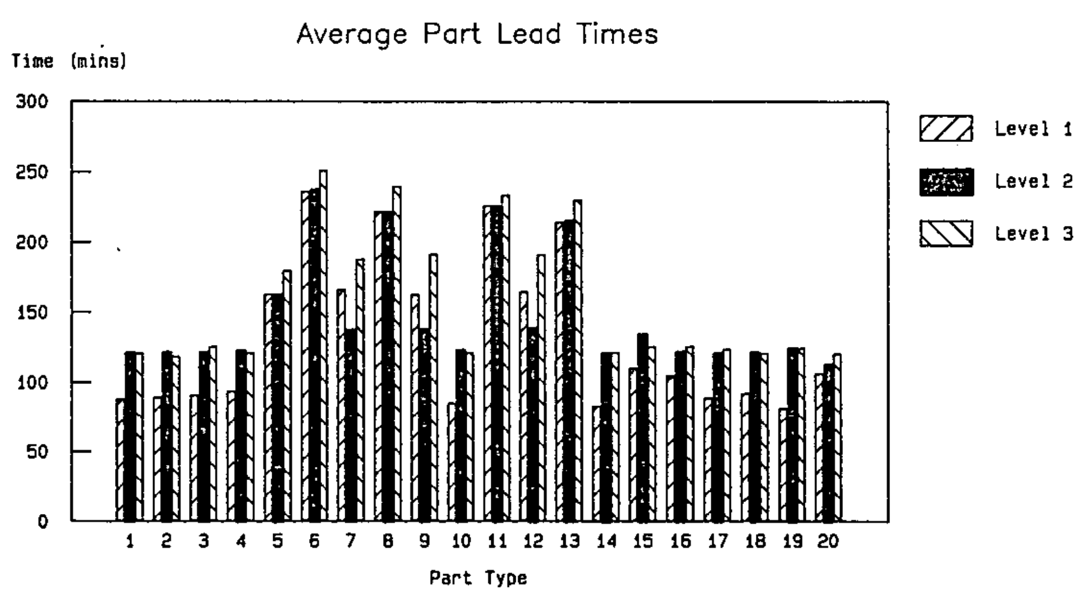

Figure 16 *Comparison of Part Lead Times from Three Levels* **LUT - FMS Research Group**