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The Application Of Computerised Modelling Techniques In Manufacturing System Design

VOL. 2

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Doctor of Philosophy

THE UNIVERSITY OF ASTON IN BIRMINGHAM

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Appendix A Survey of Cell Design Projects

A.1 Terms Of Reference

1. To assemble a body of knowledge on the subject of cell design for the two purposes of:

   a. constructing a training module for use by Group Training and

   b. writing a code of practice for use by Lucas Systems Engineering Projects.

2. To work within the context of factory redesigns and designs for new manufacturing systems.

3. To consider automotive and aerospace factories and, if an example becomes available, a small company in Lucas Industrial Systems.

4. To extend from market and product analysis, through analysis of manufacturing routes and methods to cell definition and steady state cell design.

5. To exclude financial analysis, bottom up costing, job design and investment appraisal.

6. To draw experience from several Task Force Projects including:

   Fordhouses
   Cwmbran Car Drum Breaks
   Cwmbran Heavy Duty Breaks
   Sudbury Nozzle Unit
   Pontypool SCS

7. To include (or to include references to) other suitable sources for training in and codifying techniques of:

   S.W.O.T. analysis
   Trade-off analysis
   Product Characteristic analysis
   Production Flow analysis
   Material Flow charting
   Input/Output analysis
   Information Flow charting
   Pareto analysis, ABC analysis
   Brain Storming
   Volume, Variety, Frequency analysis
   Failure Mode and Effect Analysis

8. To assess the efficiency and productivity aspects of the various techniques.

   Timescale 3 months
   Control 3 monthly reviews.

A.2 Types of Required Data

The information acquired from each task force project was sorted into nine categorise relating to:

1. design of manufacturing cells,
2. design of cell relationships,
3. the design process,
4. design data,
5. sources of data,
6. handling of data,
7. techniques used,
8. analyses used,
9. elements of steady state and dynamic design,

A.3 Survey Questionnaire

In order to structure the interviews with the task forces and obtain the required information for each of the above categories, a list of questions was prepared.

1. Design of Manufacturing Cells

- how many cells were designed;
- what size are the cells in terms of:

  output volume,
  output value,
  floor area,
  operators and
  machines;

- what factors define the cells;
- what are the unique characteristics of each cell;
- what features differentiate one cell from another.

2. Design of Modules/Cell Groupings

- how many modules were designed;
- what size are the modules in terms of:

  cells,
  output volume,
  output value,
  floor area,
  operators and
  machines;

- what factors define the modules;
- what are the unique characteristics of each module;
- what major features differentiate one module from another.

3. The Design Process

- was there a plan;
- was it adhered too;
- what design stages did the task force go through;
- how was the team organized;
- did the team work together or on independent

projects;

- was the design process linear;
- were there parallel stages;
- were there design iterations/loops;
- was the process structured, organised, logical and consistent or haphazard;
- did the teams undertake any of the following stages:

    problem definition,
    terms of reference,
    data requirements,
    data collection,
    analysis,
    system design,
    re-definition,
    re-analyse,
    design modification.

4. Design Data

- what information did the task forces use;
- market requirements:

    volume, frequency and mix,
    competitor profile,
    product cost, quality and delivery,
    market forecast;

- bill of material:

    product variety,
    product content, parts count and complexity,
    buy-out or make-in,
    levels;

- part characteristics:
- routes:

    number of operations,
    material flow routes,
    production complexity,
    unique/common machines;

- machines:

    capability,
    capacity;

- how accurate was the data;
- how reliable was the data;
- what data modifications were required.

5. Sources of Data

- where was data obtained from:

    engineering databases,
    engineering department,
    sales and marketing department,
    production planning department,

works department,
quality department;

- in what form was data retrieved:

  paper,
  micro film,
  magnetic disk.

6. Handling of Data

- how was data stored and manipulated:

  PC computers,
  computer spreadsheets,
  computer databases.

7. Techniques Used

- what design techniques were used:

  material flow charting,
  input/output charting,
  BOM/process charting,
  tabulation,
  spreadsheets,
  tree structures,
  brain storming,
  gantt charts.

8. Analysis Used

- what design analysis was undertaken:

  S.W.O.T. analysis,
  Trade-off analysis,
  Product Characteristic analysis,
  Production Flow analysis,
  Input/Output analysis,
  Pareto analysis, ABC analysis,
  Volume, Variety, Frequency analysis,
  Failure Mode and Effect Analysis.

9. Elements of Stead State and Dynamic Design

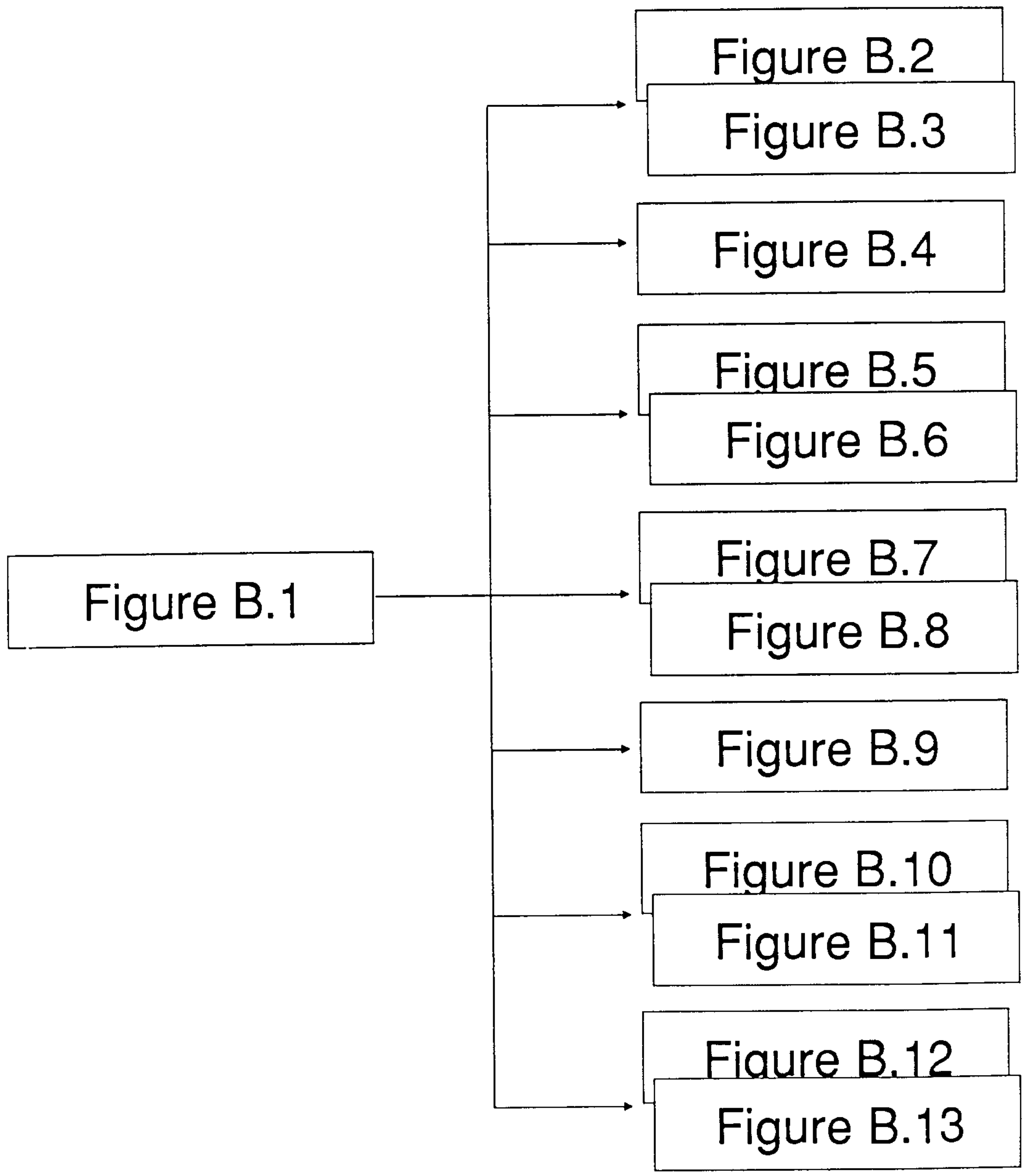
- what aspects of the cells operation required designing;
- was there a need to design the production process and/or products.
- what system elements were designed:

  process layout,
  material flow routes,
  production control/scheduling system,
  manning levels,
  operating procedures,
  external cell communication,
  identification of bottlenecks,
  establishments of cell utilization, output and WIP levels.

Key:

@ A Manufacturing Action

Relationship of Figures:



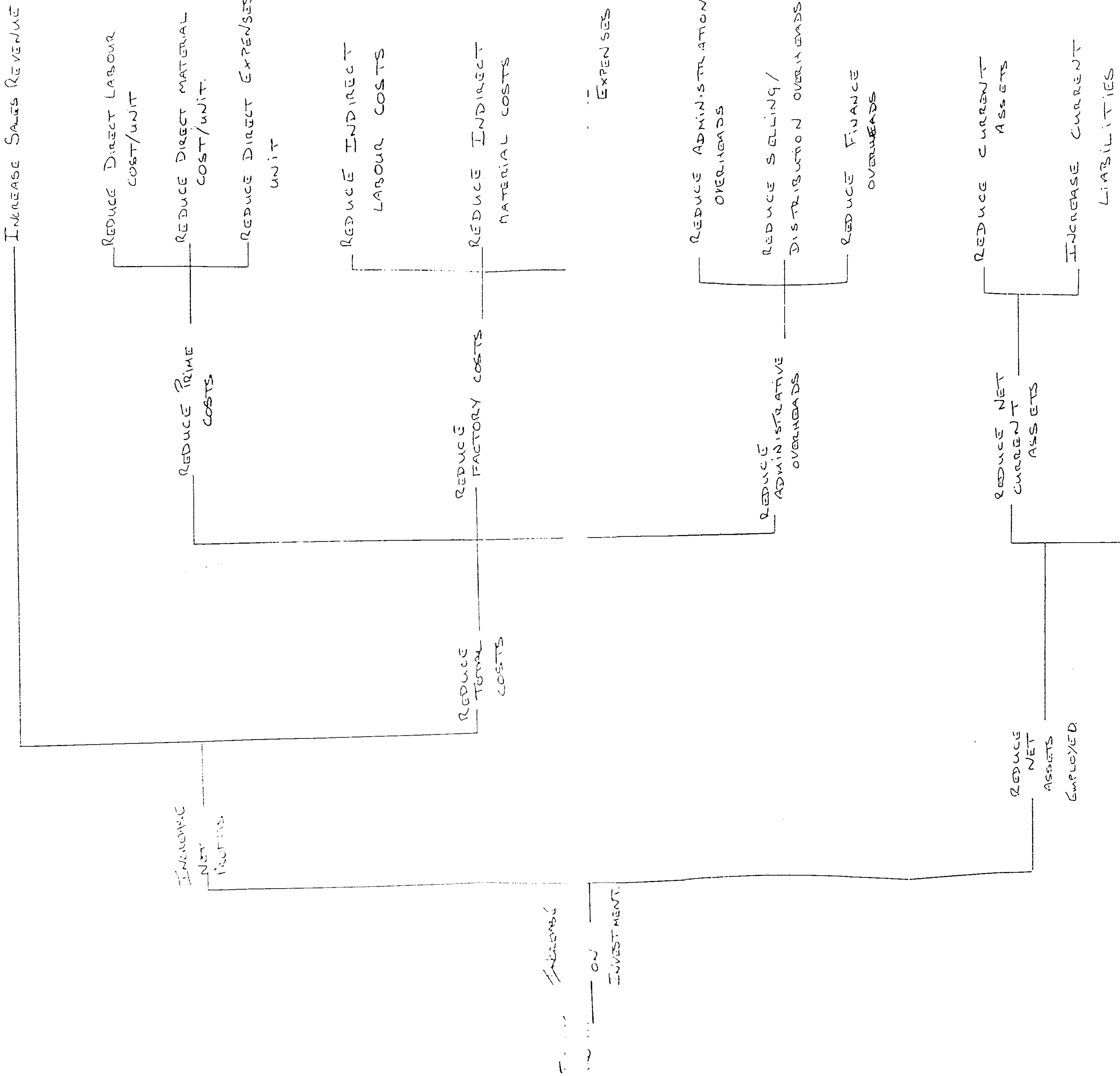


Figure B.1 Initial Decision Tree Branches

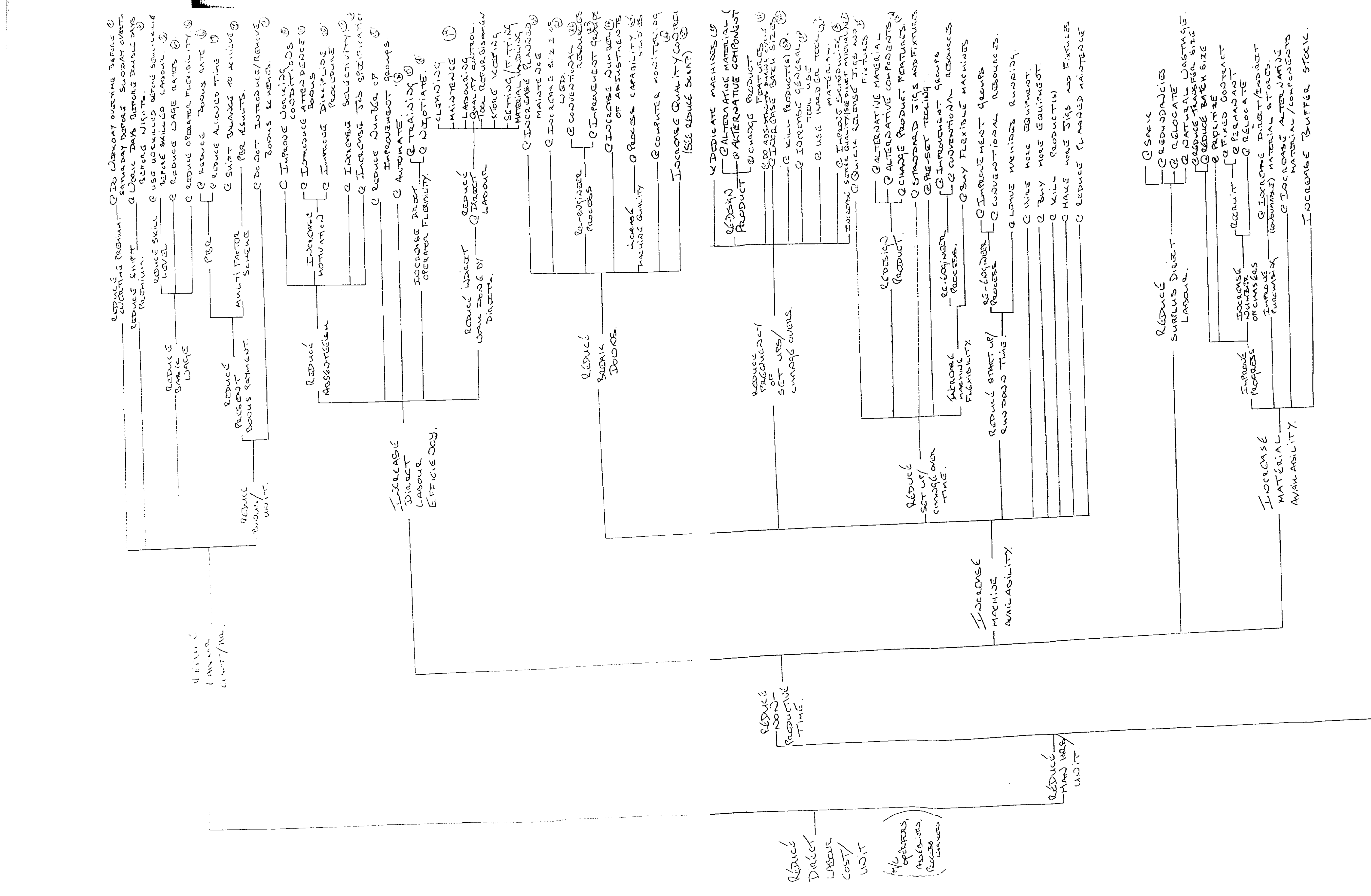


Figure B.2 Reduce Direct Labour (a)

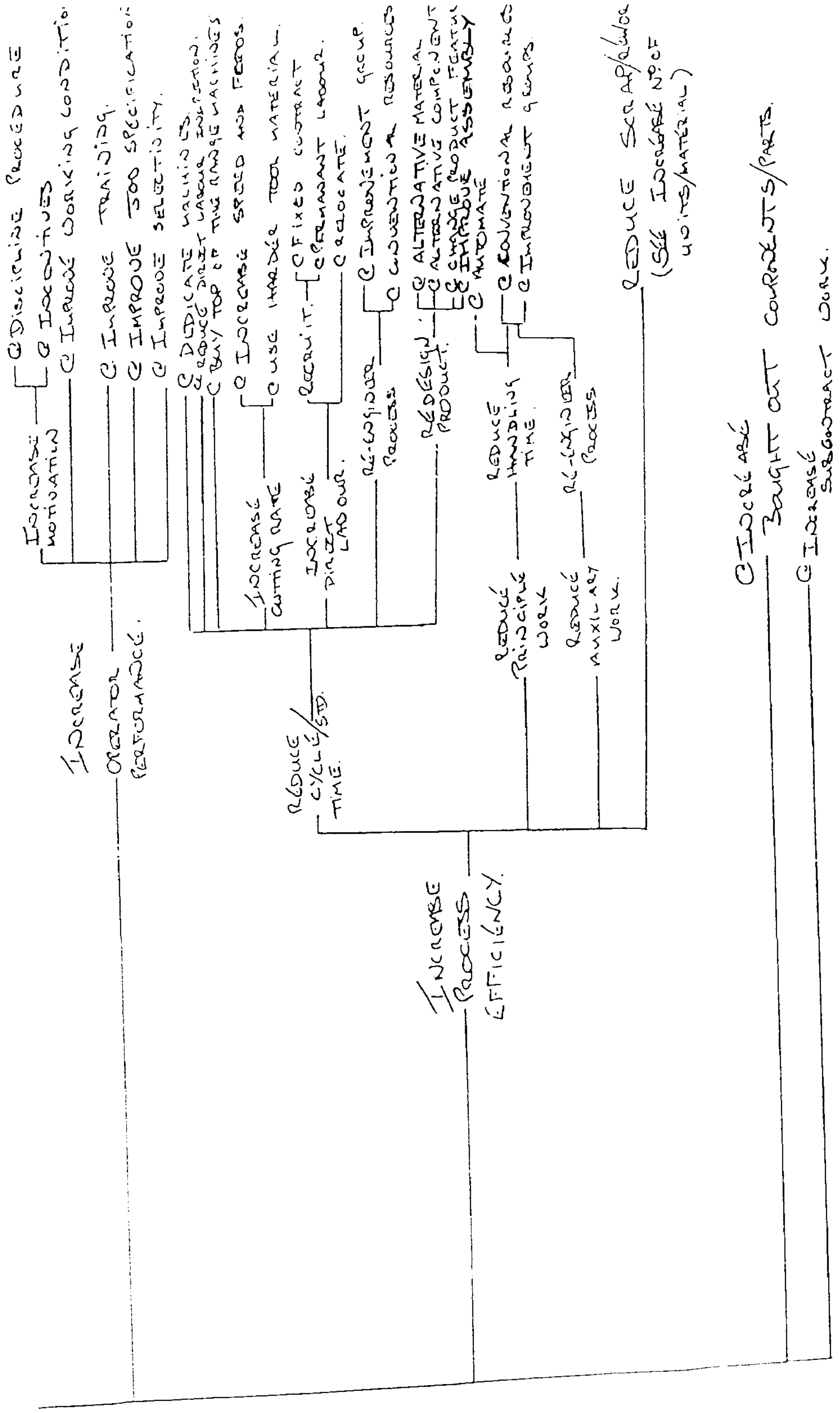


Figure B.3 Reduce Direct Labour (b)

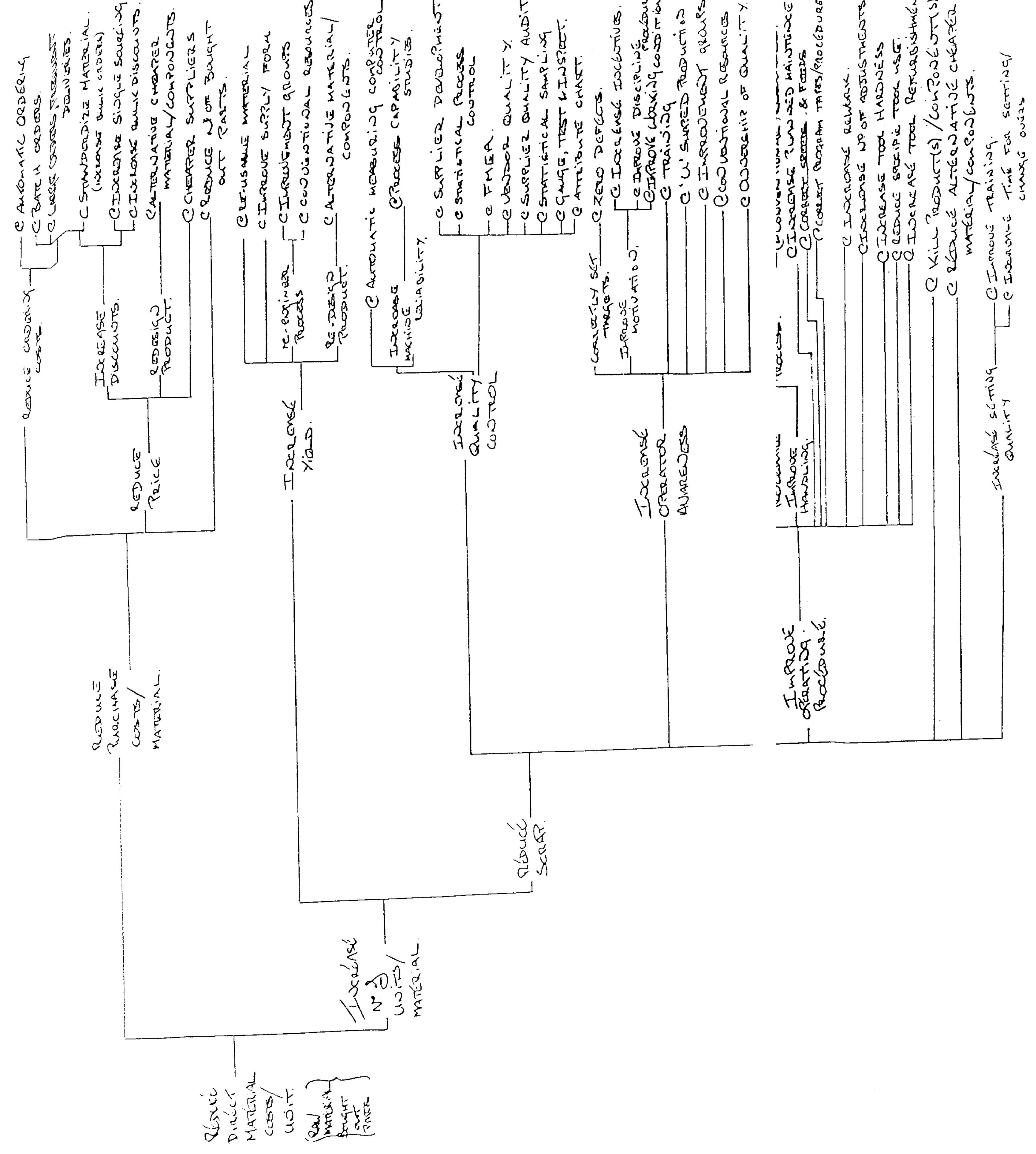


Figure B.4 Reduce Direct Material

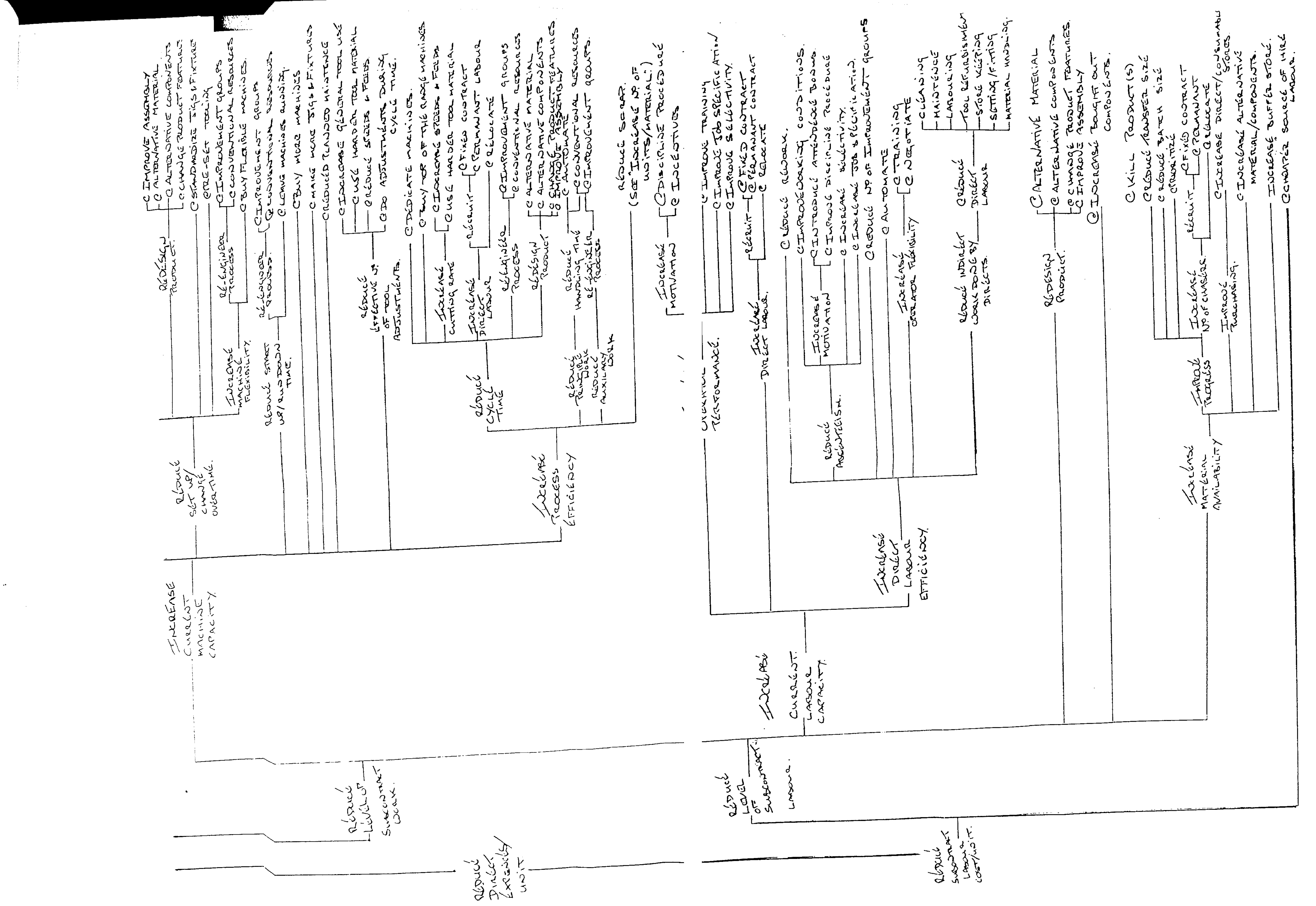


Figure B.5 Reduce Direct Expences (a)

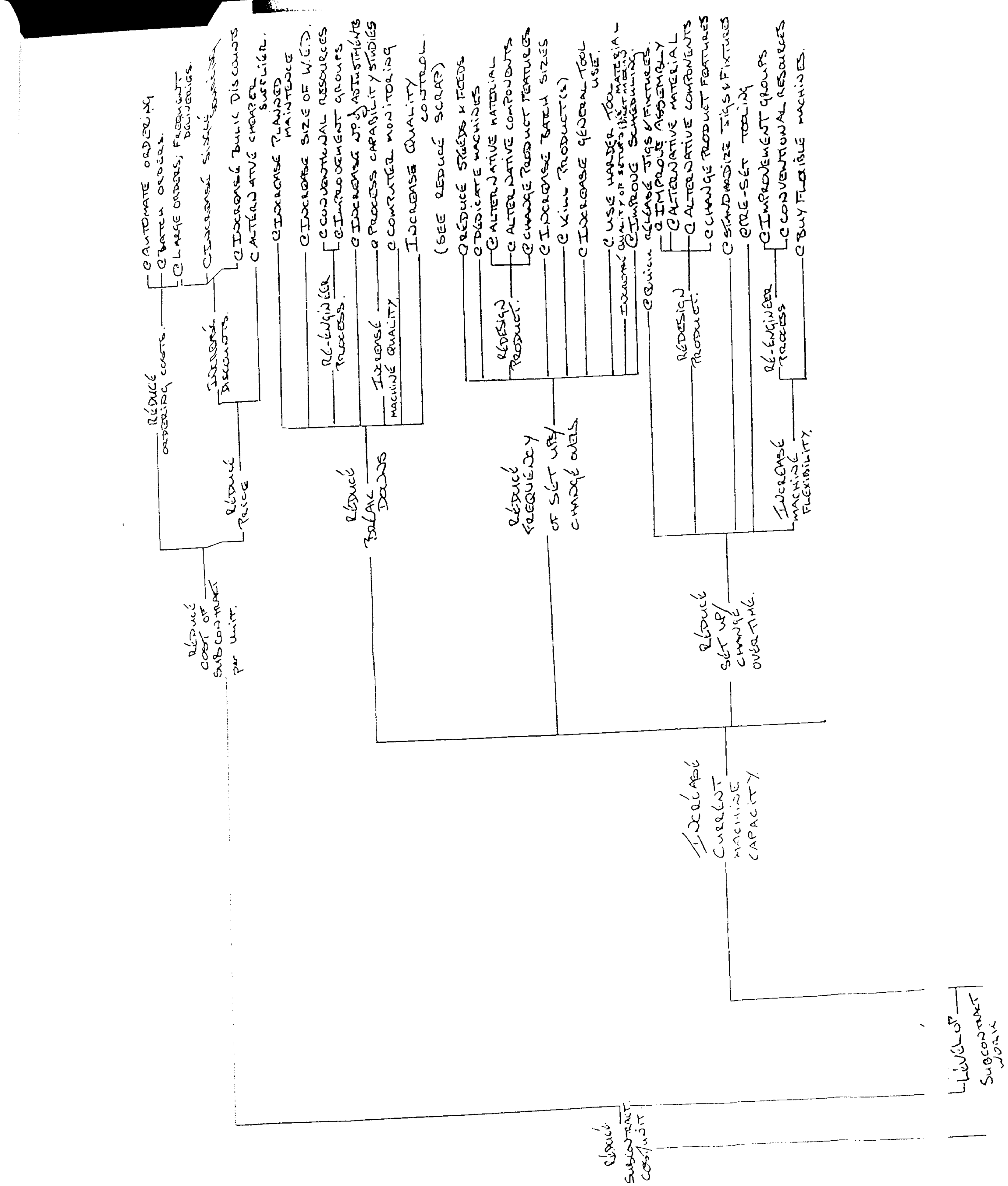


Figure B.6 Reduce Direct Expences (b)

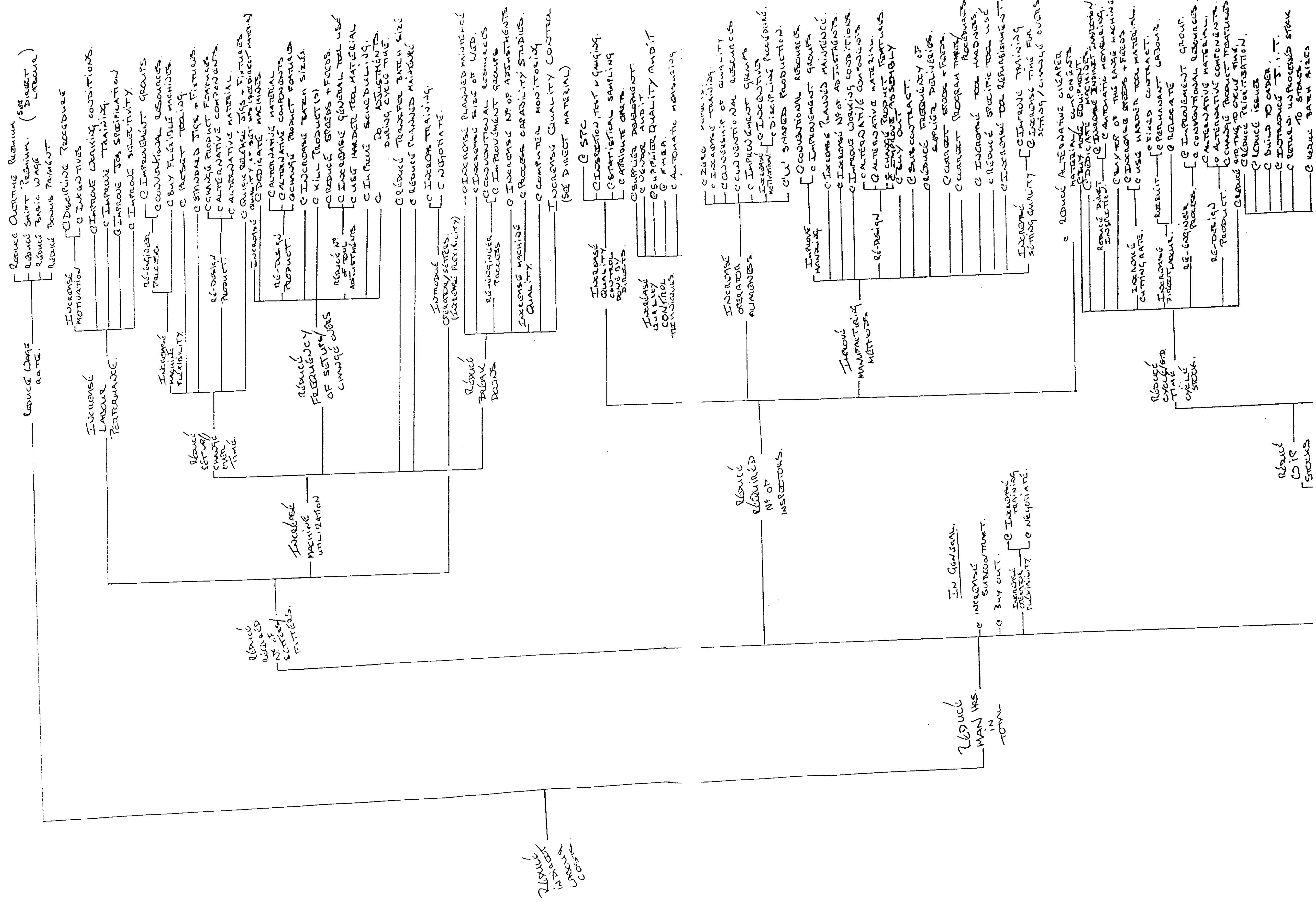


Figure B.7 Reduce Indirect Labour (a)

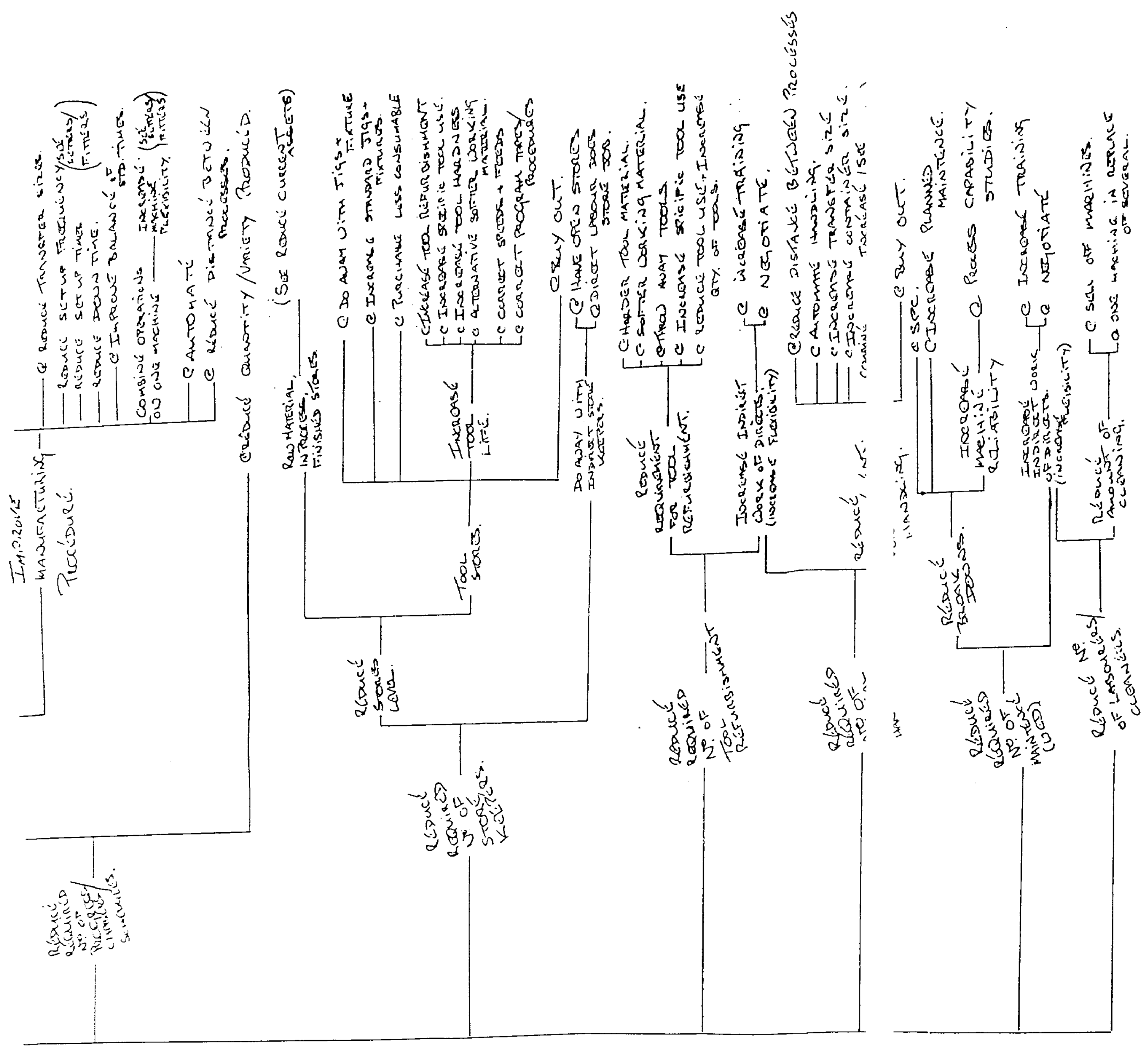


Figure B.8 Reduce Indirect Labour (b)

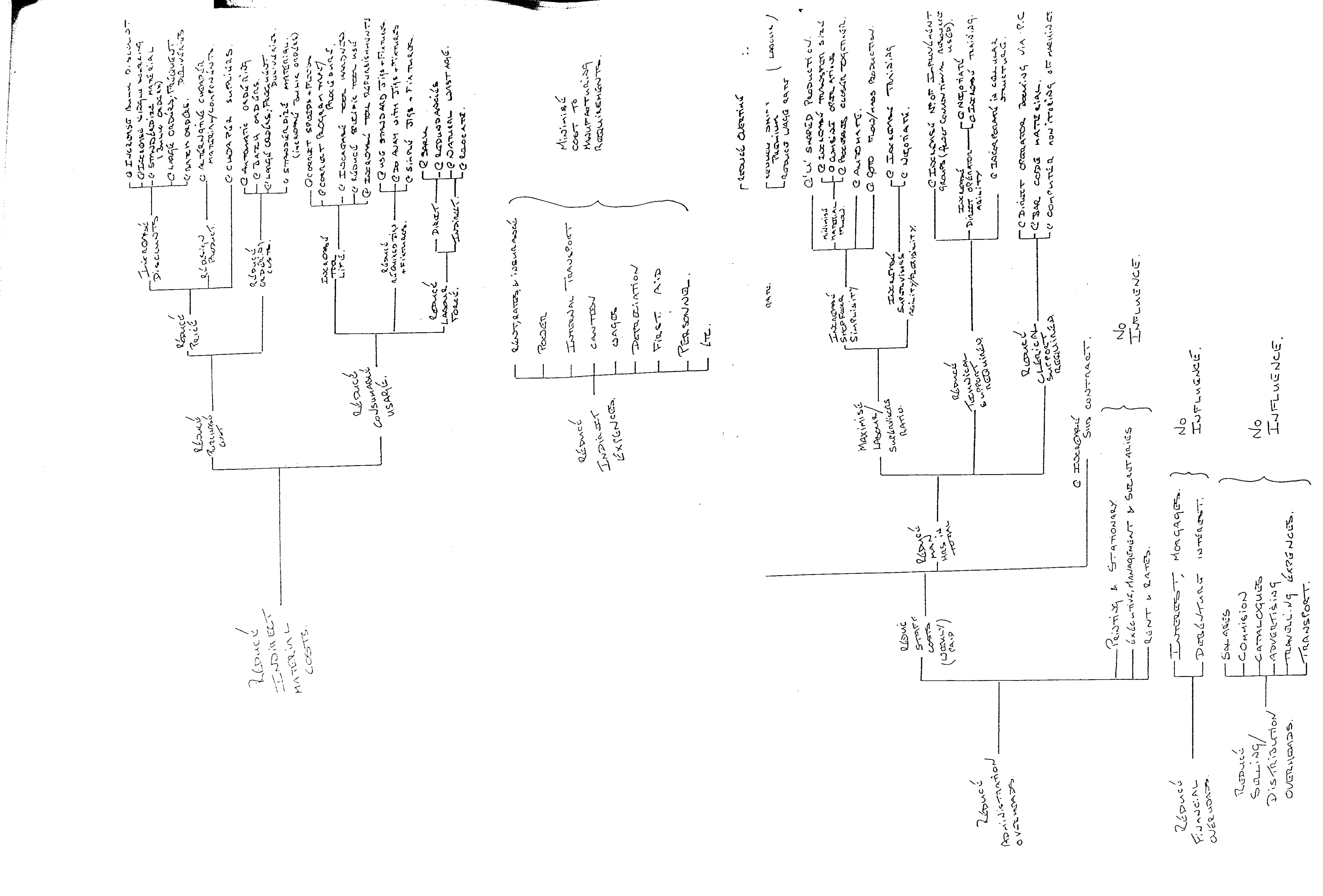


Figure B.9 Reduce Indirect Material, Expences & Overheads

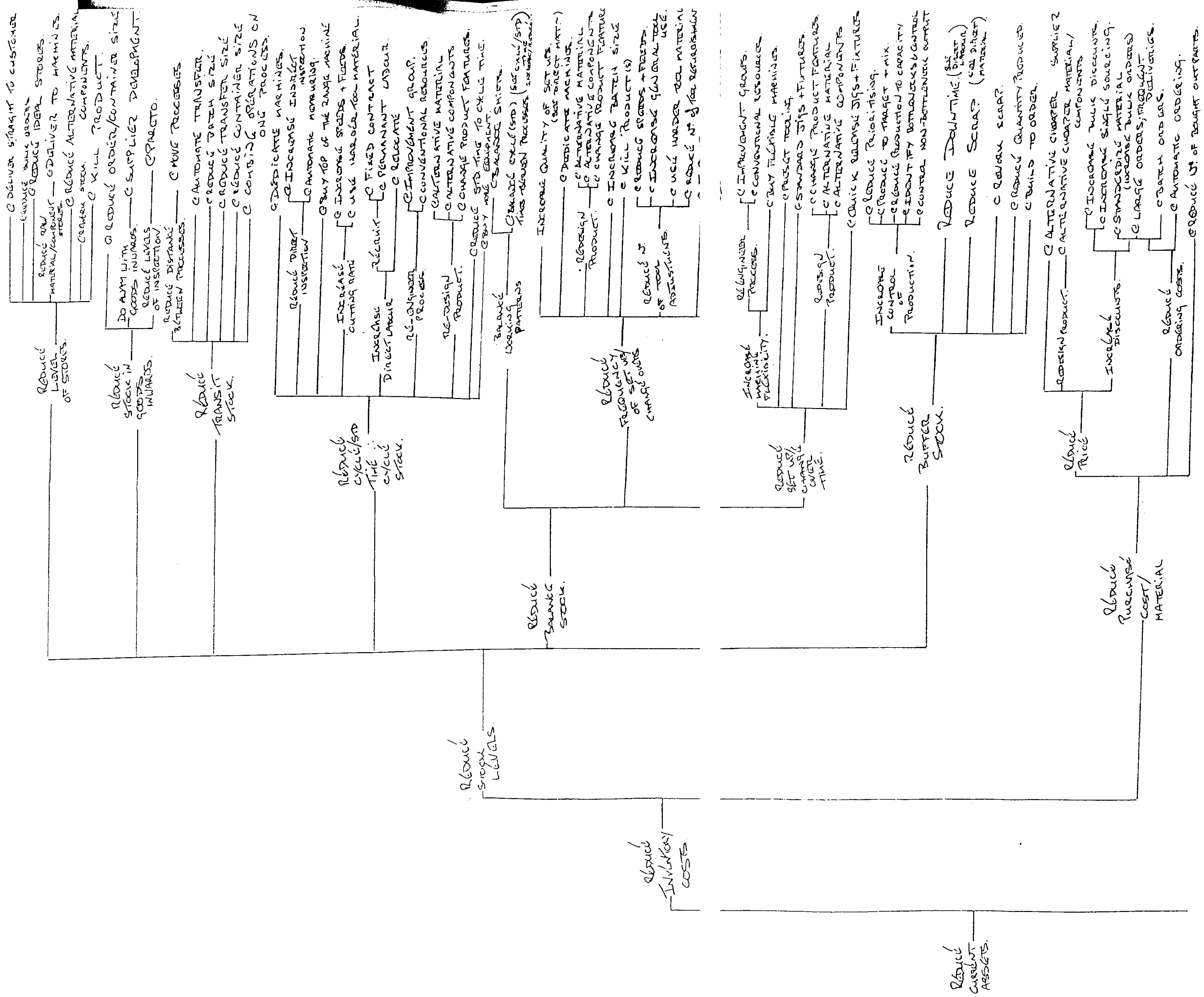


Figure B.10 Reduce Net Current Assets (a)

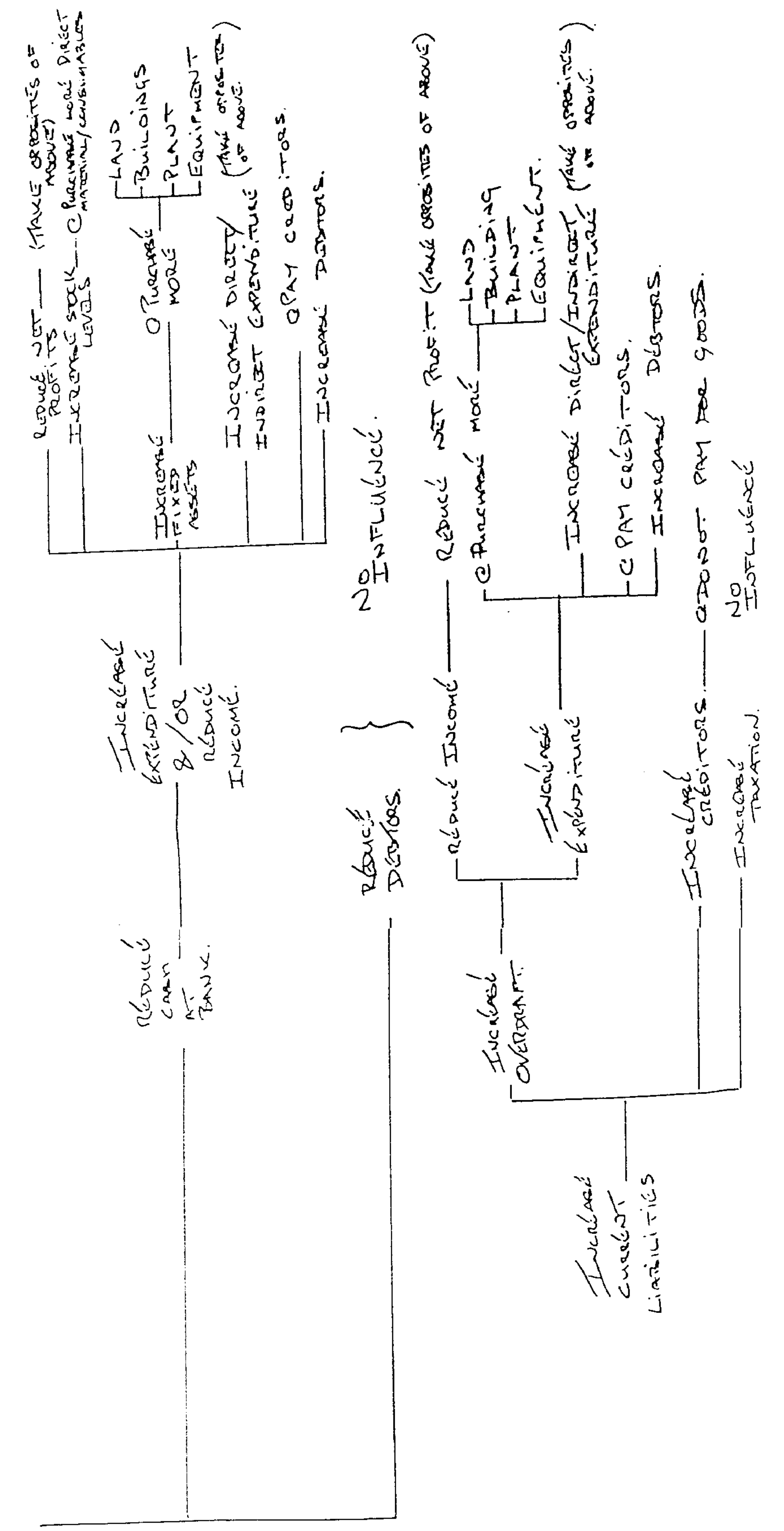


Figure B.11 Reduce Net Current Assets (b)

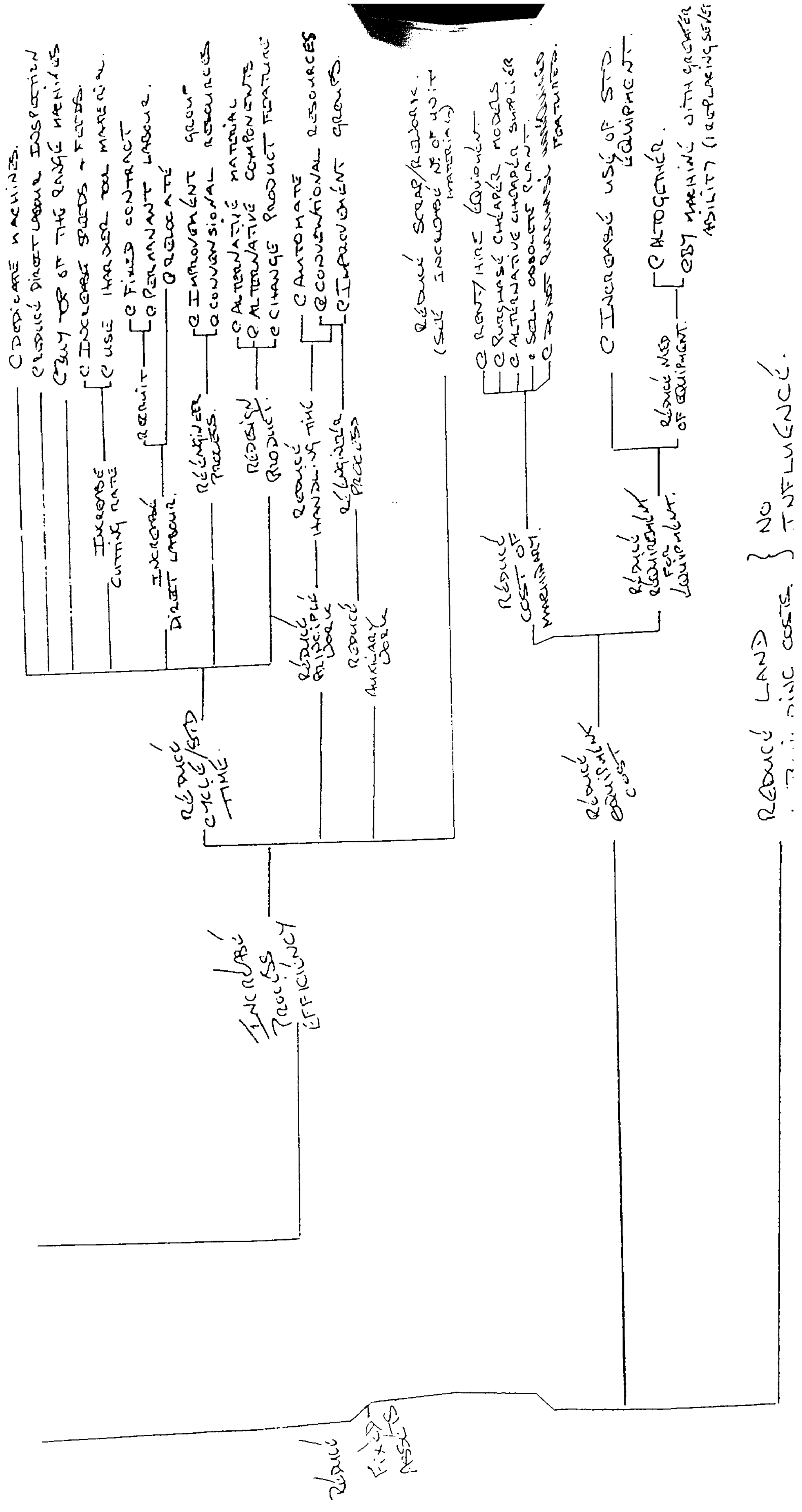


Figure B.12 Reduce Fixed Assets (a)

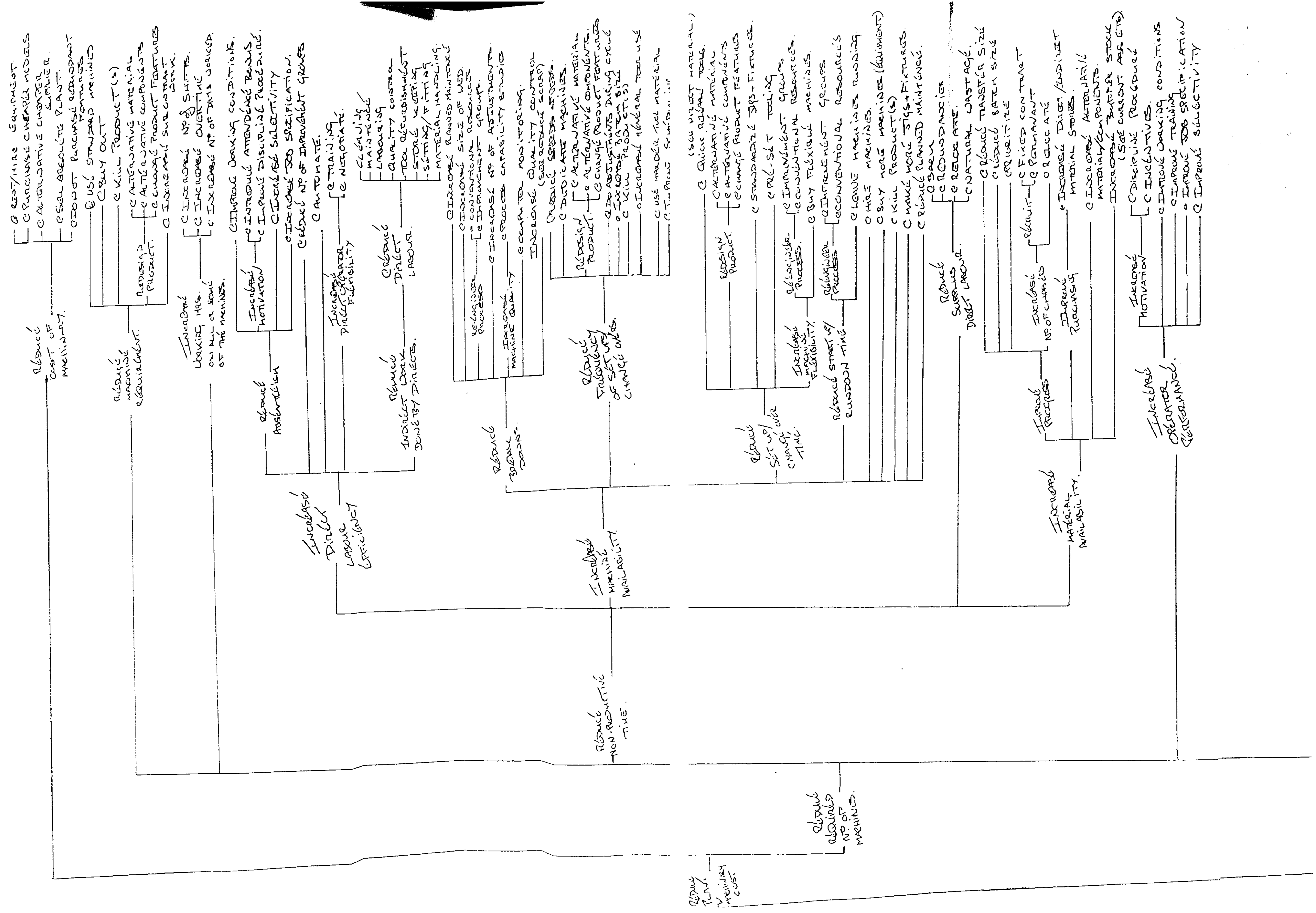


Figure B.13 Reduce Fixed Assets (b)

Appendix C Atoms: User Documentation

C.1 Screen Format

Throughout Atoms a standard screen format is used. (figure C.1). This comprises of upper and lower screen margins, both on a blue background, with a main work area in the middle on a black background. The upper margin displays the current date and time along with the name and version number of the model currently residing in memory. Whereas the lower margin displays all user inputs (in response to data requests) via a data entry field to the right of the screen, in addition to informing the user of how much RAM is available and the current location within the system. Whilst the main work area lists all operational information including menus, data input requirements and both simulation and mathematical run-time results.

C.2 Menus

Atoms is totally menu driven, with all options being selected either by the appropriately yellow highlighted number or letter or by moving a red bar selector to the relevant choice and pressing RETURN. The menu structure is shown in figure C.2 and all areas and their associated subroutines are comprehensively described in sections C.9 to C.15. At any menu the user has the ability to save the current model

```
==================================================================

19 April 1990          8:21 am        Model            Version


                        1.  Input Model Data

                        2.  Automatically Build A Model

                        3.  Add Work-In-Progress

                        4.  View An Existing Model

                        5.  Run Mathematical Model

                        6.  Run Simulation Model

                        7.  File Manager

                        0.  Quit ATOMS [F2 = Save]


Memory Available (in bytes) 164719                   Select
Action : \
==================================================================
```

Figure C.1 Atoms Main Menu

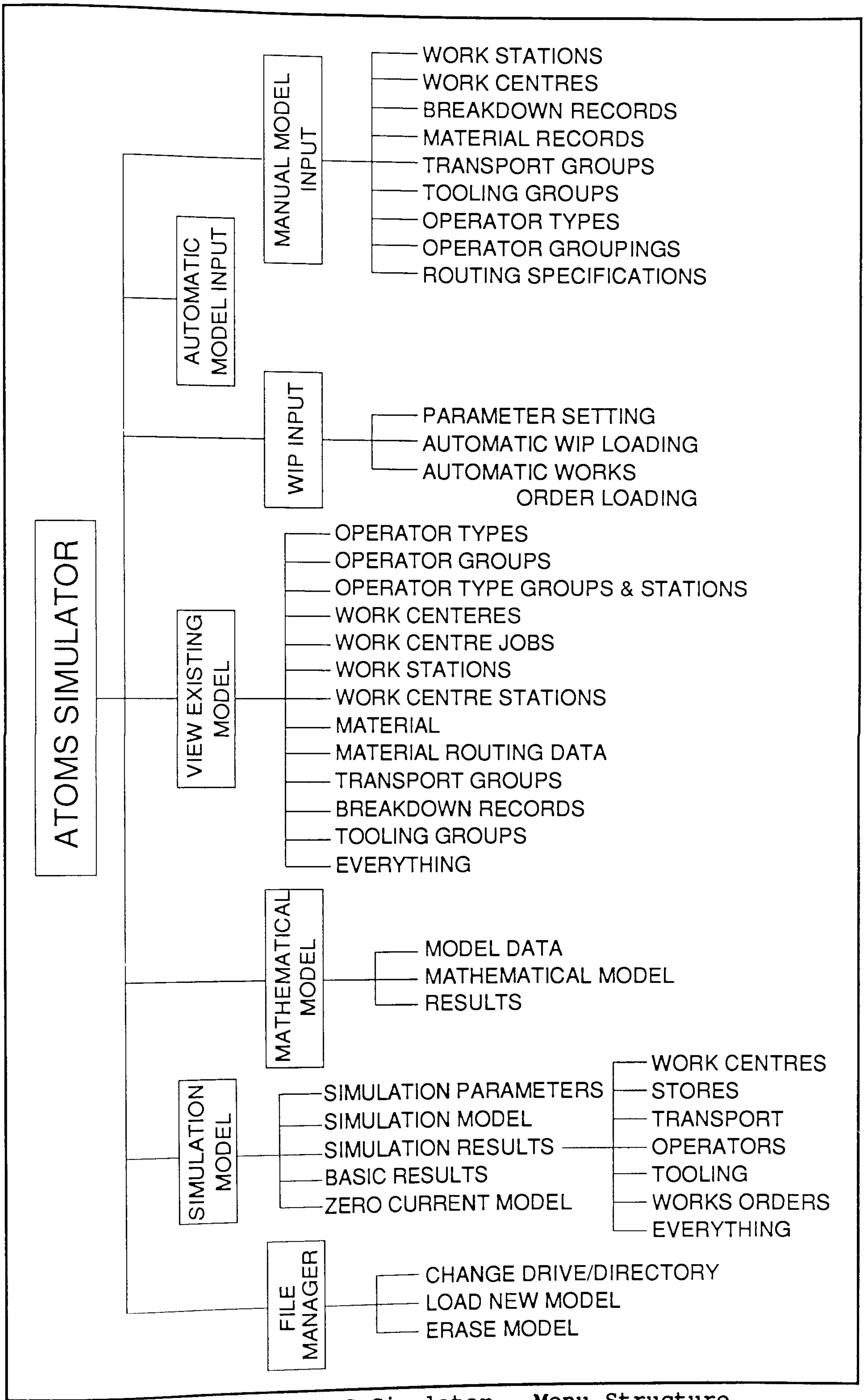


Figure C.2 ATOMS Simulator - Menu Structure specification by pressing the F2 key (section C.4). To reach the main menu from any subsequent lower-level, the user simply selects the "Quit" menu option an appropriate number of times and this moves the system backwards through the menus one level at a time. Whilst the same option at the main menu exists the system, returning the user to the Dos prompt.

C.3 Model And File Input Specification

In Atoms there are situations which require the identification of an appropriate model or text file. Entering any of the first six options on the main menu or selecting the "Load New Model" option in the file manager, involves having to specify the name of either a new or existing model description. Whereas other areas of the system require the name of ASCII text files. Both the above can be achieved in one of two ways.

Firstly if the model data or text files are known and in the current default subdirectory then the name can be directly typed in and entered by pressing RETURN. However if it's not known what model or text files are in the current subdirectory and/or the subdirectory needs to be changed then a directory listing can be obtain by pressing the space-bar. (In order to change the current drive specification the file manager has to be used). The space-bar option identifies the current drive and subdirectory path and lists all models or text files (.TXT extensions) that exist within it (depending upon the required specification), together with any further subdirectories. Additionally for each model a summary description is displayed, which can be entered either when they are first created or saved to disk, whilst for text files the first line of each file is highlighted.

A new subdirectory can easily be displayed by moving the cursor to the appropriate name and pressing RETURN, or in a similar way a model/text file can be selected. If in the selection of an existing model description the subdirectory is changed then this becomes the new default, which does not occur when choosing a text file.

On selecting a model/text file the directory listing is removed, whilst the chosen name appears within the data entry field in the lower margin. The name can now be edited, if required and then entered into the system by again pressing RETURN. A user can leave the directory listing without selecting a file name by pressing the ESC key. In this case the system defaults to the original file name, if any, displayed before the space-bar was selected.

If a user starts to type in a file name and then requires a directory listing then the ESC key has to be pressed before the space-bar. If no name at all is entered, then the system quits the input routine without any action being taken.

C.4 Saving A Model Specification

Atoms never automatically saves a model specification, even after a simulation or mathematical evaluation. Instead the user implements the model saving routine by pressing the F2 key at any menu listing. Furthermore the system prompts the user to save a model when loading a new one or quitting the system without first saving a previously modified specification currently resident in memory. Although the user has the option to ignore the prompt.

The model saving routine allows a model specification, resident in memory, to be saved to disk either under its current name or a new one. On entering the saving routing the current name of the model is set as the default and placed in the data entry field. A new name can now be typed in or the default edited, but when correct the name is entered by pressing RETURN. However a name can be selected from a directory listing obtained by pressing the space-bar (section C.3).

When a model is given the same name as one that already exists in the current subdirectory then there is the option to cancel the save routine or write over the existing model. If on entering the save routine a user want to quit without saving the current model, then the ESC key has to be pressed before RETURN.

The save routine always returns to the previous location within the system before F2 was pressed or continues the activity it started before prompting the user to save the current model. On completing an F2 implemented save the current model name is up dated to that which was saved or defaults to the original name if the routine was aborted.

C.5 Data Types

Data types represent all user inputs. There are three types: entry, keyword and selection.

An entry data type is simply where a user is required to enter some information. The data is typed in and entered by pressing an entry key, which includes the RETURN, PGUP, PGDN and up and down arrow keys. Entry data types include all numeric input, the identification of particular model resources (e.g. work centres, operator type, etc.) and the specification of a model or text file.

A keyword data type represents an input which has only a limited range of options. The system therefore provides a list of all discrete alternatives. To cycle forward through the list the user simply presses the space-bar. When the desired choice is displayed it is entered by pressing one of the enter keys. An example is the work centre modelling level which can only be DEPARTMENT, CENTRE or STATION.

A selection data type is where the user is required to control the display of information on the screen (e.g. output reports) or the movement of the cursor in a directory listing. User control is provided in the form of an appropriate combination of cursor control keys, specified to the right of the lower margin. The choice generally comprises of such options as the RETURN, ESC, PGUP, PGDN, HOME, END and left, right, up and down arrow keys.

C.6 Data Input

All data inputs are entered in response to "questions" or prompts displayed in the main work area of the computer screen. The data input routines provide a very simple and user-friendly approach to adding and modifying data necessary to describe a particular manufacturing model. The input routines control data entry, thereby making the process very efficient by only requesting information relevant to a particular model description. Furthermore the editor checks all inputs in order to isolate data errors and therefore prevent the specification of inconsistent models.

All main menu options have some data requirements which necessitate a user input. All data requirements are described within the main work area, with anything between one and ten data requests displayed on any given screen. Hence data requirements are highlighted sequentially in yellow, to indicate the necessary relevant input. In addition to focusing attention on the appropriate "question", the default or previous answer (depending on whether the question has been asked before in relation to the specific resource) is highlighted, within an adjacent data field, on a red background. Progress is made down a screen by answering the specific data requirements.

Data input is always via the entry field to the right of the lower margin, in square brackets. Here all data inputs are echoed before being entered by pressing RETURN, up arrow, down arrow, PGUP or PGDN keys. The home and end keys move the flashing cursor to the beginning and end of the entry field, whilst the left and right arrows move it one character in the appropriate direction. ESC deletes the current entry within the brackets. Underneath the entry field is always an indication of the range of the required input. For instance with some numeric data requirements it could say "Whole Number 1 to 99" or "Any Whole Positive Number". Whilst for a keyword requirement it simply says "Press Space-Bar or RETURN" and for selection requirements a list is displayed of all available keys from which to select. Hence all data requirements have a range of acceptable answers against which Atoms can verify all user inputs.

On entering a particular data requirement the system up dates the appropriate data field adjacent to the specific question. Whilst progressing down the screen the user can backtrack previous questions by pressing the up arrow key. Furthermore the input session for a given screen can be terminated early by pressing the PGUP or PGDN key, thereby skipping all remaining questions. When the input session for a particular screen has been completed, then the system inquires whether all data inputs are correct and therefore allows them to be altered if necessary. Corrections can be made by pressing the "N" key, whilst the "Y" and PgDn keys accept the inputs and move the system on to the next screen. However the PgUp key, though accepting the data inputs, moves the system back to the previous screen. The majority of options on the manual model input menu entail two or more screens of input. When describing a new resource or component routing operation all screens have to be displayed. Therefore the PGUP key does not allow a user to exit an input session at the first screen until all subsequent ones have been displayed, whereas with a previously defined resource or operation or other menu options this is not the case.

C.7 Production Control Systems

Atoms explicitly provides four alternative methods of production control MRP, Kanban, Statistical and Reorder point and can, by implication represent a further one, OPT. Consequently Atoms allows either separate or a combination of control systems to be modelled. This is achieved by allowing the specification of a production control method for each individual material component (section C.9.4).

An MRP control system can be easily employed in a model by utilizing the hooks in Atoms which allow a user to specify precisely the release of new production work batches (section C.11.3). The specification of batches can be taken from the recommended orders provide by a full mainframe MRP system or packages such as Lotus 123 and dBase, in which a user has defined the release of each work batch. Once created in a model, the work batches automatically pass from one operation to the next, as defined in the routing specification, and on completion Atoms provides a thorough and detailed analysis of its manufacturing life.

The representation of a kanban production control method in Atoms has been achieved in such away that it can emulate various implementations, including one and two card kanbans. In Atoms, for each material component, a kanban control system is specified in two stages (figure C.3). The first is the specification of the production kanban or batch size in which a component is produced, along with the current quantity available at the supplier (section C.9.4). Then at each work centre which undertakes an assembly operation requiring the kanbaned component, then the kanban or delivery quantity is specified, together with the number of components currently available at the centre (section C.9.2). The delivery quantity has to be multiplies of the production kanban. On emptying a kanban at a work centre, it is immediately returned to the supplier, where the appropriate number of production kanbans (equivalent to the delivery kanban) are issued for the corresponding component. If at the supplier there is a store of the material component, then the empty kanbaned is immediately filled and returned to the work centre. However if there is no store or the kanban is only partially filled then the kanbans queue, in order of arrival, for the next production kanban to be completed. When the kanbans are filled they are returned to the appropriate work centre.

A statistical control method requires the specification of three parameters. These define the release of the first production work batch, the release of subsequent batches and the actual batch size (section C.9.4). Once initiated the control method is self-perpetuating.

A reorder point control method is implemented by specifying the reorder point or stores level at which a new batch is released and the reorder quantity or batch size. Atoms then automatically monitors the stores level, releasing a new production work batch when the reorder point is reached. The stores level being reduced by customer sales orders (section C.14.2) and/or the issue of components to assembly operations. Only one work batch can ever exist for a reorder point component, even though before the completion of a work batch, the component store level may decreases further.

The representation of an OPT control system is achieved in Atoms through the use of two key features. The MRP production control method is utilized to release new production work batches of OPT material components, whilst the SCHEDULE sequencing rule (section C.9.2) is used to control precisely the operations undertaken at a particular work centre. Consequently OPT can only be represented at the CENTRE and STATION levels of abstraction because of the necessity to schedule the work centres.

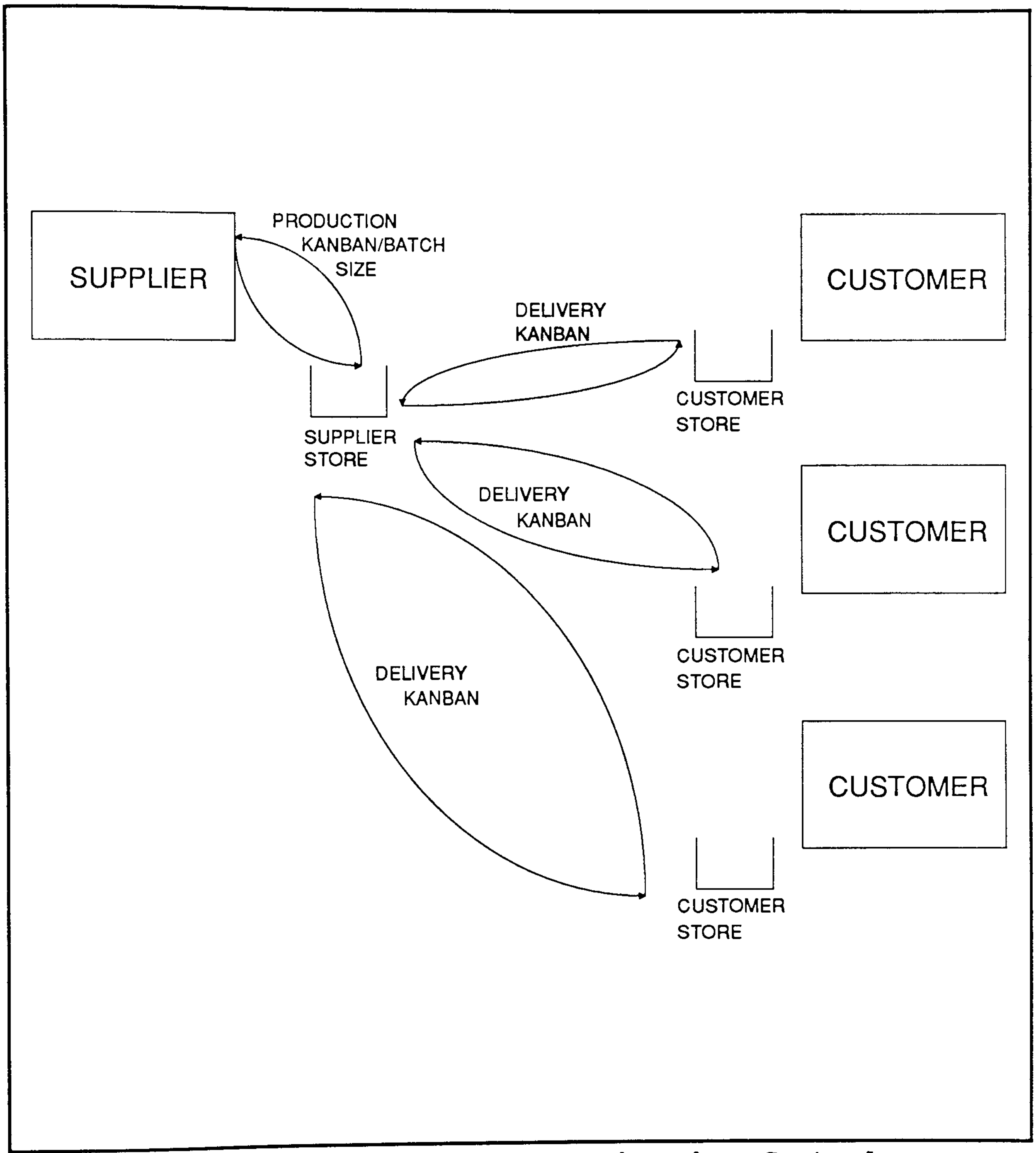


Figure C.3 ATOMS Implemented Kanban Control

C.8 Symbol and Term Definition

This section explains the special symbols used in subsequent sections to define the syntax of the various file inputs into Atoms.

[] Square brackets indicate an optional item or keyword. The square are not to be entered.

... An ellipsis indicates that one or more elements of the type listed can be specified.

/ A forward slash indicates that one option or another can be specified, but not both.

<> Angle brackets indicate that an item, of the type requested inside the brackets, must be specified. The angle brackets are not to be entered.

Mandatory Compulsory user input; there is no default value.

C.9 Manual Model Input

The MANUAL MODEL INPUT option on the main menu allows the specification and editing of all data requirements necessary to describe and construct a coherent computer simulation model. The main function of this subsection is to provide a simple and friendly interface to the internal database. Furthermore the routines include full error checking facilities, which prevent the specification of an inconsistent model.

On selecting the manual model input, Atoms requests the name of the model that is to be loaded into the internal database (section C.3). The model may already be memory resident or else is automatically retrieved from disk. If no name is specified then the system returns to the main menu. However if the name of a new and previously undefined model is specified then the system informs the user that it cannot find the appropriate files. Atoms therefore assumes the specification of a new manufacturing model. Consequently the system initialises the internal database and allows a summary description of the model to be entered for future reference, appearing as it does within a directory listing adjacent to the appropriate name. Having entered the input option a submenu is displayed and the alternative choices are described in sections C.9.1 to C.9.9. Regardless of whether a new or existing model is specified, the input routines allow the specification of new resources and operations, in addition to the modification or deletion of any previous definitions.

All the data requirements described in sections C.9.1 to C.9.9 are optional. An Atoms model will successively execute without the specification of operation times or resource requirements, whilst other parameters have default settings. However some inputs are defined as "optional", indicating that their required specification is dependent upon that of previous data inputs. For a particular system specification therefore, Atoms may not request the input of certain irrelevant "optional" data.

C.9.1 Work Station

A work station represents an individual machine or work area, which may be subject to discrete breakdowns. Work stations are associated with one or more work centres at a STATION modelling level (section C.9.2). The data input screen is illustrated in figure C.4, whilst the data requirements, along with their default values, are documented below.

1. This is a variable, of maximum length ten characters, which identifies a particular work station. If a previously defined station is specified then it's corresponding data is retrieved, else the parameters are set to the default values. If a previous work station specification is retrieved then this can be deleted by typing the reserved word DELETE in place of the resource name. Atoms will then confirm the request before removing the work station from the model description. The delete function only works with models which contain no work-in-progress and have not been executed, i.e. are at zero simulation time. To exit the work station record the user simply specifies no resource name.

   Default = Mandatory.

2. This is a keyword which specifies the manner in which the work station operates. The keywords are MANUAL, INDEX, PROCESS, ASSEMBLY and STORE.

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WORK STATION RECORD

1. Work Station Name                                [  PRESS220]

2. Work Station Type                                [  Assembly]

3. Possible Work Station Operator(s)           1.   [ PRESS_OPS]



4.         BreakDown                1.        2.        3.        4.

   Breakdown Record Number        [ 4]      [14]      [ 0]      [ 0]

5. Work Station Efficiency (100% = Std. Rate)          [100.00 %]

6. Station Jobs From Most Restricted Work Centre First Y/N [N]

7. Processing Capacity of Work Station  (Std. Part)     [   200]
==============================================================
```

Figure C.4 Work Station Input

MANUAL	is where a number of parts, from the same work batch, are simultaneously processed from start to finish before work is started on any other parts. INDEX is where a number of parts, from the same work batch, are only partially processed when work is started on other parts in the batch;
PROCESS	is where a number of dissimilar work batches are simultaneously processed;
ASSEMBLY	is similar to the manual one except that the process entails two or more parts combining together to form a new one;
STORE	at present is identical to assembly.

Default = MANUAL.

3. Listing of all previously defined operator types which can work at this particular work station.

   Default = None.

4. Restricted listing of previously defined breakdown records with which a work station is associated. A work station can have up to four different types of breakdowns.

   Default = None.

5. This is a percentage variable which specifies the operating efficiency of the work station.

   Default = 100%.

6. This is a keyword and in effect gives priority to batches waiting at work centres which have the lowest machine capacity, as a result of having the least number of work stations allocated to it. The keywords are Y and N for yes and no.

   Default = N.

7. This is an optional numeric variable, only required and therefore displayed when the work station type is PROCESS. For PROCESS represents furnaces and chemical baths and therefore the work stations have to be given a capacity, relating to the number of total standard parts they can simultaneously process. The user has therefore to select a "standard component" against which all others are scaled (section C.9.4).

   Default = 0 Standard Parts.

C.9.2 Work Centre

A work centre represents a group of one or more work stations which can undertake the same operations. All operations within Atoms are performed at specific work centres. In addition to work stations, a work centre contains two queues representing batches waiting either to be processed or moved to the next operation, respectively. The available processing capacity of a particular work centre can be represented at one of three different levels of detail. Therefore the modelling level determines the precise data requirements. Hence there are a number of different data input screens. The first screen is common to all modelling levels, however all subsequent ones are dependents upon which level is specified. The level of representation is indicated for all subsequent screens by the number immediately following the "Work Centre Record" heading:

level 1 = department;
level 2 = centre;
level 3 = station.

The data inputs relating to the first screen are illustrated in figures C.5, whilst the requirements, along with their default values, are documented below.

1. This is a variable, of maximum length ten characters, which identifies a particular work centre. If a previously defined centre is specified then it's corresponding data is retrieved, else the parameters are set to the default values. If a previous work centre specification is retrieved then this can be deleted by typing the reserved word DELETE in place of the resource name. Atoms will then confirm the request before removing the work centre from the model description. The delete function only works with models which contain no

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WORK CENTRE RECORD

1. Work Centre Name                                [PRESS-12TN]

2. Work Centre Type                                [  Assembly]

3. Modelling Level                                 [   Station]

4. Work Input Buffer Size    [   100.0]   5. Size Units   [Batch]

                                        / 1. No. of Batches \
                                        | 2. No. of Parts    |
                                        \ 3. Process Time    /

6. Work Output Buffer Size   [   100.0]   7. Size Units   [Batch]

8. Assembly Kanbans
        Kanbaned  Part         Kanban Size       Current Quantity
  1.    [     GEAR_A]          [ 1500]            [   1212.00]
  2.    [     GEAR_B]          [ 1500]            [   4560.00]
  3.    [     GEAR_C]          [ 1500]            [   3220.00]
==============================================================
```

Figure C.5 Work Centre Input - General Page 1

work-in-progress and have not been executed, i.e. are at zero simulation time. To exit the work centre record the user simply specifies no resource name.

Default = Mandatory.

2. This is a keyword which specifies the manner in which the work station operates. The keywords are MANUAL, INDEX, PROCESS, ASSEMBLY and STORE.

MANUAL	is where a number of parts, from the same work batch, are simultaneously processed from start to finish before work is started on any other parts.
INDEX	is where a number of parts, from the same work batch, are only partially processed when work is started on other parts in the batch;
PROCESS	is where a number of dissimilar work batches are simultaneously processed;
ASSEMBLY	is similar to the manual one except that the process entails two or more parts combining together to form a new one;
STORE	at present is identical to assembly.

Default = MANUAL.

3. This is a keyword which specifies the level of detail to which the available processing capacity, of a particular work centre, is to be represented. The keywords are DEPARTMENT, CENTRE and STATION. Hence this determines subsequent data input requirements. For the DEPARTMENT and STATION there is only one further screen, whilst for the CENTRE there are two. The actual data requirements for the three modelling levels are illustrated in figure C.6 to C.9.

Default = DEPARTMENT.

4. This numeric variable specifies the maximum size for the queue containing batches waiting to be processed. However if no transport device is specified to transfer components between two operations, then this limit is ignored. For it is only when components move via a transport device that the destination queue is firstly checked to determine whether it can accommodate the parts. Consequently an input queue can exceed the specified maximum.

Default = 1.

5. This keyword determines how the previously specified maximum queue size is to be measured. The keywords are BATCH, PART and TIME.

BATCH	indicates a maximum queues size based on the actual number of waiting batches, irrespective of the number of parts that

they contain e.g. one waiting batch could have 1000 parts, whilst another has 1.

PARTS bases the maximum queue size on the actual number of components in the queue, distributed between all waiting batches.

TIME bases the maximum queue size on the total amount of work, expressed in standard minutes, represented by the waiting batches.

Default = BATCH.

6. This numeric variable specifies the maximum size for the queue containing batches waiting to move onto the next operation, but are prevented because either there are no available transport devices or operators and/or the destination queue is full. However if no transport device is specified to transfer components between two operations, then the batch does not wait at the work centre but immediately moves to the next operation.

Default = 1.

7. This keyword determines how the previously specified maximum queue size is to be measured. The keywords are BATCH, PART and TIME.

BATCH indicates a maximum queues size based on the actual number of waiting batches, irrespective of the number of parts that they contain e.g. one waiting batch could have 1000 parts, whilst another has 1.

PARTS bases the maximum queue size on the actual number of components in the queue, distributed between all waiting batches.

TIME bases the maximum queue size on the total transfer time, expressed in minutes, represented by the waiting batches.

Default = BATCH.

8. This is an optional unrestricted listing, only relevant when the work centre type is ASSEMBLY or STORE. These data fields detail all kanban stores at a particular work centre (section C.7). Only material components that have been previously defined as operating under a kanban production control method can be specified (section C.9.3). The additional fields detail the size of the kanbans (i.e. the delivery quantity, which must be multiplies of the production kanban) and the total quantity of a particular kanbaned component at a centre.

Default = None.

for DEPARTMENT (Dept) work centres (figure C.6):

Dept 9. This is an unrestricted list clearly defining the operating pattern of a particular work centre. The listing comprises of three data fields. The start and finish times for a particular shift, (specified in a 24 hour format e.g. 3:30, 16:30) whilst the other details the number of work stations available. On entering a start time, the system by default adds eight hours for the the finish time and sets the number of work stations to one. To delete a shift simply specify zero start time.

Atoms simply works sequentially through a specified list, repeating the cycle until the simulation is terminated. The system compares the start time of the next shift with that of the current, to determine if it commences on the same or following day. If the start time for the next shift is greater than the current, Atoms assumes it begins later the same day, whereas a time earlier or equal implies that it commences the next day. Hence the listing can work in a number of ways. The operating shifts for a day or week can be specified and these will automatically be repeated either daily or weekly.

Shifts can overlap, the start time of a subsequent shift does not have to be later than the finishing time of an earlier one. The two data fields are independent. Furthermore, it is valid for the finish time of a shift to be earlier than its start, as this denotes that a shift terminates the following day.

Default = None.

Dept 10. This is a percentage variable which specifies the operating efficiency of the work stations.

Default = 100%.

==

WORK CENTRE RECORD - DEPARTMENT

9.	Shift No.	Start Time	Finish Time	No. Stations
	1.	[6: 0]	[14: 0]	[2]
	2.	[14: 0]	[1:30]	[2]

10. Work Station Efficiency (100% = Std. Rate) [90.00 %]

11. Processing Capacity of Work Station (Std. Part) [200]

==

Figure C.6 Work Centre Input - DEPARTMENT Page 2

Dept 11. This is an optional numeric variable, only required and therefore displayed, when the work centre type is PROCESS. For PROCESS represents furnaces and chemical baths therefore the work stations have to be given a capacity, relating to the number of total standard parts they can simultaneously process. The user has therefore to select a "standard component" against which all others are scaled (section C.9.4).

Default = 0 Standard Parts.

for CENTRE (Cen) work centres (figure C.7 and C.8):

Cen 9. This is an unrestricted list clearly defining the operating pattern of a particular work centre. The listing comprises of three data fields. The start and finish times for a particular shift, (specified in a 24 hour format e.g. 3:30, 16:30) whilst the other details the number of work stations available. On entering a start time, the system by default adds eight hours for the the finish time and sets the number of work stations to one. To delete a shift simply specify zero start time.

Atoms simply works sequentially through a specified list, repeating the cycle until the simulation is terminated. The system compares the start time of the next shift with that of the current, to determine if it commences on the same or following day. If the start time for the next shift is greater than the current, Atoms assumes it begins later the same day, whereas a time earlier or equal implies that it commences the next day. Hence the listing can work in a number of ways. The operating shifts for a day or week can be specified and these will automatically be repeated either daily or weekly.

Shifts can overlap, the start time of a subsequent shift does not have to be later than the finishing time of an earlier one. The two data fields are independent. Furthermore, it is valid for the finish time of a shift to be earlier than its start, as this denotes that a shift terminates the following day.

Default = None.

Cen 10. This is a keyword which specifies whether or not to regroup similar transfer batches queuing to be processed at a particular work centre. The original batch quantity being split during one of the previous operations. The keywords are Y and N for yes and no.

Default = Y.

Cen 11. This keyword specifies whether to override the queuing priority of a work centre input buffer, in order that the next batch to be processed is identical, in terms of material component and operation, to the previous one, so minimizing set-

```
==================================================================

WORK CENTRE RECORD - CENTRE


9.    Shift No.     Start Time     Finish Time     No. Stations

          1.          [ 6: 0]        [14: 0]           [  2]
          2.          [14: 0]        [ 1:30]           [  2]


10. Group Similar Waiting Batches (Y/N)                          [Y]

11. Select Next Batch Similar To Last Batch (Y/N)                [N]

12. Split Batches Between All Available Work Stations(Y/N)       [Y]

13. Only Consider The First Queuing Batch (Y/N)                  [N]
==================================================================
```

Figure C.7 Work Centre Input - CENTRE Page 2

```
==================================================================

WORK CENTRE RECORD - CENTRE


14. Work Station BreakDown Percentage                   [  3.91 %]
    (% of Operation Time)


15. Work Station Machine Efficiency                     [ 95.00 %]
    (As a %, Where 100% = Std. Rate)


16. Work Station Indirect Operator Losses               [  0.00 %]
    (% of Operation Time)


17. Sequencing Rule For Queuing Batches               [       FIFO]
    / i.e. FIFO, Schedule, LIFO,   \
    \      ShortSetUp, LeastSlack  /


18. Processing Capacity of Work Stations  (Std. Part)  [   250]
==================================================================
```

Figure C.8 Work Centre Input - CENTRE Page 3

ups. The keywords are Y and N for yes and no.

Default = N.

Cen 12. This is a keyword which specifies whether or not to split a work batch into transfer quantities which are processed by all available work stations within the centre. The alternative is for one work station to process the whole batch but pass the work on in discrete transfer quantities. The keywords are Y and N for yes and no.

Default = N.

Cen 13. This keyword can restrict processing consideration to only the first work batch in an input queue. Consequently, if work cannot start on that batch, then the work stations in the centre remain idle. The keywords are Y and N for yes and no.

Default = N.

Cen 14. This is a percentage variable which specifies the amount of work station capacity lost as a result of discrete breakdowns.

Default = 0%.

Cen 15. This is a percentage variable which specifies the operating efficiency of the work stations.

Default = 100%.

Cen 16. This is a percentage variable which specifies the amount of labour capacity lost as a result of having to perform indirect operations such as cleaning, material handling, inspection, etc.

Default = 0%.

Cen 17. This keyword prioritizes the batches waiting in a particular work centre queue. The keywords are FIFO, LIFO, SHORTSETUP, LEASTSLACK and SCHEDULE.

FIFO is first in first out.
LIFO is last in first out.
SHORTSETUP gives priority to batches with the shortest set-up times.
LEASTSLACK basis priority on the remaining operations and the batch due date. The calculation is:

$$\frac{\text{Due Date - (Remaining Set-up and Process Times)}}{\text{Number Of Remaining Operations}}$$

SCHEDULE specifies precisely the work batches that are to be processed at a work centre and the order in which they are to be done. The specification is by way of a text file, a different file for each work centre schedule and all ending in .SCH. Unlike all other text file, Atoms re-writes the schedule file during operation, deleting each batch reference from the file once it has been completed. When specifying a scheduling priority rule therefore, Atoms asks for the name of the text file (section C.3), and further enquires whether a work centre is allowed to work on batches other than those detailed in the schedule. This latter variable is a keyword, either Y or N for yes or no. If processing consideration is restricted to only the first batch in an input queue (data input 13), then this confines the system to only the first batch on a schedule. If this cannot start then the system will consider any batches waiting to be processed at a centre, unless told otherwise. The line format of the schedule text file is:

<ComponentName> <BatchQuantity> <BatchOperation>

where

ComponentName is a variable, of maximum length ten characters, which identifies a previously defined material component.

Default = Mandatory;

BatchQuantity is a numeric variable which specifies the number of component parts to process. "0" denotes that the whole batch is to be processed regardless of actual size. Otherwise only the quantities specified in the scheduled are processed. Therefore only part of a batch is processed if the actual size is greater than the specified quantity, or a number of similar batches may be processed in order to achieve the total quota.

Default = Mandatory.

BatchOperation is a numeric variable which identifies precisely the operation that a work batch must be on. "0" denotes that any batch containing the specified material component can be processed, regardless of the actual operation it is on.

Default = Mandatory.

Default = FIFO.

Cen 18. An optional numeric variable, only required and therefore displayed, when the work centre type is PROCESS. For PROCESS represents furnaces and chemical baths therefore the work stations have to be given a capacity, relating to the number of total standard parts they can simultaneously process. The user has therefore to select a "standard component" against which all others are scaled (section C.9.4).

Default = 0 Standard Parts.

for STATION (Stat) work centres (figure C.9):

Stat 9. This is a keyword which specifies whether or not to regroup similar transfer batches queuing to be processed at a particular work centre. The original batch quantity being split during one of the previous operations. The keywords are Y and N for yes and no.

Default = Y.

Stat 10. This keyword specifies whether to override the queuing priority of a work centre input buffer, in order that the next batch to be processed is identical, in terms of material component and operation, to the previous one, so minimizing set-ups. The keywords are Y and N for yes and no.

Default = N.

Stat 11. This is a keyword which specifies whether or not to split a work batch into transfer quantities which are processed by all available work stations within the centre. The alternative is for one work station to process the whole batch but pass the work on in discrete transfer quantities. The keywords are Y and

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=============================================================

WORK CENTRE RECORD - STATION

1. Group Similar Waiting Batches (Y/N)                          [Y]

2. Select Next Batch Similar To Last Batch (Y/N)                [N]

3. Split Batches Between All Available Work Stations (Y/N)      [Y]

4. Only Consider The First Queuing Batch (Y/N)                  [N]

5. Sequencing Rule For Queuing Batches              [       FIFO]
   / i.e. FIFO, Schedule, LIFO,   \
   \      ShortSetUp, LeastSlack /
6. Work Stations Included                     1.    [   PRESS219]
                                              2.    [   PRESS220]

=============================================================
```

Figure C.9 Work Centre Input - STATION Page 2

N for yes and no.

Default = N.

Stat 12. This keyword can restrict processing consideration to only the first work batch in an input queue. Consequently, if work cannot start on that batch, then the work stations in the centre remain idle. The keywords are Y and N for yes and no.

Default = N.

Stat 13. This keyword prioritizes the batches waiting in a particular work centre queue. The keywords are FIFO, LIFO, SHORTSETUP, LEASTSLACK and SCHEDULE.

FIFO is first in first out.
LIFO is last in first out.
SHORTSETUP gives priority to batches with the shortest set-up times.
LEASTSLACK basis priority on the remaining operations and the batch due date. The calculation is:

$$\frac{\text{Due Date - (Remaining Set-up and Process Times)}}{\text{Number Of Remaining Operations}}$$

SCHEDULE specifies precisely the work batches that are to be processed at a work centre and the order in which they are to be done. The specification is by way of a text file, a different file for each work centre schedule and all ending in .SCH. Unlike all other text file, Atoms re-writes the schedule file during operation, deleting each batch reference from the file once it has been completed. When specifying a scheduling priority rule therefore, Atoms asks for the name of the text file (section C.3), and further enquires whether a work centre is allowed to work on batches other than those detailed in the schedule. This latter variable is a keyword, either Y or N for yes or no. If processing consideration is restricted to only the first batch in an input queue (data input 12), then this confines the system to only the first batch on a schedule. If this cannot start then the system will consider any batches waiting to be processed at a centre, unless told otherwise. The line format of the schedule text file is:

<ComponentName> <BatchQuantity> <BatchOperation>

where

ComponentName is a variable, of maximum length ten characters, which identifies a previously defined material component.

Default = Mandatory;

BatchQuantity is a numeric variable which specifies the number of component parts to process. "0" denotes that the whole batch is to be processed regardless of actual size. Otherwise only the quantities specified in the scheduled are processed. Therefore only part of a batch is processed if its actual size is greater than the specified quantity, or a number of similar batches may be processed in order to achieve the total quota.

Default = Mandatory.

BatchOperation is a numeric variable which identifies precisely the operation that a work batch must be on. "0" denotes that any batch containing the specified material component can be processed, regardless of the actual operation it is on.

Default = Mandatory.

Default = FIFO.

Stat 14. Unrestricted listing of all, previously defined individual work stations that are available in a particular work centre. The same work station can appear in several work centre listings, however the station type has to coincide with that of the centres.

Default = None.

C.9.3 Breakdown Record

A breakdown record details a discrete stoppage in the operation of a work station. The records contain sufficient flexibility to represent both random breakdowns and planned maintenance. Whilst a specific breakdown record can be associated with one or more work stations.

When selecting the breakdown record option, the system requires a record number. A maximum of 20 breakdowns can be specified and each are referenced by the appropriate number. Therefore for each new number the defaults values are set or else the details previously specified against the record number are retrieved. The data input screens are illustrated in figure C.10 and C.11, whilst the data requirements, along with their default values, are documented below.

1. This keyword identifies the type of breakdown that is being specified. The keywords are RUNTIME, TIMEOUTPUT and UNITOUTPUT.

```
=================================================================

BREAKDOWN RECORD - No. 14

1. Breakdown Type   / RunTime     \                  [TimeOutPut]
                    | TimeOutPut  |
                    \ UnitOutPut  /

2. BreakDown Distribution                              [     Fixed]

3. Interval (Days/Hrs/Units)                            [   200.0]

4. Deviation (Span/Dev/Loop)                            [     0.0]

5. Wait Till End Of Job (Y/N)                                  [N]

7. Tooling List                    Part                Quantity

       1.                   [           ]          [        0]
       2.                   [           ]          [        0]
       3.                   [           ]          [        0]
=================================================================
```

Figure C.10 Breakdown Input Page 1

```
=================================================================

BREAKDOWN RECORD - No. 14

7. Repair Operator   [ ENGINEERS]  8. Job Priority (P/S)     [S]
   i.e. ([Station] Or Group Name)

9. Repair Distribution                                 [     Fixed]

10. Interval (Mins)                                     [   120.0]

11. Deviation (Span/Dev/Loop)                           [     0.0]

12. Waiting Distribution                               [     Fixed]

13. Interval (Mins)                                     [     0.0]

14. Deviation (Span/Dev/Loop)                           [     0.0]

15. Waiting Allowance      [   0]   16. Restart Time  [  0.00 %]
                                        (% Setup)
17. Restart Operator [           ] 18. Job Priority (P/S)    [P]
    i.e. ([Station] Or Group Name)

=================================================================
```

Figure C.11 Breakdown Input Page 2

RUNTIME	breakdowns occur regardless of whether or not a work station has been operating.
TIMEOUTPUT	breakdowns only occur after a work station has been operating for a certain duration, though not necessarily continuously.
UNITOUTPUT	breakdowns only occur after a work station has produced a certain number of parts, though not necessarily continuously.

Default = RUNTIME.

2. This is a keyword which identifies the probability distribution for the time or number of units between successive breakdowns. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

   Default = FIXED.

3. This is a numeric variable which identifies the mean or average time/units between successive breakdowns.

   Default = 0 Days/Hours/Units depending on the breakdown type.

4. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

   Default = 0.

5. This keyword determines whether a breakdown, which occurs during an operation, stops the current process or waits until the work batch has been completed. Thus emulating either random breakdowns or planned maintenance. The keywords are Y or N for yes or no.

   Default = N.

6. This is a restricted list which identifies tooling necessary to undertake the repair operation. The list allows up to three tools to be specified. The data fields identify the necessary pre-defined tooling group, along with the required quantity.

   Default = None.

7. This identifies the operator grouping (section C.9.8) which lists the individual operator types capable of performing the repair operation. Alternatively the reserved word STATION can be entered which implies that the operator type should be chosen from those listed as able to work at the particular work station which breaks down (section C.9.1).

Default = None.

8. This is an optional keyword only necessary when a repair operator is required and which specifies if the repair activity is a primary or secondary job. A Secondary job being one which can be interrupted and the operator seized by any primary job. Furthermore a secondary job can utilize operators, which although idle are waiting for a work station to finish processing, in order to unload the components they previously loaded. The keywords are P and S for primary and secondary.

   Default = P.

9. This is a keyword which identifies the probability distribution for the time to repair a work station. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

   Default = FIXED.

10. This is a numeric variable which identifies the mean or average time to repair a work station.

    Default = 0 Minutes.

11. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

    Default = 0.

12. This is a keyword which identifies the probability distribution for the time a partially processed work batch remains at a work station, which has broken-down, before being removed and loaded onto an alternative available station. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

    Default = FIXED.

13. This is a numeric variable which identifies the mean or average time a work batch waits.

    Default = 0 Minutes.

14. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.
    Default = 0.

15. This is a numeric variable which adds an allowance onto the previous waiting time. Consequently, if a batch is to be removed from a work station, on which

the repairs will be completed in three minutes, then an allowance of five minutes results in the batch remaining at the station.

Default = 0 Minutes.

16. This is a percentage of the original set-up time, which determines the time to reset the work station in order to continue processing the batch it had started before the breakdown occurred.

    Default = 0%.

17. This identifies the operator grouping (section C.9.8) which lists the individual operator types capable of resetting the work station. Alternatively the reserved word STATION can be entered which implies that the operator type should be chosen from those listed as able to work at the particular work station (section C.9.1).

    Default = None.

18. This is an optional keyword only necessary when a reset operator is required and which specifies if the reset activity is a primary or secondary job. A Secondary job being one which can be interrupted and the operator seized by any primary job. Furthermore a secondary job can utilize operators, which although idle are waiting for a work station to finish processing, in order to unload the components they previously loaded. The keywords are P and S for primary and secondary.

    Default = P.

C.9.4 Material Components

Material components represent temporary objects which follow a pre-defined route through a manufacturing model, visiting a number of work centres before leaving the system. The release of material components into a model can be controlled by one of four available production control methods. The control methods therefore determine the precise data requirements. Hence there are a number of common data inputs (figure C.12) with more specific requirements relating to the appropriate method of control (figures C.13 to C.17). This menu option therefore provides a basic description of all components before detailing their precise routing specification. All data requirements, along with their default values, are documented below.

1. This is a variable, of maximum length ten characters, which identifies a particular material component. If a previously defined component is specified then it's corresponding data is retrieved, else the parameters are set to the default values. If a previous material component specification is retrieved then this can be deleted by typing the reserved word DELETE in place of the resource name.

```
==============================================================

MATERIAL RECORD

1. Part Name Or Code Number                         [   BAR_12MM]

2. Scale : Part's Equivalent to Std. Part                [  0.1]

3. Production Ordering                              [        MRP]
   i.e. [MRP, Kanban, Statistics]
4. Material Attribute                               [           ]
5. Material Attribute                               [           ]

6. Purchase LeadTime Distribution                    [    Fixed]

7. Interval (Days)                                     [    10.0]

8. Deviation (Span/Dev/Loop)                           [     0.0]

==============================================================
```

Figure C.12 Material Input - General Page

Atoms will then confirm the request before removing the material component from the model description. The delete function only works with models which contain no work-in-progress and have not been executed, i.e. are at zero simulation time. To exit the material component record the user simply specifies no resource name.

Default = Mandatory.

2. This is a numeric variable which specifies the size of the particular component with reference to a standard part. The user therefore has to select a "standard component" against which all others are scaled.

   Default = 1.0.

3. This keyword identifies the method of production control employed to manage a particular component. The keywords are MRP, KANBAN, STATISTICS and ORDERPOINT (section C.7).

   Default = MRP.

4. & 5. These allow two component attributes, such as wight, colour, finish, etc., to be specified on which operations can be set-up (section C.9.9), as apposed to different component name or number.

   Default = None.

6. This is a keyword which identifies the probability distribution for the purchase lead-time for a component. The keywords are FIXED, UNIFORM,

EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

7. This is a numeric variable which identifies the mean or average purchase lead-time for a component.

   Default = 0 Minutes.

8. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

   Default = 0.

for MRP (Mrp) material components (figure C.13):

Mrp 9. This is numeric variable which specifies the initial store quantity for a MRP component.

   Default = 0 Units.

for KANBAN (Kan) material components (figure C.14):

Kan 9. This is a numeric variable which specifies the production quantity for a KANBAN component, i.e. the number of parts manufactured in one batch.

   Default = 0 Units.

```
================================================================

MATERIAL RECORD

1. Part Name Or Code Number                         [  BAR_12MM]

2. Scale : Part's Equivalent to Std. Part               [   0.1]

3. Production Ordering                              [       MRP]
   i.e. [MRP, Kanban, Statistics]
4. Material Attribute                               [          ]
5. Material Attribute                               [          ]

6. Purchase LeadTime Distribution                    [    Fixed]

7. Interval (Days)                                     [   10.0]

8. Deviation (Span/Dev/Loop)                           [    0.0]

9. Total Stores Quantity                             [    71.00]
================================================================
```

Figure C.13 Material Input - MRP Page

```
================================================================
MATERIAL RECORD

 1. Part Name Or Code Number                       [      GEAR_A]

 2. Scale : Part's Equivalent to Std. Part             [   0.1]

 3. Production Ordering                            [      Kanban]
    i.e. [MRP, Kanban, Statistics]
 4. Material Attribute                             [       Green]
 5. Material Attribute                             [            ]

 6. Purchase LeadTime Distribution                  [      Fixed]

 7. Interval (Days)                                   [      1.0]

 8. Deviation (Span/Dev/Loop)                         [      0.0]

 9. Kanban Size                                        [ 1500]

10. Total Stores Quantity                           [       0.00]
================================================================
```

Figure C.14 Material Input - Kanban Page

Kan 10. This is a numeric variable which specifies the initial store quantity for a KANBAN component, at the supplier (section C.7).

Default = 0 Units.

for an ORDERPOINT (Ord) material component (figure C.15):

Ord 9. This is a numeric variable which specifies the initial store quantity for an ORDERPOINT component.

Default = 0 Units.

Ord 10. This numeric variable specifies the stores level at which a production work batch for an ORDERPOINT component is released.

Default = 0 Units.

Ord 11. This is a numeric variable which specifies the reorder quantity for an ORDERPOINT component.

Default = 0 Units.

for a STATISTICS (Sta) material component (figure C.16 and C.17):

Sta 9. This is a numeric variable which specifies the initial store quantity for a STATISTICS component.

Default = 0 Units.

```
==================================================================

MATERIAL RECORD

 1. Part Name Or Code Number                          [    GEAR_AB]

 2. Scale : Part's Equivalent to Std. Part                [  1.0]

 3. Production Ordering                               [OrderPoint]
    i.e. [MRP, Kanban, Statistics]
 4. Material Attribute                                [          ]
 5. Material Attribute                                [          ]

 6. Purchase LeadTime Distribution                     [    Fixed]

 7. Interval (Days)                                       [    0.0]

 8. Deviation (Span/Dev/Loop)                             [    0.0]

 9. Total Stores Quantity                               [     0.00]

10. Reorder Point Level [   0.0] 11. Reorder Quantity [   1.0]
==================================================================
```

Figure C.15 Material Input - Orderpoint Page

```
==================================================================

MATERIAL RECORD

1. Part Name Or Code Number                           [  BAR_12MM]

2. Scale : Part's Equivalent to Std. Part                 [  0.1]

3. Production Ordering                                [Statistics]
   i.e. [MRP, Kanban, Statistics]
4. Material Attribute                                 [    Yellow]
5. Material Attribute                                 [          ]

6. Purchase LeadTime Distribution                      [    Fixed]

7. Interval (Days)                                        [   10.0]

8. Deviation (Span/Dev/Loop)                              [    0.0]

9. Total Stores Quantity                                [    71.00]
==================================================================
```

Figure C.16 Material Input - Statistics Page 1

```
================================================================

MATERIAL RECORD

10. Works Order Arrivals (Y/N)                              [Y]
    e.g. ([N] For Purchase Deliveries)
11. 1st Order Arrival Distribution                   [     Fixed]

12. Interval (Mins)                                     [     0.0]
13. Deviation (Span/Dev/Loop)                           [     0.0]


14. MTB Orders Distribution                          [     Fixed]

15. Interval (Mins)                                     [     0.0]
16. Deviation (Span/Dev/Loop)                           [     0.0]


17. Order Size Distribution                          [     Fixed]

18. Interval (Mins)                                     [     0.0]
19. Deviation (Span/Dev/Loop)                           [     0.0]

================================================================
```

Figure C.17 Material Input - Statistics Page 2

Sta 10. This is a keyword which indicates whether works or purchase orders are being statistically controlled. The keywords are Y and N for works and purchase orders respectively.

Default = Y.

Sta 11. This is a keyword which identifies the probability distribution for the duration between the start of simulation time and the release of the first production batch or purchase order. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Sta 12. This is a numeric variable which identifies the mean or average duration between the start of simulation time and the release of the first production batch or purchase order.

Default = 0 Minutes.

Sta 13. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Sta 14. This is a keyword which identifies the probability distribution for the time between the release of successive production batches or purchase orders. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Sta 15. This is a numeric variable which identifies the mean or average time between the release of successive production batches or purchase orders.

Default = 0 Minutes.

Sta 16. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Sta 17. This is a keyword which identifies the probability distribution for determining the size of production batches or purchase orders. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Sta 18. This is a numeric variable which identifies the mean or average batch or order size.

Default = 0 Minutes.

Sta 19. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

C.9.5 Transport Group

A transport group represents a manufacturing system resource which moves components from one operation to another; from the output queue of one work centre to the input queue of another. There are two alternative types, trucks or conveyors. The data input screen is illustrated in figure C.18, whilst the data requirements, along with their default values, are documented below.

1. This is a variable, of maximum length ten characters, which identifies a particular transport group. If a previously defined group is specified then it's corresponding data is retrieved, else the parameters are set to the default values. If a previous transport group specification is retrieved then this can be deleted by typing the reserved word

===

TRANSPORT RECORD

1. Name of Transport Group	[HANDTRUCKS]
2. Type Of Transport Device	[DISCRETE]
3. Number of Devices in Group	[2]
4. Time Response Distribution	[Fixed]
5. Interval (Mins)	[4.0]
6. Deviation (Span/Dev/Loop)	[0.0]
7. Speed of Transport (Distance per Mins)	[10.0]
8. Capacity Of Conveyor Transport	[0.0]

===

Figure C.18 Transport Input

DELETE in place of the resource name. Atoms will then confirm the request before removing the transport group from the model description. The delete function only works with models which contain no work-in-progress and have not been executed, i.e. are at zero simulation time. To exit the transport group record the user simply specifies no resource name.

Default = Mandatory.

2. This is a keyword which identifies the type of transport device that is being represented. The keywords are TRUCK and CONVEYOR.

TRUCK is a discrete transport device which moves one work batch at a time and has limited availability.

CONVEYOR is permanently fixed between two work centres, is always available and can handle a number of different work batches simultaneously, though there is a maximum capacity limitation.

Default = TRUCK.

3. This is an optional numeric variable which specifies the number of available trucks. For conveyors the value is always one.

Default = 1.

4. This is a keyword which identifies the probability

distribution for the time an available transport device takes to respond to a request to move a work batch. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

5. This is a numeric variable which identifies the mean or average time an available transport device takes to respond to a request to move a work batch.

   Default = 0 Minutes.

6. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

   Default = 0.

7. This is a numeric variable which specifies how fast a transport device travels. This variable is used if, in the routing specification, the transfer distance is specified rather than the time.

   Default = 1 Distance unit per minute.

8. This is an optional numeric variable, only required for conveyor transport devices. It specifies the capacity of a conveyor as the total number of standard parts that it can be transferring simultaneously. The user has therefore to select a "standard component" against which all others are scaled (section C.9.4).

   Default = 0 Standard Parts.

C.9.6 Tooling Group

A tooling group represents a collection of similar limited manufacturing resources such as cutting tools, jigs, fixtures and pallets. The data input screen is illustrated in figure C.19, whilst the data requirements, along with their default values, are documented below.

1. This is a variable, of maximum length ten characters, which identifies a particular tooling group. If a previously defined group is specified then it's corresponding data is retrieved, else the parameters are set to the default values. If a previous tooling group specification is retrieved then this can be deleted by typing the reserved word DELETE in place of the resource name. Atoms will then confirm the request before removing the tooling group from the model description. The delete function only works with models which contain no work-in-progress and have not been executed, i.e. are at zero simulation time. To exit the tooling group record the user simply specifies no resource

```
=================================================================
TOOLING RECORD

1. Name of Tooling Group                              [    FIXTURE]

2. Quantity of Tools in Group                                 [ 1]
=================================================================
```

Figure C.19 Tooling Input

name.

Default = Mandatory;

2. This numeric variable specifies the number of individual tools available in a particular group.

   Default = 1.

C.9.7. Operator Types

An operator type is a collection of similar limited manufacturing resources which have a restricted period of availability. Operator types are associated with a number of different operations including machine set-up, work loading and unloading, job processing, material handling and the maintenance and/or repair of work stations. The data input screen is illustrated in figure C.20, whilst the data requirements, along with their default values, are documented below.

1. This is a variable, of maximum length ten characters, which identifies a particular operator type. If a previously defined type is specified then it's corresponding data is retrieved, else the parameters are set to the default values. If a previous operator type specification is retrieved then this can be deleted by typing the reserved word DELETE in place of the resource name. Atoms will then confirm the request before removing the operator type from the model description. The delete function only works with models which contain no work-in-progress and have not been executed, i.e. are at zero simulation time. To exit the operator type record the user simply specifies no name.

   Default = Mandatory.

2. This percentage variable which specifies the performance efficiency of the operator type.

   Default = 100%.

===

OPERATOR TYPE RECORD

1. Name of Operator Group [PRESS_OPS]

2. Efficiency [90.00 %]

3. Shift No. Start Time Finish Time Variable O/T No. Operators

Shift No.	Start Time	Finish Time	Variable O/T	No. Operators
1.	[6: 0]	[14: 0]	[0]	[2]
2.	[14: 0]	[1:30]	[0]	[2]

4. Job Priority Order
   i.e. [Operation, Repair,
   Material, Setting]

First [Operation]
Second [Repair]
Third [Material]
Fourth [Setting]

===

Figure C.20 Operator Type Input

3. This is an unrestricted list clearly defining the operating pattern for a particular operator type. The listing comprises of four data fields which describe each operating shift. The data fields refer to a shifts start and finish time (specified in a 24 hour format e.g. 3:30, 16:30), variable overtime and the number of available individual operators. The variable overtime represents a further period of time that an operator type is available, in addition to the specified shift. However if during this period any individuals of an operator type are idle, then they become unavailable for work, until the start of the next shift.

   On entering a start time, the system by default adds eight hours for the the finish time and sets the variable overtime to zero and the number of individual operators to one. To delete a shift simply enter zero start time.

   Atoms simply works sequentially through a specified list, repeating the cycle until the simulation is terminated. The system compares the start time of the next shift with that of the current, to determine if it commences on the same or following day. If the start time for the next shift is greater than the current, Atoms assumes it begins later the same day, whereas a time earlier or equal implies that it commences the next day. Hence the listing can work in a number of ways. The operating shifts for a day or week can be specified and these will automatically be repeated either daily or weekly.

   Shifts can overlap, the start time of a

subsequent shift does not have to be later than the finishing time of an earlier one. The two data fields are independent. Furthermore, it is valid for the finish time of a shift to be earlier than its start, as this denotes that a shift terminates the following day.

Default = None.

4. Within Atoms there are four basic types of jobs that an operator can undertake; machine setting, job processing (including machine loading and unloading), material handling and machine maintenance. This keyword listing therefore prioritizes the jobs that a specific operator type can perform. However all job classifications do not have to be included. For if an operator type is not specified for any machine set-up or material handling operations within a model, then neither of these classifications need be included in the priority listing. The keywords are:

   OPERATION for job processing;
   REPAIR for machine maintenance;
   MATERIAL for material handling;
   SETTING for machine setting and
   <blank> for no option.

   Default = None.

C.9.8 Operator Groupings

Operator groupings represent a collection of one or more operator types, with the appropriate capabilities to undertake a particular operation. Operator types can be members of more than one operator grouping. Therefore the groupings allow the specification of alternative operators for individual jobs. All operator requirements within Atoms, regardless of the job, are specified as a particular operator grouping. The data input screen is illustrated in figure C.21, whilst the data requirements, along with their default values, are documented below.

1. This is a variable, of maximum length ten characters, which identifies a particular operator grouping. If a previously defined grouping is specified then it's corresponding data is retrieved, else the parameters are set to the default values. If a previous operator group specification is retrieved then this can be deleted by typing the reserved word DELETE in place of the resource name. Atoms will then confirm the request before removing the operator group from the model description. The delete function only works with models which contain no work-in-progress and have not been executed, i.e. are at zero simulation time. To exit the operator grouping record the user simply specifies no resource name.

   Default = Mandatory.

==

OPERATOR GROUP RECORD

1. Operator Group Name [SETTERS]

2. Group Operators

1. [CRAFTSMEN]
2. [PRESS_OPS]

==

Figure C.21 Operator Group Input

2. Unrestricted listing of all, previously defined operator types that are associated with a particular operator grouping. The same operator type can appear in several operator group listings.

   Default = None.

C.9.9 Routing Specification

All the previous modules generally relate to specific individual resources available in a particular manufacturing system. The routing specification however details how all the resources interact. Consequently there is a routing description for each manufactured component detailing the necessary operations, including specific resource requirements, through which they must pass.

On selecting the routing specification menu option, Atoms requests the name of the pre-defined material component to which the following routing description or modification relates. Having completed the specification of a component routing, the system returns to this request prompt. To return from here to the manual model input menu the user simply enters no component name.

On entering a pre-defined component name, Atoms retrieves any previous routing specification and notes the component name in the lower screen margin at the end of the "Action" listing. The prompt now is for the number of the operation to define or edit. The system prompts with the number of the next operation to be defined. Therefore, if three operations had been defined previously then the prompt would be 4, or for the routing specification of a new component the prompt is 1. The prompt can be over written with the number of a previously defined operation, in which case Atoms retrieves all the appropriate data, or else all variables are set to the default values. A "0" operation number returns the system to the prompt requesting the name of a component.

Having entered an operation number Atoms displays this in the top right of the main work screen and requests the identification of the work centre where this operation will take place. If the operation has previously been defined then the work centre location that was specified before is displayed. The specification of no work centre location returns the system to the initial prompt requesting the name of a component. If the operation has previously been defined then it can be deleted by typing in the word "DELETE". All subsequent operations are then moved up one and the location for the next operation is highlighted. If there are no more operations then no work centre is displayed.

All subsequent input routing screens depend upon the level at which the specified work centre was defined. The level of representation is indicated on all screens by the name immediately following the "Routing Record" heading (i.e. Department, Centre or Station).

The data requirements for each level of representation, along with their default values, are documented below. Having completed specifying or modifying an operation the system asks if there is another operation ? If there is not then Atoms requests a new component. However if there is another operation then the system requests the work centre location, displaying the one previously identified, although this will be blank when a new operation is being specified.

for an operation at a DEPARTMENT (Dept) work centre (figures C.22 to C.24):

Dept 1. This variable identifies the work centre location at which the particular component operation will take place.

Default = Mandatory.

Dept 2. This is a keyword which identifies the probability distribution for the time to set-up and prepare a work station in order to carry out the component operation. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Dept 3. This is a numeric variable which specifies the mean or average time to set-up and prepare a work station in order to carry out the component operation.

Default = 0 Minutes.

Dept 4. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Dept 5. This is a keyword which identifies the probability distribution for the standard time to simultaneously process a number of components. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

```
==============================================================
ROUTING RECORD - LEVEL DEPARTMENT          Operation Number  1

1. Work Centre                                     [   PRESS-2]
2. SetUp Time Distribution                         [     Fixed]
3. Interval (Mins)                                   [     0.0]
4. Deviation (Span/Dev/Loop)                         [     0.0]
5. Standard Time Distribution                      [     Fixed]
6. Interval (Mins)                                 [      0.00]
7. Deviation (Span/Dev/Loop)                         [     0.0]
8. Load Quantity i.e. ([Batch] Or A Number)            [Batch]
==============================================================
```

Figure C.22 DEPARTMENT Routing Operation Input - Page 1

```
==============================================================
ROUTING RECORD - LEVEL DEPARTMENT          Operation Number 1

 9. Group Performance (100% = Std. Rate)     [100.00 %]
10. Number Of Index Stations                       [ 0]
11. Scrap Percentage For Operation (%)       [  0.00 %]
12. Transport Required To Pass Work On     [           ]
13. Transport Distribution                  [    Fixed]
14.  Interval  (in  Minutes Or  Distance)    [      0.0] Units
                                                       [ Mins]
15. Deviation (Span/Dev/Loop)                 [     0.0]
==============================================================
```

Figure C.23 DEPARTMENT Routing Operation Input - Page 2

==

ROUTING RECORD - LEVEL DEPARTMENT Operation Number 1

16. Kitting Quantity i.e. ([Batch] Or Transfer Qty) [Batch]

17. Kitting List	Part	Quantity
1.	[GEAR_AB]	[2.00]

==

Figure C.24 DEPARTMENT Routing Operation Input - Page 3

Dept 6. This is a numeric variable which specifies the mean or average standard time to simultaneously process a number of parts.

Default = 0 Minutes.

Dept 7. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Dept 8. This is a numeric variable which specifies the number of components that are simultaneously processed. Alternatively the reserved word BATCH can be entered denoting that, regardless of size, a work batch will be processed in the specified standard time.

Default = BATCH.

Dept 9. This percentage variable specifies the group performance for a particular operation, and has a direct influence on the actual process time for an operation. The process time for an operation is:

$$\frac{\text{Standard Time * (Batch Size / Load Quantity)}}{\text{Group Performance}}$$

If the group performance is zero then the work station operating efficiency is used, defined in the relevant work centre specification. However if both parameters are zero then group performance is reset to 100%.

Default = 100%.

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Dept 10. This is an optional numeric variable only required with work centres of type INDEX. The variable specifies the number of index stations required for this operation, including the load/unload station.

Default = 1 Station.

Dept 11. This variable specifies the percentage of a work batch scraped as a result of the particular operation. The scrap quantity is always rounded to the nearest whole number.

Default = 0%.

Dept 12. This variable identifies the transport group required to transfer a work batch from this operation to the next.

Default = None.

Dept 13. This is a keyword which identifies the probability distribution for the time or distance to move a work batch from the current operation to the next. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Dept 14. This numeric variable specifies the mean or average time or distance to move a work batch from the current operation to the next.

Default = 0 Minutes/Distance.

In order to identify if the variable is time or distance related there is an optional units keyword. If no transport group is specified then the variable can only be time. The keywords are MINS and DIST for time and distance, respectively.

Default = MINS.

Dept 15. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Dept 16. This is an optional numeric variable, only required and therefore displayed, when the work centre type is either ASSEMBLY or STORE. The variable specifies the quantity in which sub-components are issued to an assembly operation. The reserved word BATCH can be entered, which indicates that sub-components are only issued when there are sufficient to complete a whole work batch, otherwise the operation cannot commence. Alternatively the transfer quantity can be specified. This implies that an assembly operation can start if there are enough sub-components to produce a transfer quantity. Once the transfer quantity has been completed another batch of sub-components are collected. This is repeated until the whole work batch is completed. This variable is fixed at BATCH for all DEPARTMENT work centre operations, because at this level of abstraction the transfer quantity cannot be specified and the default is BATCH.

Default = BATCH.

Dept 17. This is an optional unrestricted listing, only required and therefore displayed, when the work centre type is either ASSEMBLY or STORE. The listing identifies the sub-components necessary to undertake an assembly or store operation. The list comprises of two data fields. The first field identifies the pre-defined sub-components required to perform the operation. Whilst the other specifies the quantity of each sub-component necessary to produce one parent. Therefore the total sub-component requirements equals:

Batch/Transfer Qty. X Sub-component Qty. Per Parent.

Default = None.

for an operation at a CENTRE (Cen) work centre (figures C.25 to C.28):

Cen 1. This variable identifies the work centre location at which the particular component operation will take place.

Default = Mandatory.

Cen 2. This is a keyword which identifies the probability distribution for the time to set-up and prepare a work station in order to carry out the component operation. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Cen 3. This is a numeric variable which specifies the mean or average time to set-up and prepare a work station in order to carry out the component operation.

Default = 0 Minutes.

Cen 4. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

```
=================================================================
ROUTING RECORD - LEVEL CENTRE                 Operation Number  2

1. Work Centre                                        [   PRESS-3]
2. SetUp Time Distribution                            [     Fixed]
3. Interval (Mins)                                    [       0.0]
4. Deviation (Span/Dev/Loop)                          [       0.0]
5. Standard Time Distribution                         [     Fixed]
6. Interval (Mins)                                    [      0.00]
7. Deviation (Span/Dev/Loop)                          [       0.0]
8. Load Quantity i.e. ([Batch] Or A Number)              [Batch]
=================================================================
```

Figure C.25 CENTRE Routing Operation Input - Page 1

```
=================================================================
ROUTING RECORD - LEVEL CENTRE                 Operation Number  2

 9. Minimum SetUp Qty                                   [     1]

10. Transfer Quantity i.e. ([Batch] Or A Number)        [Batch]

11. Number Of Index Stations                            [ 0]

12. Group Performance (100% = Std. Rate)             [100.00 %]

13. Operator Efficiency (100% = Std. Rate)           [100.00 %]

14. Check For End Of Shift                              [N]
=================================================================
```

Figure C.26 CENTRE Routing Operation Input - Page 2

```
=============================================================
ROUTING RECORD - LEVEL CENTRE                Operation Number 2

15. Tooling List                  Part                Quantity

        1.                   [          ]         [         0]
        2.                   [          ]         [         0]
        3.                   [          ]         [         0]

16. Scrap Percentage For Operation (%)        [  0.00 %]

17. Transport Required To Pass Work On       [          ]

18. Transport Distribution                   [     Fixed]

19. Interval (in Minutes Or Distance)          [    0.0] Units
                                                        [ Mins]
20. Deviation (Span/Dev/Loop)                  [    0.0]
=============================================================
```

Figure C.27 CENTRE Routing Operation Input - Page 3

```
=============================================================
ROUTING RECORD - LEVEL CENTRE                Operation Number 2


21. Kitting Quantity i.e. ([Batch] Or Transfer Qty)    [Batch]


22. Kitting List                  Part                Quantity

        1.                   [    GEAR_AB]          [     2.00]
=============================================================
```

Figure C.28 CENTRE Routing Operation Input - Page 4

Cen 5. This is a keyword which identifies the probability distribution for the standard time to simultaneously process a number of components. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Cen 6. This is a numeric variable which specifies the mean or average standard time to simultaneously process a number of parts.

Default = 0 Minutes.

Cen 7. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Cen 8. This is a numeric variable which specifies the number of components that are simultaneously processed. Alternatively the reserved word BATCH can be entered denoting that, regardless of size, a work batch will be processed in the specified standard time.

Default = BATCH.

Cen 9. This is a numeric variable which specifies the minimum number of batch components for which the particular operation should be performed. Alternatively the reserved word BATCH can be specified denoting that, regardless of the actual size, the operation can only be performed for a complete work batch.

Default = 1.

Cen 10. This numeric variable specifies the number of components that have to be processed before being transferred to the next operation. The number must be a multiple of the load quantity. Alternatively the reserved word BATCH can be specified which indicates that, regardless of size, components are only transferred when the complete work batch has been processed.

Default = BATCH.

Cen 11. This is an optional numeric variable only required with work centres of type INDEX. The variable specifies the number of index stations required for this operation, including the load/unload station.

Default = 1 Station.

Cen 12. This percentage variable specifies the group performance for the particular operation, and has a direct influence on the actual process time for an operation. The process time for an operation is:

$$\frac{\text{Standard Time} * (\text{Batch Size} / \text{Load Quantity})}{\text{Group Performance}}$$

If the group performance is zero then either the relevant labour or work station performance is used, which ever is the lowest. However if both these are zero then the group performance is reset to 100%.

Default = 100%.

Labour Performance = Operator Efficiency * (100 - Direct Labour Losses)

Work Station Performance = Work Station Efficiency * (100 - Work Station Breakdown Losses)

where

operator efficiency is defined in the routing specification; and

direct labour losses, work station efficiency and breakdown losses are defined in the relevant work centre specification.

Default = 100%.

Cen 13. This percentage variable specifies the operator efficiency for a particular operation.

Default = 100%.

Cen 14. This is a keyword which specifies whether it is necessary to establish, before starting the operation, if it can be completed within the current shift. If the check is necessary and the operation cannot be completed within the remaining shift, then it fails to start. Although Atoms will consider work stations on all currently operating work centre shifts. The keywords are Y and N for yes and no.

Default = N.

Cen 15. This is a restricted list which identifies tooling necessary to undertake a particular operation. The list allows up to three tools to be specified. The first data field identifies a particular pre-defined tooling group, whilst the next specifies the required quantity of tools. The final data field is a keyword which specifies the release of the tool. The keywords are OPERATION, RETAIN, RELEASE.

OPERATION is where a tool is requested for the one particular operation and therefore released on completion of the process.

RETAIN denotes that a tool is requested for the particular operation but is not released on completion.

RELEASE specifies that a tool, requested for a previous operation (through RETAIN), is released on completion of the current process.

Default = None.

Cen 16. This variable specifies the percentage of a work batch scraped as a result of the particular operation. The scrap quantity is always rounded to the nearest whole number.

Default = 0%.

Cen 17. This variable identifies the transport group required to transfer a work batch from this operation to the next.

Default = None.

Cen 18. This is a keyword which identifies the probability distribution for the time or distance to move a work batch from the current operation to the next. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Cen 19. This numeric variable specifies the mean or average time or distance to move a work batch from the current operation to the next.

Default = 0 Minutes/Distance.

In order to identify if the variable is time or distance related there is an optional units keyword. If no transport group is specified then the variable can only be time. The keywords are MINS and DIST for time and distance, respectively.

Default = MINS.

Cen 20. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Cen 21. This is an optional numeric variable, only required and therefore displayed, when the work centre type is either ASSEMBLY or STORE. The variable specifies the quantity in which sub-components are issued to an assembly operation. The reserved word BATCH can be entered, which indicates that sub-components are only issued when there are sufficient to complete a whole work batch, otherwise the operation cannot commence. Alternatively the transfer quantity can be specified. This implies that the operation can start if there are enough sub-components to produce a transfer quantity. Once the transfer quantity has been completed another batch of sub-components are collected. This is repeated until the whole work batch is completed.

Default = BATCH.

Cen 22. This is an optional unrestricted listing, only required and therefore displayed, when the work centre type is either ASSEMBLY or STORE. The listing identifies the sub-components necessary to undertake an assembly or store operation. The list comprises of two data fields. The first field identifies the pre-defined sub-components required to perform the operation. Whilst the other specifies the quantity of each sub-component necessary to produce one parent item. Therefore the total sub-component requirements equals:

Batch/Transfer Qty. X Sub-component Qty. Per Parent.

Default = None.

for an operation at a STATION (Stat) work centre (figures C.29 to C.32):

Stat 1. This variable identifies the work centre location at which the particular component operation will take place.

Default = Mandatory.

Stat 2. This is a numeric variable which specifies the minimum number of batch components for which the particular operation should be performed. Alternatively the reserved word BATCH can be specified denoting that, regardless of the actual size, the operation can only be performed for a complete work batch.

Default = 1.

Stat 3. This is a keyword which identifies the basis for setting up a work station. A set up can be incurred due to a different component or operation being processed or because of dissimilar component attributes (section C.9.4). If set-ups are based on attributes, then an additional data input is required identifying which attribute should be considered, 1 or 2. The keywords are Y and N, for set-up on part and attribute, respectively.

Default = N.

```
==============================================================
ROUTING RECORD - LEVEL STATION                Operation Number  1

 1. Work Centre                            [PRESS-12TN]

 2. Minimum SetUp Qty                          [     1]

 3. SetUp On Part (Y/N)                            [Y]
    i.e. ([N] For By Attribute)
 4. Set Up Operator                        [   SETTERS] 5. Job [P]
    i.e. ([Station] Or Group Name)                        Priority
 6. SetUp Time Distribution                 [    Fixed]

 7. Interval (Mins)                           [   30.0]

 8. Deviation (Span/Dev/Loop)                 [    0.0]

 9. Process Operator                       [   Station] 10.Job [P]
    i.e. ([Station] Or Group Name)                        Priority
11. Group Performance (100% = Std.)      [  Operator]
    i.e. ([Machine], [Operator] Or A Number)
==============================================================
```

Figure C.29 STATION Routing Operation Input - Page 1

```
==============================================================
ROUTING RECORD - LEVEL STATION                Operation Number  1

12. Load Quantity i.e. ([Batch] Or A Number)           [     1]

13. Transfer Quantity i.e. ([Batch] Or A Number)       [ 1500]

14. Standard Time Distribution                      [    Fixed]

15. Interval (Mins)                                 [     0.24]

16. Deviation (Span/Dev/Loop)                         [    0.0]

17. Number Of Index Stations                              [ 0]

18. Percentage Batch Processed (100% = Whole Batch) [100.00 %]

19. Scrap Percentage For Operation (%)              [  0.00 %]

20. Check For End Of Shift                                 [N]
==============================================================
```

Figure C.30 STATION Routing Operation Input - Page 2

```
==============================================================

ROUTING RECORD - LEVEL STATION                    Operation Number  1

21. Operator Freed Between Load and UnLoads (Y/N)               [N]

22. Loading Time Distribution                           [    Fixed]

23. Time Interval (Mins)                                  [    0.0]

24. Time Deviation (S/D/L)                                [    0.0]

25. UnLoading Time Distribution                         [    Fixed]

26. Time Interval (Mins)                                  [    0.0]

27. Time Deviation (S/D/L)                                [    0.0]

28. Tooling List                   Part                  Quantity
        1.                    [           ]           [          0]
        2.                    [           ]           [          0]
        3.                    [           ]           [          0]

==============================================================
```

Figure C.31 STATION Routing Operation Input - Page 3

```
==============================================================

ROUTING RECORD - LEVEL STATION                    Operation Number  1

29. Transport Required To Pass Work On               [HANDTRUCKS]

30. Transport Operator (i.e. Group Name)             [  HANDLERS]

31. Transport Distribution                           [     Fixed]

32. Interval (in Minutes Or Distance)                   [    5.0]
                                                    Units[  Dist]
33. Deviation (Span/Dev/Loop)                           [    0.0]

34. Kitting Quantity i.e. ([Batch] Or Transfer Qty)     [Batch]

35. Kitting List                   Part                 Quantity

        1.                  [ SPINDLE_A]           [       1.00]
        2.                  [    GEAR_A]           [       1.00]

==============================================================
```

Figure C.32 STATION Routing Operation Input - Page 4

Stat 4. This identifies the operator grouping (section C.9.8) which lists the individual operator types capable of performing the set-up operation. Alternatively the reserved word STATION can be entered which implies that the operator type should be chosen from those listed as able to work at the particular work station (section C.9.1).

Default = None.

Stat 5. This is an optional keyword only necessary when a set-up operator is required and which specifies if the set-up activity is a primary or secondary job. A Secondary job being one which can be interrupted and the operator seized by any primary job. Furthermore a secondary job can utilize operators, which although idle are waiting for a work station to finish processing, in order to unload the components they previously loaded. The keywords are P and S for primary and secondary.

Default = P.

Stat 6. This is a keyword which identifies the probability distribution for the time to set-up and prepare a work station in order to carry out the component operation. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Stat 7. This is a numeric variable which specifies the mean or average time to set-up and prepare a work station in order to carry out the component operation.

Default = 0 Minutes.

Stat 8. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Stat 9. This identifies the operator grouping (section C.9.8) which lists the individual operator types capable of performing the process operation. Alternatively the reserved word STATION can be entered which implies that the operator type should be chosen from those listed as able to work at the particular work station (section C.9.1).

Default = None.

Stat 10. This is an optional keyword only necessary when a process operator is required and which specifies if the process activity is a primary or secondary job. A Secondary job being one which can be interrupted and the operator seized by any primary job. Furthermore a secondary job can utilize operators, which although idle are waiting for a work station to finish processing, in order to unload the components they previously loaded. The keywords are P and S for primary and secondary.

Default = P.

Stat 11. This percentage variable specifies the group performance for the particular operation, and has a direct influence on the actual process time for an operation. The process time for an operation is:

$$\frac{\text{Standard Time} * (\text{Batch Size} / \text{Load Quantity} * \text{Batch \%})}{\text{Group Performance}}$$

Alternatively the reserved words MACHINE or OPERATOR can be specified. This indicates that the group performance is based on the efficiency of either the work station or operator which are selected during evaluation to undertake the process.

Default = 100%.

Stat 12. This is a numeric variable which specifies the number of components that are simultaneously processed. Alternatively the reserved word BATCH can be entered denoting that, regardless of size, a work batch will be processed in the specified standard time.

Default = BATCH.

Stat 13. This numeric variable specifies the number of components that have to be processed before being transferred to the next operation. The number must be a multiple of the load quantity. Alternatively the reserved word BATCH can be specified which indicates that, regardless of size, components are only transferred when the complete work batch has been processed.

Default = BATCH.

Stat 14. This is a keyword which identifies the probability distribution for the standard time to simultaneously process a number of components. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Stat 15. This is a numeric variable which specifies the mean or average standard time to simultaneously process a number of parts.
Default = 0 Minutes.

Stat 16. This is an optional numeric variable necessary to fully describe the probability distributions

UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Stat 17. This is an optional numeric variable only required with work centres of type INDEX. The variable specifies the number of index stations required for this operation, including the load/unload station.

Default = 1 Station.

Stat 18. This variable specifies the percentage of a work batch that is to be processed during a particular operation. The process quantity is always rounded to the nearest whole number.

Default = 100%.

Stat 19. This variable specifies the percentage of a work batch scraped as a result of the particular operation. The scrap quantity is always rounded to the nearest whole number.

Default = 100%.

Stat 20. This is a keyword which specifies whether it is necessary to establish, before starting an operation, if it can be completed within the current shift. If the check is necessary and the operation cannot be completed within the remaining shift, then it fails to start. Although Atoms will consider every operator capable of performing the operation and currently on shift. The keywords are Y and N for yes and no.

Default = N.

Stat 21. This keyword specifies whether the process operator is free, between loading and unloading a work station to undertake any necessary secondary activities. This would be equivalent to a semi-automatic machine. The keywords are Y and N for yes and no.

Default = N.

Stat 22. This is a keyword which identifies the probability distribution for the time to load a number of components onto a work station to be simultaneously processed. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Stat 23. This is a numeric variable which specifies the mean or average time to load a number of components onto a work station to be simultaneously processed.

Default = 0 Minutes.

Stat 24. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Stat 25. This is a keyword which identifies the probability distribution for the time to off-load a number of processed components from a work station. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Stat 26. This is a numeric variable which specifies the mean or average time to off-load a number of processed components from a work station.

Default = 0 Minutes.

Stat 27. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Stat 28. This is a restricted list which identifies tooling necessary to undertake a particular operation. The list allows up to three tools to be specified. The first data field identifies a particular pre-defined tooling group, whilst the next specifies the required quantity of tools. The final data field is a keyword which specifies the release of the tool. The keywords are OPERATION, RETAIN, RELEASE.

OPERATION is where a tool is requested for the one particular operation and therefore released on completion of the process.

RETAIN denotes that a tool is requested for the particular operation but is not released on completion.

RELEASE specifies that a tool, requested for a previous operation (through RETAIN), is released on completion of the current process.

Default = None.

Stat 29. This variable identifies the transport group required to transfer a work batch from this operation to the next.

Default = None.

Stat 30. This is an optional variable which can only be specified when a transport device is required to transfer a work batch to the next operation. This identifies the operator grouping which lists all operator types capable of transferring a work batch. The transfer operation cannot be interrupted once started, therefore there is no need to specify whether this is a primary or secondary activity.

Default = None.

Stat 31. This is a keyword which identifies the probability distribution for the time or distance to move a work batch from the current operation to the next. The keywords are FIXED, UNIFORM, EXPONENTI, ERLANG, BERNOULLI, BINOMIAL, POISSON and NORMAL.

Default = FIXED.

Stat 32. This numeric variable specifies the mean or average time or distance to move a work batch from the current operation to the next.

Default = 0 Minutes/Distance.

In order to identify if the variable is time or distance related there is an optional units keyword. If no transport group is specified then the variable can only be time. The keywords are MINS and DIST for time and distance, respectively.

Default = MINS.

Stat 33. This is an optional numeric variable necessary to fully describe the probability distributions UNIFORM, ERLANG, BINOMIAL and NORMAL. The variable represents the span, standard deviation or loop depending on the distribution.

Default = 0.

Stat 34. This is an optional numeric variable, only required and therefore displayed, when the work centre type is either ASSEMBLY or STORE. The variable specifies the quantity in which sub-components are issued to an assembly operation. The reserved word BATCH can be entered, which indicates that sub-components are only issued when there are sufficient to complete a whole work batch, otherwise the operation cannot commence. Alternatively the transfer quantity can be specified. This implies that an assembly operation can start if there are enough sub-components to produce a transfer quantity. Once the transfer quantity has been completed another batch of sub-components are collected. This is repeated until the whole work batch is completed.

Default = BATCH.

Stat 35. This is an optional unrestricted listing, only required and therefore displayed, when the work centre type is either ASSEMBLY or STORE. The listing identifies the sub-components necessary to undertake an assembly or store operation. The list comprises of two data fields. The first field identifies the pre-defined sub-components required to perform the operation. Whilst the other specifies the quantity of each sub-component necessary to produce one parent item. Therefore the total sub-component requirements equals:

Batch/Transfer Qty. X Sub-component Qty. Per Parent.

Default = None.

C.10 Automatic Model Input

The AUTOMATIC MODEL INPUT option on the main menu allows the specification of the underlying structure of a manufacturing system model to be entered via computer text files. The section provides a convenient and automated link to external databases. Thus these input routines significantly reduce the time to generate a manufacturing model by alleviating the necessity to type in the description of a system. An automatically generated model can be further enhanced by the addition of more detailed information entered via the manual model input option.

The section requires five text files to describe the complete basic structure of a manufacturing model, resulting in an outlined specification of work stations, work centres, material components, operators, tooling and component operations.

On selecting the automatic model input, Atoms requests a name for the model that is to be generated (section C.3), along with an appropriate description, which appears in the directory listings. The system then sequentially prompts the user for the name of the five text files (all with an extension of .TXT), which relate to operators, material components, work station and work centres, work station and operator relationships and component routing and associated tooling, respectively. None of the files are mandatory. The system in effect can generate models corresponding to the specification of any combination of files, ranging from none to all five. Having developed an appropriate model the system returns to the main menu where the model, generated in memory, can be saved to disk.

The structure of the five text files are listed below. In each file Atoms reads one line at a time and assumes that each data field corresponds in sequence with the specific line format. i.e. In the operator file, a data field immediately after the operator name is assumed to be the shift start time, the next the shift finish time and so forth.

I. The Operator File

Each line of the text file identifies an operator type and a corresponding working shift, together with optional data relating to operator efficiency and job priorities. The file name must end with a .TXT extension. The general line format, with the default values if not specified, is:

<OperatorName> [<StartTime> [<EndTime> [<ShiftOperators> [<OperatorEfficiency> [<Job1> [<Job2> [<Job3> [<Job4>]

where

OperatorName is a variable, of maximum length ten characters, which identifies a particular operator type.

Default = Mandatory;

StartTime is an optional numeric variable which specifies, in minutes when a working shift starts.

Default = 0 Mins;

FinishTime is an optional numeric variable which specifies, in minutes when a working shift finishes.

Default = 1440 Mins;

ShiftOperators is an optional numeric variable which specifies the number of operators available for the working shift.

Default = 1 Operator;

OperatorEfficiency is an optional percentage variable which specifies the performance rate of the operator type.

Default = 100%;

Job1/2/3/4 are optional keywords which specify the type of jobs the operators undertake and their relative importance. The Keywords are OPERATION, SETTING, REPAIR and MATERIAL.

Default = None.

Every time a new operator name appears on a line the system creates a corresponding record, which includes operator efficiency and job priorities, in addition to specifying the working shift. Consequently every initial reference to an operator type requires all data fields to be specified. Though only the appropriate job priority keywords need be listed. For all subsequent reference to a particular operator type the operator efficiency and job priorities are ignored and only a further working shift is noted. The overall shift pattern for a particular operator type is assumed to coincide with the order in which individual working shifts are listed in the file. However the working shifts for an operator type do not have to be sequential lines within a file, they can be mixed with the specification for other operators.

The default value for un-assignable variables include:

variable shift overtime = 0 Mins.

II. The Material File

The file is a unique listing of part numbers, together with operational data relating to the specific method of production control utilized for this component. The file name must end with a .TXT extension. The general line format, with the default values if not specified, is:

<ComponentNumber> <ProductionControl> [<MRPQuantity>]/
[<StatisticQuantity>]/[<KanbanQuantity> [<KanbanSize]/
[<OrderPointQuantity> [<ReorderPoint> [<ReorderQuantity>]

where

ComponentNumber is a variable, of maximum length ten characters, which identifies a particular material component.

Default = Mandatory;

ProductionControl is a keyword which identifies the method of issuing corresponding component works orders. The keywords are MRP, KANBAN, ORDERPOINT and STATISTICS.

Default = Mandatory;

MRPQuantity is an optional numeric variable which specifies, for Components under MRP control, the initial store quantity.

Default = 0 Units.

StatisticQuantity is an optional numeric variable which specifies, for components under STATISTICS control, the initial store quantity.

Default = 0 Units.

KanbanQuantity is an optional numeric variable which specifies, for components under KANBAN control, the initial store quantity.

Default = 0 Units;

KanbanSize is an optional numeric variable which specifies, for components under KANBAN control, the reorder quantity.

Default = 0 Units.

OrderpointQuantity is an optional numeric variable which specifies, for components under ORDERPOINT control, the initial store quantity.

Default = 0 Units;

ReorderPoint is an optional numeric variable which specifies, for components under ORDERPOINT control, the stores level at which the component is reordered.

Default = 0 Units;

ReorderQuantity is an optional numeric variable which specifies, for components under ORDERPOINT control, the reorder quantity for the component.

Default = 0 Units.

The system only considers the first reference to a particular component number, all subsequent references are ignored (unless the initial reference fails to create a material record).

The default value for un-assignable variables include:

component scale	= 0.1;
purchase lead-time	= 1 Day;
purchase lead-time distribution	= FIXED;
component attributes	= None;

III. The Work Centre File

The file is a listing of work centres which exist in a particular model, together with information pertaining to it's level of abstraction and available capacity. The file name must end with a .TXT extension. The general line format, with the default values if not specified, is:

<WorkCentreName> <Abstraction> <OperationType> [<StartTime>
[<FinishTime> [<WorkStationNumber>]/[<WorkStation1>
<WorkStation2> ....]

where

WorkCentreName is a variable of length ten characters which identifies a unique work area.

Default = Mandatory;

Abstraction is a keyword which specifies the level at which the work centre capacity is represented. The keywords are DEPARTMENT, CENTRE and STATION.

Default = Mandatory;

OperationType is a keyword which specifies the manner in which the work centre operates (section C.9.2). The keywords are MANUAL, INDEX, PROCESS, ASSEMBLY and STORE.

Default = Mandatory;

StartTime is an optional numeric variable which specifies, in minutes for DEPARTMENT and CENTRE work centres, when a working shift starts.

Default = 0 Mins;

FinishTime is an optional numeric variable which specifies, in minutes for DEPARTMENT and CENTRE work centres, when a working shift finishes.

Default = 1440 Mins;

WorkStationNumber is an optional numeric variable which specifies, for DEPARTMENT and CENTRE work centres, the number of individual machines or work stations available for the particular shift.

Default = 1 Work Station.

WorkStation1, WorkStation2, ... is a list of optional variables, with a maximum length ten characters, which identifies the work stations available at a particular STATION work centre. The same work station name can appear in several work centre listings, however the station type has to coincide with the centre's operation type.

Default = 1 New work station with the same name as the work centre.

The text file is a unique listing of all work centres at the work STATION level of abstraction, but all other work centres may appear a number of times because of having to specify there particular shift pattern.

Work centres at levels DEPARTMENT and CENTRE are treated similarly to the operator file listing. That is every initial reference to such work centres produces a new record in addition to specifying the working shift. Then every subsequent reference simply adds another working shift. However unlike the operator file, all subsequent references to a work centre must include the obsolete abstraction and operation type data.

In addition to creating a new work centre record, at the STATION level of abstraction work stations are also created. The system considers each individual work station reference in turn. If the name has not appeared in a previous work centre listing a new station record is created with an operation type identical to the specific work centre and the two are linked together. However if the station has already been created the system checks that the operation types are the same before linking the two together. Subsequent references to a particular STATION work centre are ignored (unless the initial reference fails to create a work centre record).

The default value for un-assignable variables include:

for ALL work centres -

maximum input buffer size	= 100 Batches;
maximum output buffer size	= 100 Batches;
kanbaned parts	= None;

for DEPARTMENT work centres -

work station efficiency	= 100%;

```
     process capacity              = 99999 Std. parts
                                     (for type = process);

for CENTRE work centres -

     work station efficiency       = 100%;
     work station breakdown        = 0%;
     work station direct losses    = 0%;
     group waiting batches         = Yes;
     select next batch             = No;
     split batches                 = Yes;
     process only first batch      = No;
     scheduling rule               = FIFO;
     process capacity              = 99999 Std. parts
                                        (for type = process);

for STATION work centres -

     group waiting batches         = Yes;
     select next batch             = No;
     split batches                 = Yes;
     process only first batch      = No;
     scheduling rule               = FIFO;

for WORK STATIONS -

     work station operation type   = Same as the work centre;
     work station efficiency       = 100%;
     breakdowns                    = None;
     work station operators        = None;
     restricted work centre first  = No;
     process capacity              = 99999 Std. parts
                                        (for type = process);
```

IV. The Relation File

The file identifies operator types with the appropriate skills to carry out operations at specific work stations. The file name must end with a .TXT extension. The general line format, with the default values if not specified, is:

<WorkStationName> [<OperatorType1> <OperatorType2> ....]

where

WorkStationName is a variable, of maximum length ten characters, which identifies a particular existing work station.

Default = Mandatory;

OperatorType1, OperatorType2, ... is a list of optional variables, with a maximum length ten characters, which identifies the existing operator types able to work at the particular work station. The same operator type can appear in several work station listings.

Default = None.

The system can only accept work stations and operator types that have been defined earlier by the appropriate input of a previous file. The listing of work stations does not have to be unique. For each reference to a work station simply appends additional operator types to those previously allocated. If the work station has not been defined then the line is skipped. If the operator type is undefined or has already been allocated to the particular station, then the system skips to the next operator type or line, if no other operators are specified.

V. The Routing File

The file is a unique listing of all operations for particular component numbers. Each line contains data relating to a specific component operation, including the work centre where it is performed and the duration of the job. The file name must end with a .TXT extension. The general line format, with the default values if not specified, is:

```
<ComponentNumber> <OperationNumber> <WorkCentreName>
      [<SetUpTime> [<StandardTime> [<LoadQuantity>
              [<GroupPerformance> [[/T<ToolName> <ToolQuantity>]
                       [[/A<AssemblyPart> <AssemblyQuantity>]]
```

where

ComponentNumber is a variable, of maximum length ten characters, which identifies a particular material component.

Default = Mandatory;

OperationNumber is a numeric variable which sequential numbers all operations for a given component number.

Default = Mandatory;

WorkCentreName is a variable, of maximum length ten characters, which identifies a particular work area.

Default = Mandatory;

SetUpTime is an optional numeric variable which specifies the duration for setting the machine to undertake the particular operation.

Default = 0 Mins;

StandardTime is an optional numeric variable which specifies the duration for processing the component in batches indicated by the LoadQuantity.

Default = 0 Mins;

LoadQuantity is an optional numeric variable which specifies the number of parts that are simultaneously processed. To specify the whole batch enter -1.

Default = 1 Part.

GroupPerformance is an optional percentage variable which specifies the performance of the particular operation, and has therefore a direct influence on it's actual process duration. Alternatively for STATION operations only, either -1 or -2 can be specified indicating that the group performance is based on the efficiency of either the the operator or work station which are selected during evaluation to undertake the operation, respectively.

Default = 100%

/TToolName and ToolQuantity is the optional specification of a necessary tool, such as a jig, fixture or pallet. There is a keyword /T immediately followed by a variable, of maximum length ten characters, which identifies the particular tool and a numeric variable which specifies the number of tools required. If no quantity is specified then the tooling is not recorded.

Default = None;

/AAssemblyPart and AssemblyQuantity is the optional specification of a required assembly item of which the component is comprised. There is a keyword /A immediately followed by a variable, of maximum length ten characters, which identifies the assembly part and a numeric variable which specifies the number of parts required to every one component. If no quantity is specified or the work centre operation type is not assembly or store then the assembly item is not recorded.

Default = None;

The specification of component number, assembly part and work centre name is not dependent upon any of the four previous files. For if the system finds a component, part or work centre that has not been defined then it firstly creates appropriate records. Similarly with tooling, all initial references produce a corresponding record. All operations for a particular component number do not have to be sequential within the file, they can be mixed up with other component operations. However it is assumed that the order in which they do appear within the file corresponds to the sequence of operations. i.e. the initial specification of a component is operation one, whilst subsequent references are operations two, three, four and so fourth.

The default value for un-assignable variables include:

for a COMPONENT NUMBER or ASSEMBLY PART that has not previously been defined -

production control method	= MRP;
stores quantity	= 0 Units;
component scale	= 0.1;

purchase lead-time	= 1 Day;
purchase lead-time distribution	= FIXED;
component attributes	= None;

for a WORK CENTRE centre that has not previously been defined-

level of abstraction	= CENTRE;
Operation Type	= PROCESS;
shift pattern	= 1 default shift;

all other variables as defined in for the work centre file;

for ALL operations -

set-up and standard times distribution	= FIXED;
kiting quantity for assembly items	= BATCH;
scrap	= 0%;
transport device	= None;
transport time	= 0 Mins;
index stations	= 1 Station; (for work centre type = index);

for DEPARTMENT operations -

processing factor	= 100%

for CENTRE operations -

minimum set-up quantity	= 1 Part;
operator efficiency	= 0%;
group performance	= 100%;
check for end of shift	= No;
transfer quantity	= BATCH;

for STATION operations -

set-up on part	= Yes;
set-up operator	= STATION;
set-up priority	= Primary;
process operator	= STATION;
process priority	= Primary;
set process operator free	= No;
process batch percent	= 100%;
minimum set-up quantity	= 1 Part;
check for end of shift	= No;
transfer quantity	= BATCH;
group performance	= 100%;
transport operator	= None;

C.11 Work-In-Progress Input

The WORK-IN-PROGRESS (WIP) option on the main menu provides an ability to enter work batches into a particular simulation model. The module allows the input of two types of work batches. With initialized models, which have not been executed, batches can be placed at specific operations and therefore work centre input queues. This feature can be used in order that a model reflects a systems current WIP. Thus allowing a user to specify the initial starting conditions for any particular simulation model. Furthermore through this subsection a user can control the time at which new batches of work are issued into a specific model, during it's execution. Thereby representing an MRP production control system and the release of new works orders.

On selecting the WIP option, Atoms requests the name of an existing model (section C.3). It may already be memory resident or can be retrieved from disk. If no name or the name of a non-existent model is specified then the system returns to the main menu. Having entered the WIP input option a submenu is displayed and the alternative choices are described below.

C.11.1 Parameter Setting

This option enables the conversion of real dates into simulation time. Generally the release of work into a system is known in terms of real dates (i.e. 02/08/88 or 30/06/89). However time in Atoms is represented as periods, days and minutes. Therefore this option allows the user to set the first day of simulation (i.e. period 1, day 1) to a real date. The system can then automatically convert real dates into periods and days. This option should be executed before the addition of any WIP or future work orders. The data requirements are illustrated in figure C.33 and documented below.

1. This is a date variable (i.e. DD/MM/YY), which identifies a specific day as a datum, representing period 1, day 1 of simulation time.

   Default = 02/01/89.

2. This numeric variable identifies how many days per period to simulate (e.g. 5 working days or a full 7 day week).

   Default = 5 Days.

3. This numeric variable specifies the weekend. In order for the system to correctly convert real dates into simulation time, it requires the number of days between each period (i.e. the number of non-working days).

```
==============================================================
  1. First Day of Simulation                        [22/01/90]

  2. Number of Days per Period                          [ 5]

  3. Number of Days per Weekend                         [ 2]

  4. Bring Weekend Orders Forward Or Delay (F/D)        [D]
==============================================================
```

Figure C.33 WIP - Parameter Setting

Default = 2 Days.

4. This keyword determines whether new work batches, scheduled for release between two working periods (i.e. a weekend), should be pulled forward and issued on the last day of the previous period or delayed and issued on the first day of the subsequent one. The keywords are F and D for forward and delayed respectively.

   Default = D.

C.11.2 Automatic WIP Input

This option allows a user to enter batches of WIP into a model at specific operations and therefore work centre input queues. The details are specified in a computer text file, which has an extension .TXT. On reading the file Atoms automatically creates discrete batches of work, placing them in the appropriate queues. WIP can only be added to a model at zero simulation time, that is before it has been executed.

On selecting the automatic WIP input option, the system prompts the user for the name of the text file which contains the details. The user can abort the routine at this stage by simply entering no name. Having specified a correct file name Atoms immediately creates corresponding work batches and on completion returns the system to the WIP submenu. Atoms will not allow this option to be selected for any model that has been executed. In order to add WIP to such a model, it would have to be zeroed (section C.14.6). The general line format, with the default values if not specified, is:

<ComponentNumber> <BatchQuantity> <OperationNumber> <DueDate> <LaunchDate> [<WorksNumber>]

where

ComponentNumber is a variable, of maximum length ten characters, which identifies a particular pre-defined material component.

Default = Mandatory;

BatchQuantity is a numeric variable which specifies the size of the batch.

Default = Mandatory;

OperationNumber is a numeric variable which identifies the operation, by it's sequential number, at which the batch is to be inserted into the model.

Default = Mandatory;

DueDate is a real date variable (i.e. 02/01/89) which specifies the day a work batch is expected to be completed and delivered into stores. The expected time of delivery is fixed at 23:00 hrs. on the specified day. When creating the batch the system automatically converts the real time into the simulation equivalent.

Default = Mandatory;

LaunchDate is a real date variable (i.e. 02/01/89) which specifies the day a work batch was originally issued into a system. As the work batch is WIP at zero simulation time, it is correct for the launch date to be earlier than the date datum (section C.11.1). When this occurs the system records zero time for the launch date, over riding the date originally specified.

Default = Mandatory;

WorksNumber is an optional variable, of maximum length ten characters, which specifies a user's batch reference number, which simply appears on output reports to help traceability.

Default = None.

If the component number does not exist or there is no operation equivalent to that specified or the batch quantity is zero, then the batch is not created. Furthermore care must be taken in specifying the launch date, for if it is earlier than the datum then zero simulation time is recorded.

C.11.3 Automatic Works Order Creation

This option allows a user to specify the time at which new work batches are released into a model. These batches, unlike the WIP ones, always start at the first operation. The details are specified in a computer text file, which has an extension .TXT. The file must be arranged in order of ascending launch date. Consequently Atoms only records the launch date of the first work batch. On reaching the specified date the work is issued and the launch of the next batch is recorded. This continues until either the end of the file is reached or the simulation is stopped. The system then automatically carries on from where it left off when the simulation restarts. The text file can be up dated and re-created at any time.

On selecting the automatic works order creation option, the system prompts the user for the name of the text file which contains the details. The user can abort the routine at this stage by simply entering no name. Having specified the correct file name Atoms opens the file notes the launch of the first work batch and returns the system to the submenu. The general line format, with the default value if not specified, is:

<ComponentNumber> <BatchQuantity> <DueDate> <LaunchDate> [<WorksNumber>]

where

ComponentNumber is a variable, of maximum length ten characters, which identifies a particular pre-defined material component.

Default = Mandatory;

BatchQuantity is a numeric variable which specifies the size of the batch.

Default = Mandatory;

DueDate is a real date variable (i.e. 02/01/89) which specifies the day a work batch is expected to be completed and delivered into stores. The expected time of delivery is fixed at 23:00 hrs. on the specified day. When creating the batch the system automatically converts the real time into the simulation equivalent.

Default = Mandatory;

LaunchDate is a real date variable (i.e. 02/01/89) which specifies the date of release for a work batch into a model. Atoms automatically converts the real date into simulation time. The release of a batch of work is fixed at 01:00 hrs. on the specified day.

Default = Mandatory;

WorksNumber is an optional variable, of maximum length ten characters, which specifies a user's batch reference number, which simply appears on output reports to help traceability.

Default = None.

If the component number does not exist or no routing has been specified for the component or the batch quantity is zero, then the batch is not released. Furthermore care must be taken in specifying both launch and due dates, for if they are earlier than the datum then illogical negative simulation times are recorded and again the individual batches are not released.

C.12 View An Existing Model

The VIEW AN EXISTING MODEL option on the main menu provides information regarding the configuration of a particular Atoms model. This module produces a range of summary reports, identifying all pre-defined resources and operations. The output reports help when manually inputting a model specification or returning to a model a number of weeks or months after it was last used.

The manual specification of a model (section C.9) requires the user to enter the name of a resource in order to add a new or modify an existing description or specify the logical relationship between certain resources, but does not help by listing those which have already been defined. All output reports can be directed to a screen monitor, a line printer or a text file, therefore providing a permanent record of a model's configuration. Furthermore there is an "everything" option which automatically outputs all reports which contain any information.

On selecting the view option, Atoms requests the name of the model to use (section C.3). It must be the name of an existing model, which may already be memory resident or can be retrieved from disk. If no name or the name of a non-existent model is specified then the system returns to the main menu. Having entered the routine a submenu is displayed and the alternative choices are described below. When selecting one of the submenu options, Atoms will firstly enquire whether the reports are to be sent to the computer screen, a line printer or a text file. On directing a report to a text file, the user specifies the name of the corresponding file, which will automatically have an extension, .MOD. Whilst the screen option can only display a maximum of 15 lines at a time, the user therefore controls the display of information through the use of five cursor control keys, as indicated in the lower margin. These are PGUP, PGDN and UP and DOWN arrow keys, whilst ESC is used to quit the display.

C.12.1 Operator Types Report

This report provides a listing of all specified operator types, together with an appropriate summary description. The report is illustrated in figure C.34 and documented below.

Number, is the sequential numbering of all operator types, in the order in which they were defined.

OperatorName, this identifies the name of each operator type and the label by which they are referenced.

NumberShifts, this indicates the number of shifts which have been specified for a particular operator type.

NumberOperators, is the total number of operators which have been specified over all shifts relating to a given operator type.

JobPriorities, identifies all classes of operations undertaken by a particular operator type, in priority order.

No.	Operator Name	Number Shifts	Number Operators	Job Priorities Job 1	Job 2	Job 3	Job 4
1	AUTO_OP_SP	2	2	Operation	Repair		
2	HT_OPS	2	2	Operation			
3	GRIND_OPS	2	4	Operation			
4	AUTO_OP_GR	2	2	Operation			
5	MILL_OPS	2	8	Operation	Setting	Repair	
6	BROACH_OPS	2	4	Operation			
7	PRESS_OPS	2	4	Operation	Repair	Material	Setting
8	INSPECTORS	2	4	Operation	Setting		
9	CRAFTSMEN	2	6	Setting	Repair		
10	MTRL_HDLRS	2	5	Material			

Figure C.34 Operator Type View Report

C.12.2 Operator Groups Report

This report provides a listing of all specified operator groups, in addition to identifying all operator types associated with a specific group. The report is illustrated in figure C.35 and documented below.

Number, is the sequential numbering of all operator groups, in the order in which they were defined.

GroupName, identifies the name of each operator group and the label by which each record is referenced.

OperatorsIncluded, lists all operator types associated with a particular operator group, in priority order.

===

Number	Group Name	Operators Included
1	SETTERS	CRAFTSMEN
		PRESS_OPS
		MILL_OPS
2	HANDLERS	MTRL_HDLRS
3	ENGINEERS	CRAFTSMEN
		AUTO_OP_SP
		MILL_OPS

===

Figure C.35 Operator Group View Report

C.12.3 Operator Type Groups and Work Stations Report

In addition to listing all operator types, this report identifies, for each type, the operator groups and work stations they are associated with. The report is illustrated in figure C.36 and documented below.

Number, is the sequential numbering of all operator types, in the order in which they were defined.

TypeName, identifies of the name of each operator type and the label by which each record is referenced.

IncludedOperatorGroup, lists all operator groups with which a specific operator type is associated.

IncludedMachineGoup, lists all work stations with which a specific operator type is associated.

Number	Type Name	Included Operator Groups	Included Machine Groups
1	AUTO_OP_SP	ENGINEERS	CMATIC203
		----------	CMATIC204
		----------	CMATIC205
2	HT_OPS	----------	HEAT-TR206
3	GRIND_OPS	----------	GRIND207
		----------	GRIND208
		----------	GRIND209
		----------	GRIND210
4	AUTO_OP_GR	----------	CMATIC211
		----------	CMATIC212
5	MILL_OPS	ENGINEERS	MILL213
		SETTERS	MILL214
		----------	MILL215
		----------	MILL216
6	BROACH_OPS	----------	BROACH217

Figure C.36 Operator Type Groups and Work Stations View Report

C.12.4 Work Centres Report

This report provides a listing of all specified work centres, together with an appropriate summary description. The report is illustrated in figure C.37 and documented below.

Number, is the sequential numbering of all work centres, in the order in which they were defined.

WorkCentreName, identifies the name of each work centre and the label by which each record is referenced.

WorkCentreLevel, identifies the level of abstraction at which a work centre is modelled.

WorkCentreType, identifies a work centres operation type.

ScheduleRule, identifies the scheduling rule used to prioritise batches waiting in a work centre's input queue.

ShiftNumber, indicates the number of shifts which have been specified for a particular work centre.

WorkStationNumber, is the total number of work stations which have been specified over all shifts relating to a given work centre.

No.	Name	Work Centre Level	Type	Schedule Rule	Shifts Number	Station Number
1	CMATIC-MAC	Station	Assembly	FIFO	N/A	2
2	FELL-MILL	Station	Manual	FIFO	N/A	4
3	PER-BROACH	Station	Manual	FIFO	N/A	2
4	CMATIC-TRN	Station	Assembly	FIFO	N/A	3
5	HEAT-TREAT	Station	Manual	FIFO	N/A	1
6	GRIND	Station	Manual	FIFO	N/A	4
7	PRESS-12TN	Station	Assembly	FIFO	N/A	2
8	INSPECTION	Station	Manual	FIFO	N/A	3
9	PRESS-2	Department	Assembly	FIFO	2	4
10	PRESS-3	Centre	Assembly	FIFO	2	4

Figure C.37 Work Centres View Report

C.12.5 Work Centre Jobs Report

This report provides a summary of all operations which have been detailed to take place at a specific work centre. On selecting this option the system requests the name of the work centre to consider. Having displayed the relevant report the system returns to the previous prompt. To exit from this the user simply presses RETURN without specifying a work centre. The report is illustrated in figure C.38 and documented below.

Number, is the sequential numbering of all operations performed at the particular work centre, in the order in which they were defined.

PartNumber, identifies the component which requires an operation performed at the particular work centre.

OperationNumber, identifies the precise component operation performed at the particular work centre.

No.	Part Number	Operation Number	Set Up Time	Standard Time	Load Quantity	Transfer Quantity	Scrap
1	SP_ASSY_B	1	30.0 F	0.2 F	1	1500	0.00%
2	SP_ASSY_C	1	30.0 F	0.2 F	1	1500	0.00%
3	SP_ASSY_D	1	30.0 F	0.2 F	1	1500	0.00%
4	GEAR_AA	3	0.0 F	0.0 F	Batch	Batch	0.00%
5	SP_ASSY_A	1	30.0 F	0.2 F	1	1500	0.00%

Figure C.38 Work Centre Jobs View Report

SetUpTime, specifies the set-up time for a particular operation.

StandardTime, specifies the standard time for a particular operation.

LoadQuantity, specifies the number of parts processed simultaneously during a particular operation.

TransferQuantity, specifies the batch size used to transfer components between this and the next operation.

Scrap, identifies the percentage of scrap produced on a particular operation.

C.12.6 Work Stations Report

This report provides a listing of all specified work stations, together with an appropriate summary description. The report is illustrated in figure C.39 and documented below.

Number, is the sequential numbering of all work stations, in the order in which they were defined.

WorkStationName, identifies the name of each work station and the label by which each record is referenced.

WorkStationType, identifies the work station operation type.

Breakdowns 1/2/3/4, lists all breakdown records with which a work station is associated.

IncludedWorkCentres, lists all work centres with which a work station is associated.

No.	Work Station Name	Work Station Type	Breakdowns 1	Breakdowns 2	Breakdowns 3	Breakdowns 4	Included Work Centres
1	CMATIC211	Assembly	3	12	0	0	CMATIC-MAC
2	CMATIC212	Assembly	3	12	0	0	CMATIC-MAC
3	MILL213	Manual	5	15	0	0	FELL-MILL
4	MILL214	Manual	5	15	0	0	FELL-MILL
5	MILL215	Manual	5	15	0	0	FELL-MILL
6	MILL216	Manual	5	15	0	0	FELL-MILL
7	BROACH217	Manual	5	15	0	0	PER-BROACH
8	BROACH218	Manual	5	15	0	0	PER-BROACH
9	CMATIC203	Assembly	4	13	0	0	CMATIC-TRN
10	CMATIC205	Assembly	4	13	0	0	CMATIC-TRN
11	HEAT-TR206	Manual	5	15	0	0	HEAT-TREAT
12	GRIND207	Manual	1	10	0	0	GRIND

Figure C.39 Work Station View Report

C.12.7 Work Centre Stations Report

This report identifies all work stations associated with each work centre. The report is illustrated in figure C.40 and documented below.

Number, is the sequential numbering of all work centres, in the order in which they were defined.

CentreName, identifies the name of each work centre and the label by which each record is referenced.

StationIncluded, lists all work stations associated with a particular work centre, in priority order.

C.12.8 Material Report

This report provides a listing of specified material components, together with an appropriate summary description. The report is illustrated in figure C.41 and documented below.

Number, is the sequential numbering of all components, in the order in which they were defined.

PartName, identifies the name of each component and the label by which each record is referenced.

PartScale, specifies the scale of a component in relation to a "standard part".

RoutingSpecified, indicates whether or not any manufacturing operations have been specified for a component.

Number	Centre Name	Stations Included
1	CMATIC-MAC	CMATIC211
		CMATIC212
2	FELL-MILL	MILL213
		MILL214
		MILL215
		MILL216
3	PER-BROACH	BROACH217
		BROACH218
4	CMATIC-TRN	CMATIC203
		CMATIC204
		CMATIC205
5	HEAT-TREAT	HEAT-TR206
6	GRIND	GRIND207
		GRIND208
		GRIND209

Figure C.40 Work Centre Stations View Report

No.	Part Name	Scale	Routing Specified	Ordering Method	Store Qty	Purchase Lead-Time
1	BAR_16MM	0.1	No	MRP	347.00	10.0 F
2	BAR_45MM	0.1	No	MRP	358.00	10.0 F
3	BAR_50MM	0.1	No	MRP	378.00	10.0 F
4	BAR_55MM	0.1	No	MRP	311.00	10.0 F
5	GEAR_A	0.1	Yes	Kanban	0.00	1.0 F
6	GEAR_B	0.1	Yes	Kanban	0.00	1.0 F
7	GEAR_C	0.1	Yes	Kanban	0.00	1.0 F
8	GEAR_D	0.1	Yes	Kanban	0.00	1.0 F
9	SPINDLE_A	0.1	Yes	Kanban	0.00	1.0 F
10	SPINDLE_B	0.1	Yes	Kanban	0.00	1.0 F
11	SPINDLE_C	0.1	Yes	Kanban	0.00	1.0 F

Figure C.41 Material View Report

OrderingMethod, specifies the production control method employed for a particular component.

StoreQty, specifies a components current store quantity.

PurchaseLead-Time, specifies the lead-time to buy-in a component.

C.12.9 Material Routing Data Report

This report provides a summary of all operations which have been specified for a particular component. On selecting this option the system requests the name of the component to consider. Having displayed the relevant report the system returns to the previous prompt. To exit from this the user simply presses RETURN without specifying a component. The report is illustrated in figure C.42 and documented below.

OperationNumber, is the sequential numbering of all component operations.

WorkCentreName, identifies the work centre where the operation is performed.

SetUpTime, is the set-up time for a particular operation.

StandardTime, is the standard time for a particular operation.

LoadQty, specifies the number of parts processed simultaneously during a particular operation.

TransportTime, specifies the time (or distance) to transfer a batch of components from this operation to the next.

Op. No.	Work Centre Name	Set Up Time	Standard Time	Load Qty	Transport Time	Transfer Quantity
1	CMATIC-MAC	240.0 F	31.5 F	150	5.0 F	1500
2	FELL-MILL	15.0 F	0.5 F	1	5.0 F	1500
3	PER-BROACH	30.0 F	0.2 F	1	5.0 F	1500

Figure C.42 Material Routing Data View Report

TransferQuantity, specifies the batch size used to transfer components between this and the next operation.

C.12.10 Transport Groups Report

This report provides a listing of all specified transport devices, together with an appropriate summary description. The report is illustrated in figure C.43 and documented below.

Number, is the sequential numbering of all transport groups, in the order in which they were defined.

TransportName, identifies the name of each transport group and the label by which they are referenced.

TransportType, identifies the type of devices that a particular transport group is comprised.

TransportQty, is the total number of devices available in a particular transport group.

TransportSpeed, specifies of the travelling speed of individual transport devices belonging to a particular group.

TransportCapacity, specifies the transfer capacity of devices belonging to a particular transport group.

ResponceTime, is the average time for a device to respond to a call to move a batch of work.

Number	Name	Type	Transport Qty	Speed	Capacity	Responce Time
1	HANDTRUCKS	Discrete	2	10.0	0.0	4.0 F

Figure C.43 Transport View Report

C.12.11 Breakdown Records Report

This report provides a listing of all discrete types of breakdowns, together with an appropriate summary description. The report is illustrated in figure C.44 and documented below.

BreakdownNumber, is the sequential numbering of all discrete breakdowns and the label by which they are referenced.

BreakdownType, identifies the type of breakdown.

BreakdownInterval, specifies the duration between discrete breakdowns.

RepairOperator, is the operator group required to repair a broken work station.

RepairInterval, is the mean time to repair a broken work station.

WaitingInterval, is the time a partially processed work batch will wait on a broken work station before being off loaded.

ToolingTypes, is the total number of tools required to undertake the repair of a work station.

C.12.12 Tooling Groups Report

This report provides a listing of all specified tooling, together with an appropriate summary description. The report is illustrated in figure C.45 and documented below.

Number, is the sequential numbering of all tool, in the order in which they were defined.

ToolName, identifies the name of each tool and the label by which they are referenced.

ToolingQty, is total number of tools available in a particular group.

Number	Breakdown Type	Interval	Repair Operator	Repair Interval	Waiting Interval	Tooling Types
1	TimeOutPut	6.0 F	ENGINEERS S	5.0 F	60.0 F	0
2	TimeOutPut	8.0 F	ENGINEERS S	5.0 F	60.0 F	0
3	TimeOutPut	16.0 F	ENGINEERS S	5.0 F	60.0 F	0
4	TimeOutPut	20.0 F	ENGINEERS S	5.0 F	60.0 F	0
5	TimeOutPut	100.0 F	ENGINEERS S	480.0 F	0.0 F	0
6	TimeOutPut	150.0 F	ENGINEERS S	480.0 F	0.0 F	0

Figure C.44 Breakdown Records View Report

Number	Tool Name	Tooling Qty
1	FIXTURE	1

Figure C.45 Tooling View Report

C.13 Mathematical Model

The MATHEMATICAL MODEL option on the main menu contains all the routines necessary to configure, execute and display the results of a system evaluation based on queuing theory techniques. The information required for a simulation exercise is far greater than that for a mathematical one. Hence the description of a queuing theory model is automatically retrieved and re-configured from the specification of the corresponding simulation model. All work centres are evaluated the same, regardless of the level of simulation abstraction. The total data requirements for a mathematical model are illustrated in figure C.46. The extraction of the necessary data from the simulation model specification is explained in section C.13.1.

On selecting the mathematical model, Atoms requests the name of the model to use (section C.3). It must be the name of an existing model, which may already be memory resident or can be retrieved from disk. If no name or the name of a non-existent model is specified then the system returns to the main menu. Having entered the routine a submenu is displayed and the alternative choices are described below in sections C.13.2 to C.13.4.

C.13.1 Sources Of Mathematical Data

A lot of the data for a mathematical model is retrieved directly from the specification of a corresponding simulation model and re-configured accordingly. However exactly what data is selected and how is it configured? To answer these questions this section goes through the process of configuring a mathematical model, identifying where and how Atoms obtains the appropriate information. Throughout the section reference will be made to the model data option. This is the first choice on the mathematical model submenu and is described in section C.13.2.

I. Work Centre Relative Utilization

For work centres the relative utilization is calculated in a number of stages:

a. Firstly for each component the percentage of total demand is calculated. All material parts and associated production demand is entered via the model data option. Then the percentage demand for

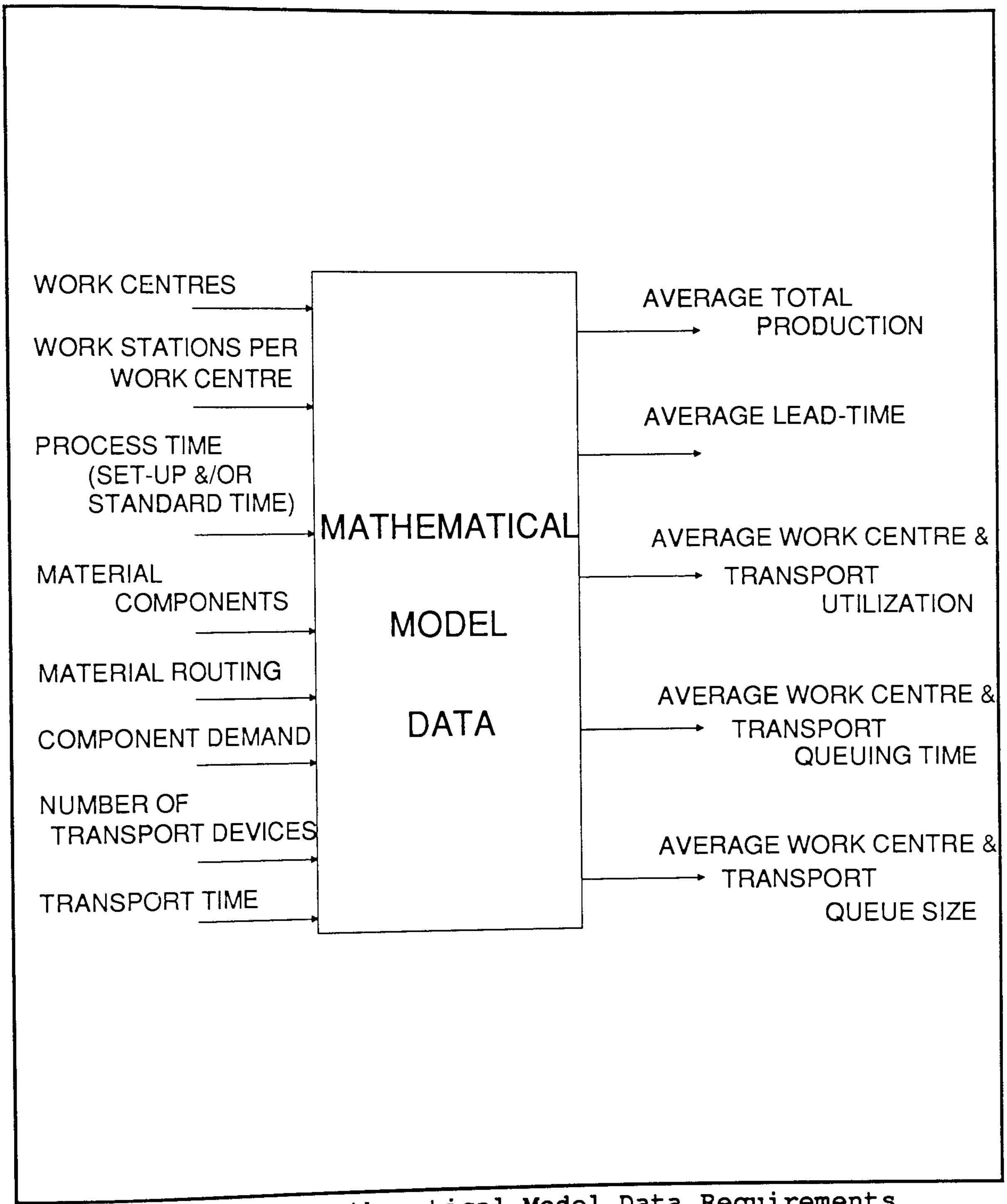


Figure C.46 Mathematical Model Data Requirements each component is:

$$\text{Percentage Demand} = \frac{\dfrac{\text{Component Demand}}{\text{Total Production Demand}}}{\dfrac{1}{\text{Total Number Of Parts}}}$$

b. The total processing time at each work centre is the accumulation of the processing time for every operation it performs. The processing time for each operation is:

$$\text{Process Time} = (<\text{Std Time}> * <\text{Percentage Demand}> * <\text{Average Batch Size}>)$$

$$+ (<\text{Set-up Time}> / <\text{Average Batch Size}>)$$

where

Average Batch Size is specified via the menu data option.

c. The average processing time at each work centre is now:

$$\text{Average Processing Time} = \frac{\text{Total Processing Time at Work Centre}}{\text{Number of Operations at Work Centre}}$$

Whilst the work centre routing probability is:

$$\text{Routing Probability} = \frac{\text{Number of Operation at Work Centre}}{\text{Total Number Of Operations Performed}}$$

where
the end of a component routing specification accounts for an extra operation, (i.e. an unloading operation is assumed).

d. The average transport time can either be calculated as an average of all those times specified in the corresponding simulation model or can be directly enter through the model data option. If a value is specified for the average transport time in the model data option then this is used. However if this is zero then the time is calculated. Hence there may be a need to specify the speed of the transport in the model data option, if the duration of the transporting activity is defined in terms of distance as opposed to minutes. For the mathematical model does not use the transport speed as defined for each group in the simulation model.

e. Hence the calculation of the relative utilization for each work centre is:

$$\text{Relative Utilization} = \frac{\text{Routing Probability} * (1/\text{Ave Transport Time})}{(1/\text{Average Processing Time})}$$

The relative utilization for a transport device in the mathematical model is 1.

II. Number Of Work Centre Servers

The number of transport servers is directly entered through the model data option. For each work centre the number of servers are determined from the simulation specification.

For a work centre at the department or centre levels of abstraction the number of servers equals the average number of specified work stations over all working shifts.

For a work centre at the station level of abstraction the number of servers equals the number of discrete work stations it refers too.

III. Number Of Batches In the System

As the mathematical techniques equate a manufacturing system to a closed-loop queuing network (Solberg, 1976; Solberg, 1977), in effect all completed work batches are immediately replaced by a new one. The amount of WIP never changes. Consequently the user has to specify the initial number of batches in the system. This is entered through the model data option.

IV. Number of Work Centres

As a result of the mathematical model allowing the user to specify which components are to be considered when undertaking an analysis exercise, it cannot be assumed that all work centres will inevitably to be included in such a model. Therefore from the list of components that are to be considered in a mathematical analysis, (enter through the model data option) Atoms automatically identifies the relevant work centres from the specification of their particular component routes.

C.13.2 Model Data

Though most data for a mathematical model is retrieved for the the corresponding simulation specification, there are some data requirements unique to the analytical evaluation. These requirements are entered by selecting the model data option on the mathematical model submenu. Therefore this must be chosen before a mathematical model can be correctly executed. The data inputs are illustrated in figure C.47 and documented below.

1. This represents the fixed number of batches continually circulating around a mathematical model. This is used directly in the mathematical calculations (Solberg, 1977).

   Default = 1 Item;

2. This represents the average size of the batches travelling around the model. It is used to calculate the average processing time for each work centre.

   Default = 1 Part.

==

1. Number Of WIP Items in Model [23]

2. Average Batch Size [1500]

3. Number Of Transport Devices [2]

4. Average Transport Time [5.00]

5. Speed of Transport (Distance per Mins) [1.0]

6. Material Parts and Production Demand to Model

	Part	Quantity
1.	[SP_ASSY_A]	[1872]
2.	[SPINDLE_B]	[9048]

==

Figure C.47 Mathematical Model Data Inputs

3. This represents the number of servers or individual devices available within a transport group. In the mathematical model it is assumed that there is only one transport group available (Solberg, 1977).

   Default = 1 Device.

4. This represents the average travelling time between two operations for all work batches. If specified this is the value used in the mathematical analysis for calculating work centre relative utilization. However if undefined then the value is calculated by averaging the total transfer times declared within the simulation defined routes for those components being considered in the analysis (see field six).

   Default = 0.0 Mins.

5. This represents the travelling speed of all devices or servers within the single transport group. The requirement for this parameter arises when the system has to calculate the average transport time from component routing specifications. For it is conceivable that the transfer distance is specified as opposed to the time. Therefore the distance is divided by the speed to produce a transfer time.

   Default = 1 Dist. Unit per Min.

6. This lists the material components that are to be considered in a particular mathematical analysis. Furthermore it identifies the production demand for each component over a typical working period (i.e. days, weeks or months). From this Atoms can determine what proportion of production demand a

component represents and therefore weight its routing specification accordingly (section C.13.1). Furthermore it identifies all work centres and operations that are to be considered. The field allows the user to enter each individual component into Atoms, or by typing "ALL" at any time produces a unique listing of all defined components, with the same production demand of one part.

Default = None.

C.13.3 Execute Model

This submenu option does exactly as it's title suggests, executes the mathematical model. On selecting this option it firstly automatically retrieves and prepares the necessary data requirements and then continues on to solve the mathematical equations. If no components have been specified for consideration within the model data option, or a work centre has no specified work stations or no set-up or standard times have been declared for any operation at a particular work centre then the execution is aborted and no results are produced. During a successful execution, Atoms goes through three stages, each of which displays an appropriate screen message to inform the user of its progress. The stages are:

- "Preparing Model Data . . .";
- "Calculating Matrix . . .";
- "Calculating Work Centre Data . . .".

On completion of the evaluation, Atoms returns to the mathematical model submenu. The results of the analysis are now read for output.

C.13.4 Results

This option provides the results of a mathematical model evaluation. The output report can be directed to a screen monitor, a line printer or text file, thereby providing a permanent record of a models analysis.

On selecting the results option, Atoms will firstly enquire whether the report is to be sent to the computer screen, line printer or text file. On directing a report to a text file, the user specifies the name of the corresponding file, which will automatically have an extension, .CAN. Whilst the screen option can only display a maximum of 15 lines at a time, the user therefore controls the display of information through the use of five cursor control keys, as indicated in the lower margin. These are PGUP, PGDN and UP and DOWN arrow keys, whilst ESC is used to quit the display. The results are illustrated in figure C.48 and documented below.

Production Rate, the average total number of batches completed by a model in an hour. No reference is made to the quantity of a particular component. Therefore the total number of batches represents any conceivable combination of those components that are considered (e.g. all batches of one component or a combination of all components).

Average Production Time, the average lead-time or flow time for any batch of work. This is equivalent to averaging the flow time of all batches for all components.

Number Of Pieces in System, this field simply restates the number of WIP items in a model which was entered in the model data option.

Centre, identifies each individual work centre considered in the analysis, together with the transport centre, which is always specified last.

NumberServers, specification of the number of servers the system calculated for each work centre.

StationUtilization, the average total work centre utilization calculated analytically.

UtilizationPerServer, the average utilization per server within a particular work centre, calculated analytically.

ServerIdleness, the average idleness of each server within a particular work centre, calculated analytically.

NoPartAtStation, the average number of batches at a particular work centre, both queuing and being processed, calculated analytically.

Production Rate = 0.52 Pieces Per Hour

Average Production Time = 2647.36 Minutes

Number Of Pieces in System (N) = 23

Station	Number Servers	Station Util~	Util~ PerServer	Server Idleness	Parts AtStation	Parts InQueue
CMATIC-MAC	2	182.05	91.02	4.42	5.96	4.14
FELL-MILL	4	254.76	63.69	6.67	3.04	0.49
PER-BROACH	2	111.59	55.79	28.18	1.58	0.46
CMATIC-TRN	3	221.82	73.94	7.60	3.44	1.22
HEAT-TREAT	1	57.78	57.78	42.22	1.31	0.73
GRIND	4	313.65	78.41	2.80	4.59	1.46

Figure C.48 Mathematical Model Results

NoPartInQueue, the average number of batches queuing at a particular work centre, calculated analytically.

C.14 Simulation Model

The execution of an Atoms simulation model and presentation of statistical results is controlled by the SIMULATION MODEL main menu option.

On selecting the simulation option, Atoms requests the name of the model to use (section C.3). It must be the name of an existing model, which may already be memory resident or can be retrieved from disk. If no name or the name of a non-existent model is specified then the system returns to the main menu. Having entered the routine a submenu is displayed and the alternative choices are described below in sections C.14.1 to C.14.6. Above the submenu, an indication is given of the current simulation time within a particular model. For highlighted on a red background is the number of the period that will next be simulated. In the case of a new model, the period number will be 1.

C.14.1. Simulation Parameters

The simulation parameters option on the submenu, provides a user with certain run-time facilities which control various aspect of the execution of a model. The parameters should always be checked before running a model to ensure that it will be correctly executed. The data requirements are illustrated in figure C.49 and C.50 and documented below.

1. This numeric variable specifies how many days there are in a simulated period. Generally this is set to 5 days to represent a week, however this can be changed to 1, 7 or 20 days or any number up to 99 days.

   Default = 5 Days.

2. This numeric variable specifies the number of periods to simulate in one execution. Thus for one execution the number of simulated days equals:

   NUMBER OF DAYS/PERIOD x NUMBER OF PERIODS SIMULATED

   Default = 1 Period.

3. This numeric variable allows the user to specify when to start accumulating statistical results. Atoms automatically collects a comprehensive range of statistical results regarding the behaviour and performance of a particular manufacturing model. However a user may wish not to record any initial results, but allow the model to settle down and reach a steady state, as apposed to a transient one. This is generally the case when a model is starting from an empty state, that is without any work-in-progress.

   Default = 0 Hrs.

```
=================================================================

          1. Length Of Working Period (Days)        [ 5]

          2. Number Of Periods To Simulate         [ 30]

          3. Results Recorded After (Hrs)        [    0]

          4. Write Daily Log To File,                [N]
                Printer Or NO Log (F\P\N)

=================================================================
```

Figure C.49 Simulation Run Parameters - Page 1

```
=================================================================

5.    Record Waiting Queue              By [BATCH, PARTS or TIME]
      Size For Work Centre(s)

           Work Centre(s)                    Measure
   1.       [          ]                     [Batch]
   2.       [          ]                     [Batch]
   3.       [          ]                     [Batch]
   4.       [          ]                     [Batch]

6.    Supplier Deliveries Accepted Between The Hours

               FROM                             TO
   1.        [ 0: 0]                         [23:59]
   2.        [ 0: 0]                         [ 0: 0]
   3.        [ 0: 0]                         [ 0: 0]
   4.        [ 0: 0]                         [ 0: 0]
=================================================================
```

Figure C.50 Simulation Run Parameters - Page 2

4. This keyword specifies whether a log of ever event is to be produced, which in addition to describing the event, records the simulation time of occurrence and the resources involved. The format of the log is:

   <Period:Day> <Hours:Minutes>
   <Event Definition + Resources Involved>

   The production of an event log significantly reduces the execution speed of a modeL. The keywords are N, P and F.

   N is for no log.
   P sends the log to a line printer.
   F produces a text file on disk, with the same name as that of the model and an extension

.LOG. The creation of a log file can cause the execution of a model to terminate prematurely. This is a result of insufficient disk space, especially when running continuously for a number of periods, as the file size can very quickly be in the order of a megabyte. For every successive model execution, the log file is over written.

Event definitions include:

TRANCALLED	request for a transport device to move a work batch from a specific work centre;
JOBSTARTED	the start of a process operation at a specific work centre or station;
JOBRESTART	the restart of a process operation at a specific work centre;
JOBCOMPLETE	completion of a process operation at a specific work centre or station;
JOBMOVING	the transfer of a work batch from a specific work centre;
SOLDLATE	the late delivery of a customer's order;
JOBARRIVED	arrival of a work batch at a work centre;
BATCHFINISH	completion of a work batch;
WORKISS	issue of a production order;
NOROUTE	issue of a production order for a component which has no routing specified;
PURCHASEISS	issue of a purchase order;
PURCHASEARI	delivery of a purchase order;
SOLDONTIME	the delivery of a customer's order;
ENDWCSHIFT	end of a DEPARTMENT or CENTRE work centre shift;
STARTWCSHIFT	start of a DEPARTMENT or CENTRE work centre shift;
TRANSFERQTY	completion of a process operation on a transfer work batch at a work centre or station;
OUTOFSTOCK	number of components not delivered to a customer;

SETTINGUP	the preparation of a work station to perform a specific process operation;
WC BREAKDOWN	breakdown of a work station;
WC REPAIR	start of repair work to a broken work station;
WC REPAIRED	completion of the work station repair work;
WC RESETTING	resetting of a repaired work station;
STARTOPSHIFT	start of an operator type shift;
ENDOPSHIFT	end of an operator type shift;
KANBAN ORDER	return of an empty kanban to the supplier;
KANBANISSUED	issue of a production kanban;
LOADING	loading of a work batch onto a work station;
UNLOADING	removal of a work batch from a work station;
ENDFIXSHIFT	start of an operator type's variable overtime;
IDLEOPFINISH	completion of an operator type's variable overtime;

Default = N.

5. This is a restricted listing which allows a user to monitor the size of both the input and output queues of a particular work centre. A maximum of four work centres can be monitored simultaneously. There are two data fields. The first identifies the work centre, whilst the other is a keyword which specifies how the queues are to be monitored; in terms of total number of batches (BATCH), parts (PARTS) or process/transport time (TIME). The size of the queues are recorded every hour in a text file on disk. The line format is:

<Hour> <Input Queue Size> <Output Queue Size]>

The text files have the same name as the model and an extension .Q1, .Q2, .Q3 and Q4 for each work centre in the list. For every successive model execution, additional recordings are append to the appropriate files. For every day there are 24 recordings, the files therefore can become very large, very quickly.

Default = None.

6. This is a restricted listing of up to four periods during a day when purchase items can be received into a model. Obviously in a real manufacturing system deliveries only arrive at certain times, for example they do not generally arrive during the night. Therefore the time of every purchase arrival is checked, if it fails then a new time is calculated which is again checked. If after 20 attempts no valid arrival time has been calculated then the order is forgotten. The times are specified in the 24 hour clock as, <Hour:Minutes>.

   Default = 0:0 to 23:59 i.e. the whole day.

C.14.2 Product Demand

This option allows a user to emulate the receipt of sales orders, specifying the precise date and time of delivery required by the customer. The details are specified in a computer text file, which has an extension .TXT. The file must be arranged in order of ascending delivery date. Consequently Atoms only records the delivery date for the first sales order. On reaching the specified date the system tries to fulfil the order. Any order shortages are recorded against the specific product, in the form of back orders. This continues until either the end of the file is reached or the simulation is stopped. The system then automatically carries on from where it left off when the simulation restarts. The text file can be up dated and re-created at any time.

On selecting the product demand option, the system prompts the user for the name of the text file which contains the sales details. The user can abort the routine at this stage by simply entering no name. Having specified a correct file name Atoms opens the file, notes the first sales date and returns the system to the submenu. The general line format, with the default values if not specified, is:

<ComponentNumber> <SalesQuantity> <SalesDate>

where

ComponentNumber, is a variable, of maximum length ten characters, which identifies a particular pre-defined material component.
Default = Mandatory;

SalesQuantity, is a numeric variable which specifies the customer's order quantity for a particular product.
Default = Mandatory;

SalesDate, is a real date variable (i.e. 02/01/89) which specifies the delivery date for a particular sales order. The expected time of delivery is fixed at 23:00 hrs. on the specified day. When creating the order the system automatically converts the real time into the simulation equivalent.
Default = Mandatory;

If the component number does not exist or the sales quantity is zero, then the order is not released. Furthermore care must be taken in specifying the sales date, for if they are earlier than the datum (section C.11.1) then illogical negative simulation times are recorded and again the individual batches are not released.

C.14.3 Execute Simulation

This submenu option does exactly as it's title suggests, executes the simulation model. On selecting this option the current period, day and time is displayed in the centre of the main work area, and Atoms confirms the decision to execute the simulation model. If no works (section C.11.3) and/or sales orders (section C.14.2) have been defined, Atoms displays an I/O error .ORD and/or .SAL, respectively. If this is intentional then these messages can be ignored or there is the option to quit out of the model execution.

During an execution the simulation time display is continually up dated. A simulation run lasts for the total number of specified periods (section C.14.1), during which Atoms automatically collects statistical data regarding a model's performance (Section C.14.1).

On completion of the evaluation, Atoms returns to the simulation model submenu. The results of the analysis are now read for output.

C.14.4 Simulation Results

The simulation results option provides a comprehensive range of statistical reports relating to the behaviour and performance of the model under evaluation. All output reports can be directed to a screen monitor, a line printer or a text file, thereby providing a permanent record of a models performance. Furthermore there is an "everything" option which automatically outputs all reports, which contain some information.

On selecting the simulation results option, a further submenu is displayed and the alternative choices are described below. When selecting one of the submenu options, Atoms will firstly enquire whether the report is to be sent to the computer screen, line printer or text file. On directing a report to a text file, the user specifies the name of the corresponding file, which will automatically have an extension, .RES. Whilst the screen option can only display a maximum of 15 lines at a time, the user therefore controls the display of information through the use of five cursor control keys, as indicated in the lower margin. These are PGUP, PGDN and UP and DOWN arrow keys, whilst ESC is used to quit the display.

I. Work Centres

This report provides the specific statistical results pertaining to both work centres and stations. The report is illustrated in figures C.51 and C.52 and documented below.

Work centre data:

WorkCentre, name of the work centre;

ShiftTime, the total standard operating time that was

Work Centre Data

WorkCentre	Shift Times (Hrs)	Setting Times (Hrs)	Process Times (Hrs)	Utili' zation	Block Times (Hrs)	Out Put Btch	Good Prod.	OutPut Scrap
HEAT-TREAT	3600	34.25	1643.74	46.61	0.00	630	811200	0
GRIND	14400	119.25	8271.07	58.26	0.00	623	803028	0
PRESS-12TN	7200	218.50	3570.74	52.63	0.00	622	801528	0
INSPECTION	7200	21.67	2226.47	31.22	0.00	622	769455	32073

Work Station Data

WorkStation	Down Time (Hrs)	Repair Times (Hrs)	Setting Times (Hrs)	Process Times (Hrs)	Utili' zation	Out Put Btch	Good Prod.	OutPut Scrap
CMATIC211	140.51	99.75	480.00	1703.10	64.54	324	410460	0
CMATIC212	162.89	99.67	488.00	1686.38	64.92	306	400740	0
MILL213	105.42	22.92	26.00	2148.05	63.32	167	222740	0
MILL214	48.95	20.33	27.25	2019.12	58.20	180	226512	0
BROACH217	70.85	17.17	65.00	1728.00	51.77	342	444116	0
BROACH218	35.80	13.75	61.50	1382.82	41.11	282	359212	0
CMATIC203	92.07	64.08	452.00	1557.51	58.38	234	297408	0

Kanban Quantities

PRESS-12TN	GEAR_A	10
PRESS-12TN	GEAR_D	25
PRESS-12TN	SPINDLE_C	75

Processing Batches

MILL213	W	1	Batch	10	Op.No.	2	Qty	1500	ProcessTime(Min)	829
MILL214	W	1	Batch	15	Op.No.	2	Qty	372	ProcessTime(Min)	205
BROACH217	W	1	Batch	10	Op.No.	3	Qty	1500	ProcessTime(Min)	347
BROACH218	W	1	Batch	10	Op.No.	3	Qty	1500	ProcessTime(Min)	347
GRIND207	W	1	Batch	9	Op.No.	3	Qty	1500	ProcessTime(Min)	5

Figure C.51 Work Centre Simulation Results

Work Centre Waiting Queuing Information

Work Centre		Current	Maximum	Average		Max.	Ave.
HEAT-TREAT	Batches	0	3	0.6	Batch Q		
	Parts	0	5320	717.8	Time(Hr)	14.57	4.99
	Time(Hr)	0.00	10.29	1.39			
GRIND	Batches	2	6	0.7	Batch Q		
	Parts	2172	11172	1105.3	Time(Hr)	44.43	3.23
	Time(Hr)	17.08	87.58	8.66			
PRESS-12TN	Batches	2	7	3.9	Batch Q		
	Parts	8172	36712	17444.7	Time(Hr)	182.58	87.15
	Time(Hr)	32.69	146.85	69.78			

Waiting Batches

GRIND	1	Batch	9	Op. No.	3	Qty	300	WkDone(Hrs)	0
PRESS-12TN	1	Batch	2	Op. No.	1	Qty	1872	WkDone(Hrs)	0
PRESS-12TN	2	Batch	12	Op. No.	1	Qty	6300	WkDone(Hrs)	0

Work Centre Finished Queue Information

WorkCentre		Current	Maximum	Average
CMATIC-MAC	Batches	2	2	0.0
	Parts	1872	3000	20.8
	Time(Hr)	0.05	0.05	0.00
FELL-MILL	Batches	0	1	0.0
	Parts	0	3000	23.2
	Time(Hr)	0.00	0.01	0.00
PER-BROACH	Batches	0	1	0.0
	Parts	0	3000	21.2
	Time(Hr)	0.00	0.01	0.00

Finished Batches

CMATIC-MAC	1	Batch	22	Op No.	1	Qty.	1500
CMATIC-MAC	2	Batch	24	Op No.	1	Qty.	372

Figure C.52 Work Centre Simulation Results

available at the work centre since results were collected (section C.14.1). For each shift the available time is:

Number of Work Stations x Shift Length;

Note the shift length for work centres at station level defaults to 24 hours, as it is assumed at this level they are always available and that it is the operators who have restricted availability.

Remember that at station level work stations are not necessarily unique to a particular work centre, therefore shift times may indicate more time than is actually available.

SettingTime, the total time incurred at the work centre preparing to process work batches since results were collected (section C.14.1);

ProcessTime, the total time incurred at the work centre processing work batches since results were collected (section C.14.1);

Utilized, total work centre utilization since results were collected (section C.14.1);

$$\frac{(\text{Setting Time + Processing Time})}{\text{Shift Time}} * 100$$

BlockedTime, total time the work centre was blocked, unable to start a new work batch since results were collected (section C.14.1);

OutputBatches, total number of work batches processed at the work centre since results were collected (section C.14.1);

GoodProd, total number of satisfactory parts processed at the work centre since results were collected (section C.14.1);

OutputScrap, total number of parts scraped at the work centre since results were collected (section C.14.1).

Work station data:

WorkStation, name of the work station;

Downtime, the total time the work station was unavailable, due to breakdowns, since results were collected (section C.14.1);

RepairTime, total time the work station was being repaired since results were collected (section C.14.1); SettingTime, the total time incurred at the work station preparing to process work batches since results were collected (section C.14.1);

ProcesTime, the total time incurred at the work station processing work batches since results were collected (section C.14.1);

Utilized, total work station utilization since results were collected (section C.14.1);

$$\frac{(\text{Downtime} + \text{Setting} + \text{Process})}{(24 * \text{Number of Simulated Days})} * 100$$

OutputBatches, total number of work batches processed at the work station since results were collected (section C.14.1);

GoodProd, total number of satisfactory parts processed at the work station since results were collected (section C.14.1);

OutputScrap, total number of parts scraped at the work station since results were collected (section C.14.1).

Kanban quantities:

WorkCentre, name of the work centre;

Component, name of the material component kanbaned at the work centre;

KanbanQty, total number of parts, relating to a kanbaned component, at the work centre.

Processing batches (batches currently being worked on):

WorkCentre, name of the work centre or work station;

Number, sequential number of work batch being processed (P) at the work centre or station or waiting (W) for start of operator or work centre shift;

Batch, internal batch number, allocated by Atoms when the batch was originally issued;

Operation, current batch operation number;

Quantity, batch quantity;

JobTime, duration of current operation, either setting-up or processing.

Work centre waiting queue information:

WorkCentre, name of the work centre;

Current, current size of work centre input buffer, in terms of total number of batches, parts and processing time;

Maximum, maximum size of work centre input buffer since results were collected (section C.14.1), in terms of total number of batches, parts and processing time;

Average, average size of work centre input buffer since results were collected (section C.14.1), in terms of total number of batches, parts and processing time;

Maximum, maximum time an individual work batch had to wait at the work centre before being processed, since results were collected (section C.14.1);

Average, average time a work batch had to wait at the work centre before being processed, since results were collected (section C.14.1).

Waiting batches:

WorkCentre, name of the work centre;

Number, sequential numbering of work batch waiting to be processed at the particular work centre;

Batch, internal batch number, allocated by Atoms when the batch was originally issued;

Operation, current batch operation number;

Quantity, batch quantity;

JobTime, duration of current operation and amount already completed.

Work centre finished queue information:

WorkCentre, name of the work centre;

Current, current size of work centre output buffer, in terms of total number of batches, parts and transport time;

Maximum, maximum size of work centre output buffer since results were collected (section C.14.1), in terms of total number of batches, parts and transport time;

Average, average size of work centre output buffer since results were collected (section C.14.1), in terms of total number of batches, parts and transport time;

Finished batches:

WorkCentre, name of the work centre;

Number, sequential numbering of work batch waiting

	to be transferred from the particular work centre;
Batch,	internal batch number, allocated by Atoms when the batch was originally issued;
Operation,	current batch operation number (the one that has just been completed);
Quantity,	batch quantity;

II. Stores

This report provides the specific statistical results pertaining to each individual material component. The report is illustrated in figure C.53 and documented below.

Material action:

Material,	name of the material component with, immediately after it, a letter indicating the production planning method used to control the issue of works orders.
	M = MRP, K = Kanban, S = Statistics and O = Orderpoint;

==

Material Action
===============

Material		On Hand	Due In	Issued	Receive	Scrap	Sold On Time	Sold Late	Back Order	Lead Time (Hr)
BAR_12MM	M	88	76	1123	1064	0	0	0	0	0
BAR_14MM	M	147	362	5429	5068	0	0	0	0	0
GEAR_C	M	8320	0	249600	249600	0	0	0	0	100
GEAR_D	M	300	6000	227700	228000	0	0	0	0	132
SPINDLE_A	M	0	1872	54288	54288	0	0	0	0	155
SPINDLE_B	M	6000	0	271440	271440	0	0	0	0	89
SPINDLE_C	M	6000	0	249600	249600	0	0	0	0	116
SPINDLE_D	M	3000	6300	227700	227700	0	0	0	0	151
SP_ASSY_A	M	7635	1872	0	52113	2175	53566	0	0	177
SP_ASSY_B	M	36185	0	0	260580	10860	26023	0	0	77

Work-In-Progress Batches
========================

1	GEAR_A	1	Batch	15	WN	GE/A30	OpNo	2	Qty	1500	WC	FELL-MILL
2	GEAR_A	2	Batch	15	WN	GE/A30	OpNo	2	Qty	372	WC	FELL-MILL
3	SPINDLE_D	1	Batch	9	WN	SP/D30	OpNo	3	Qty	1500	WC	GRIND
4	SPINDLE_D	2	Batch	9	WN	SP/D30	OpNo	3	Qty	1500	WC	GRIND
5	SP_ASSY_A	1	Batch	2	WN	SA/A30	OpNo	1	Qty	1872	WC	PRESS-12TN
6	SP_ASSY_D	1	Batch	12	WN	SA/D30	OpNo	1	Qty	6300	WC	PRESS-12TN

==

Figure C.53 Store Simulation Results

OnHand,	the total number of completed material parts currently in stores;
DueIn,	the total number of material parts currently being processed;
Issued,	the total number of material parts issued for assembly since results were collected (section C.14.1);
Received,	the total number of completed material parts received into stores since results were collected (section C.14.1);
Scrap,	the total number of material parts scraped since results were collected (section C.14.1);
SoldOnTime,	the total number of material parts sold to a customer on time (section C.14.2) since results were collected (section C.14.1);
SoldLate,	total number of material parts sold late to a customer since results were collected (section C.14.1);
BackOrders,	total number of material parts currently owing to customers;
AveFlowTime,	average batch lead-time, calculated from all work batches completed since results were collected (section C.14.1).

Work-in-progress batches:

Number,	sequential numbering of all work batches;
Material,	name of material component;
Batch,	internal batch number, allocated by Atoms when the batch was originally issued;
OrderNumber,	works order number, a user-specified reference number;
Operation,	current batch operation number;
Quantity,	batch quantity;
WorkCentre,	current work centre location.

III. Transport

This report provides the specific statistical results relating to individual transport groups. The report is illustrated in figure C.54 and documented below.

Transport data:

Transport,	name of the transport group;

TotalQty, total number of individual devices available in the group;

QtyIdle, total number of individual devices currently available;

LoadsTransported, total number of loads transferred by the group since results were collected (section C.14.1);

TransportingTime, total time incurred by the transport group in transferring work batches between operations since results were collected (section C.14.1).

Transport waiting queue information:

Transport, name of the transport group;

Current, current number of work batches waiting to be transferred, in terms of total number of loads and transport time;

==

Transport Data
==============

Transport	Total Qty	Qty Idle	No. Loads Transported	Total Time Transporting (Hr)
HANDTRUCKS	2	2	4829	500.15

Transport Waiting Queue Information
===================================

Transport		Current	Maximum	Average		Max.	Ave.
HANDTRUCKS	Loads	2	2	0.0	Batch Q		
	Time(Hr)	0.05	0.05	0.00	Time(Hr)	4.60	0.01

Batches Waiting Transport
=========================

HANDTRUCKS 1 Batch 22 Op. No. 1 Qty. 1500 CMATIC-MAC

Processing Batches
==================

HANDTRUCKS 1 Batch 24 Op. No. 1 Qty. 372 FELL-MILL

==

Figure C.54 Transport Simulation Results

Maximum,	maximum number of work batches waiting to be transferred since results were collected (section C.14.1), in terms of total number of loads and transport time;
Average,	average number of work batches waiting to be transferred since results were collected (section C.14.1), in terms of total number of loads and transport time;
Maximum,	maximum time an individual work batch had to wait before being transported, since results were collected (section C.14.1);
Average,	average time a work batch had to wait before being transferred, since results were collected (section C.14.1);

Batches waiting transfer:

Transport,	name of the transport group;
Number,	sequential numbering of work batches waiting for transportation (a work batch can appear in a work centre's output buffer waiting for transportation and not be displayed in this list, because a transport device has been allocated to the batch but due to its response time has not yet arrived at the work centre);
Batch,	internal batch number, allocated by Atoms when the batch was originally issued;
Operation	Current batch operation number (the one that has just been completed);
Quantity,	batch quantity;
WorkCentre,	current work centre location.

Transport Processing:

Transport,	name of the transport group;
Number,	sequential numbering of work batches either being transported or have been allocated a transport device but because of its response time has not yet arrived at the work centre;
Batch,	internal batch number, allocated by Atoms when the batch was originally issued;
Operation,	current batch operation number (the one that has just been completed);
Quantity,	batch quantity;
WorkCentre,	name of the work centre being transferred

too.

IV. Operators

This report provides the specific statistical results relating to individual operator types. The report is illustrated in figure C.55 and documented below.

Operator data:

Operator, name of the operator type;

ShiftTime, the total operating time that operator types have been available, since results were collected (section C.14.1). For each shift the available time is:

Number Of Operators x Shift Length;

OverTime, total variable overtime incurred by the operator type, since results were collected (section C.14.1);

SettingTime, the total time incurred by the operator type preparing work stations to process work batches, since results were collected (section C.14.1);

==

Operator Data
=============

Operator	Shift Times (Hrs)	OverTime (Hrs)	Setting Times (Hrs)	Process Times (Hrs)	Material Handling (Hrs)	Repair Times (Hrs)
AUTO_OP_SP	2250.00	0.00	0.00	548.17	0.00	0.00
HT_OPS	2250.00	0.00	0.00	1643.74	0.00	0.00
GRIND_OPS	5847.00	0.00	0.00	821.09	0.00	0.00
AUTO_OP_GR	2550.00	0.00	0.00	192.48	0.00	0.00
INSPECTORS	4500.00	0.00	21.67	2226.47	0.00	0.00
CRAFTSMEN	8770.50	0.00	2887.00	0.00	0.00	1398.50

Operator Working
================

MILL_OPS	1	Processing	Batch	15	OpNo.	2	WorkStation	MILL215
MILL_OPS	2	Processing	Batch	10	OpNo.	2	WorkStation	MILL213
MILL_OPS	3	Processing	Batch	10	OpNo.	2	WorkStation	MILL216
MILL_OPS	4	Processing	Batch	15	OpNo.	2	WorkStation	MILL214
BROACH_OPS	1	Processing	Batch	10	OpNo.	3	WorkStation	BROACH217
BROACH_OPS	2	Processing	Batch	10	OpNo.	3	WorkStation	BROACH218
PRESS_OPS	1	Processing	Batch	12	OpNo.	1	WorkStation	PRESS219

==

Figure C.55 Operator Simualtion Results

ProcessTime, the total time incurred by the operator type processing work batches, since results were collected (section C.14.1);

TransportingTime, total time incurred by the operator type transferring work batches from one operation to the next, since results were collected (section C.14.1);

RepairingTime, total time incurred by the operator type repairing broken work stations, since results were collected (section C.14.1);

Operator working:

Operator, name of the operator type;

Number, sequential numbering of activity;

JobType, specification of job type, i.e. REPAIRING, TRANSPORTING, SETTING or PROCESSING.

for REPAIRING:

WorkStation, name of work station being repaired.

for SETTING:

WorkStation, name of work station being set-up.

for PROCESSING:

Batch, internal batch number, allocated by Atoms when the batch was originally issued;

Operation Current batch operation number;

WorkStation, name of work station where operation is being performed.

for TRANSPORTING:

Batch, internal batch number, allocated by Atoms when the batch was originally issued;

Operation, current batch operation number (the one that has just been completed);

Transport, name of transport group being used.

V. Tooling

This report provides the specific statistical results relating to individual tooling. The report is illustrated in figure C.56 and documented below.

Tooling data:

ToolName, name of the tooling group;

Tooling Data

Tool Name	Utilization To Date (Hrs)	Utilization Per Tool (Hrs)
FIXTURE	0.00	0.00

Figure C.56 Tooling Simulation Results

DateUtilization, total group utilization since results were collected (section C.14.1);

ToolUtilization, total utilization per tool, since results were collected (section C.14.1).

VI. Completed Orders

This report provides the specific statistical results relating to individual work batches completed during a model evaluation. The report is illustrated in figure C.57 and documented below.

Material, name of material component;

Batch, internal batch number, allocated by Atoms when the batch was originally issued;

OrderNumber, Works order number, a user-specified reference number;

Time The simulation time a batch was completed;

FlowTime, total lead-time from issue to completion of the work batch;

Yield, total number of parts produced;

Scrap, total number of parts scrapped;

QueueTime, total queuing time incurred by the work batch;

ProcessTime, total processing time incurred by the work batch;

SetTime, total set-up time incurred by the work batch;

TransportTime, total transport time incurred by the work batch;

BreakdownTime, total breakdown time incurred by the work batch;

```
==============================================================

GEAR_B (3)  Works Order GE/B-1 Completed - 01:03  13:22
      Flow Time 60:22    Yield 9048 Scrap 0
      QuT 56:60  PrT 155:55  SeT 10:00  TrT 01:33  BrT 00:20
      OpWaitngT 40:04    DueDate -  02:01  01:00

SP_ASSY_B (4)  Works Order SA/B-1 Completed - 01:03  19:28
      Flow Time 66:28    Yield 8686 Scrap 362
      QuT 66:13  PrT 65:21  SeT 02:13  TrT 01:27  BrT 00:10
      OpWaitngT 13:40    DueDate -  02:01  01:00

SPINDLE_B (2)  Works Order SP/B-1 Completed - 01:04  00:27
      Flow Time 71:27    Yield 9048 Scrap 0
      QuT 64:46  PrT 161:25  SeT 13:15  TrT 02:10  BrT 02:55
      OpWaitngT 64:54    DueDate -  02:01  01:00

GEAR_C (6)  Works Order GE/C-1 Completed - 01:04  18:25
      Flow Time 89:25    Yield 8320 Scrap 0
      QuT 76:18  PrT 143:19  SeT 10:00  TrT 01:52  BrT 00:50
      OpWaitngT 35:50    DueDate -  02:01  01:00

SP_ASSY_C (7)  Works Order SA/C-1 Completed - 01:04  20:59
      Flow Time 91:59    Yield 7987 Scrap 333
      QuT 92:45  PrT 60:05  SeT 02:13  TrT 01:02  BrT 00:10
      OpWaitngT 10:10    DueDate -  02:01  01:00

==============================================================
```

Figure C.57 Completed Orders Simulation Results

OperatorDelay, total time the work batch waited for a process operator;

DueDate, original due date for the work batch specified, by the user, when the batch was issued (only for MRP orders).

C.14.5 Basic Simulation Results

This option provides very concise information regarding the current state of a particular model and it's performance over the last period. The results are illustrated in figure C.58 and documented below.

```
==============================================================

        Number Of WIP Batches 6 and Quantity 29016

   Number Of Completed Batches 12 and Total Quantity 80038

      Number Of Input Orders 12 and Total Quantity 81120

==============================================================
```

Figure C.58 Basic Simulation Results

Work-in-Progress, this specifies both the total number of work batches and individual parts (within the batches) currently being processed in a particular model.

CompletedOrders, this specifies the total number of work batches and individual parts (within the batches) that completed processing during the last period. This is irrespective of how they were originally ordered, i.e. MRP, kanban, orderpoint or statistical.

ReleasedOrders, this specifies the total number of batches and individual parts (within the orders) for which work orders were issued during the last period.

In addition to this menu option, Atoms automatically records these simplistic results in a text file to disk for every period. Therefore regardless of the number of periods that are continuously simulated, there will always be periodic results. Whereas the results provide by the two simulation model submenu options, simulation results and basic simulation results can only be obtained between model executions, which could last for a number of periods. The text file has the same the name as the model, with the extension .WK. The results for each period are appended to the file, with the first line relating to time zero, before a model has been executed. The line format of the file is:

<WIPBatches> <WIPParts> <IssuedBatches> <IssuedParts>
<CompletedBatches> <CompletedParts> <ProcessTime>
<Operations> <SoldOnTime>

where

WIPBatches, total number of work batches currently being processed in a particular model;

WIPPatrs, total number of parts represented by the work batches currently being processed in a particular model;

IssuedBatches, total number of orders issued during the last period;

IssuedParts, total number of parts represented by the orders issued during the last period;

CompletedBatches, total number of batches that completed processing during the last period;

CompletedParts, total number of parts represented by the batches that completed processing during the last period;

ProcessTime, total processing time incurred during the last period, in hours and including both set-up and operation times;

Operations,	total number of operations that were completed during the last period;
SoldOnTime,	total number of sale orders that were satisfied on time during the last period.

C.14.6 Zero Model

Simulation revolves around an iterative procedure of model specification and evaluation, because of the absence of any analytical procedures. This routine therefore resets a model to simulation time zero, so alterations can be made to the specification and an alternative solution evaluated.

On selecting zero model, Atoms confirms the request to reset the model before re-initialising the results data, deleting all work-in-progress and resetting the operational state of all resources. Now resource and operation specifications can be modified or deleted, new ones can be added and the work-in-progress specified. If user-defined work centre schedules had previously be used, then these would have to be re-specified. Once completed the new model specification can be evaluated. If the model name is the same as those previous evaluated then the log and various results files will be overwritten. A new model name can be specified be simply saving the new description under a different name before starting the evaluation procedure.

C.15 File Manager

The file manager is a set of routines dealing with the disk storage of Atoms models, and therefore provides an interface to DOS. Through the file manager the default disk drive and subdirectory can be changed, a new model can be loaded into memory or a model can be deleted from disk.

The change directory option displays the current drive and subdirectory path. It allows the user to change the default path by simply typing in a new specification one step at a time. The user can specify a new drive (i.e. A:), or subdirectory name or use the standard DOS features "\" and ".." to change the path. The system continually updates the "current directory" display after each entry. To exit the option the user presses RETURN without specifying anything.

The load new model option allows an existing model to be loaded into memory from disk. The routine requires the user to specify a model name, as described in section C.3 and then retrieves it from disk. If the system cannot find it, the message "Model Not Found" is displayed. To abort the routine without loading a new model, the user simply presses RETURN without specifying a name. The system then reverts back to the model originally resident in memory. Whereas specifying an non-existent model clears memory without loading a new definition.

The erase model option allows a user to delete a particular model definition stored on disk. The routine requires the user to specify a model name, as described in section C.3. It then verifies that this is the correct model to delete before removing it from disk. If the system cannot find the model, the message "Model Not Found" is displayed. To abort the routine without deleting a model, the user simply enters either no name or the name of an non-existent model.

This option has no effect on any model currently memory resident.

C.16 Model Size Limitations

The major restriction in the size of model that Atoms can accommodate is directly related to computer memory availability. For Atoms can accommodate up to 4500 system components, which includes all individual resource and operation specifications, together with a maximum of 400 work batches. Unfortunately however Atoms, running on a computer with 640k base memory, only provides approximately 270k for model specification and execution. Whilst each resource and operation record approximately consumes:

work station record	201 bytes + 8 bytes per operator type;
DEPARTMENT work centre record	327 bytes + 31 bytes per shift;
CENTRE work centre record	350 bytes + 31 bytes per shift;
STATION work centre record	320 bytes + 8 bytes per work station;
material record	232 bytes;
transport record	133 bytes;
tooling record	35 bytes;
operator type record	125 bytes + 63 bytes per shift;
operator group record	19 bytes + 8 bytes per operator type;
DEPARTMENT operation record	83 bytes + 16 bytes per assembly component;
CENTRE operation record	103 bytes + 16 bytes per assembly component;
STATION operation record	142 bytes + 16 bytes per assembly component;
work batch	89 bytes + 68 bytes per transfer quantity.

Also during the execution of a model additional memory will be allocated for event records and work batch waiting and finishing queues at work centres. However Atoms does utilize the available computer memory very efficiently, allowing the specification of vastly varying model configurations. For there are no precise limitations on the number of specific resources or operations that can be defined, such as work centres, material components, operator types or operations per routing.

Appendix D Atoms: Program Documentation

D.1 Introduction

In order to support, implement and evaluate the derived modelling methodology, a computer manufacturing simulator was developed, focusing particularly on the hierarchical representation of manufacturing systems. The computer simulator, called Atoms, was produced in Turbo Pascal and takes advantage of the advanced features available in such a language. These include dynamic variable allocation, record types with fixed and variant fields, record arrays and linked lists.

Atoms contains very few pre-defined variables (section D.3), relying instead on dynamic memory allocation during program execution. This approach means the simulator utilizes available computer memory very efficiently. Atoms initially only allocating sufficient memory for program code, whilst the remaining free memory forms the heap, in which dynamic variables are stored. All or part of the heap can then be used to define and evaluate a particular model specification.

In Atoms all resources (operators, work centres, tooling, etc.) and operations are defined through standard record type variables, dynamically allocated during model specification. The various record structures are defined in section D.2, together with additional record types which form related linked lists. A linked list being a dynamic data structure containing further information, the extent of which is dependent upon the particular resources and operations. This includes the kiting list for assembly operations, the operator type list for work stations, the work stations list for work centres and the queue of work into and out of work centres. As a result of utilizing standard record types, Atoms models are saved to disk in typed files. That is each record type is saved in an appropriate file. Therefore saving a model creates 30 files (although, depending upon the particular specification, some may be of zero size) and these are identified in section D.4 .

Principally, Atoms consists of two main record structures, an ENTITYRECORD and BATCHRECORD array. The EntityRecord array comprises a record structure with variant fields, so that it is able to point to any resource or operation dynamic record variable. The array can reference a maximum of 4500 records. Whilst the BatchRecord array points to only one type of dynamic record variable, (i.e. WorksOrder) and can reference a maximum of 400 orders. Section D.5 illustrates the relationships between the various records and arrays within Atoms and additionally highlights the connections between specific record types.

Final section D.6 illustrates the program structure implemented in Atoms. Identifying specific features such as overlays, which reduces the program's total run-time memory requirements, and the procedures controlling user input to and output from Atoms.

D.2 Record Structure Specification

D.2.1 MathsDataRecord

TotalTime,	numeric variable containing the sum of the set-up and standard times for all operations performed at a particular work centre.
NoOfJobs,	numeric variable identifying the total number of operations performed at a work centre.
AverageTime,	numeric variable containing the result of TotalTime / NoOfJobs.
RoutingProbability,	numeric variable specifying the probability of an operation being performed at a work centre, for a mathematical model.
RelativeUtilization,	numeric variable recording the relative utilization for a work centre, calculated during a mathematical evaluation.
NoOfServers,	numeric variable identifying the average number of work stations assigned to a work centre.
WorkCentreNumber,	numeric variable identifying a particular work centre by it's EntityRecord array number.
ForwardCentre,	pointer to the next work centre MathsData Record.
BackwardCentre,	pointer to the previous work centre MathsDataRecord.

D.2.2 KanbanRecord

Number,	numeric variable identifying, by it's EntityRecord array number, the material store or work centre location for a kanban component.
MatNumber,	numeric variable identifying a specific kanban component, by way of it's EntityRecord array number.
KanbanSize,	numeric variable specifying the kanban size for a specific material component.
OnHandQty,	numeric variable recording the number of of individual parts currently at a specific location, belonging to a particular material item.

OriginalKanban, numeric variable recording the number of parts belonging to a particular material item, initially assigned to a specific location.

NextKanban, pointer to the next material KanbanRecord, for the same location.

D.2.3 WCBasicDataRecord

Number, numeric variable specifying the EntityRecord array number of a particular work centre.

WCName, string variable specifying the name of the work centre.

WCState, type variable indicating the current state of the work centre.

WCType, type variable identifying the type of work centre.

MaxWaitingQSize, numeric variable specifying the maximum size of the work centre input queue.

WaitingQUnits, type variable identifying the units for MaxWaitingQSize.

WaitingQSizes, one dimensional numeric array recording the current input queue size in terms of PARTS, BATCHES and TIME.

WaitingQResults, two dimensional numeric array recording the AVERAGE and MAXIMUM input queue size, in terms of PARTS, BATCHES and TIME, during a simulation run.

WaitingQBasePointer, pointer to a linked list data structure containing WaitingRecords identifying batches waiting in the work centre input queue.

BatchWaitingTime, one dimensional numeric array recording the AVERAGE and MAXIMUM time batches wait in the work centre input queue, during a simulation run.

MaxFinishedQSize, numeric variable specifying the maximum size of the work centre output queue.

FinishedQUnits, type variable identifying the units for MaxFinishedQSize.

FinishedQSizes, one dimensional numeric array recording the current output queue size in terms of PARTS, BATCHES and TIME.

FinishedQResults, two dimensional numeric array recording the AVERAGE and MAXIMUM output queue size, in terms of PARTS, BATCHES and TIME, during a simulation run.

FinishedQBasePointer, pointer to a linked list data structure containing FinishedRecords identifying batches waiting in the work centre output queue.

NextWCPointer, numeric variable identifying the next work centre definition, by way of it's EntityRecord array number.

FirstOpPointer, numeric variable identifying the first defined operation to be performed at the work centre, by it's EntityRecord array number.

KanbanData, pointer to a linked list data structure containing KanbanRecords detailing material items stored in kanbans at the work centre.

MathematicData, pointer to the work centre's MathsDataRecord.

NumberOfServers, numeric variable specifying the total number of work stations assigned to the work centre.

AverageUtilization, numeric variable recording the average total utilization for the work centre, calculated mathematically.

Idleness, numeric variable recording the average work station idleness, calculated mathematically.

NoOfPartsAtWC, numeric variable recording the average total number of parts at a work centre, (both queuing and being processed) calculated mathematically.

NextMathsCentre, numeric variable identifying the next work centre, by it's EntityRecord array number, to be considered when performing a mathematical evaluation.

D.2.4 CentreShiftRecord (figure D.1)

NextWCShift, pointer to the next CentreShiftRecord, for a particular work centre.

LastWCShift, pointer to the previous CentreShiftRecord, for a particular work centre.

WCReference, numeric variable identifying a particular work centre by it's EntityRecord array number.

ShiftReference, numeric variable identifying the number

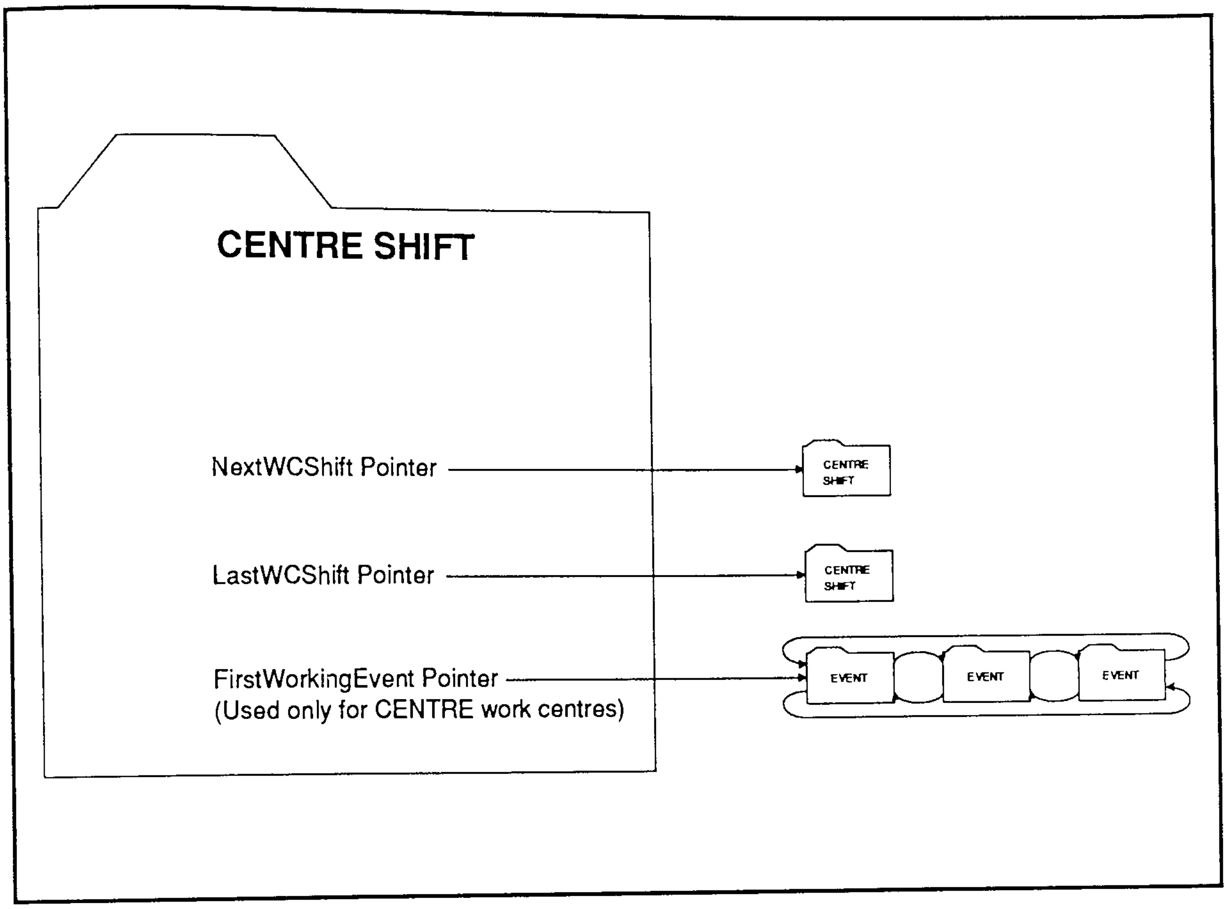


Figure D.1 Work Centre Shift Record Pointers

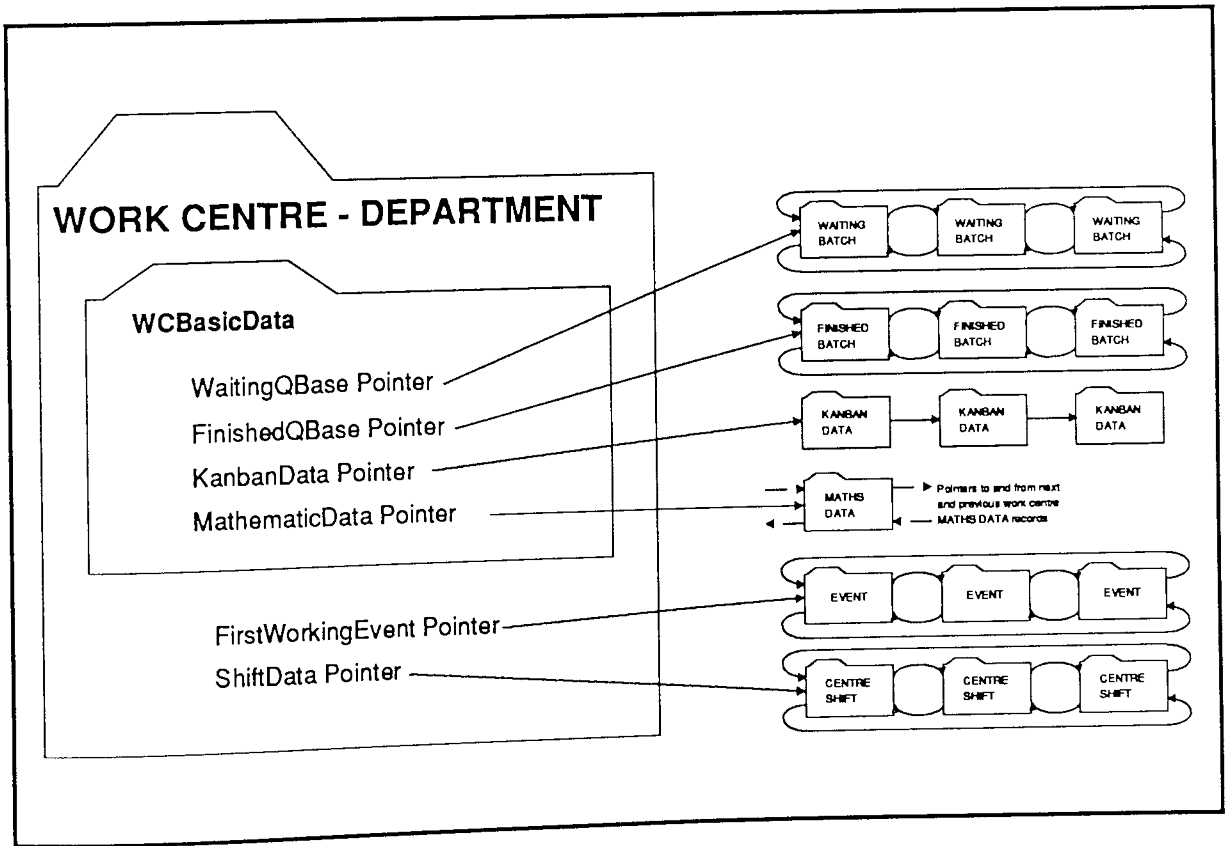


Figure D.2 Work Centre DEPARTMENT Record Pointers of the CentreShiftRecord for a particular work centre.

StartTime, numeric variable specifying the start time of a particular shift, in minutes from the beginning of the day.

EndTime, numeric variable specifying the finish time for a particular shift, in minutes from the beginning of the day.

WSNumber, numeric variable specifying the number of work stations assigned to a particular shift.

QtyIdle, numeric variable recording the number of work stations currently available.

ShiftOn, boolean variable identifying whether a particular shift is in operation.

FirstWorkingEvent, pointer identifying the first and most imminent event to occur relating to a particular work centre and shift.

D.2.5 WorkCentreDEPARTMENT (figure D.2)

WCBasicData, WCBasicDataRecord.

ShiftData, pointer to a linked list data structure containing CentreShiftRecords detailing a work centre's shift pattern.

ProcessCapacity, one dimensional numeric array used for PROCESS type work centres and specifies the MAXIMUM, AVAILABLE and USED processing capacity.

TimeWCStopped, numeric variable recording the time, in minutes that a work centre became blocked.

TotalWorkStationHrs, numeric variable recording the total amount of available machining time.

CurrentWSNumber, numeric variable recording the current number of available work stations, overall operating shifts.

ProductionTimes, one dimensional numeric array recording the total time, in minutes, a work centre was BUSY, SETTING and BLOCKED, during a simulation run.

ProductionOutput, one dimensional numeric array recording the total number of BATCHES and PARTS produced, together with the parts SCRAPed, during a simulation run.

FirstWorkingEvent, pointer identifying the first and most imminent event to occur relating to the particular work centre.

MachineEfficiency, numeric variable specifying the efficiency of the work stations assigned to a centre.

D.2.6 WorkCentreCENTRE (figure D.3)

WCBasicData, WCBasicDataRecord.

ShiftData, pointer to a linked list data structure containing CentreShiftRecords detailing a work centre's shift pattern.

RegroupBatches, boolean variable specifying whether to regroup transfer batches at a particular work centre.

SequencingRule, type variable specifying the sequencing rule to use at a particular work centre.

SimilarNextBatch, boolean variable specifying whether to select the next processing batch similar to the previous one.

SplitBatches, boolean variable specifying whether to split a batch in to a number of transfer batches distributed between available work stations.

ProcessFirstBatch, boolean variable specifying whether only the first batch in the input queue can be considered for processing next.

CurrentWSNumber, numeric variable recording the current number of available work stations, overall operating shifts.

TimeWCStopped, numeric variable recording the time, in minutes that a work centre became blocked.

TotalWorkStationHrs, numeric variable recording the total amount of available machining time.

ProcessCapacity, one dimensional numeric array used for PROCESS type work centres and specifies the MAXIMUM, AVAILABLE and USED processing capacity.

WCPerformance, one dimensional numeric array specifying a work centre's operating performance in terms of losses due to BREAKDOWNS and LABOURLOSSES and work station EFFICIENCY.

ScheduleFile, string variable identifying the name of the file containing the scheduling details, for work centres whose SequencingRule = SCHEDULE.

ScheduleIdle, boolean variable used when SequencingRule = SCHEDULE to specify whether, if a batch

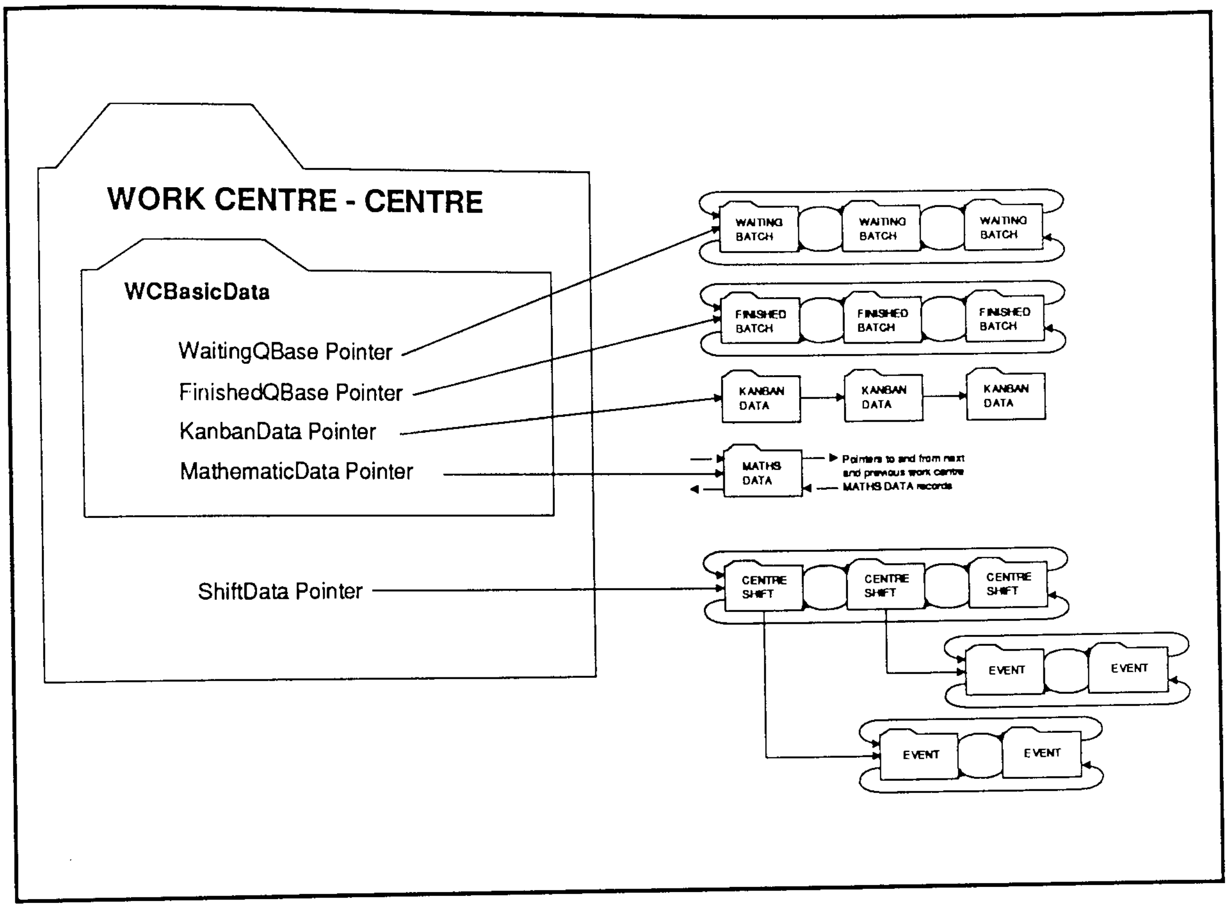


Figure D.3 Work Centre CENTRE Record Pointers

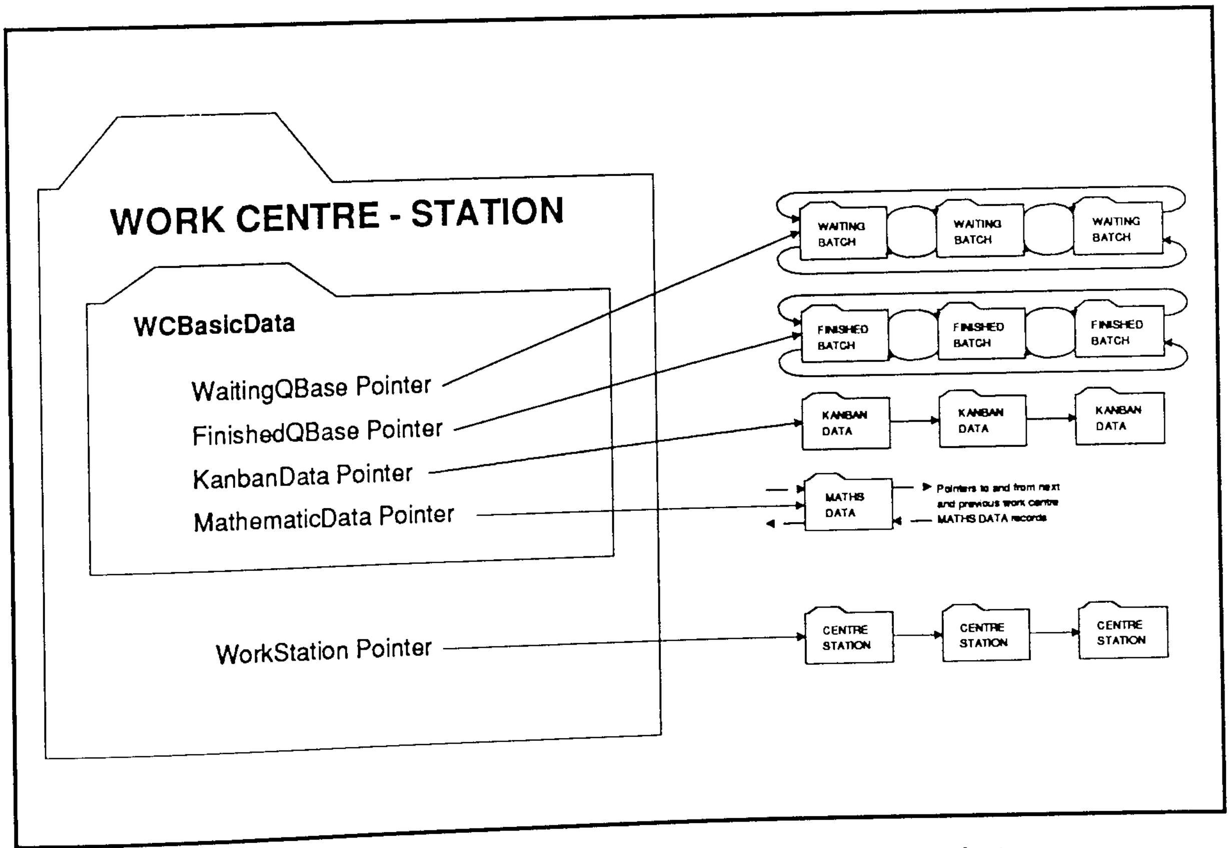


Figure D.4 Work Centre STATION Record Pointers cannot be selected from the schedule, then try processing any waiting batches.

ProductionTimes, one dimensional numeric array recording the total time, in minutes, a work centre was BUSY, SETTING and BLOCKED, during a simulation run.

ProductionOutput, one dimensional numeric array specifying the total number of BATCHES and PARTS produced, together with the parts SCRAPed, during a simulation run.

D.2.7 CentreStationRecord

EntityNumber, numeric variable identifying the parent work centre or station by it's EntityRecord array number.

MemberEntity, numeric variable identifying, by it's EntityRecord array number, a particular work station or centre related to the parent.

NextEntity, pointer to the next CentreStationRecord with the same parent.

D.2.8 WorkCentreSTATION (figure D.4)

WCBasicData, WCBasicDataRecord.

RegroupBatches, boolean variable specifying whether to regroup transfer batches at a particular work centre.

SequencingRule, type variable specifying the sequencing rule to use at a particular work centre.

SimilarNextBatch, boolean variable specifying whether to select the next processing batch similar to the previous one.

SplitBatches, boolean variable specifying whether to split a batch in to a number of transfer batches distributed between available work stations.

ProcessFirstBatch, boolean variable specifying whether only the first batch in the input queue can be considered for processing next.

TotalWSNumber, numeric variable specifying the total number of work stations assigned to a work centre.

TotalWSIdle, numeric variable recording the current number of available work stations.

ScheduleFile, string variable identifying the name of the file containing the scheduling details, for work centres whose SequencingRule = SCHEDULE.

ScheduleIdle, boolean variable used when SequencingRule = SCHEDULE to specify whether, if a batch cannot be selected from the schedule, then try processing any waiting batches.

TimeWCStopped, numeric variable recording the time, in minutes that a work centre became blocked.

WorkStationPointer, pointer to a linked list data structure containing CentreStationRecords identifying the previously defined work stations assigned to a particular work centre.

TotalProductionTimes, one dimensional numeric array recording the total time, in minutes, a work centre was BUSY, SETTING and BLOCKED, during a simulation run.

TotalProductionOutput, one dimensional numeric array recording the total number of BATCHES and PARTS produced, together with the parts SCRAPed, during a simulation run.

WCQueueNumber, numeric variable used to record the current input queue number being considered, when selecting the next batch to process.

WCSimilarCount, numeric variable used to record the current input queue number being considered, when selecting the next batch to process which is similar to the last.

WCScheduleNumber, numeric variable used to record the current reference being considered in a schedule file when selecting the next batch to process.

D.2.9 TimeRecord

Distribution, type variable identifying an available statistical distribution.

Interval, numeric variable defining the constant, mean or average part of the selected distribution.

Deviation, numeric variable required to fully describe certain distributions.

RandomStream, numeric variable identifying the use of a specific random stream.

D.2.10 ToolingUseRecord

ToolingNumber, numeric variable identifying a previously defined tool by it's EntityRecord array number.

ToolQty, numeric variable specifying the number of ToolingNumber required.

ToolUsage, type variable specifying the release of a tool.

D.2.11 StationBreakdownRecord

BreakdownNumber, numeric variable identifying a particular breakdown record by is MachineBreakdown array number.

BreakdownType, type variable identifying the type of breakdown. BreakDownInterval, TimeRecord specifying the time interval between breakdowns.

WaitEndOfJob, boolean variable identifying whether a breakdown occurs only when the station becomes idle.

RepairInterval, TimeRecord specifying the time to repair a work station.

RepairOperator, numeric variable identifying a previously defined operator group, by it's EntityRecord array number, to repair a work station.

JobPriority, type variable specifying the priority of the repair operation.

Tooling, one dimensional ToolingUseRecord array identifying tools required to undertake the repair operation.

WaitingInterval, TimeRecord specifying the time interval that a work batch waits for a station to be repaired before being removed.

Allowance, numeric variable specifying further time, in minutes, that a work batch may wait for a station to be repaired, in addition to the WaitingInterval.

RestartDuration, numeric variable specifying the percentage of the previous set-up time, to reset a repaired work station to complete the original batch.

RestartOperator, numeric variable identifying a previously defined operator group, by it's EntityRecord array number, to reset a repaired station.

RestartPriority, type variable specifying the priority of the reset operation.

D.2.12 BreakdownDetailRecord

Number,	numeric variable identifying a particular breakdown record by it's MachineBreakdown array number.
Types,	type variable identifying the type of breakdown.
Time,	numeric variable specifying the time, in minutes, a particular breakdown next occurs.
Flag,	boolean variable specifying whether the breakdown has occurred.

D.2.13 OperatorRelationRecord

EntityNumber,	numeric variable identifying the parent operator type, group or work station by it's EntityRecord array number.
MemberEntity,	numeric variable identifying, by it's EntityRecord array number, a particular work station, operator group or type related to the parent.
NextEntity,	pointer to the next OperatorRelationRecord with the same parent.

D.2.14 WorkStationRecord (figure D.5)

Number,	numeric variable specifying the EntityRecord array number of a particular work station.
Name,	string variable specifying the name of work station.
WSType,	type variable identifying the type of work station.
CurrentState,	type variable indicating the current state of the work station.
PreviousState,	type variable indicating the previous state of the work station.
LastPart,	numeric variable identifying the last material component to be processed, by it's EntityRecord array number.
WorkingAttribute,	type variable indicating the attribute of the last material component to be processed.
LastOp,	numeric variable indicating the operation that was performed on the last material component.

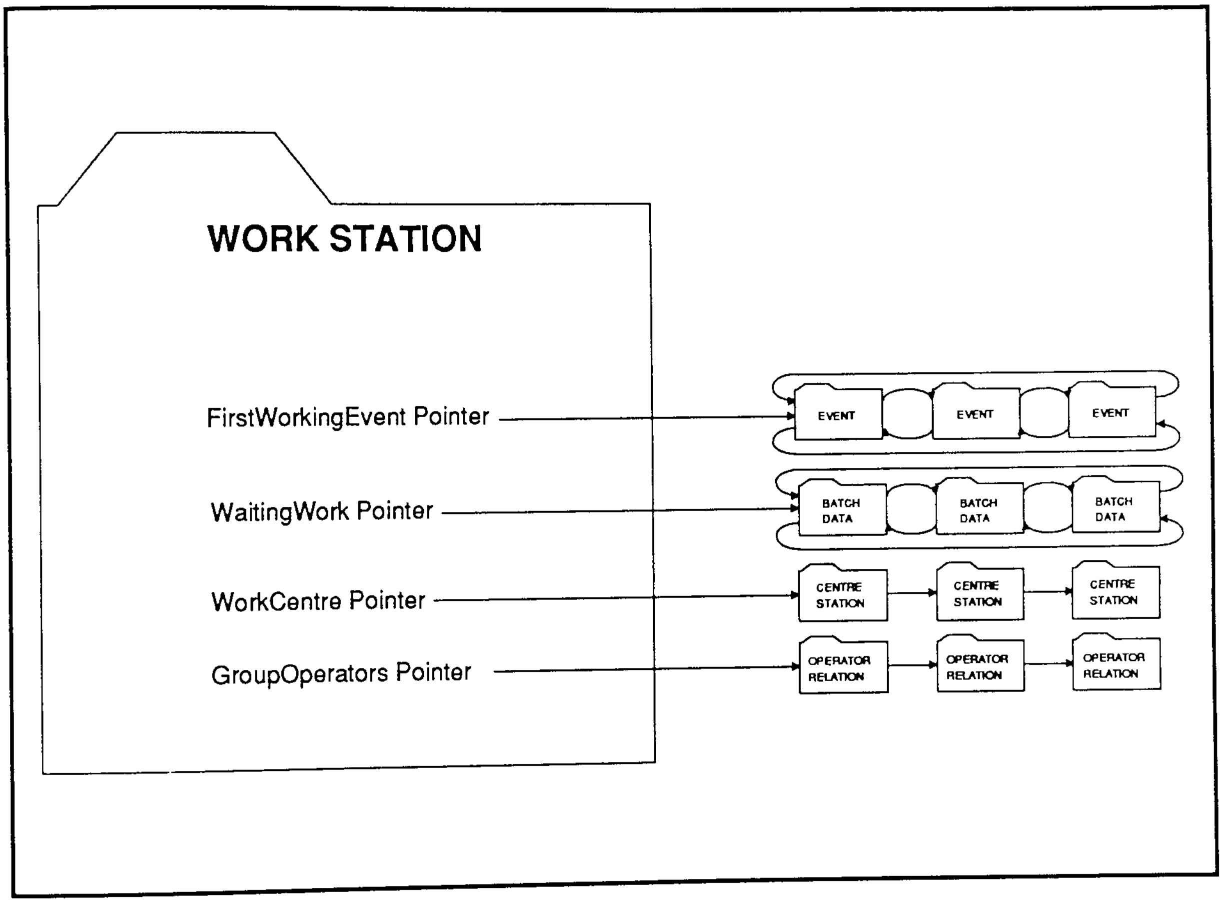


Figure D.5 Work Station Record Pointers

FirstWorkingEvent, pointer identifying the first and most imminent event to occur relating to a particular work station.

WaitingWork, pointer to a linked list data structure containing BatchDataRecords identifying work batches waiting for an operator to complete their processing.

JobsFirstWorkCentre, boolean variable indicating whether to scan the work centres as specified in the WCPointer list or start with those which have the least number of work stations assigned to them, when select the next work batch.

ProcessCapacity, one dimensional numeric array used for PROCESS type work stations and specifies the MAXIMUM, AVAILABLE and USED processing capacity.

WSEfficiency, numeric variable specifying the efficiency of a work station.

TimeWSStopped, numeric variable recording the time, in minutes that a work station stopped due to a breakdown.

ProductionTime, one dimensional numeric array recording the total time, in minutes, a work station was STOPPED, REPAIRING, BUSY, SETTING and BLOCKED, during a simulation run.

ProductionOutput, one dimensional numeric array recording the total number of BATCHES and PARTS produced, together with the parts SCRAPed, during a simulation run.

WorkCentrePointer, pointer to a linked list data structure containing CentreStationRecord identifying particular work centres, a work station has been assigned too.

GroupOperators, pointer to a linked list data structure of OperatorRelationRecords identifying previously defined operator types which have been assigned to a work station.

NextWSPointer, numeric variable identifying the next work station definition, by it's EntityRecord array number.

BreakdownData, one dimensional BreakdownDetailRecord array identifying four possible types of work station breakdowns.

BrokenFlag, boolean variable identifying whether a work station has broken down.

BreakDownType, numeric variable identifying which of the four breakdowns has occurred.

D.2.15 StoreRecord

QtyDueIn, numeric variable recording the number of work-in-progress parts belonging to a particular material component.

WeeklyAction, one dimensional numeric array recording the number of parts ISSUED, RECEIVED, SOLD, SCRAPPED, BACKORDER, SOLDLATE and FLOWTIME for a particular material component, calculated during the last simulation run.

TotalAction, one dimensional numeric array recording the number of parts ISSUED, RECEIVED, SOLD, SCRAPPED, BACKORDER, SOLDLATE and FLOWTIME for a particular material component, calculated from zero simulation time.

D.2.16 WaitingCentreRecord

MaterialNumber, numeric variable identifying a material component by it's EntityRecord array number.

Centre, numeric variable identifying a work centre waiting for a kanban quantity of a material component.

ForwardRecord, pointer to the next WaitingCentreRecord for a particular material component.

BackwardRecord, pointer to the previous WaitingCentreRecord for a particular material component.

D.2.17 MaterialRecord (figure D.6)

Number, numeric variable specifying the EntityRecord array number of a particular material item.

Name, string variable specifying the name of a material component.

NextMaterial, numeric variable identifying the next material component definition, by it's EntityRecord array number.

FirstOperation, numeric variable identifying a material components first operation by it's EntityRecord array number.

FirstWIPBatch, numeric variable identifying a material components first works order by it's BatchRecord array number.

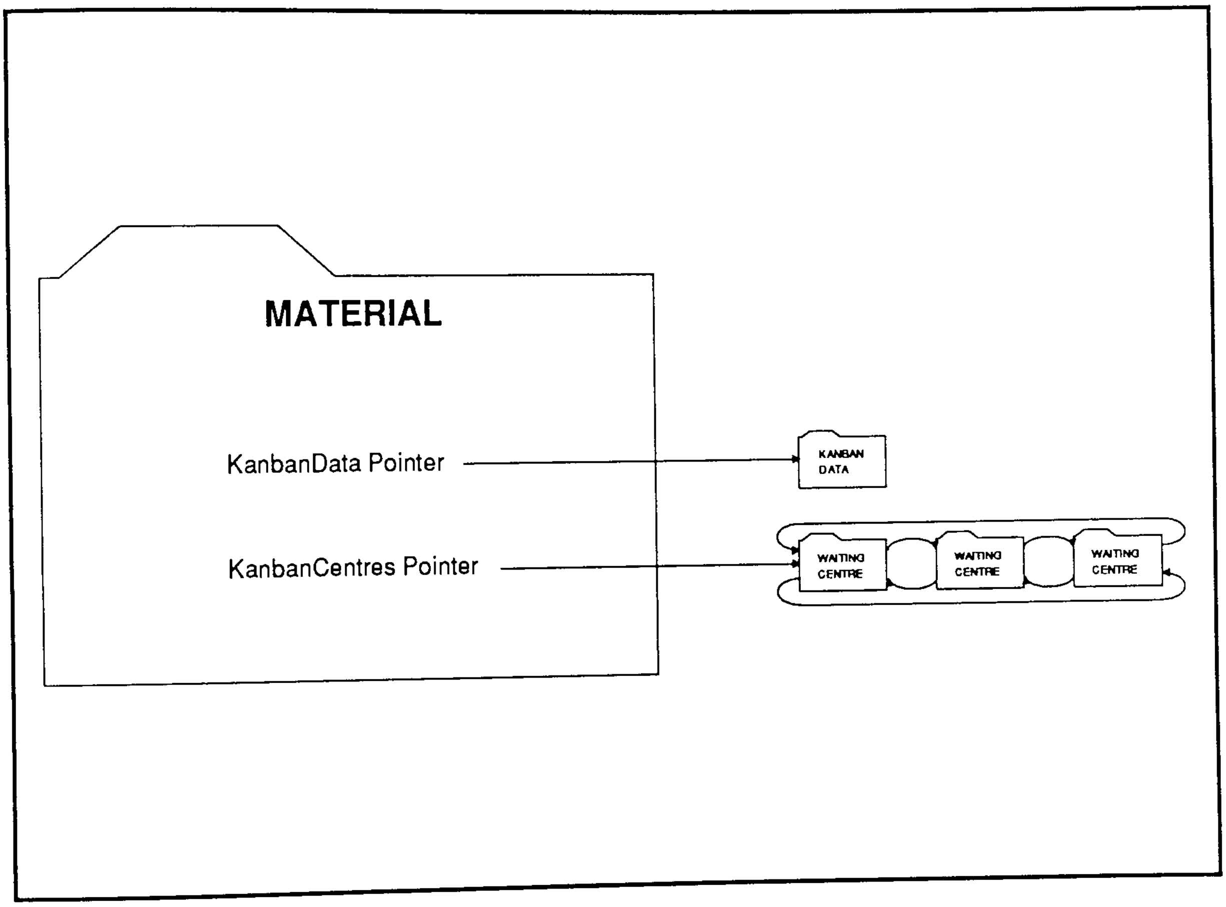


Figure D.6 Material Record Pointers

TotalOperations, numeric variable recording the total number of process operations for a material item.

Scale, numeric variable specifying the size of a material component with reference to a "standard component".

Attribute, one dimensional type array specifying two component attributes.

PurchaseLeadTime, TimeRecord defining the time to buy-in a material component.

Store, StoreRecord.

NextPart, numeric variable identifying the next material component for mathematical evaluation, by it's EntityRecord array number.

QuantityRequired, numeric variable recording component demand for use in the mathematical evaluation.

DemandProportion, numeric variable specifying QuantityRequired as a percentage of the total demand for all material components in a mathematical evaluation.

OriginalMaterial, numeric variable recording the number of parts, belonging to a particular material component, initially assigned to stores.

MaterialOrdering, type variable identifying the type of production control method applied to a material component. Furthermore this is a tag field upon which the variant fields of the record are dependent.

The variant field for MaterialOrdering = MRP is:

MRPQty, numeric variable recording the number of parts currently in store, belonging to a particular material component.

The variant fields for MaterialOrdering = STATISTICAL are:

StatsQty, numeric variable recording the number of parts currently in store, belonging to a particular material component.

FirstOrder, TimeRecord identifying the time of release for the first works or purchase order.

MTBO, TimeRecord identifying the time between subsequent order releases.

OrderQty, numeric variable identifying the size of individual orders.

ProdOrder, boolean variable specifying whether the release is of works or purchase orders (TRUE = Works Order).

The variant fields for MaterialOrdering = KANBAN are:

KanbanData, pointer to KanbanRecord detailing a particular components kanban size and quantity.

KanbanCentres, pointer to WaitingCentreRecord identifying any work centres waiting for a kanban of components.

The variant fields for MaterialOrdering = ORDERPOINT are:

ReorderQty, numeric variable recording the number of parts currently in store, belonging to a particular material component.

ReorderPoint, numeric variable identifying the level at which a works order is released.

OrderPointQty, numeric variable specifying the size of the works order.

OrderIssued, boolean variable indicating whether there is currently an outstanding works order for a particular material component.

D.2.18 JobOverSeeingRecord

Owner, numeric variable identifying the parent operator type by it's EntityRecord array number.

Entity, numeric variable identifying a work station that the parent is over seeing a job(s) on, by way of it's EntityRecord array number.

QtyJobsOverSeeing, numeric variable specifying the number of jobs that are being over seen at a particular work station.

Shift, numeric variable identifying which shift the operator type (parent) is working on.

ForwardJob, pointer to the next JobOverSeeingRecord for a particular operator type.

BackwardJob, pointer to the previous JobOverSeeingRecord for a particular operator type.

D.2.19 OperatorShiftRecord (figure D.7)

NextOpShift, pointer to the next OperatorShiftRecord,

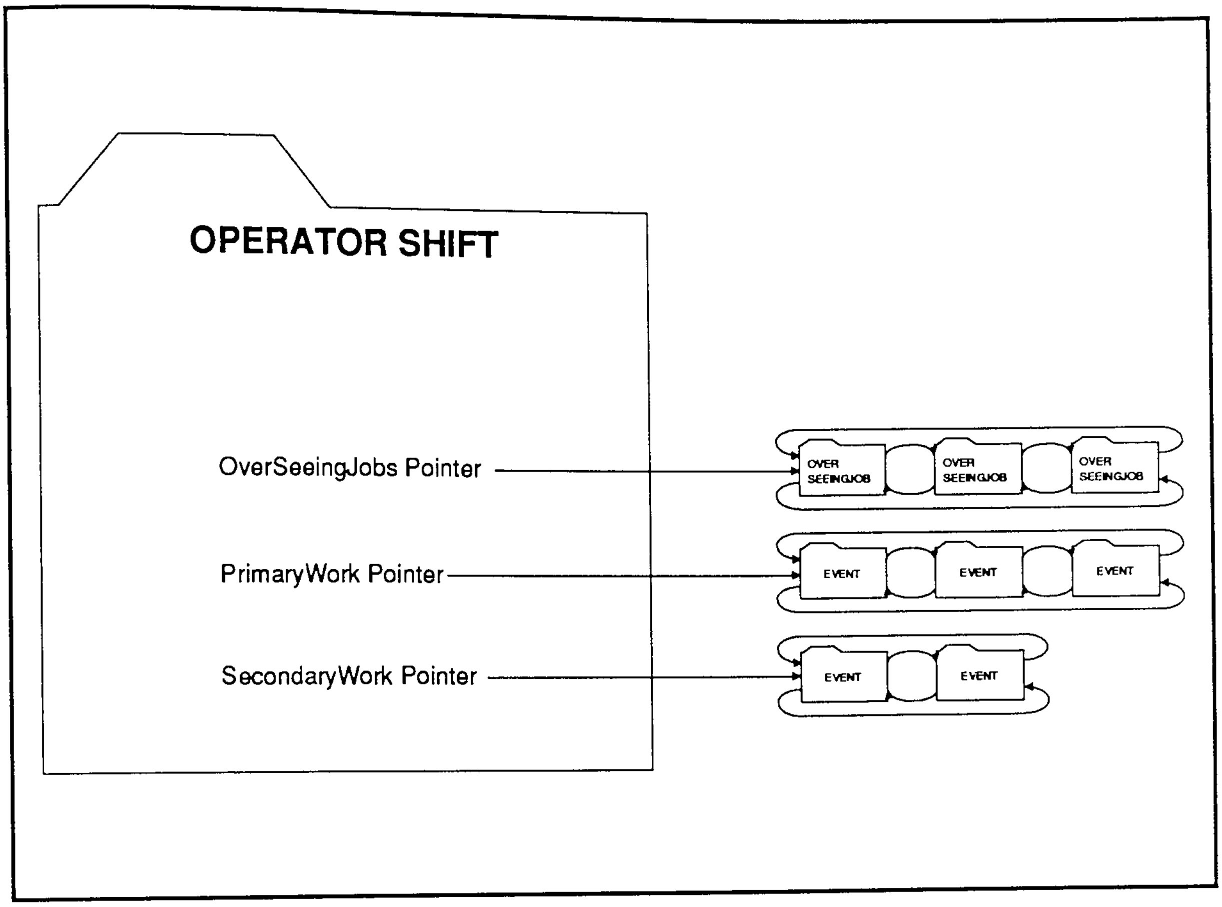


Figure D.7 Operator Shift Record Pointers

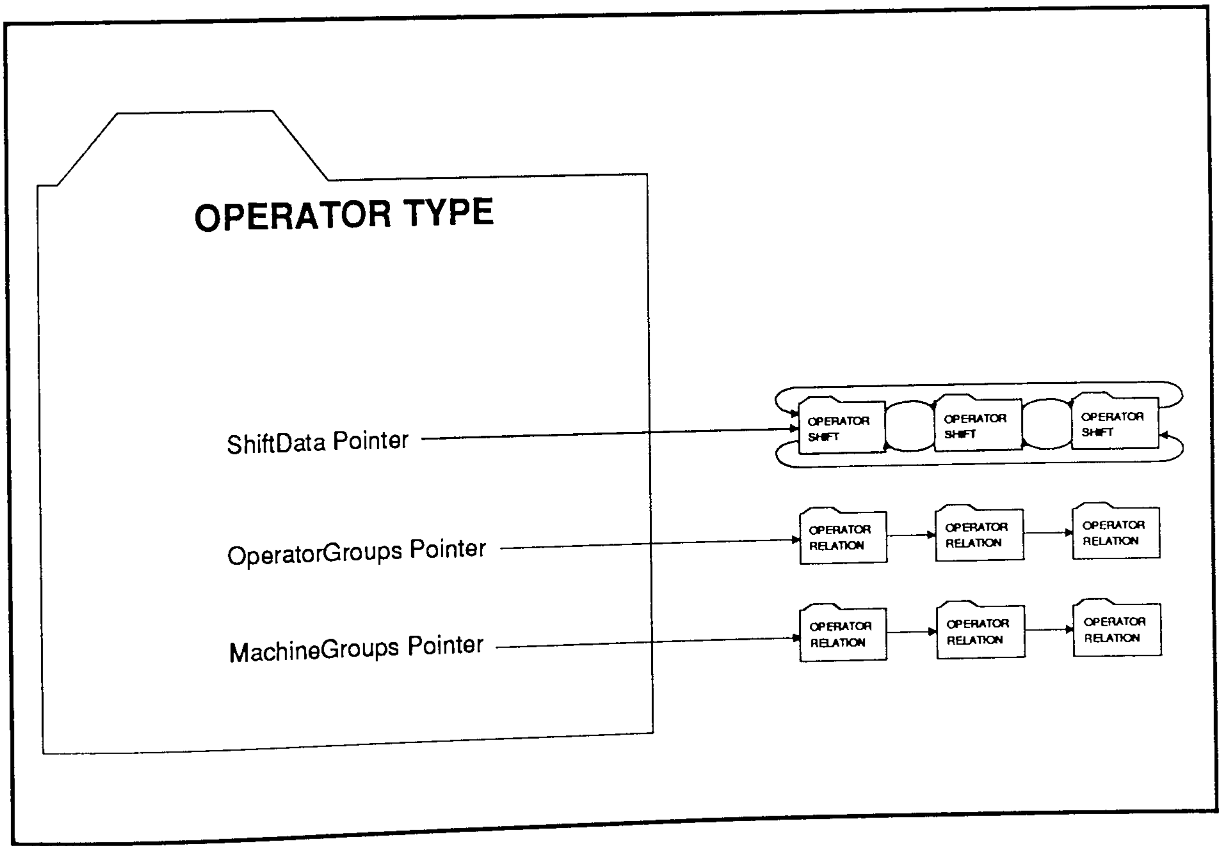


Figure D.8 Operator Type Record Pointers for a particular operator type.

LastOpShift, pointer to the previous OperatorShiftRecord, for a particular operator type.

ShiftReference, numeric variable identifying the number of the ShiftOpRecord for a particular operator type.

StartTime, numeric variable specifying the start time of a particular shift, in minutes from the beginning of the day.

EndTime, numeric variable specifying the end of the fixed portion of a particular shift, in minutes from the beginning of the day.

VariableOverTime, numeric variable specifying a further amount of shift time, in minutes, in addition to the EndTime, that can be used so long as there is work to be done.

FinishTime, numeric variable recording the simulation time a particular shift is finished, that is after the VariableOverTime.

ShiftQty, numeric variable specifying the number of operators assigned to a particular shift.

QtyIdle, numeric variable recording the number of operators currently available.

NoOfSecondaryJobs, numeric variable recording the number of secondary priority jobs currently being undertaken.

OverSeeingIdle, numeric variable recording the number of operators currently idle, that have been allocated primary process operations but have been released during the actual work processing, i.e. between load/unload operations, to undertake any in-cycle or secondary activities.

ShiftOn, boolean variable identifying whether a particular shift is in operation.

OverTimeFlag, boolean variable identifying whether variable overtime is in operation, on a particular shift.

QtyReturned, numeric variable identifying how many operators have completed the shift and are now unavailable.

PrimaryWork, pointer identifying the next event, referring to a primary operation, to occur in relation to a particular operator type and shift.

SecondaryWork, pointer identifying the next event, referring to a secondary operation, to occur in relation to a particular operator type and shift.

OverSeeingJobs, pointer to a linked list data structure containing JobOverSeeingRecords identifying work stations which have been allocated an operator to undertake a primary process operation but have released them during the actual work processing.

OverSeeingJobTotal, numeric variable recording the total number of process operations that are currently being "over seen".

LastOPFinished, numeric variable which records the simulation time that an operator finishes a shift, so that the total VariableOverTime worked by all operators can be calculated.

D.2.20 OperatorTypeRecord (figure D.8)

Number, numeric variable specifying the EntityRecord array number of a particular operator type.

Name, string variable specifying the name of an operator type.

ShiftData, pointer to a linked list data structure containing ShiftOpRecords detailing an operator type's shift pattern.

GroupState, type variable indicating the current state of an operator type.

NextOperatorTypes, numeric variable identifying the next operator type definition, by it's EntityRecord array number.

AllJobs, numeric variable identifying, by it's EntityRecord array number, the first defined operation to involve a particular operator type.

JobPriorities, one dimensional jobs array prioritizing job types for a particular operator type.

TotalOpHrs, numeric variable recording the total available time for an operator type, during a simulation run.

AllOpHrs, numeric variable recording the total available time for an operator type, from zero simulation time.

OperatorEfficiency, numeric variable specifying the efficiency of the operator type.

OperatorGroups, pointer to a linked list data structure with OperatorRelationRecords identifying the particular Operator Groups, an operator type has been assigned too.

MachineGroups, pointer to a linked list data structure with OperatorRelationRecords identifying the particular work stations, an operator type has been assigned too.

Times, one dimensional numeric array recording the total time, in minutes, an operator type incurred in OVERTIME, TRANSPORTING, SETTING-UP, BUSY, and REPAIRING during a simulation run.

TotalTimes, one dimensional numeric array recording the total time, in minutes, an operator type incurred in OVERTIME, TRANSPORTING, SETTING-UP, BUSY, and REPAIRING from zero simulation time.

OperatorsFree, boolean variable indicating whether there are any available operators of a particular type.

D.2.21 OperatorGroupRecord (figure D.9)

GroupNumber, numeric variable specifying the EntityRecord array number of a particular operator group.

Name, string variable specifying the name of an operator group.

GroupOperators, pointer to a linked list data structure of OperatorRelationRecords identifying previously defined operator types which have been assigned to an operator group.

NextGroup, numeric variable identifying the next operator group definition, by way of it's EntityRecord array number.

D.2.22 TransportRecord (figure D.10)

Number, numeric variable specifying the EntityRecord array number of a particular transport resource.

Name, string variable specifying the name of a transport resource.

GroupType, type variable identifying the type of device a particular transport resource is equivalent too.

TransportState, type variable recording the current state

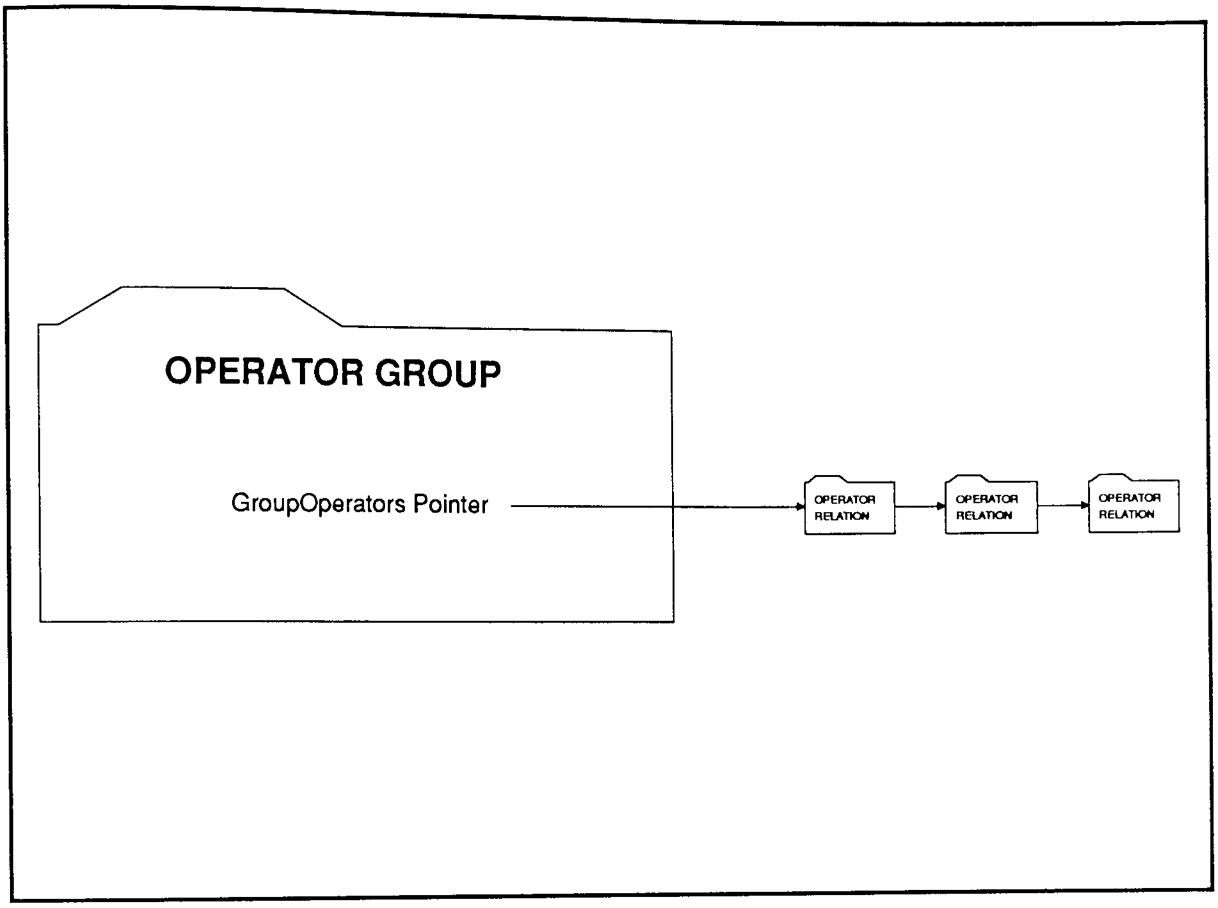


Figure D.9 Operator Group Record Pointer

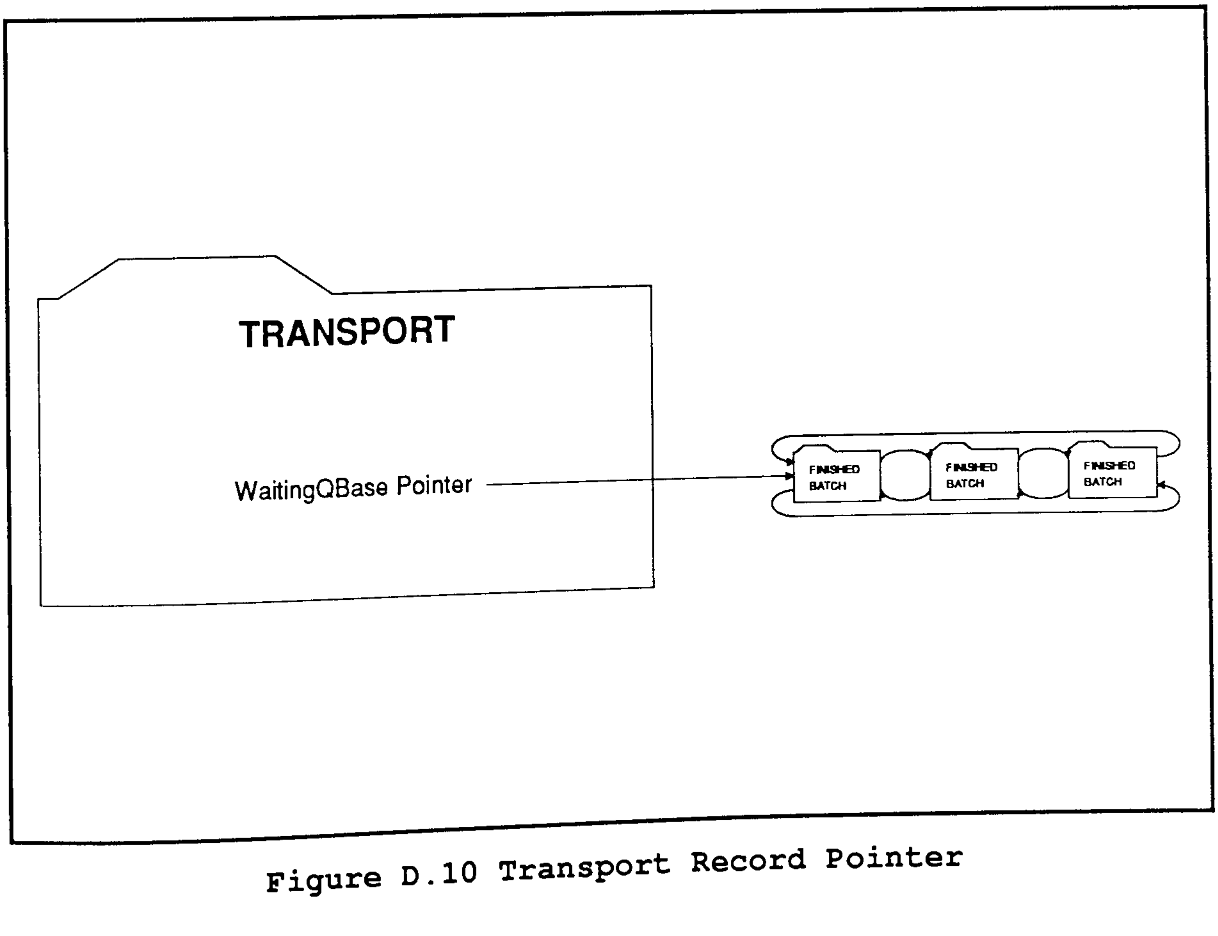


Figure D.10 Transport Record Pointer

of a transport resource.

TotalQty, numeric variable identifying the total number of available devices.

QtyIdle, numeric variable recording the current number of available devices.

RespondTime, TimeRecord specifying the time for a transport device to respond to a transfer request.

Speed, numeric variable specifying the speed of a particular transport device.

ConveyorCapacityTotal, numeric variable specifying the total transfer capacity of a CONVEYOR transport device.

ConveyorCapacity, numeric variable recording the current available transfer capacity of a CONVEYOR transport device.

NextTransport, numeric variable identifying the next transport resource definition, by it's EntityRecord array number.

WaitingQBasePointer, pointer to a linked list data structure containing FinishedRecords identifying batches waiting in work centre output queues for a particular transport resource to move them to their next operation.

WaitingQSizes, one dimensional numeric array recording the current waiting queue size in terms of LOADS and TRANSITTIME.

WaitingQResults, two dimensional numeric array recording the AVERAGE and MAXIMUM WAITING queue size, in terms of LOADS and TRANSITTIME, during a simulation run.

BatchWaitingTime, one dimensional numeric array recording the AVERAGE and MAXIMUM time batches waited for a particular transport resource, during a simulation run.

ProductionOutput, one dimensional numeric array recording the total number of LOADS transferred and the transit time incurred by a transport resource, during a simulation run.

D.2.23 ToolingRecord

Number, numeric variable specifying the EntityRecord array number of a particular tool resource.

Name, string variable specifying the name of a tool resource.

NextTool,	numeric variable identifying the next tooling resource definition, by it's EntityRecord array number.
TotalQty,	numeric variable identifying the total number of available resource tools.
IdleQty,	numeric variable recording the current number of available resource tools.
TotalTime,	numeric variable recording the total tool resource utilization, during a simulation run.
PeriodTime,	numeric variable recording the total tool resource utilization from zero simulation time.

D.2.24 KittingList

EntityNumber,	numeric variable identifying a particular operation by it's EntityRecord array number.
Part,	numeric variable identifying, by it's EntityRecord array number, a sub-component required to perform an assembly or store operation.
PartQty,	numeric variable specifying the quantity of a sub-component necessary to produce a single assembly.
NextPart,	pointer to the next KittingListRecord identifying a further sub-component for the same operation.

D.2.25 WCTypeRecord

WCType,	type variable identifying the type of work centre at which an operation will take place. Furthermore this is a tag field upon which the variant fields of the record are dependent.

The variant field for WCType = STORE or ASSEMBLY is:

KittingList,	pointer to a linked list data structure containing KittingListRecords identifying all sub-components required for a particular operation.
MinSetUp,	numeric variable identifying whether assembly is by batch (-1) or transfer quantity.

The variant field for WCType = INDEX is:

Index, numeric variable specifying the number of index stations required for a particular operation.

D.2.26 BasicOperationRecord

Number, numeric variable specifying the EntityRecord array number of a particular operation.

NextOperation, numeric variable identifying the next operation for a particular material component, by it's EntityRecord array number.

OperationNumber, numeric variable recording the sequential number of the operation for a particular material component.

MaterialNumber, numeric variable identifying the material component, for which this particular operation relates too, by it's EntityRecord array number.

WCPointer, numeric variable identifying the particular work centre, at which the component operation is performed, by it's EntityRecord array number.

NextWCJob, numeric variable identifying, by way of it's EntityRecord array number, the next operation to be defined as being undertaken at the same work centre.

WCType, WCTypeRecord.

SetUpTime, TimeRecord specifying the time, in minutes, to set-up and prepare a work station in order to carry out the component operation.

StandardTime, TimeRecord specifying the standard time, in minutes, to simultaneously process a number of components.

LoadQuantity, numeric variable specifying the number of components that are simultaneously processed, with -1 denoting a work batch regardless of size.

Scrap, numeric variable specifying the percentage of a work batch scraped as a result of a particular operation.

TransportType, numeric variable identifying, by way of it's EntityRecord array number, the transport resource required to transfer a work batch from this operation to the next.

TransportTime, TimeRecord specifying the time or distance to move a work batch from the current operation to the next.

TransportUnits, type variable identifying whether the TransportTime variable is time or distance related.

GroupPerformance, numeric variable specifying the percentage process efficiency for a particular operation and is calculated from the appropriate ProcessFactor available.

D.2.27 **DepartmentRouting** (figure D.11)

Routing, BasicOperationRecord.

ProcessFactor, numeric variable specifying the percentage group performance for a particular operation. If zero then the work station operating efficiency is used for GroupPerformance, defined in the relevant work centre specification (MachineEfficiency).

D.2.28 **CentreRouting** (figure D.12)

Routing, BasicOperationRecord.

Tooling, one dimensional ToolingUseRecord array identifying tools required to undertake the process operation.

MinOpQty, numeric variable specifying the minimum number of batch components for which the particular operation should be performed. -1 denotes that, regardless of the actual size, the operation can only be performed for a complete work batch.

TransferQty, numeric variable specifying the number of components that have to be processed before being transferred to the next operation. The number must be a multiple of LoadQuantity or -1, denoting that, regardless of size, components are only transferred when the complete work batch has been processed.

OperatorEfficiency, numeric variable specifying a percentage operator efficiency for a particular operation.

EndofShift, boolean variable specifying whether it is necessary to establish, before starting the operation, if it can be completed within the current shift.

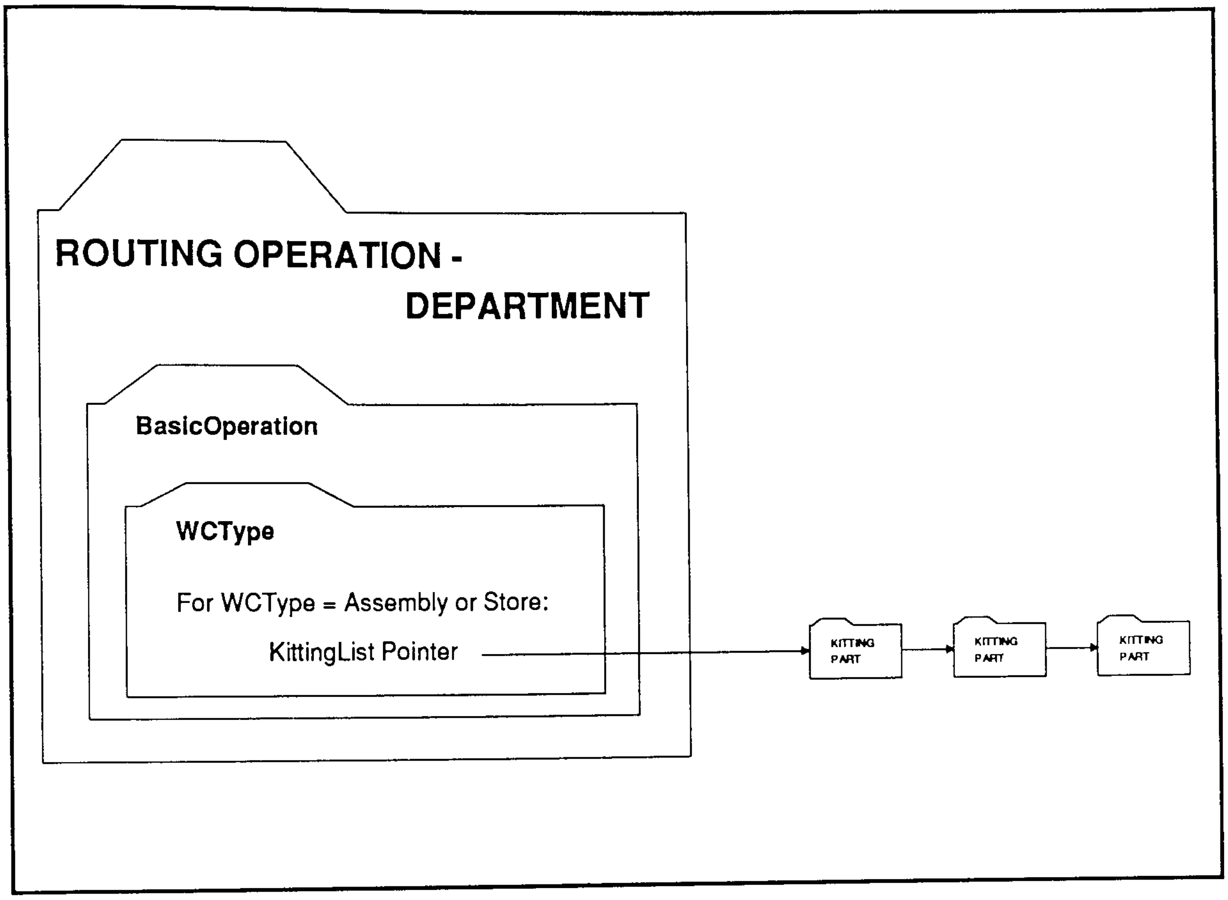


Figure D.11 DEPARTMENT Route Operation Record Pointer

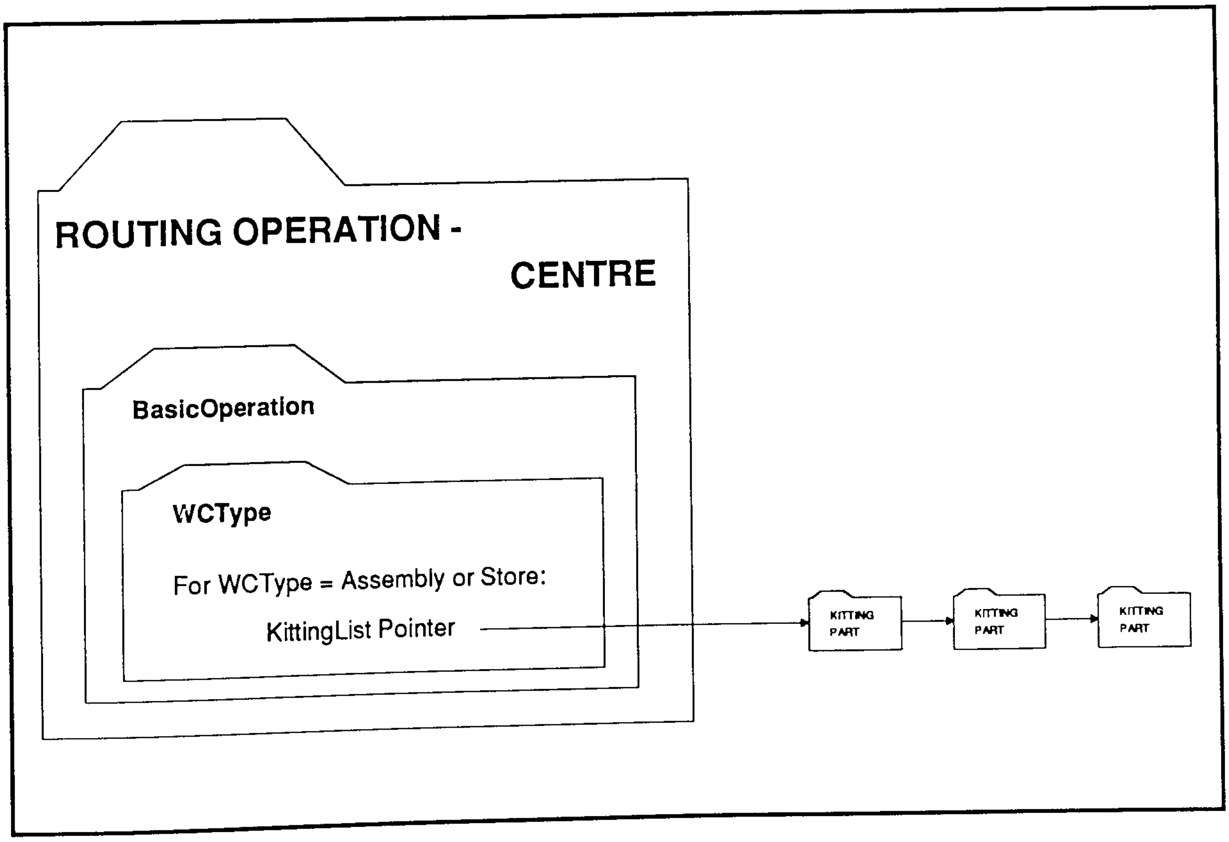


Figure D.12 CENTRE Route Operation Record Pointer

ProcessFactor, numeric variable specifying the percentage group performance for a particular operation. If zero then the relevant work station or labour performance is used.

Labour Performance = OperatorEfficiency * (100 - Direct Labour Losses)

W/S Performance = WorkStation Efficiency * (100 - Work Station Breakdown Losses)

where

OperatorEfficiency is defined in the routing specification; and direct labour losses, work station efficiency and breakdown losses are defined in the work centre specification, within WCPerformance.

D.2.29 StationRouting (figure D.13)

Routing, BasicOperationRecord.

Tooling, one dimensional ToolingUseRecord array identifying tools required to undertake the process operation.

EndofShift, boolean variable specifying whether it is necessary to establish, before starting the operation, if it can be completed within the current shift.

SetUpOnPart, boolean variable specifying the basis for setting a work station. A set is either incurred due to a different component or because of dissimilar component attributes.

AttributeNumber, numeric variable identifying which attribute should be considered, 1 or 2.

SetUpOperator, numeric variable identifying, by way of it's EntityRecord array number, the operator group required to perform the set-up operation. -1 denotes the use of operator types assigned specifically to the appropriate work station.

ProcessOperator, numeric variable identifying, by way of it's EntityRecord array number, the operator group required to perform the process operation. -1 denotes the use of operator types assigned specifically to the appropriate work station.

TransportOperator, numeric variable identifying, by way of it's EntityRecord array number, the operator group required to perform the transport operation.

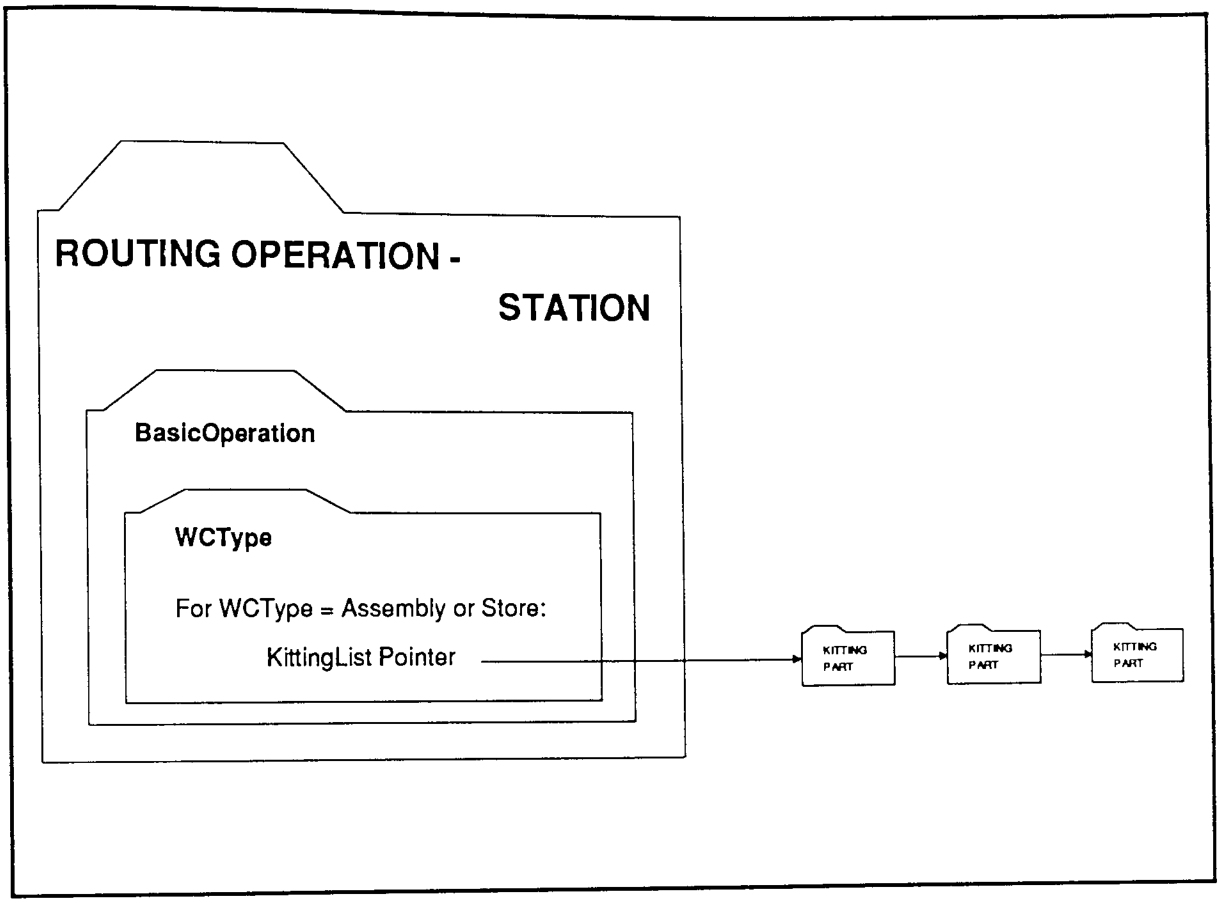


Figure D.13 STATION Route Operation Record Pointer

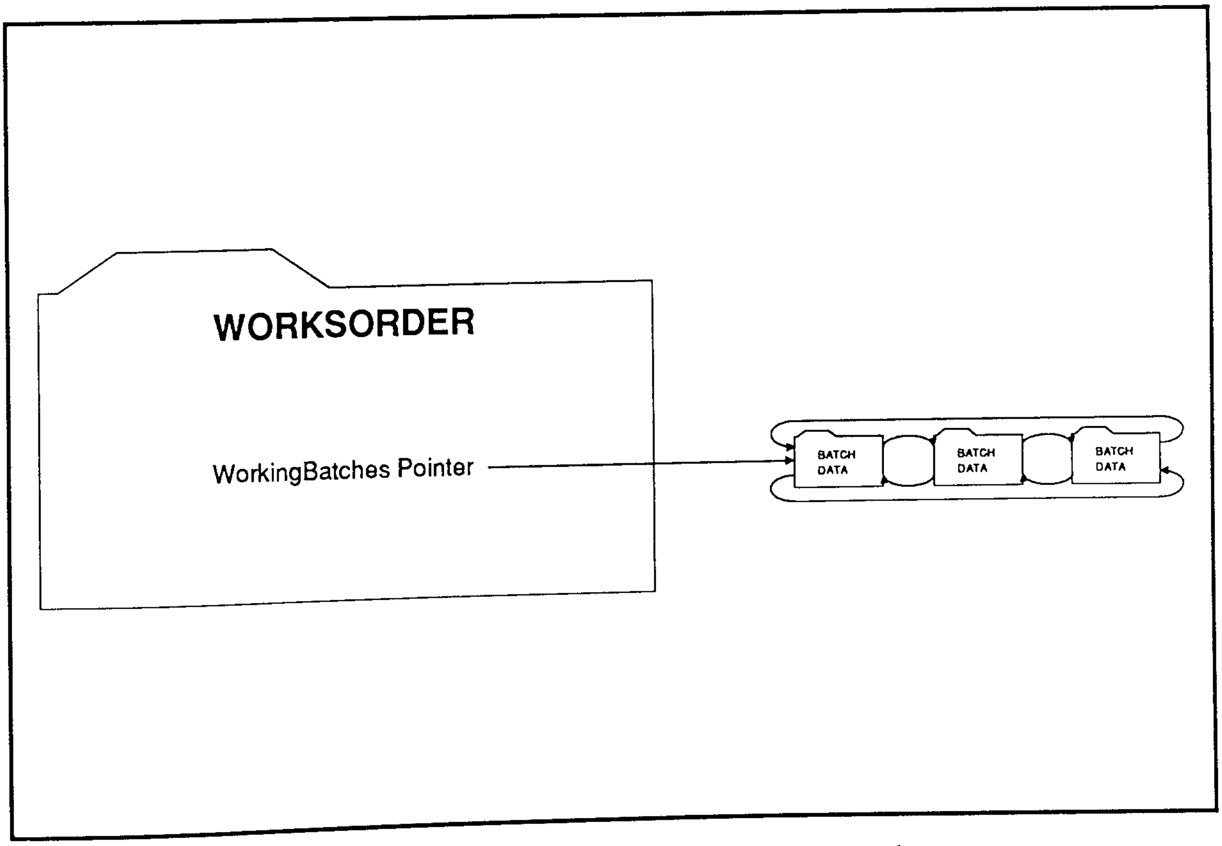


Figure D.14 Works Order Record Pointer

SetUpPriority, type variable indicating whether the set-up operation is a primary or secondary activity.

ProcessPriority, type variable indicating whether the process operation is a primary or secondary activity.

MinOpQty, numeric variable specifying the minimum number of batch components for which the particular operation should be performed. -1 denotes that, regardless of the actual size, the operation can only be performed for a complete work batch.

TransferQty, numeric variable specifying the number of components that have to be processed before being transferred to the next operation. The number must be a multiple of LoadQuantity or -1, denoting that, regardless of size, components are only transferred when the complete work batch has been processed.

ProcessPercent, numeric variable specifying the percentage of a work batch that is to be processed during a particular operation.

OperatorSetFree, boolean variable specifying whether the process operator is free, between loading and unloading a work station to undertake any necessary secondary activities.

LoadTime, TimeRecord specifying the time to load a number of components onto a work station to be simultaneously processed.

UnloadTime, TimeRecord specifying the time to off-load a number of processed components from a work station.

ProcessFactor, numeric variable specifying the percentage group performance for a particular operation. If zero then the relevant work station or operator efficiency is used, indicated by either -2 or -1 respectively. These are defined by WSEfficiency and OperatorEfficiency in a WorkStationRecord and OperatorTypeRecord respectively.

D.2.30 WorksOrderRecord (figure D.14)

Number, numeric variable specifying the BatchRecord array number of a particular works order, which is the internal batch number.

Component, numeric variable identifying, by way of it's EntityRecord array number, the material component for which the works order has been issued

OriginalQty,	numeric variable specifying the number of components that were originally ordered.
ScrappedQty,	numeric variable which records the number of components that are scrapped whilst producing the works order.
QtyDelivered,	numeric variable which records the number of completed components.
DueDate,	numeric variable specifying the time the completed order is required, in minutes from zero simulation time.
LaunchDate,	numeric variable which specifying the time the works order was released, in minutes from zero simulation time.
Queuing,	numeric variable which records the total amount of queuing time (in minutes) incurred by an order, due to waiting for both work stations and transport resources.
Processing,	numeric variable which records the total amount of setting and processing time (in minutes) incurred by an order.
Setting,	numeric variable which records the total amount of setting time (in minutes) incurred by an order.
Transit,	numeric variable which records the total amount of transfer time (in minutes) incurred by an order.
Breakdown,	numeric variable which records the total amount of work station breakdown time (in minutes) incurred by an order.
OperatorWaiting,	numeric variable which records the total amount of time (in minutes) incurred by an order waiting for a process operator, once a work station has been prepared for the operation.
NextBatch,	numeric variable identifying, by it's BatchRecord array number, the next works order for the same material component.
LastBatch,	numeric variable identifying, by it's BatchRecord array number, the previous works order for the same material component.
WorkingBatches,	pointer to a linked list data structure containing BatchDataRecords identifying all work batches relating to a particular

works order.

OrderNumber, string variable specifying a user-defined works order number, to improve work batch traceability.

D.2.31 BatchDataRecord (figure D.15)

Batch, numeric variable identifying the works order to which the record is related, by way of it's BatchRecord array number.

Qty, numeric variable identifying the number of components that the BatchDataRecord represents.

Operation, numeric variable identifying the operation the batch is currently on, by way of it's EntityRecord array number.

OperationNumber, numeric variable identifying the operation it the batch is currently on by the sequential number of the operation for the material component specified in the works order.

SettingUp, numeric variable recording the actual time incurred in preparing the particular work station for the current operation.

Std, numeric variable recording the total time actually incurred in processing the whole batch.

WSNo, numeric variable identifying work centre/station upon which the batch was processed, by way of it's EntityRecord array number.

Operator, numeric variable recording the operator type being used to undertake the current activity, be it setting, processing or transporting, by way of it's EntityRecord array number.

UsedCapacity, numeric variable recording the total amount of station capacity being occupied by a batch, when being processed on a PROCESS work station.

TimeStopped, numeric variable recording the simulation time an activity, relating to the batch, was suspended.

WorkLeft, numeric variable recording the amount of work remaining when an activity, relating to a batch, was suspended.

NextBatch, pointer to the next BatchDataRecord which is also related to the same works order.

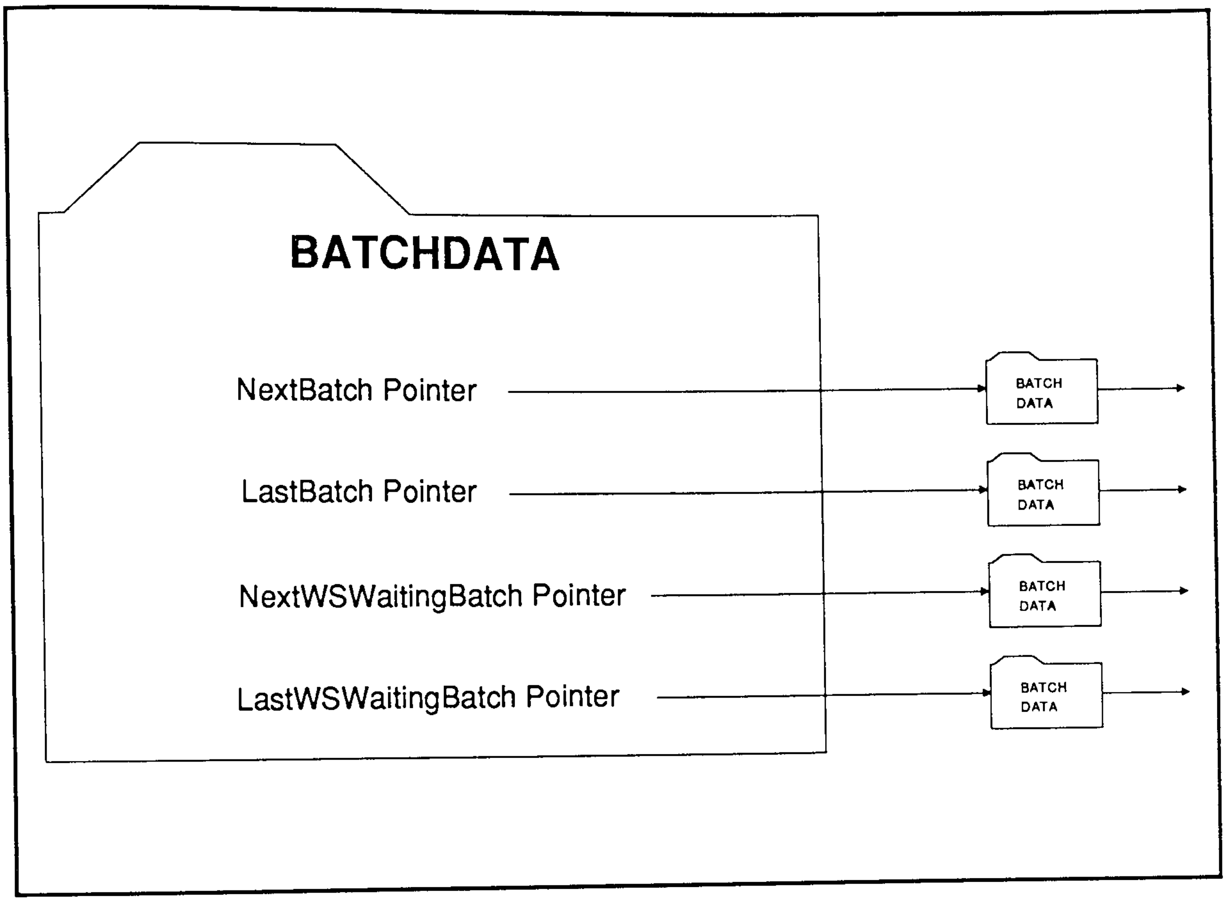


Figure D.15 Batch Data Record Pointers

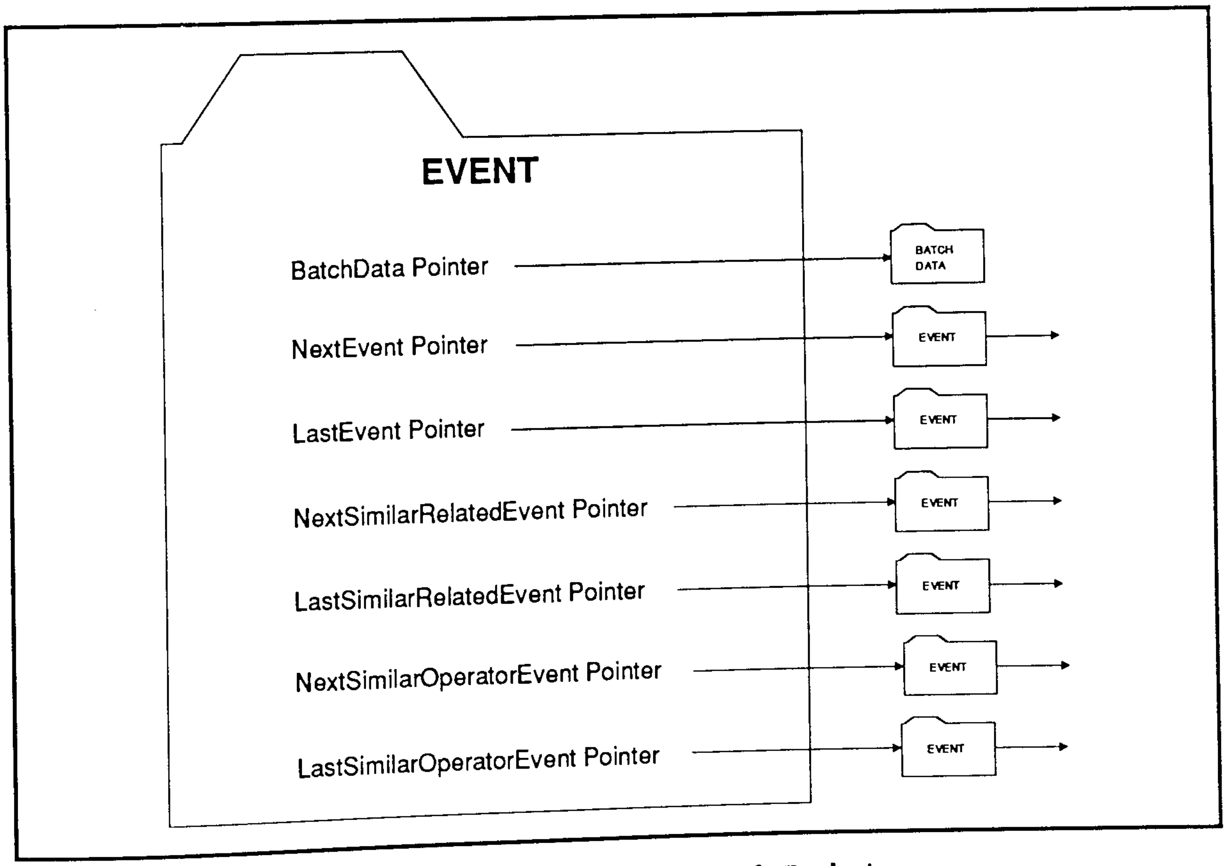


Figure D.16 Event Record Pointers

LastBatch, pointer to the previous BatchDataRecord which is also related to the same works order.

NextWSWaitingBatch, pointer to the next BatchDataRecord waiting for a process operator at the same work station.

LastWSWaitingBatch, pointer to the previous BatchDataRecord waiting for a process operator at the same work station.

D.2.32 EventRecord (figure D.16)

Time, numeric variable specifying the simulation time at which an event will occur.

Entity, numeric variable identifying the model entity to which an event relates, by way of it's EntityRecord array number.

Event, type variable identifying the type of event the record represents.

BatchData, pointer to a BatchDataRecord identifying the batch to which an event relates.

StartTime, numeric variable recording the time a work batch operation original started.

SpareByte, spare numeric variable used to record different types of data depending upon the event type.

SpareReal, spare numeric variable used to record different types of data depending upon the event type.

NextEvent, pointer to the next occurring EventRecord.

LastEvent, pointer to the EventRecord occurring immediately prior to the current one.

NextSimilarRelatedEvent, pointer to the next EventRecord relating to the same Entity.

LastSimilarRelatedEvent, pointer to the previous EventRecord relating to the same Entity.

NextSimilarOperatorEvent, pointer to the next EventRecord referring to the same operator type.

LastSimilarOperatorEvent, pointer to the previous EventRecord referring to the same operator type.

D.2.33 WaitingRecord (figure D.17)

WaitingBatch, pointer to the BatchDataRecord detailing a work batch queuing at a particular work

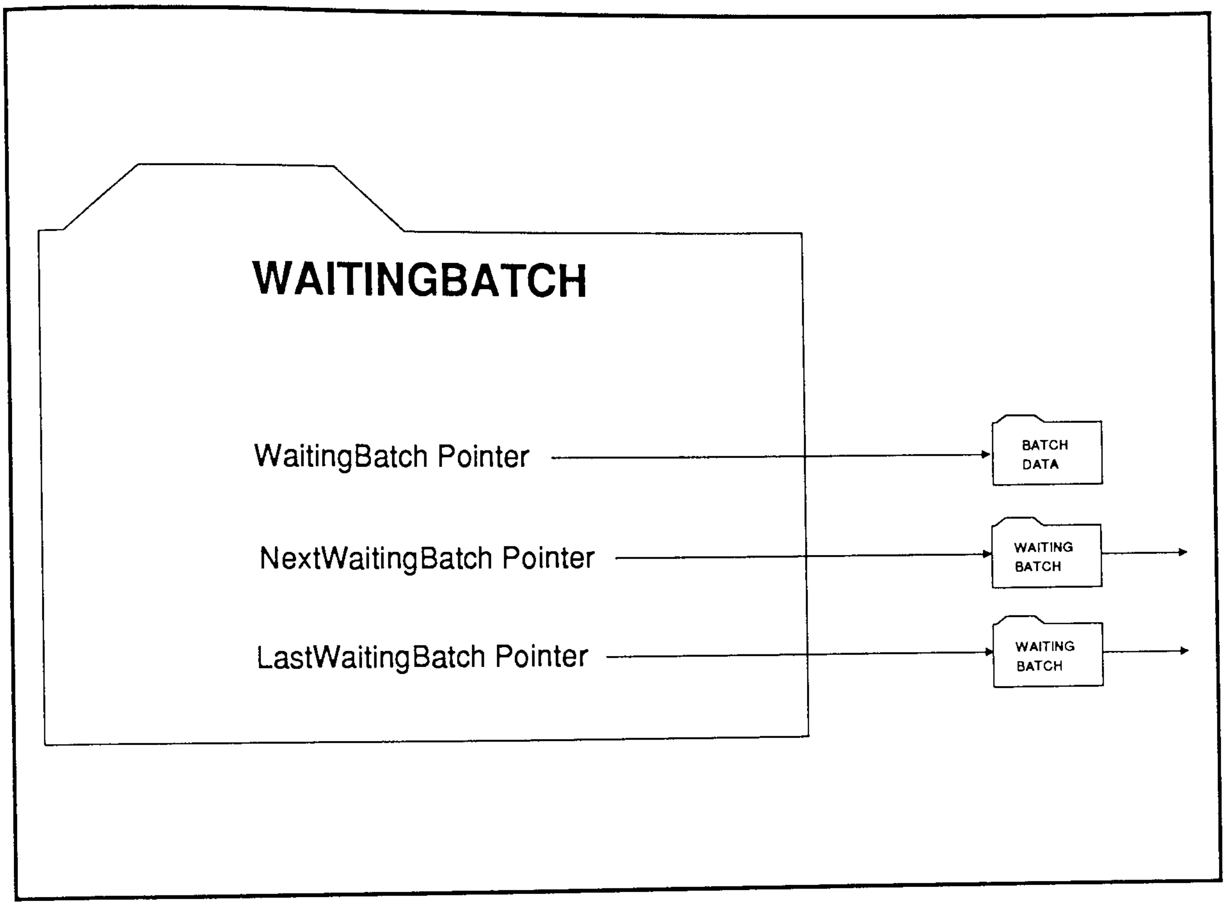


Figure D.17 Waiting Batch Record Pointers

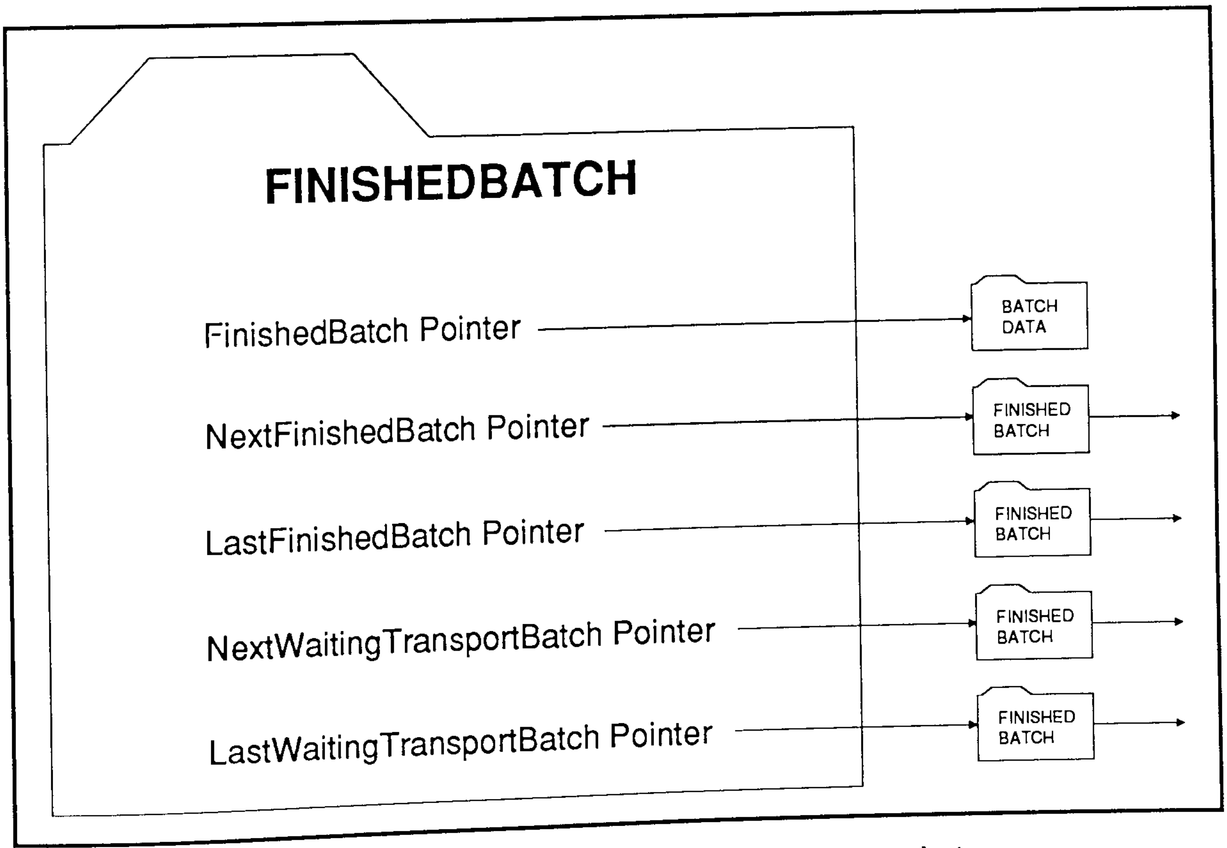


Figure D.18 Finished Batch Record Pointers centre.

BatchPriority, numeric variable specifying a work batch's queuing priority.

WorkLeft, numeric variable recording, for work batches suspended during an activity, the amount of work remaining.

QueuingTime, numeric variable recording the time a work batch started queuing.

NextWaitingBatch, pointer to a WaitingRecord representing the next work batch queuing at a particular work centre.

LastWaitingBatch, pointer to a WaitingRecord representing the previous work batch queuing at a particular work centre.

D.2.34 **FinishedRecord** (figure D.18)

FinishedBatch, pointer to the BatchDataRecord detailing a work batch queuing at a particular work centre waiting for a transport device.

TransportPriority, numeric variable specifying a work batch's queuing priority for a transport device.

NextFinishedBatch, pointer to a FinishedRecord representing the next work batch queuing at a particular work centre waiting for a transport device.

LastFinishedBatch, pointer to a FinishedRecord representing the previous work batch queuing at a work centre waiting for a transport device.

NextWaitingTransportBatch, pointer to a FinishedRecord representing the next work batch waiting for the same type of transport device, queuing at any work centre.

LastWaitingTransportBatch, pointer to a FinishedRecord representing the previous work batch waiting for the same type of transport device, queuing at any work centre.

D.3 Global Variables

Clock, numeric variable recording the current simulation time, in minutes.

Period, numeric variable recording the current simulation period.

Day, numeric variable recording the current simulation day.

DaysPeriod, numeric variable specifying the number of days per period.

RecordResults, numeric variable specifying, in minutes, the simulation time, at which to start accumulating statistical results.

DailyLog, type variable specifying if a log event is to be produced and on what it is to be outputted

RecordQueues[1..4], one dimensional numeric array identifying, by their EntityRecord array number, up to four particular work centre whose input and output queues are to be monitored hourly during a model execution.

RecordMeasures[1..4], one dimensional type array specifying, for each work centre, the units in which the queues are to be monitored.

Supplies[1..4,1], column one of a two dimensional numeric array, specifying the start time, in minutes for up to four periods during which purchase items will be received into a model.

Supplies[1..4,2], column two of a two dimensional numeric array, specifying the finish time, in minutes, for up to four periods during which purchase items will be received into a model.

ModelDescription, string variable recording a brief description of a particular model.

Version, numeric variable identifying a particular model by it's version number.

BatchPointer, numeric variable identifying the next available record space in the BatchRecord array. "0" signifies no room, the array is full.

EntityPointer, numeric variable identifying the next available record space in the EntityRecord array. "0" signifies no room, the array is full.

FirstEntity[WorkCentre..Tool], one dimensional numeric array identifying the first defined work centre, work station, material, transport, operator type, operator group and tooling record, by way of their EntityRecord array number.

BreakDownPointer, numeric variable identifying the next available record space in the MachineBreakdown array. "0" signifies no room, the array is full.

FirstDemandPart, numeric variable identifying, by way of it's EntityRecord array number, the first material component to be detailed for consideration in a mathematical analysis, by the product demand listing.

FirstCentre, numeric variable identifying, by way of it's EntityRecord array number, the first work centre to be considered in a mathematical analysis, determined by the first operation for the FirstDemandPart.

TransportServers, numeric variable identifying the number of servers or devices available within the single transport group permitted in a mathematical analysis.

TransportTime, numeric variable specifying the average time to transfer a work batch from one operation to another.

TransportSpeed, numeric variable specifying the travelling speed of all devices or servers within the single transport group.

NumberOfParts, numeric variable specifying the exact number of parts continually circulating around a mathematical model.

ProductionBatchSizes, numeric variable specifying the average size of the batches circulating in a mathematical model.

MathsProductionOutPut, numeric variable recording the average hourly total number of batches completed by a manufacturing system, calculated through a mathematically model.

FlowTime, numeric variable recording the average lead-time for any work batch to flow through a manufacturing system, calculated through a mathematically model.

TransportUtilization, numeric variable recording the average total utilization for the transport group depicted within a mathematical model.

TransportIdleness, numeric variable recording the average idleness of each device available in the transport group, depicted within a mathematical model.

TransportQueue, numeric variable recording the average number of batches, both queuing for a transport device and in transit, calculated through a mathematical model.

ModelEdit, boolean variable specifying whether a manual entity record input, is the creation of a new record or simply the editing of an existing one.

StartDay,	numeric variable recording the day part of a real date entered specifically as a datum, representing period 1, day 1 of simulation time.
StartMonth,	numeric variable recording the month part of a real date entered specifically as a datum, representing period 1, day 1 of simulation time.
StartYear,	numeric variable recording the year part of a real date entered specifically as a datum, representing period 1, day 1 of simulation time.
Weekend,	numeric variable specifying the number of days in a weekend.
DelayOrders,	boolean variable indicating whether work orders scheduled for release during a weekend, should be pulled forward and issued on the last day of the previous week, or delayed and issued on the first day of the subsequent one.
LastMRPOrders,	numeric variable recording the total number of work orders issued during the last period.
LastMRPOrderQty,	numeric variable recording the total number of parts represented by the work orders issued during the last period.
LastFinishedNo,	numeric variable recording the total number of work batches that completed processing during the last period.
LastFinishedQty,	numeric variable recording the total number of parts represented by the work batches that completed processing during the last period.

D.4 File Structure Specification

File Extension	Record Structure
.OSJ	File of JobOverSeeing
.CWK	File of WaitingCentres
.SIM	Text File: Clock Period Day DaysPeriod RecordResults RunPeriod DailyLog RecordQueues[1]

```
                                RecordQueues[2]
                                RecordQueues[3]
                                RecordQueues[4]
                                RecordMeasures[1]
                                RecordMeasures[2]
                                RecordMeasures[3]
                                RecordMeasures[4]
                                Supplies[1,1]
                                Supplies[1,2]
                                Supplies[2,1]
                                Supplies[2,2]
                                Supplies[3,1]
                                Supplies[3,2]
                                Supplies[4,1]
                                Supplies[4,2]

.MIS              Text File:
                                ModelDescription
                                Version
                                BatchPointer
                                EntityPointer
                                FirstEntity[WorkCentre]
                                FirstEntity[Material]
                                FirstEntity[Operators]
                                FirstEntity[Transport]
                                BreakDownPointer
                                FirstEntity[Tool]
                                FirstDemandPart
                                FirstEntity[WorkStation]
                                MathsProductionOutPut
                                FlowTime
                                NumberOfParts
                                TransportSpeed
                                TransportServers
                                TransportUtilization
                                TransportIdleness
                                TransportQueue
                                FirstCentre
                                TransportTime
                                ProductionBatchSizes
                                FirstEntity[OpGroups]
                                ModelEdit
                                StartDay
                                StartMonth
                                StartYear
                                Weekend
                                DelayOrders
                                LastMRPOrders
                                LastMRPOrderQty
                                LastFinishedNo
                                LastFinishedQty

.WSB              File of WorkStationBreakDownRecord;

.WIP              File of WorksOrderRecord;

.WC2              File of WorkCentre2Record;

.WC3              File of WorkCentre3Record;
```

.WC4	File of WorkCentre4Record;
.WCS	File of WorkCentreShift;
.WS	File of WorkStationRecord;
.MAT	File of MaterialRecord;
.TOL	File of ToolingRecord;
.OP	File of OperatorRecord;
.OS	File of ShiftOpRecord;
.GOP	File of OperatorGroupRecord;
.TRA	File of TransportRecord;
.RR2	File of RoutingRecord2;
.RR3	File of RoutingRecord3;
.RR4	File of RoutingRecord4;
.DR	File of DemandRecord;
.KAN	File of KanbanRecord;
.CS	File of CentreStationRecord;
.OPL	File of OperatorType;
.KIT	File of KittingList;
.EVE	File of EventRecord;
.BD	File of BatchDataRecord;
.FR	File of FinishedRecord;
.WR	File of WaitingRecord;
.RSF	File of RandomArrayRecord;

D.5 Record and Array Relationships

Figures D.19 to D.31 illustrate the record and array relationships.

D.6 Program Structure Specification

Figures D.32 to D.80 illustrate the programming structure, with the key defined on page 189.

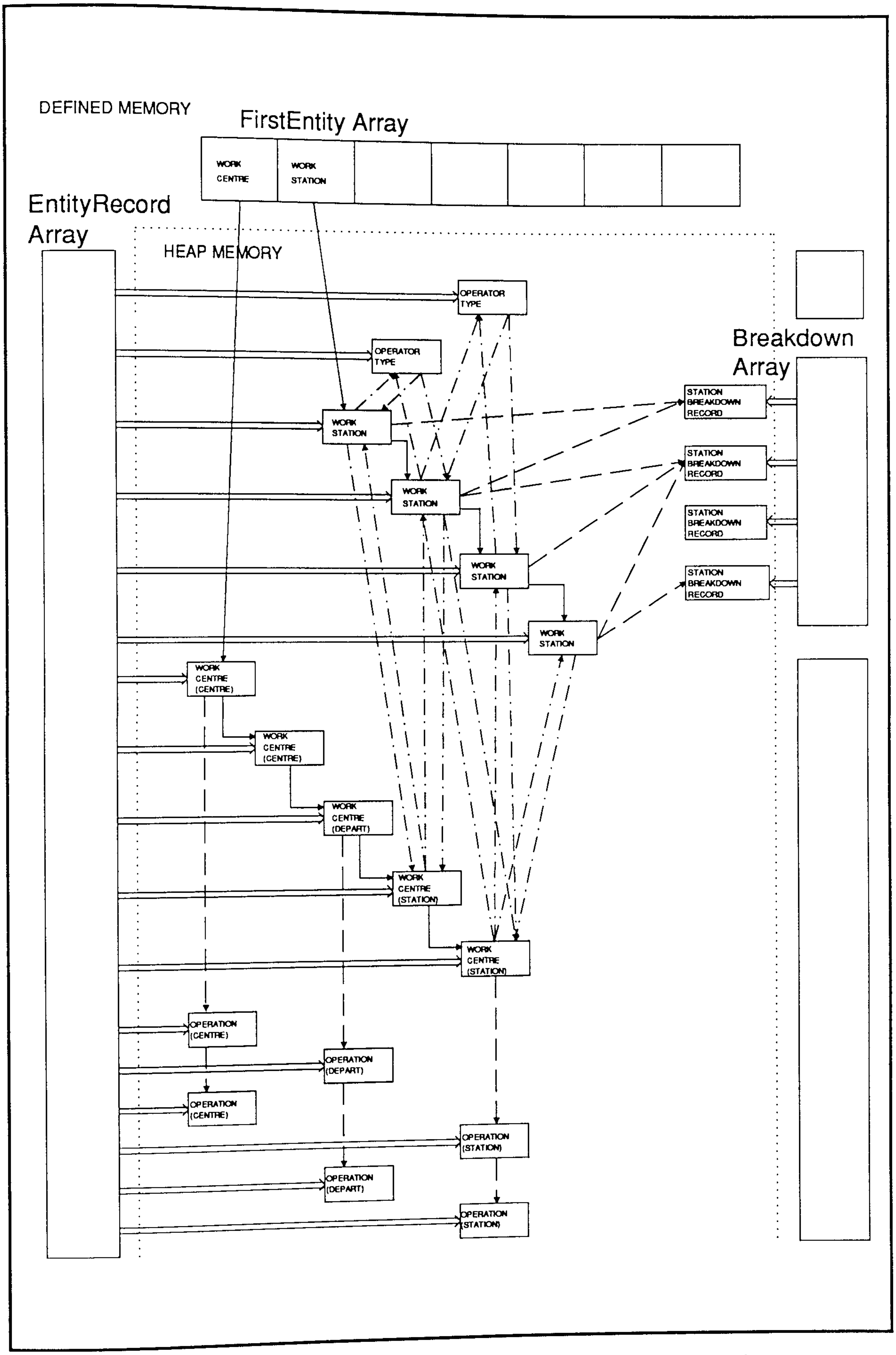


Figure D.19 Work Centre and Station Record Links

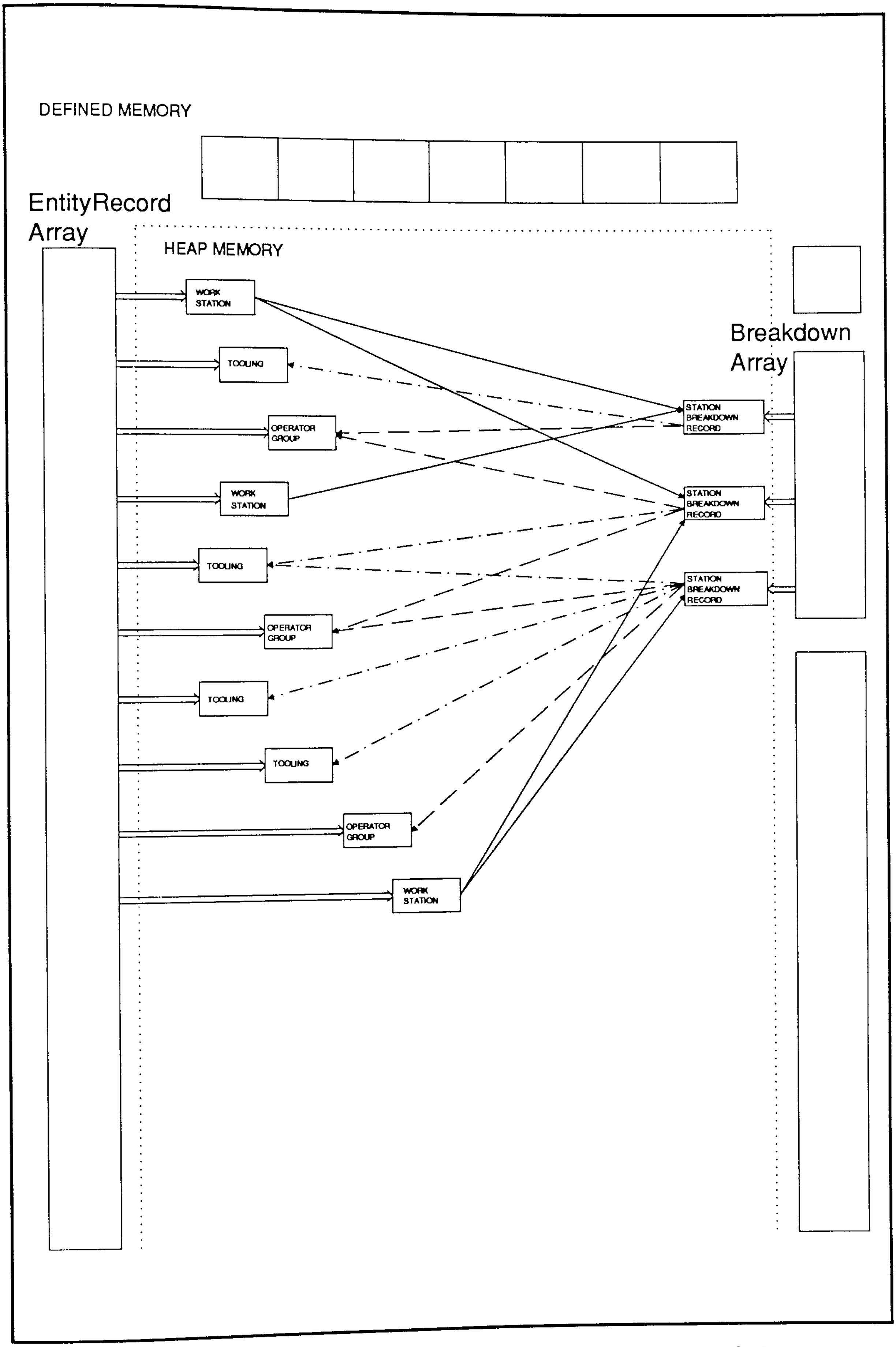


Figure D.20 Work Station Breakdown Record Links

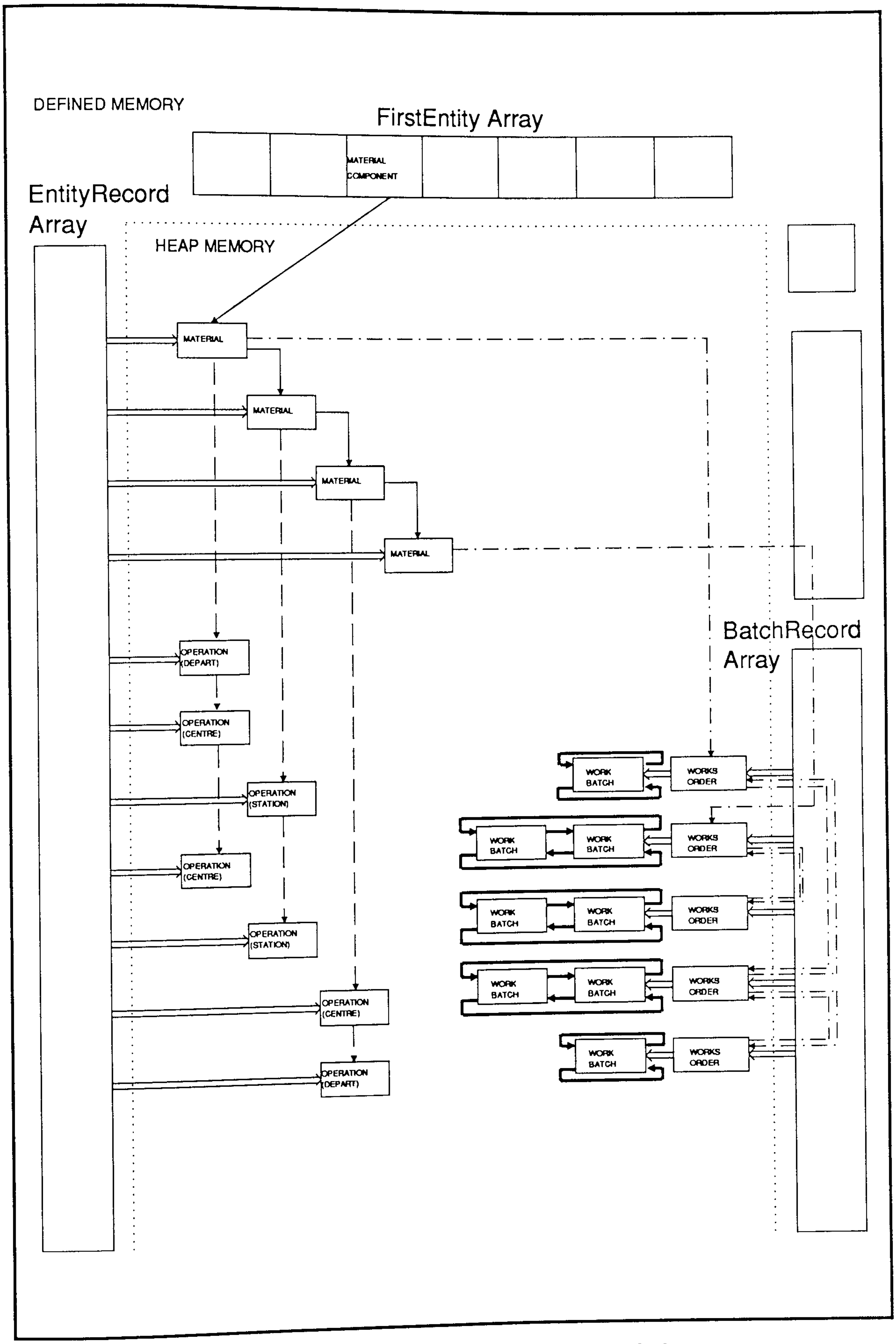


Figure D.21 Material Record Links

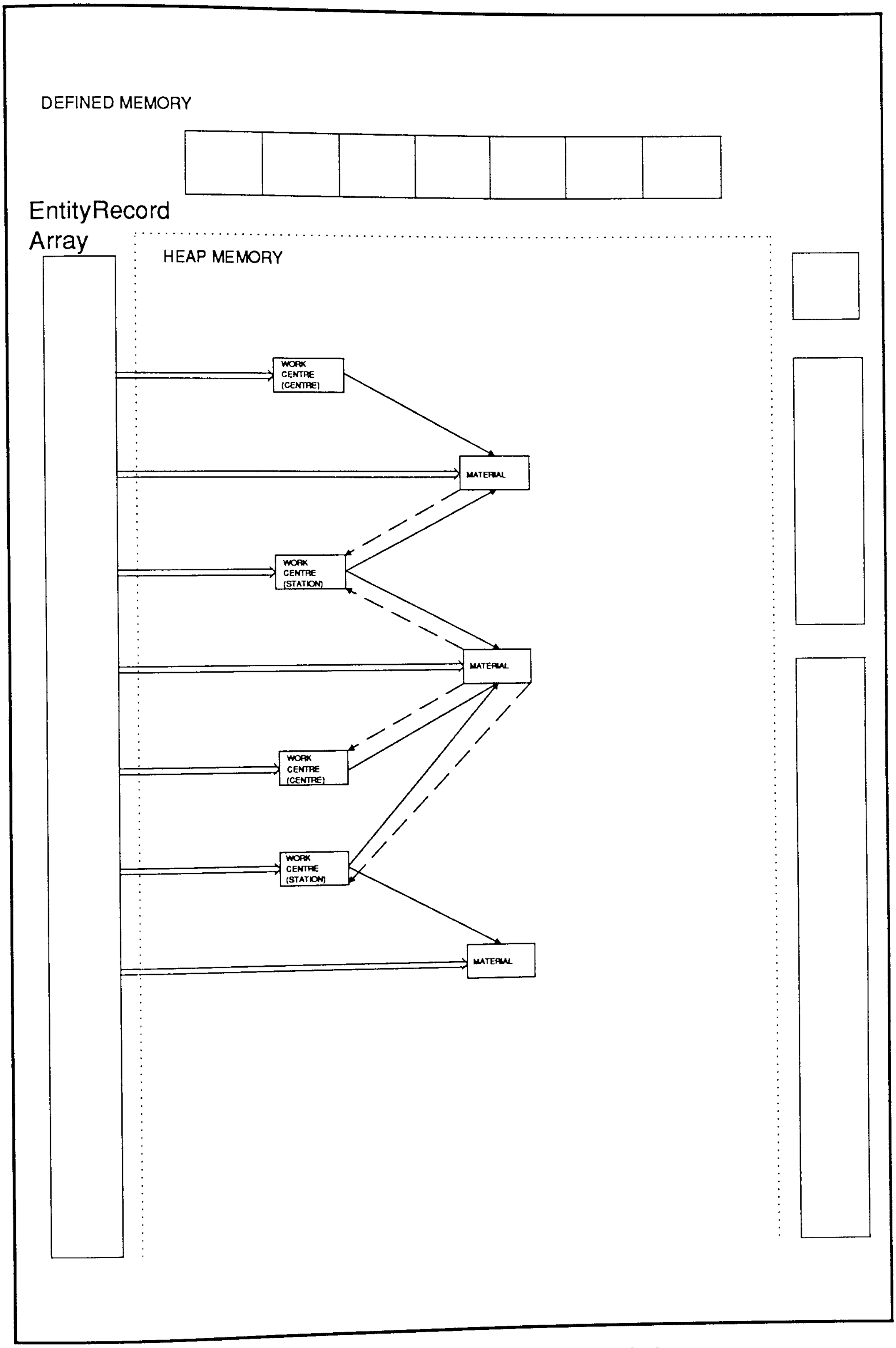


Figure D.22 Kanban Control Links

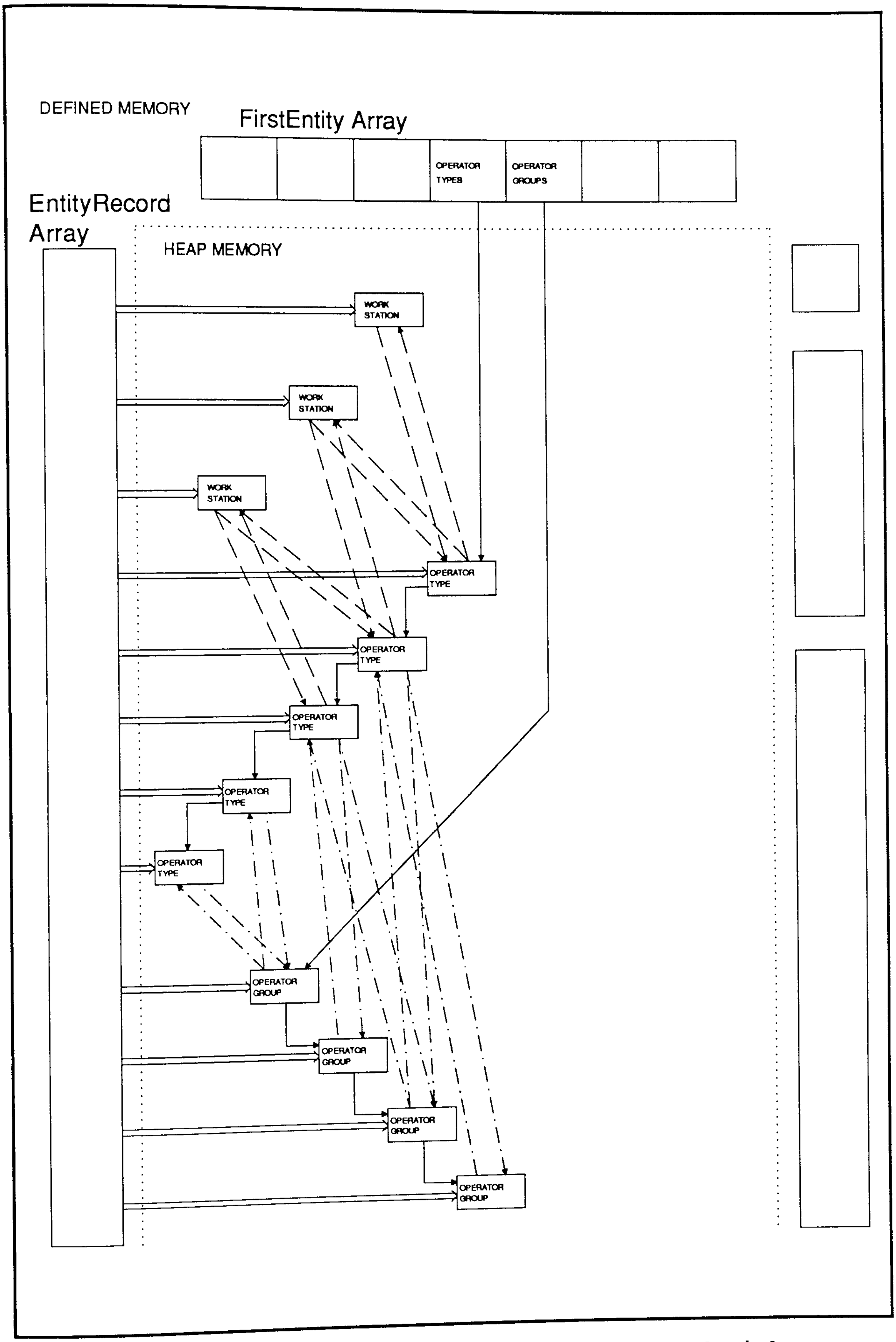


Figure D.23 Operator Type and Group Record Links

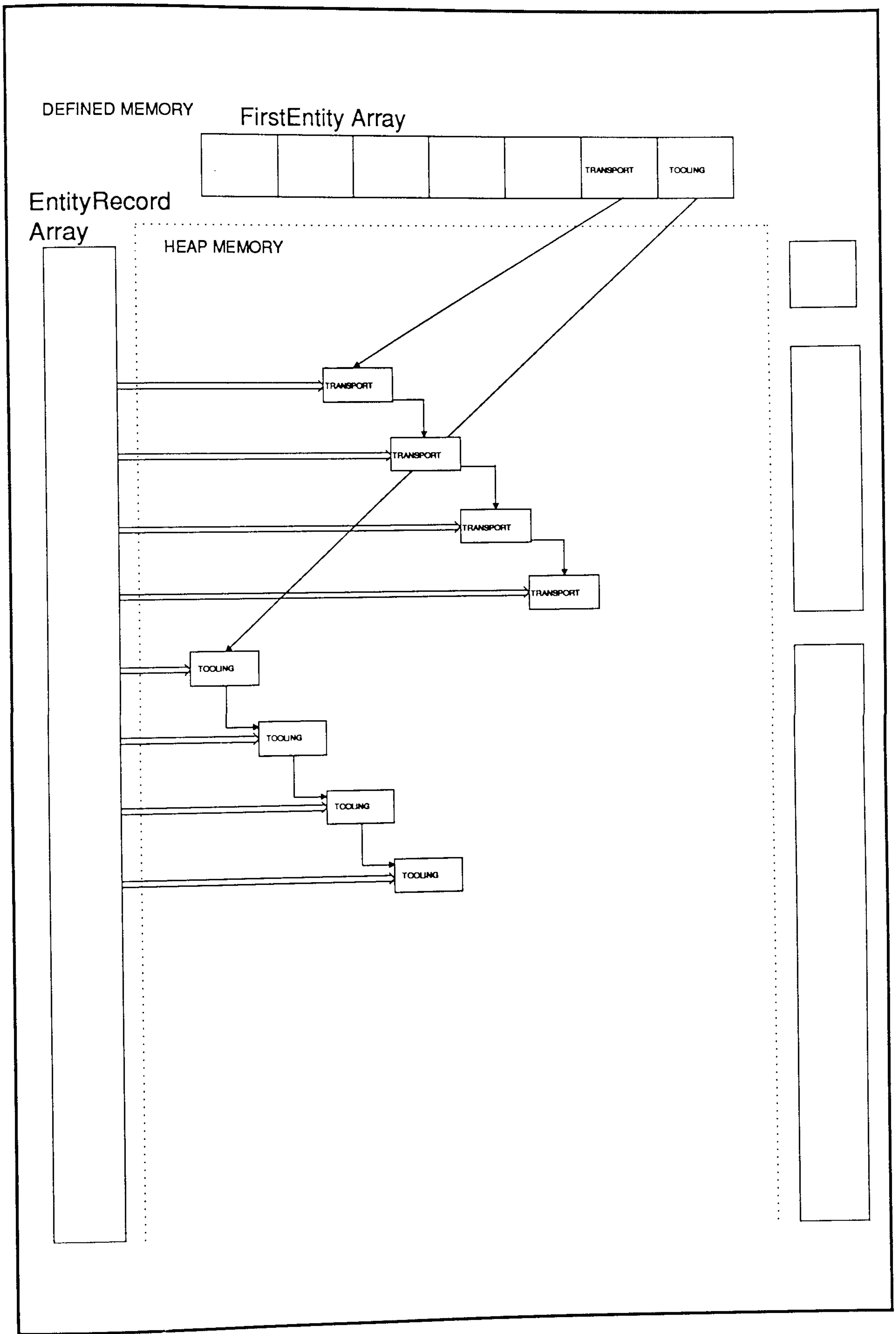


Figure D.24 Transport and Tooling Record Links

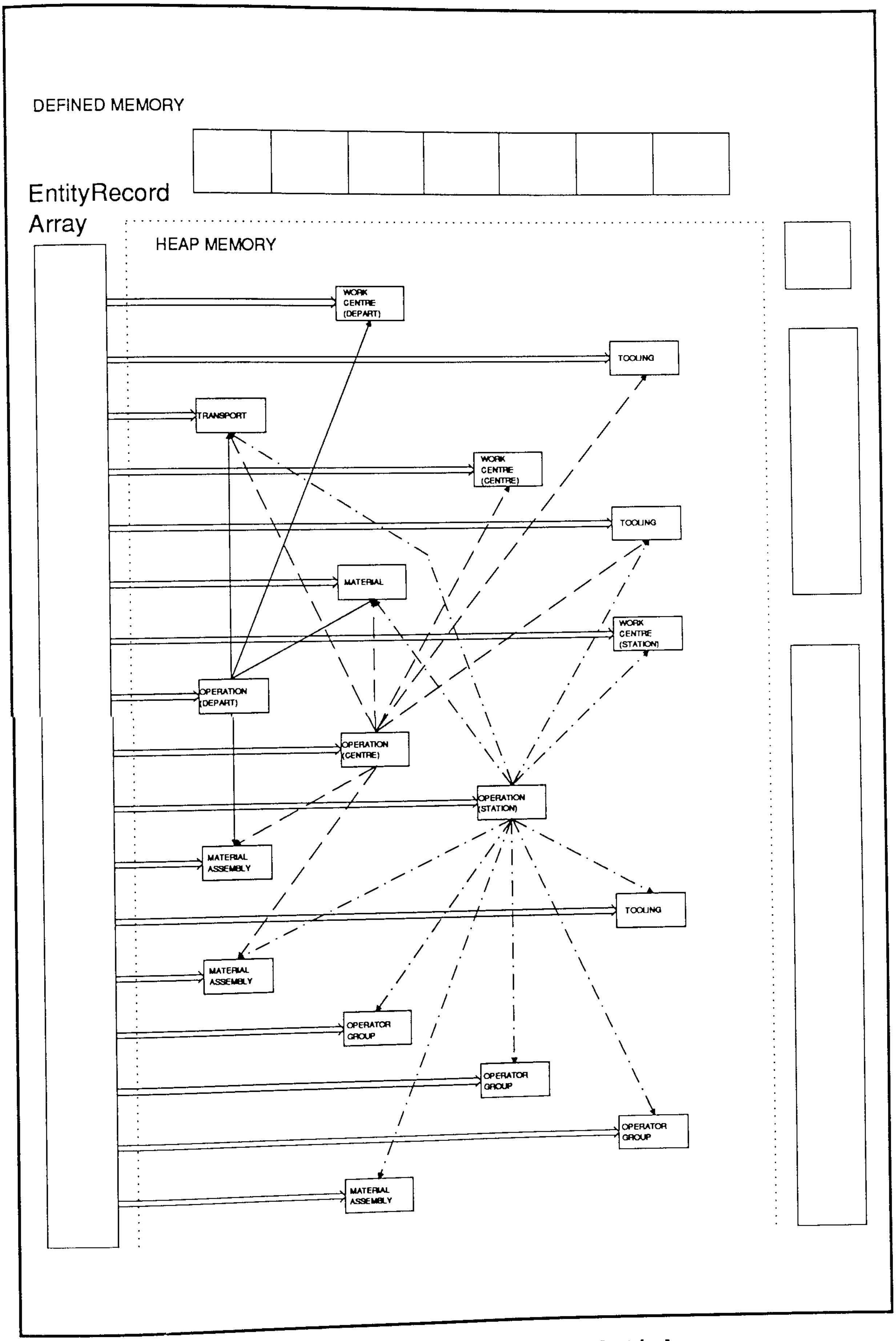


Figure D.25 Operator Record Links

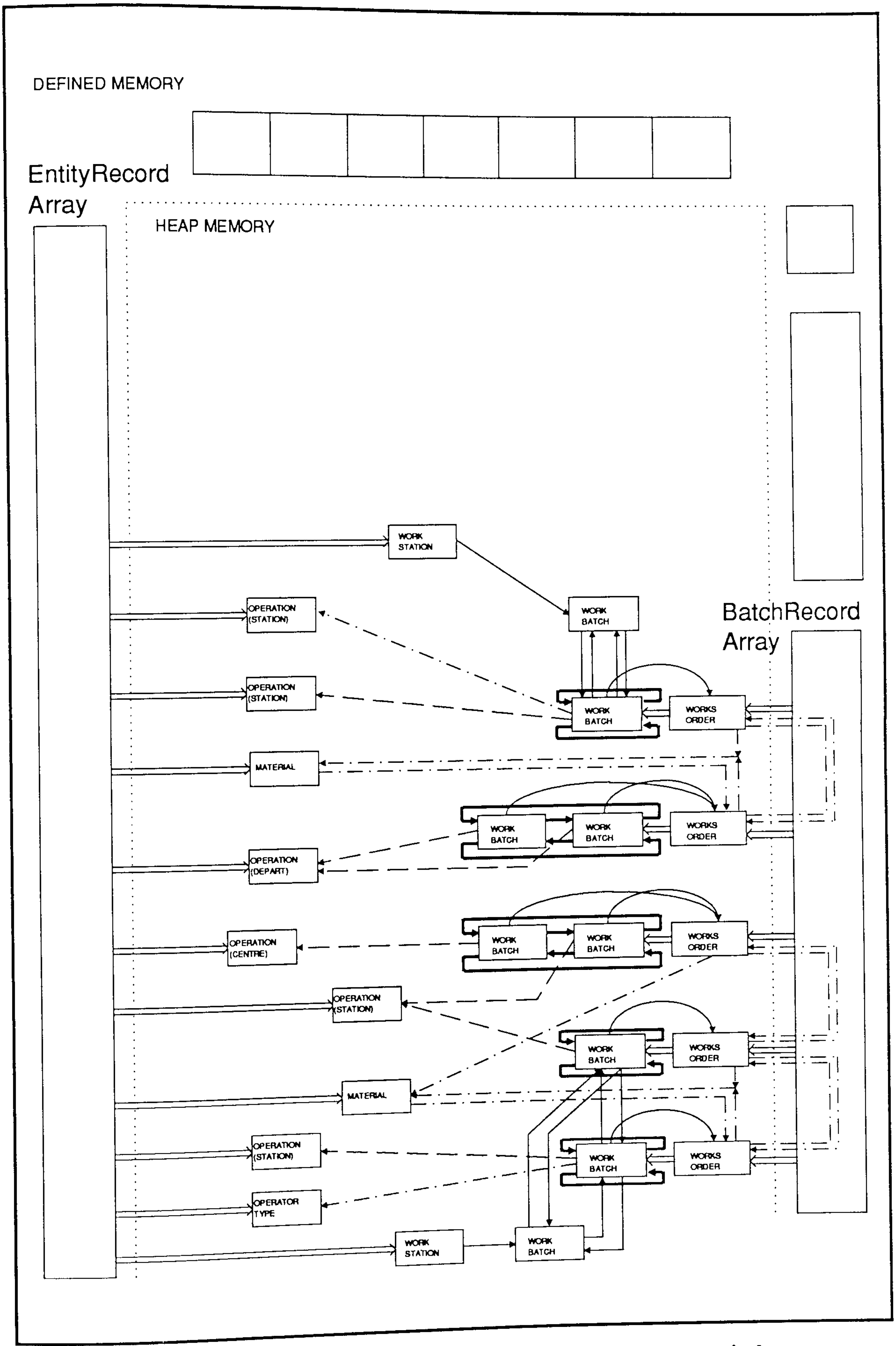


Figure D.26 Works Order and Batch Record Links

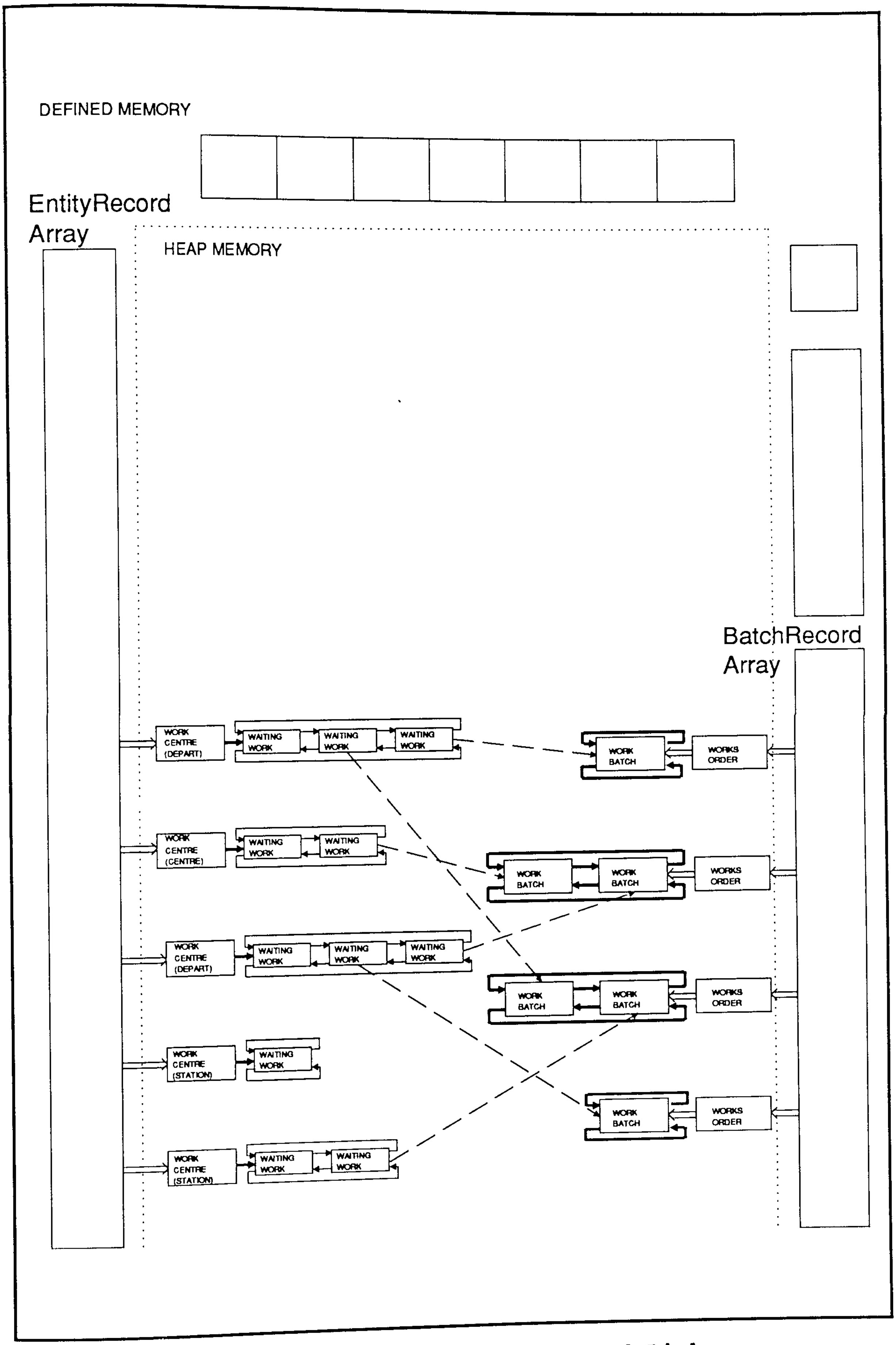


Figure D.27 Waiting Work Record Links

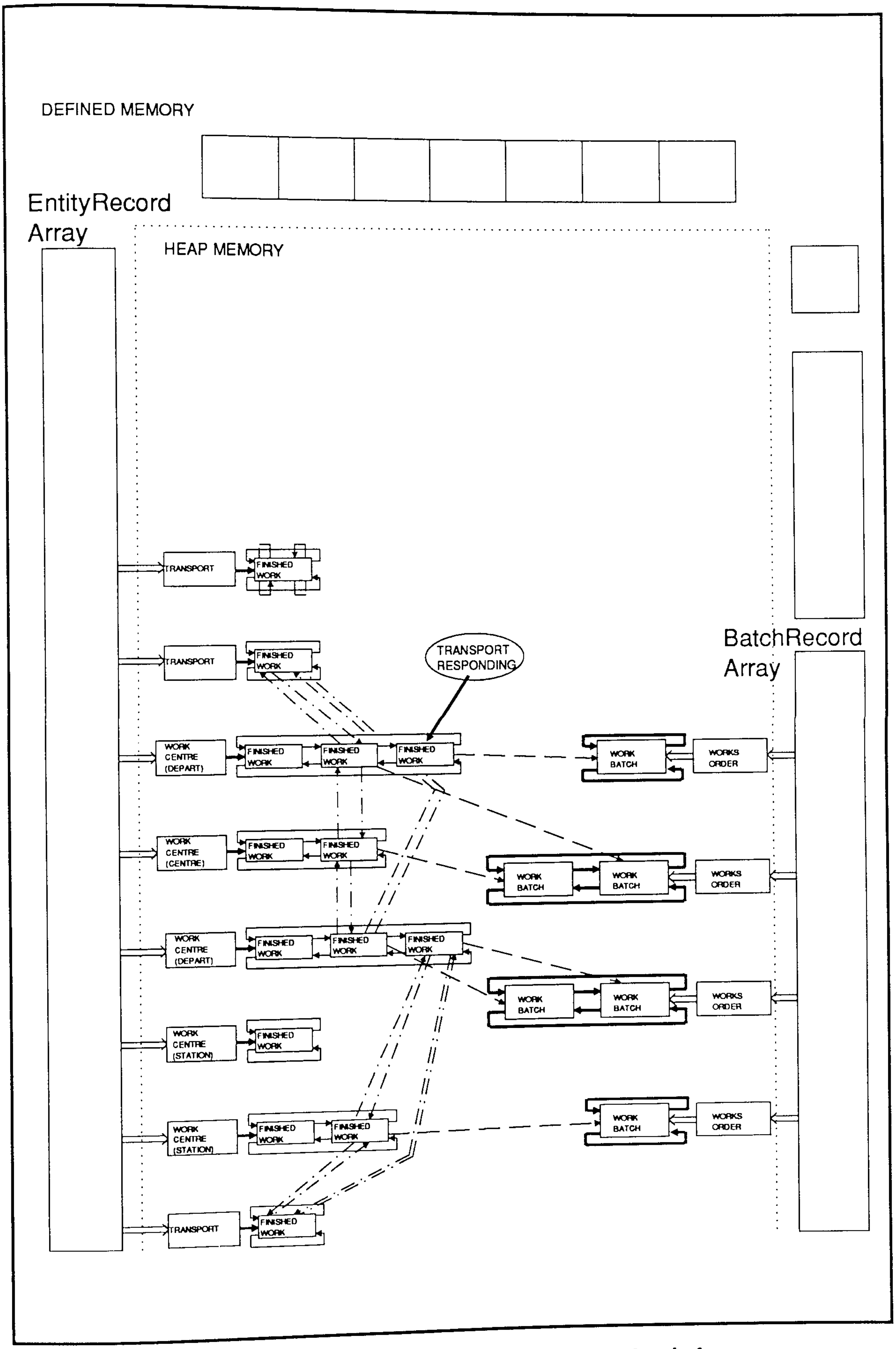


Figure D.28 Finished Work Record Links

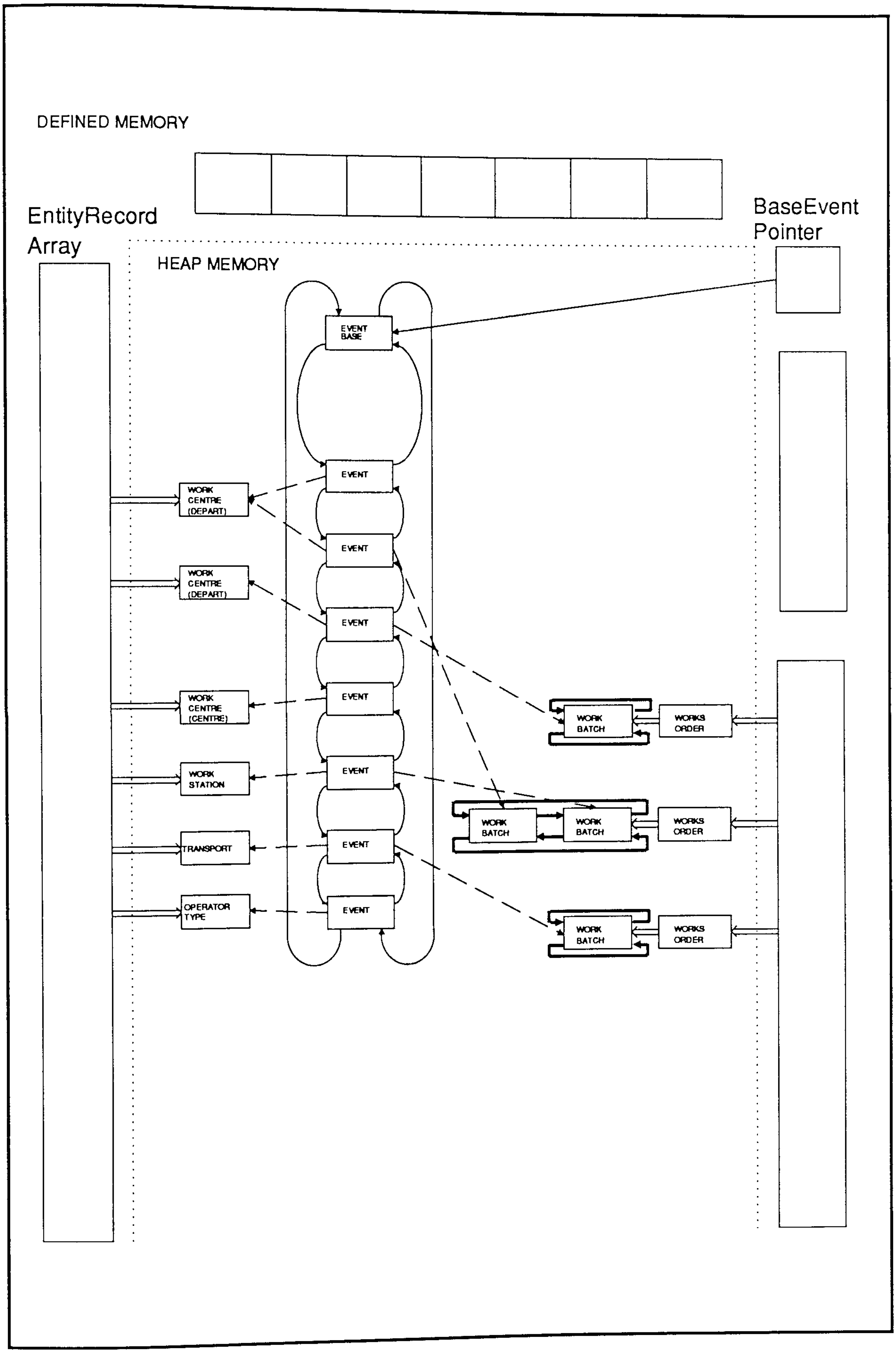


Figure D.29 Event Record Links

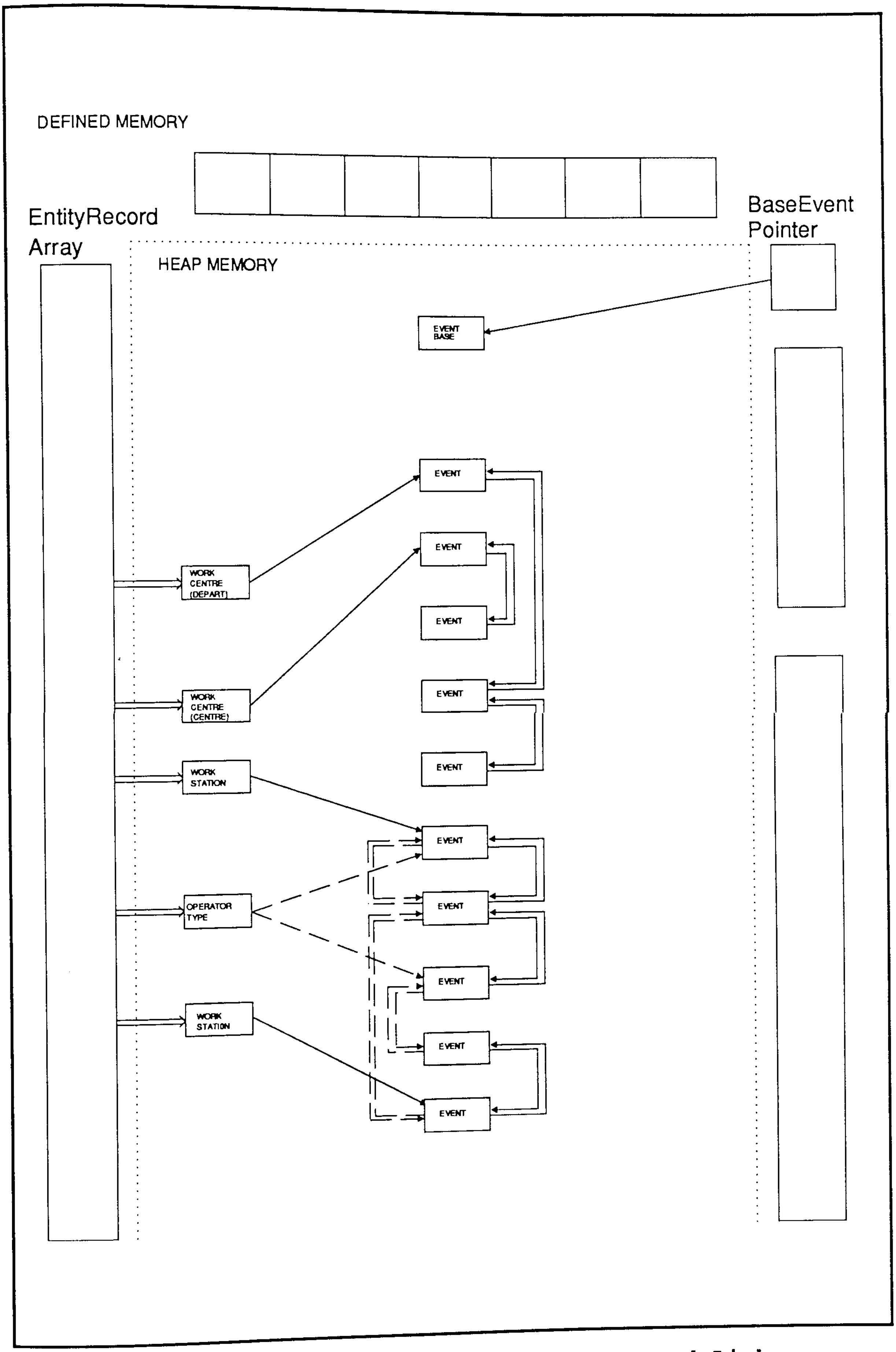


Figure D.30 Work Processing Event Record Links

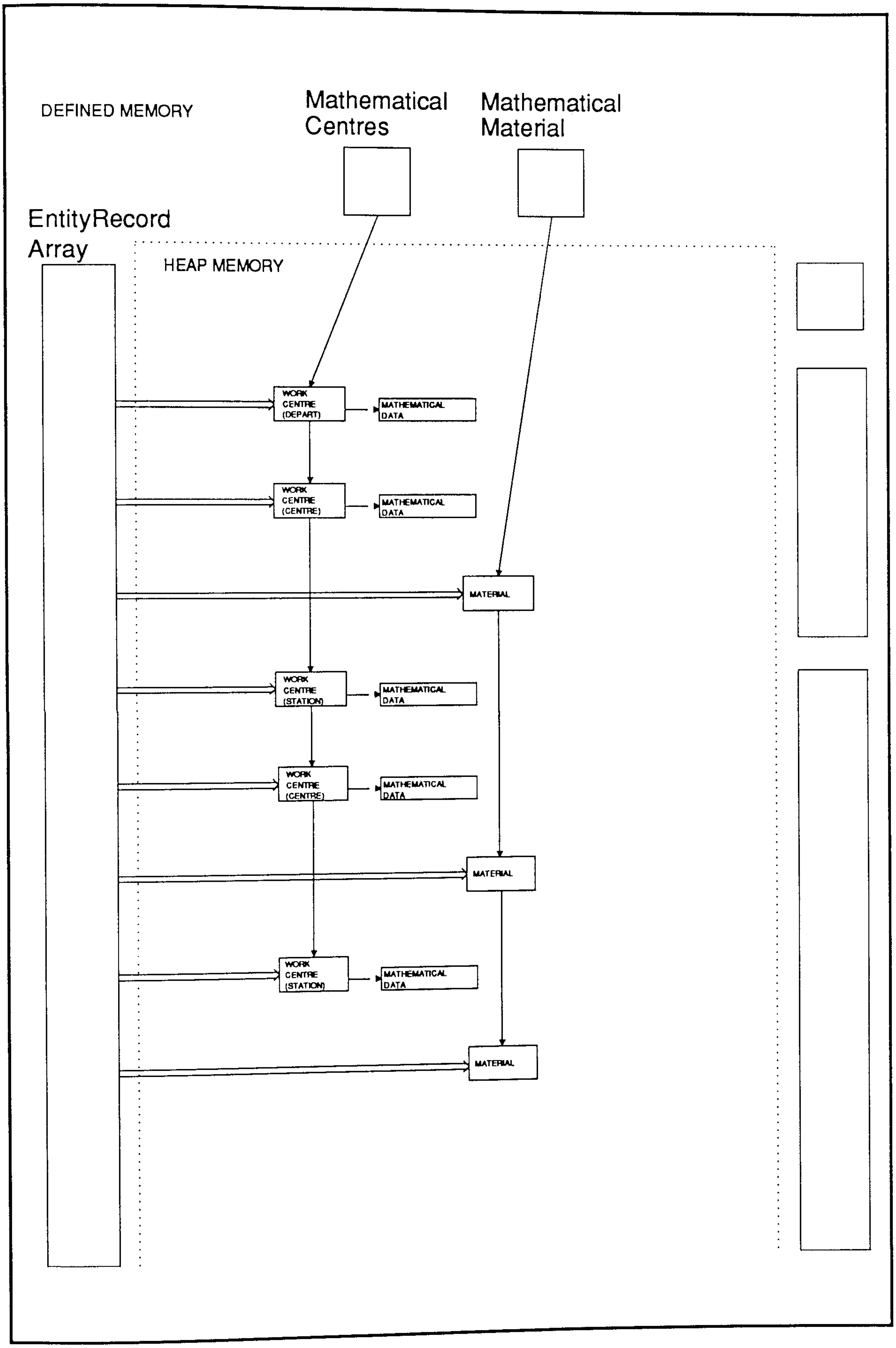
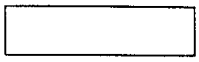


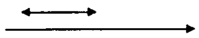
Figure D.31 Mathematical Modelling Record Links

Key:

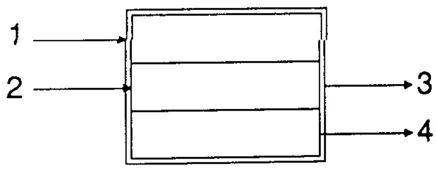


Identification of a specific procedure/function

Indicates an overlay procedure



Identifies the direction of a procedure/ function call by the main arrow, whilst the smaler one indicates the direction of data flow.



Grouping of similar procedures in order to simplify documentation.

1. identifies where a procedure calls each procedure within the grouping.
2. indicates one call to a specific grouped procedure.
3. identifes a call made by all of the grouped procedures.
4. indicates a call made only by a specific procedure.

◆

Indicates a conditional call, where a procedure will call only one procedure from a range of allternatives.

*

indicates where a procedure has not been fully described and reference should be made to an alternative figure.

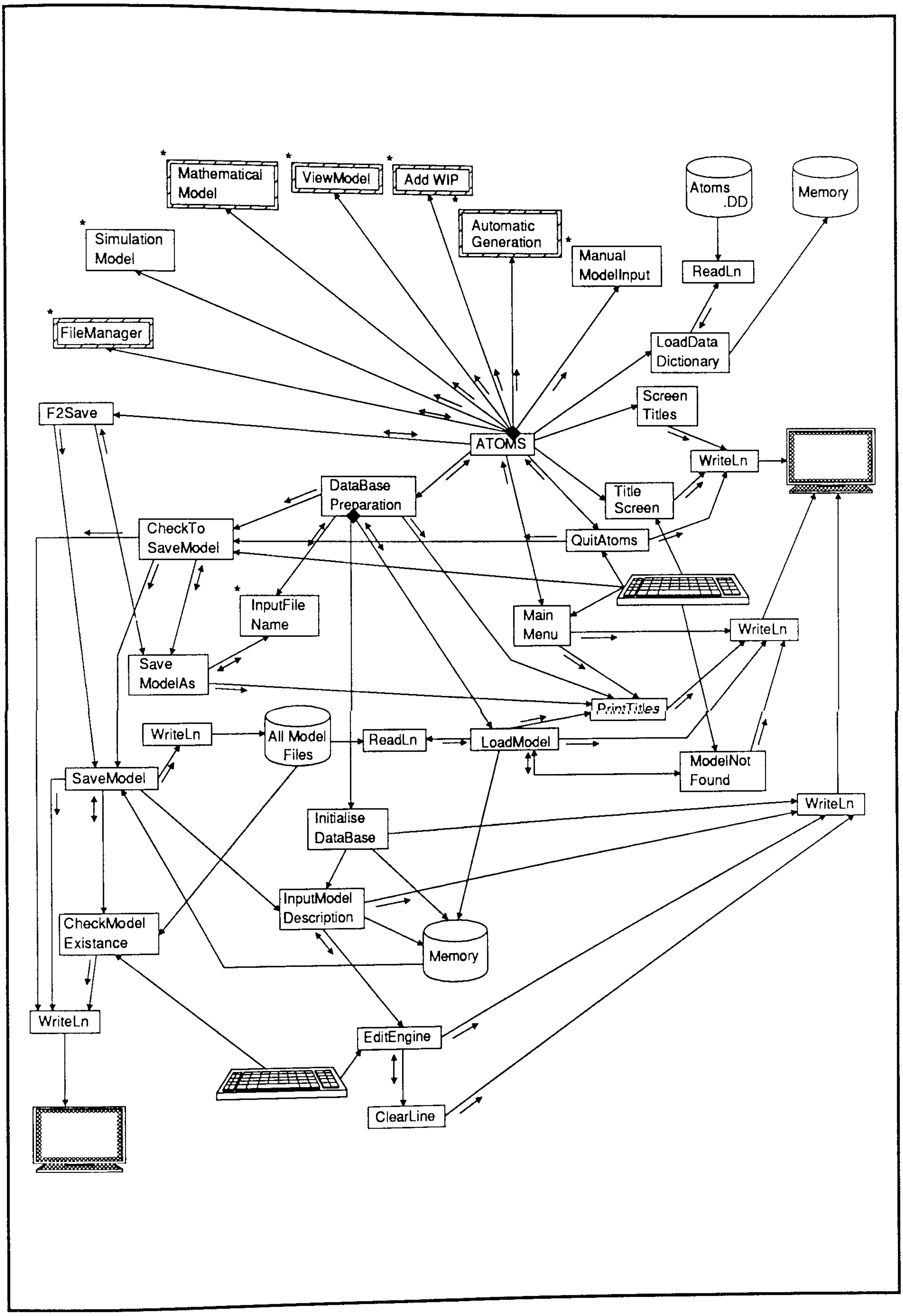


Figure D.32 ATOMS Manufacturing Simulator Program

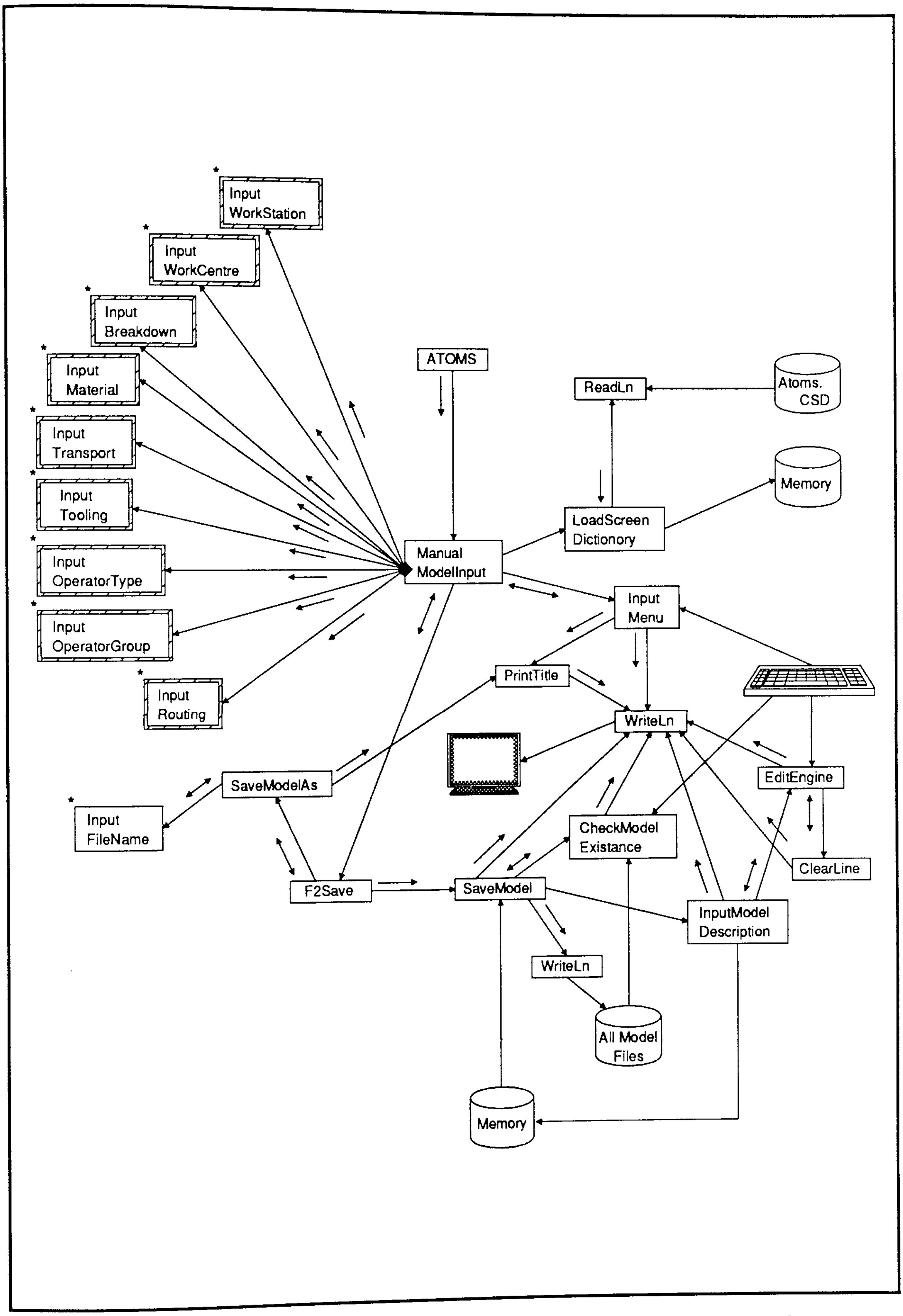


Figure D.33 ATOMS Manual Model Input Program Unit

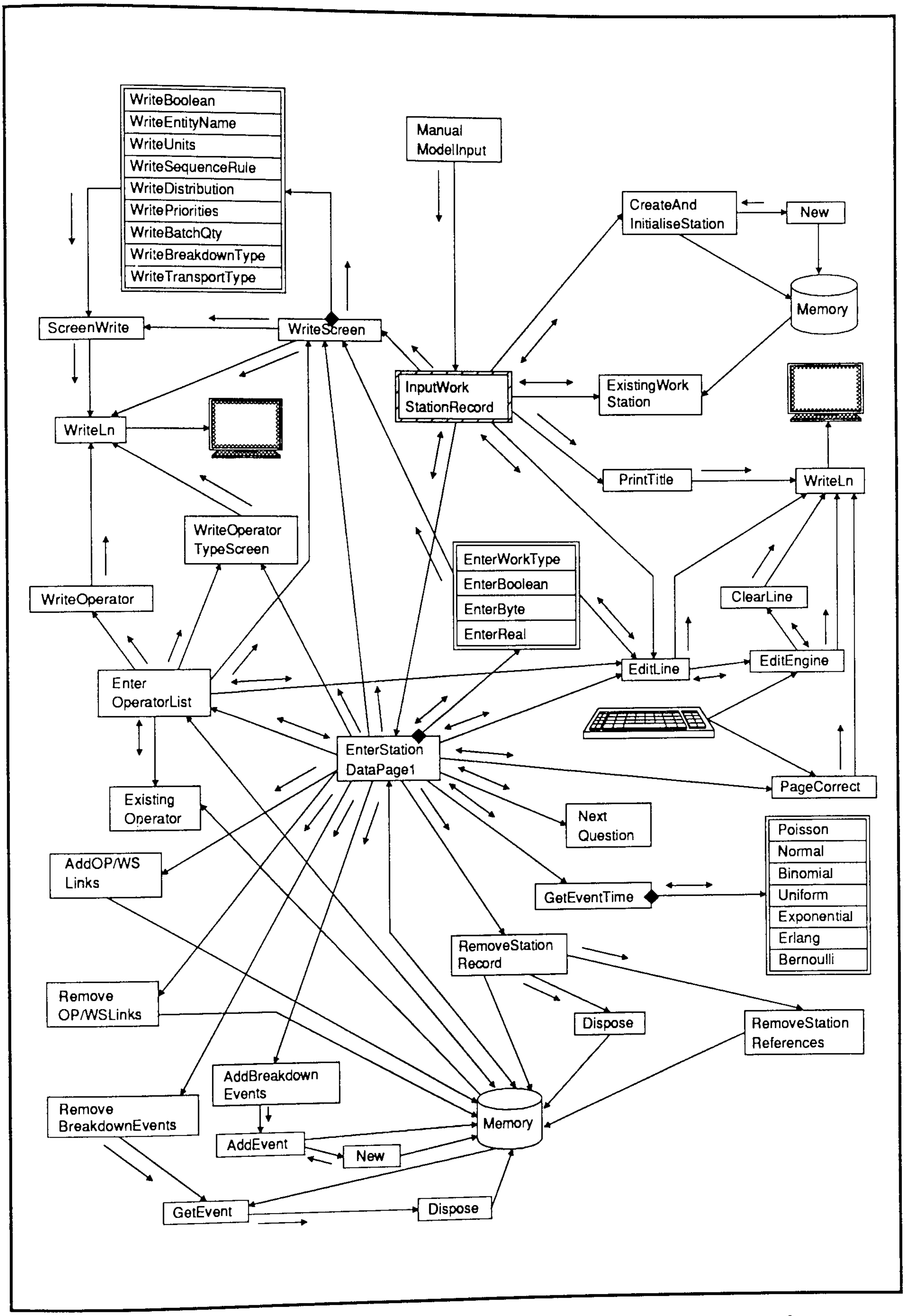


Figure D.34 ATOMS Work Station Input Program Unit

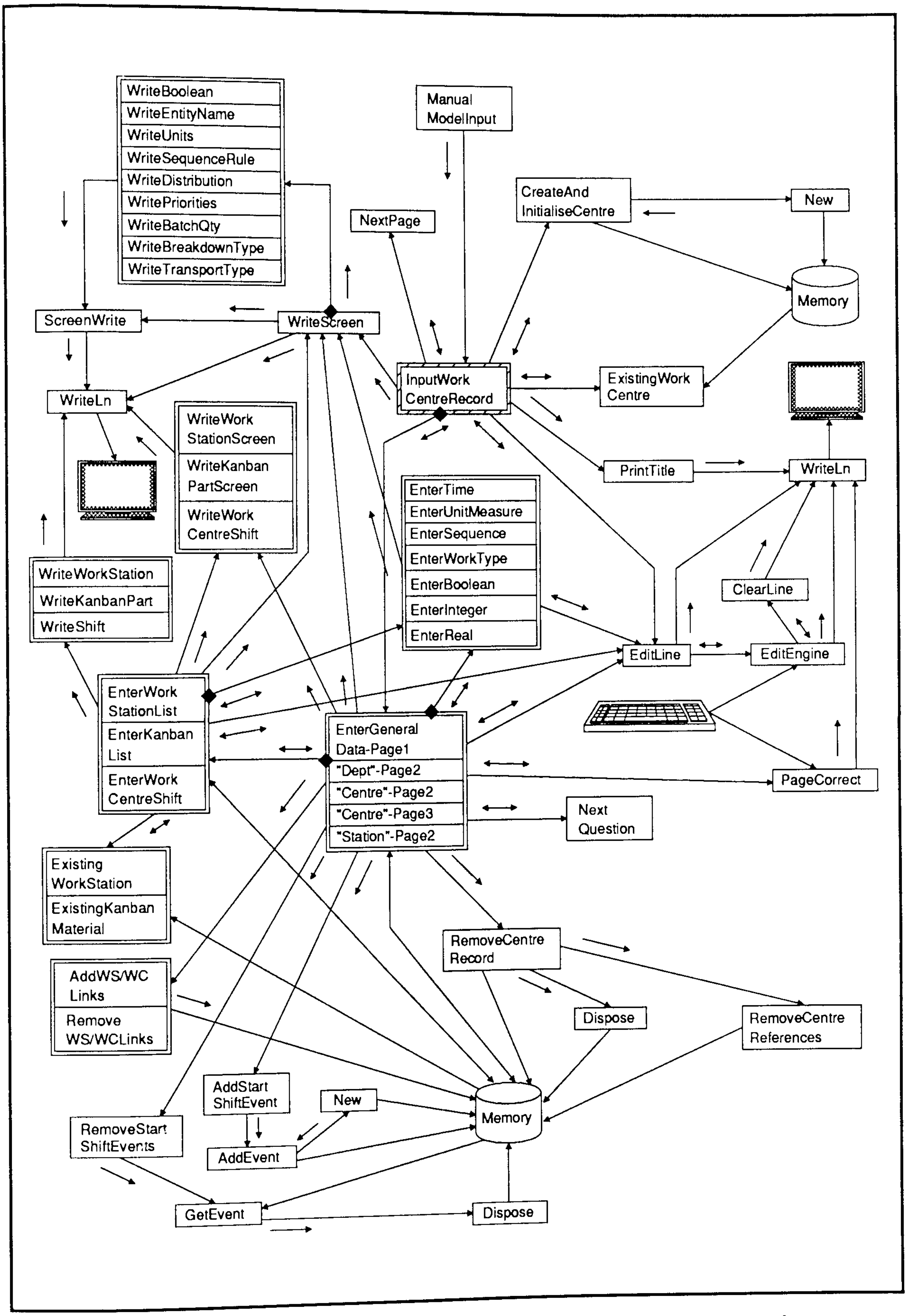


Figure D.35 ATOMS Work Centre Input Program Unit

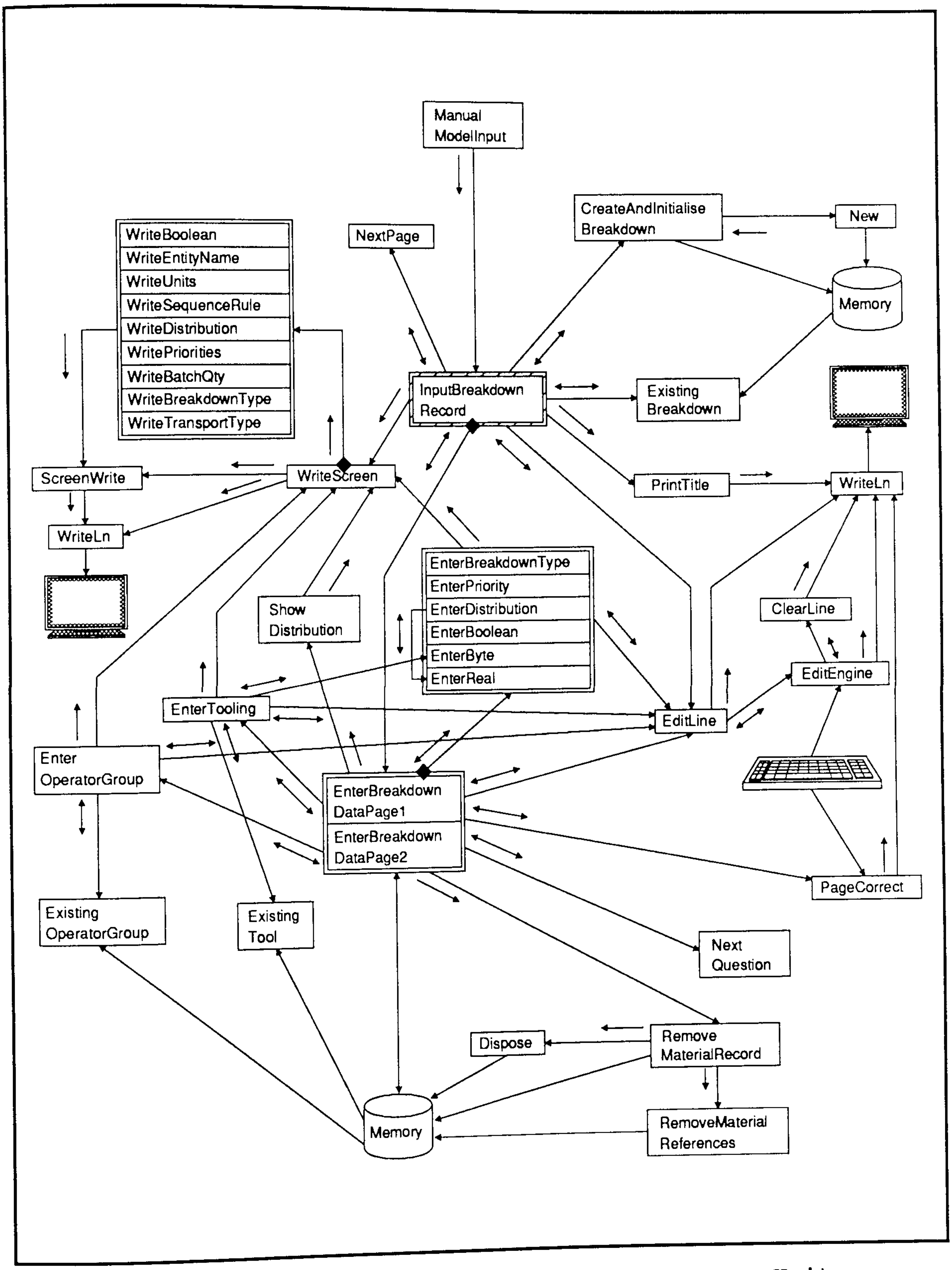


Figure D.36 ATOMS Breakdown Input Program Unit

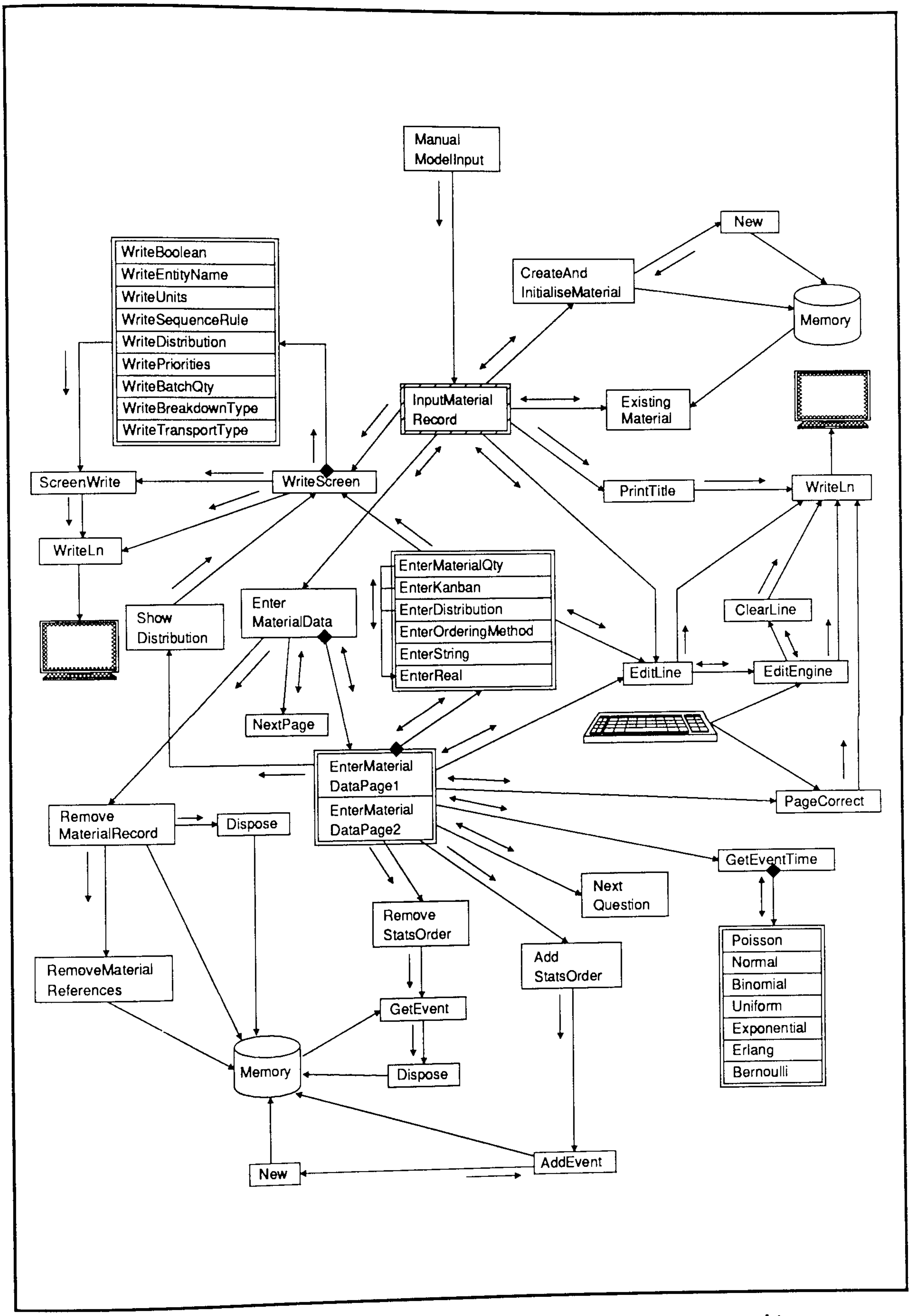


Figure D.37 ATOMS Material Input Program Unit

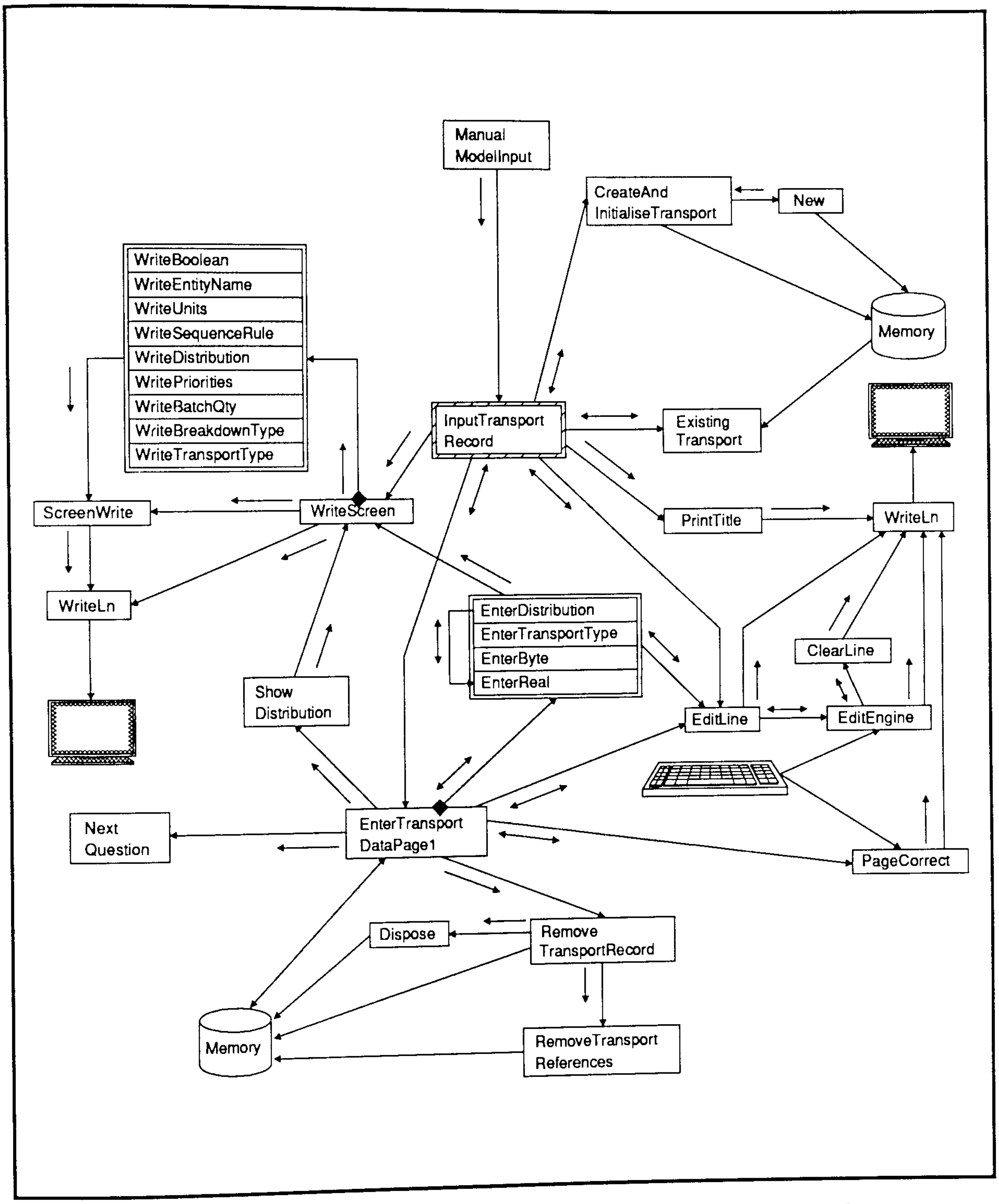


Figure D.38 ATOMS Transport Input Program Unit

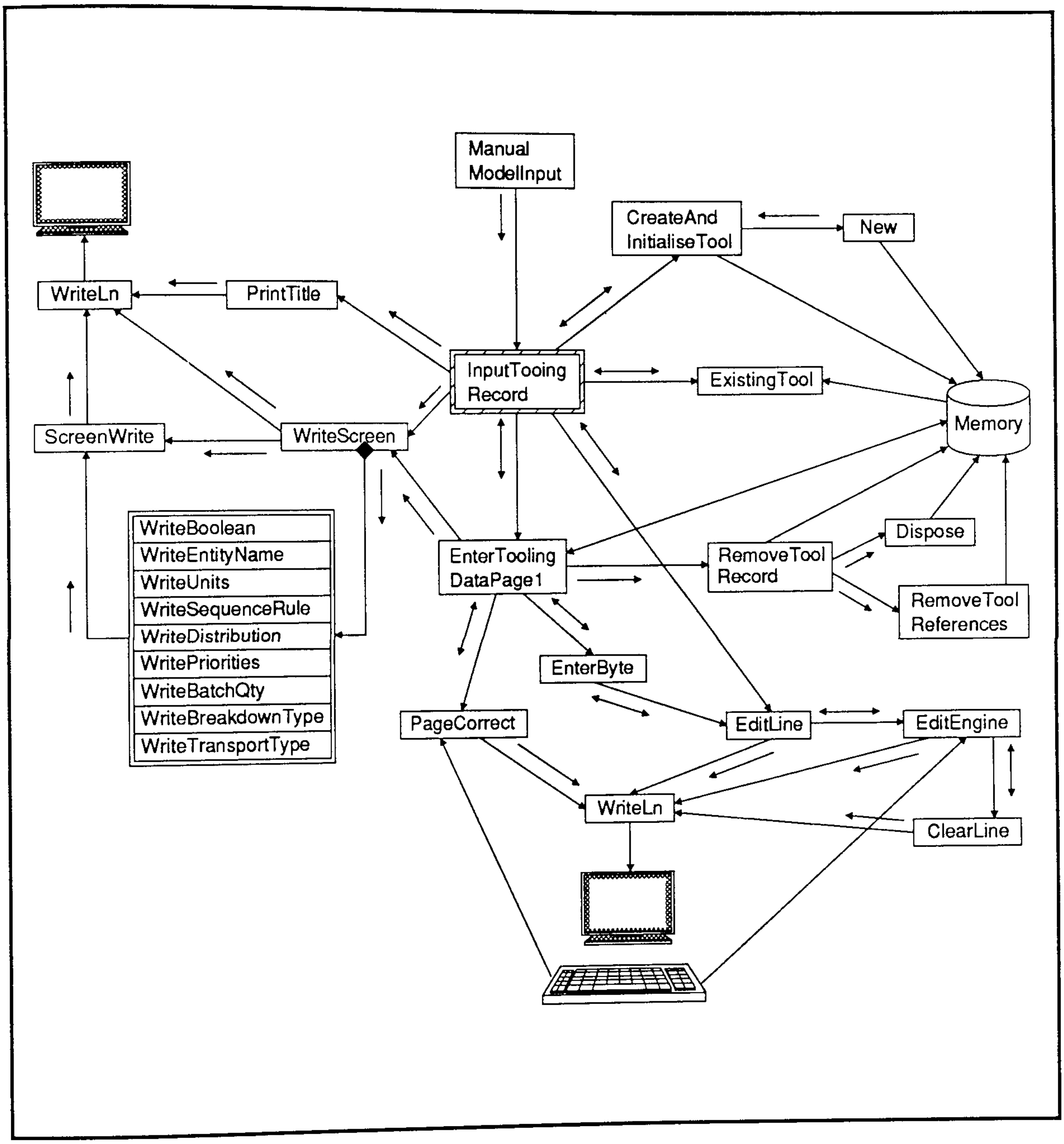


Figure D.39 ATOMS Tooling Input Program Unit

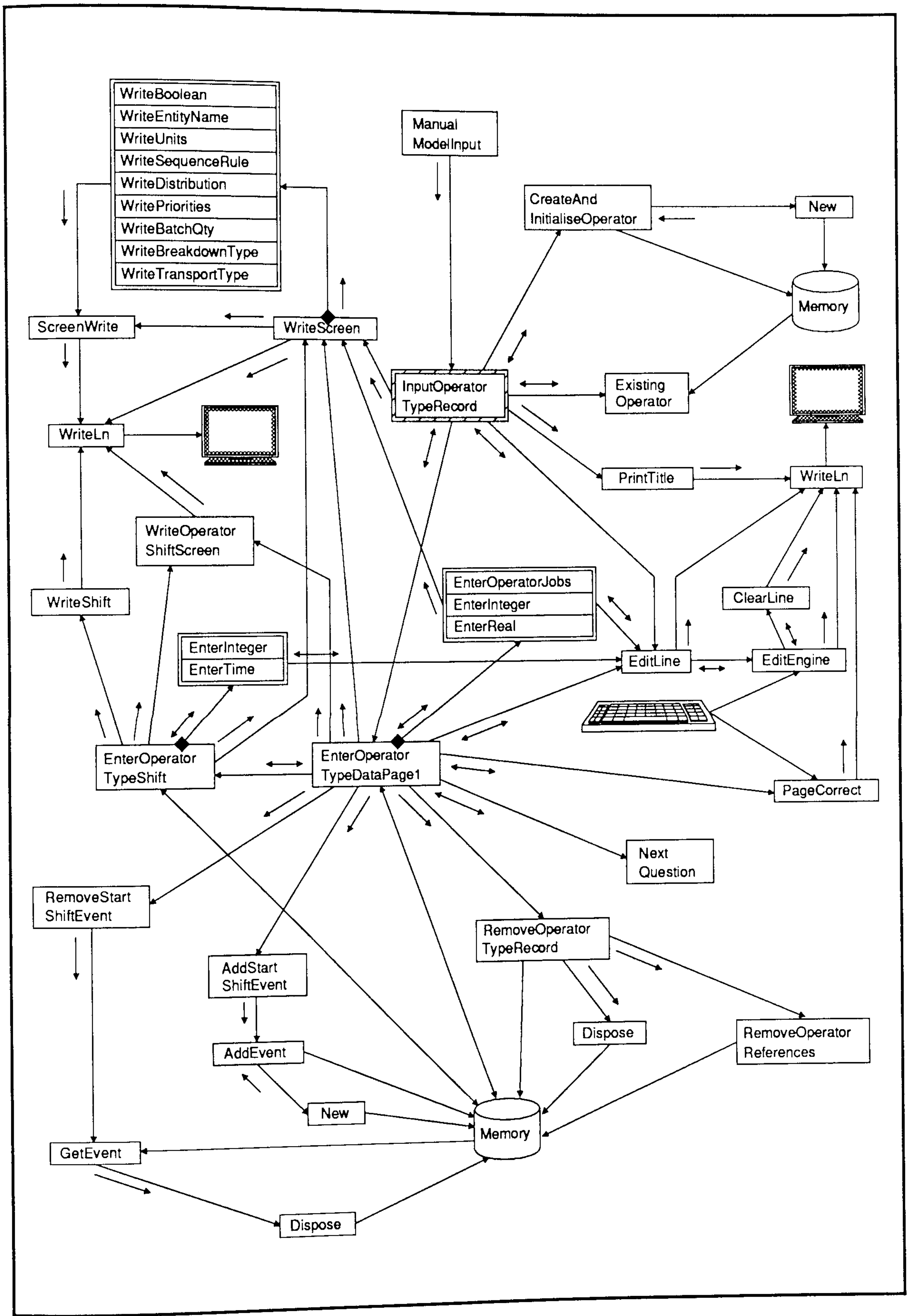


Figure D.40 ATOMS Operator Type Input Program Unit

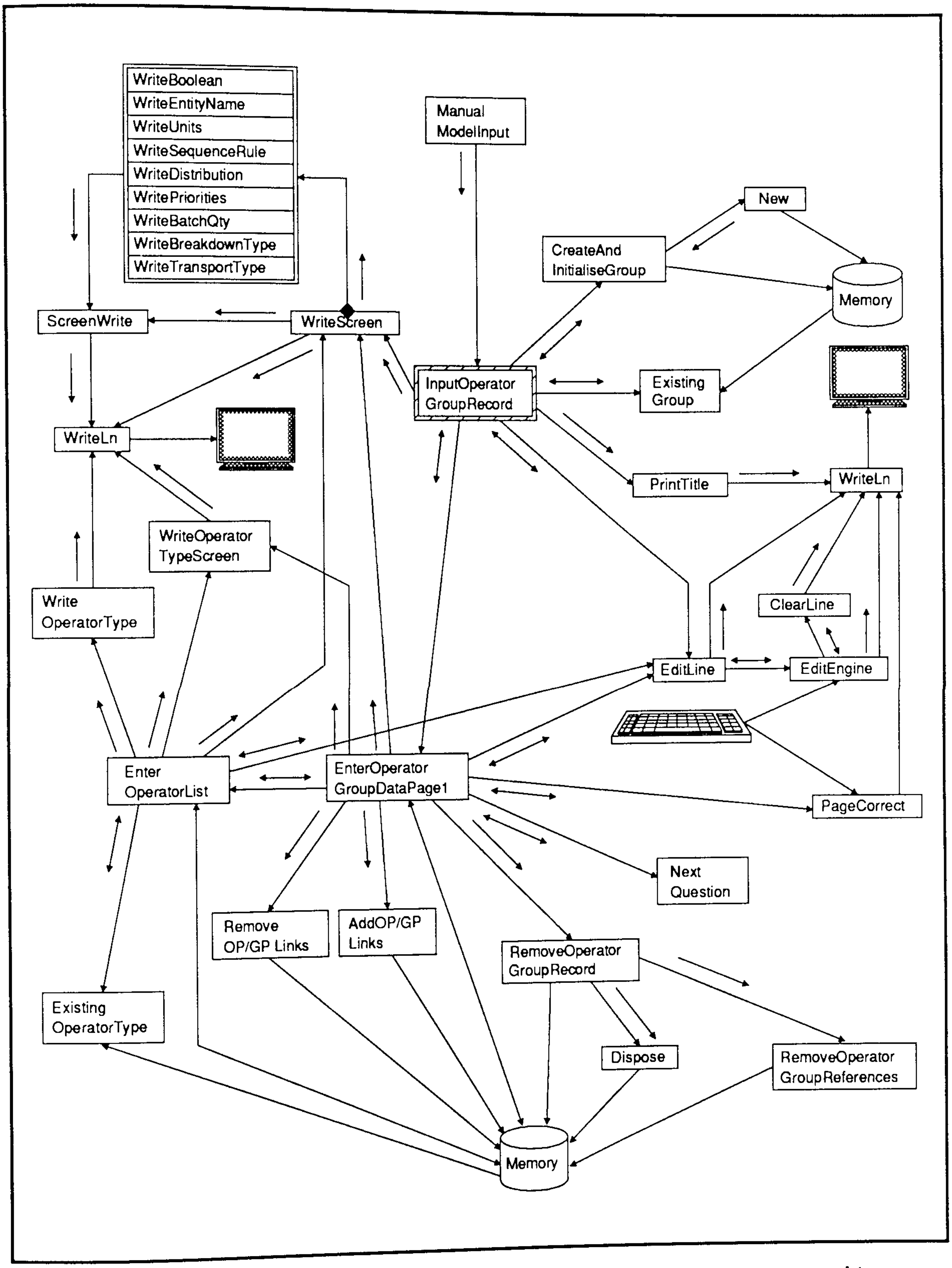


Figure D.41 ATOMS Operator Group Input Program Unit

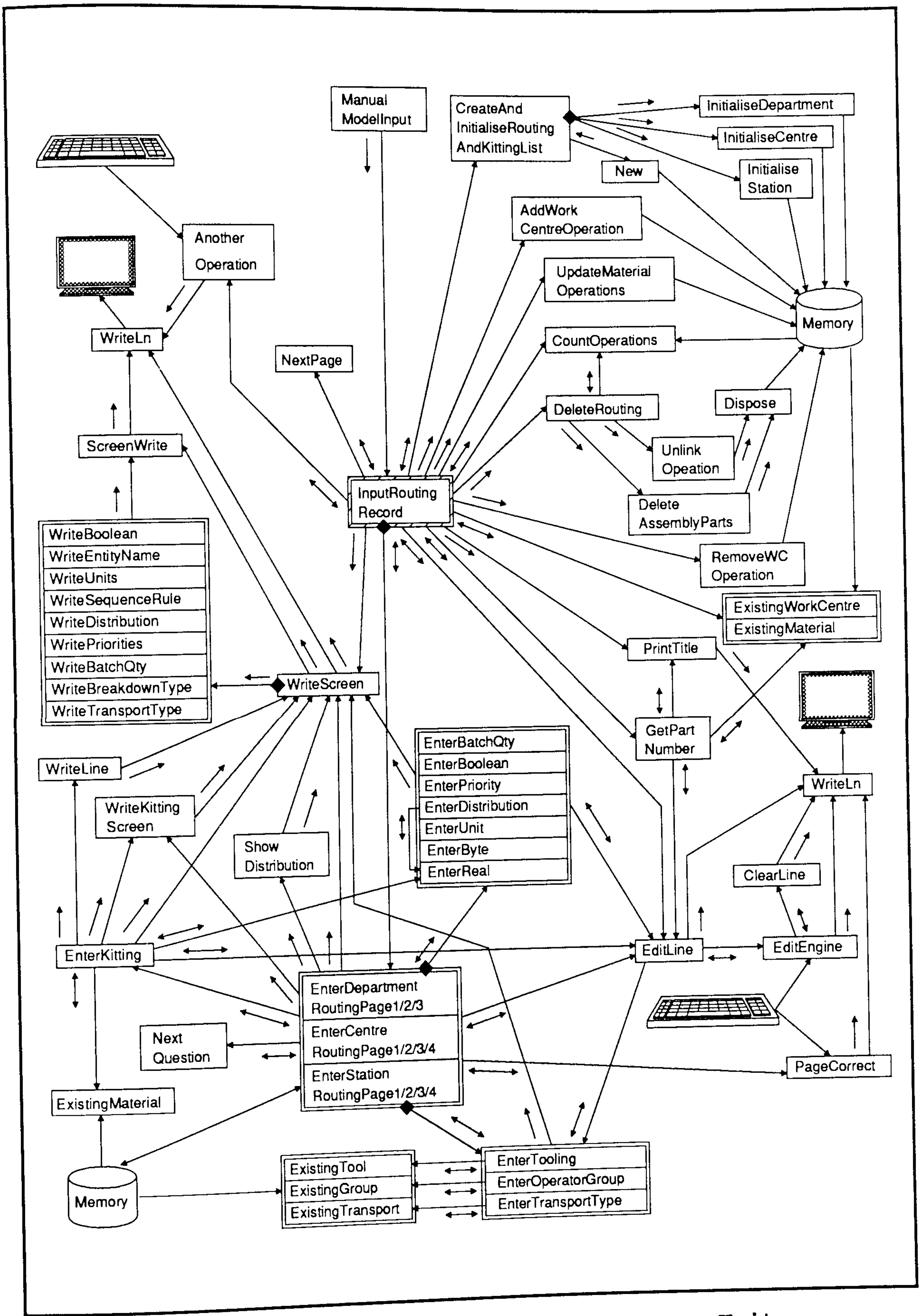


Figure D.42 ATOMS Route Input Program Unit

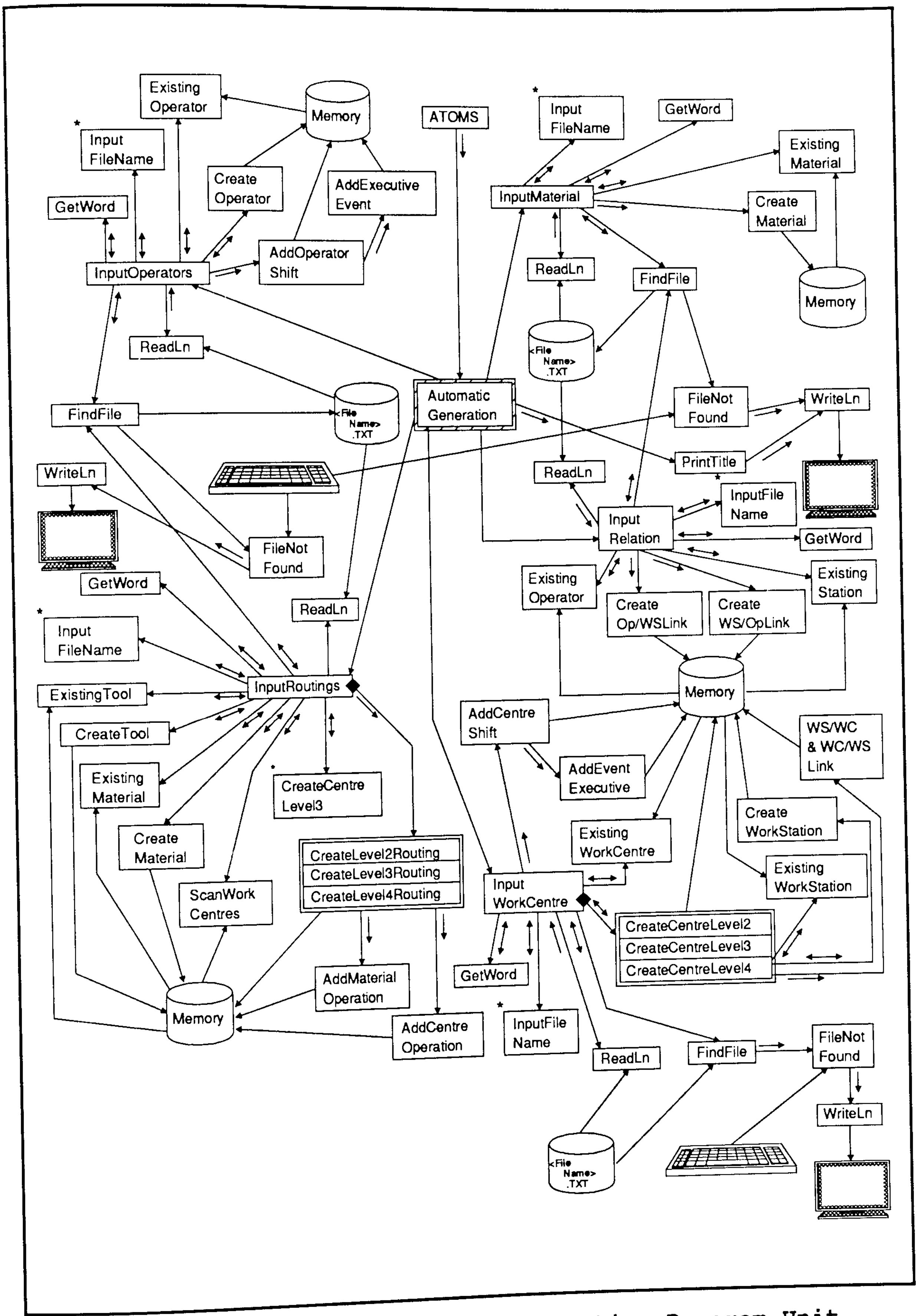


Figure D.43 ATOMS Automatic Generation Program Unit

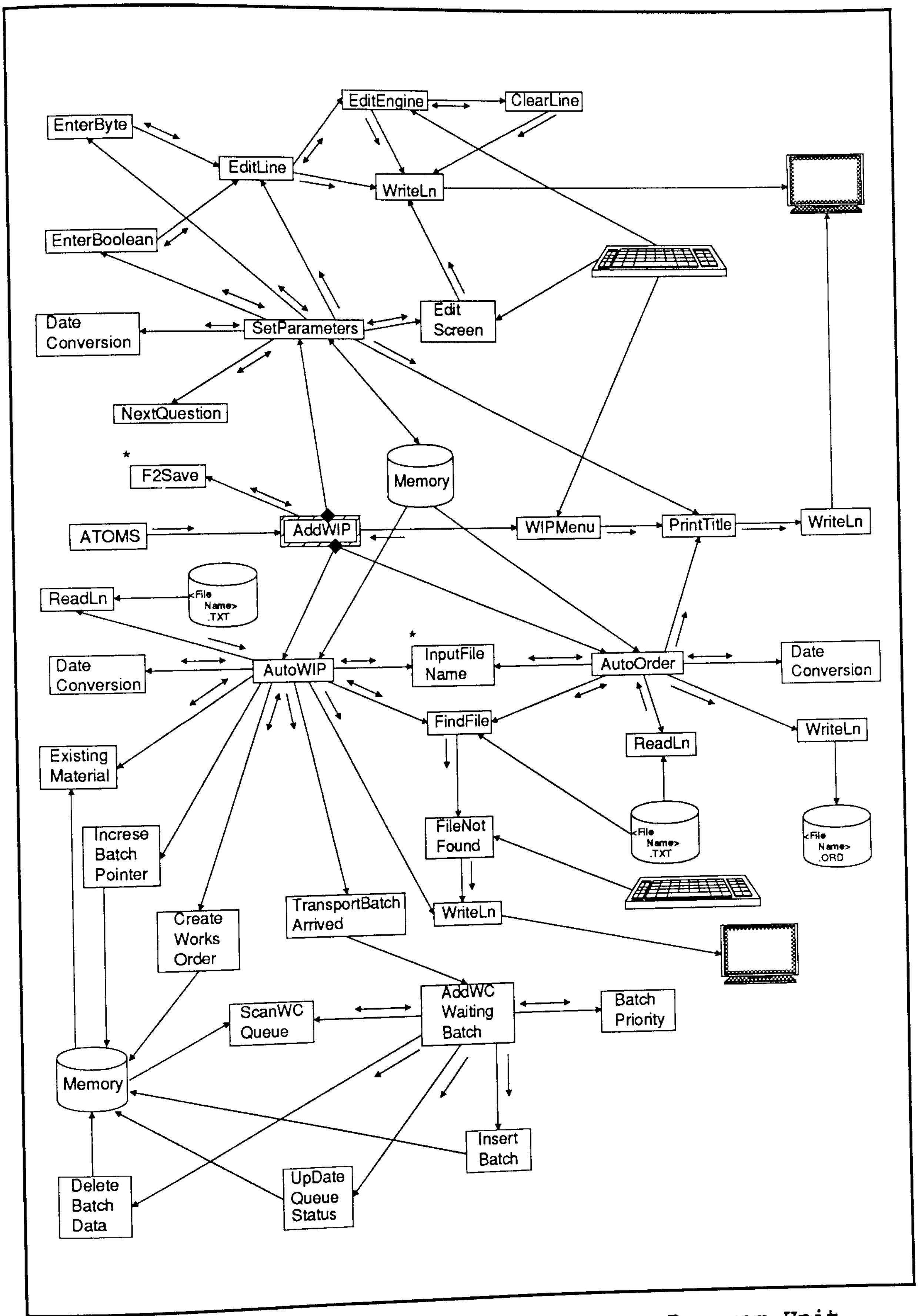


Figure D.44 ATOMS Add Work-in-Progress Program Unit

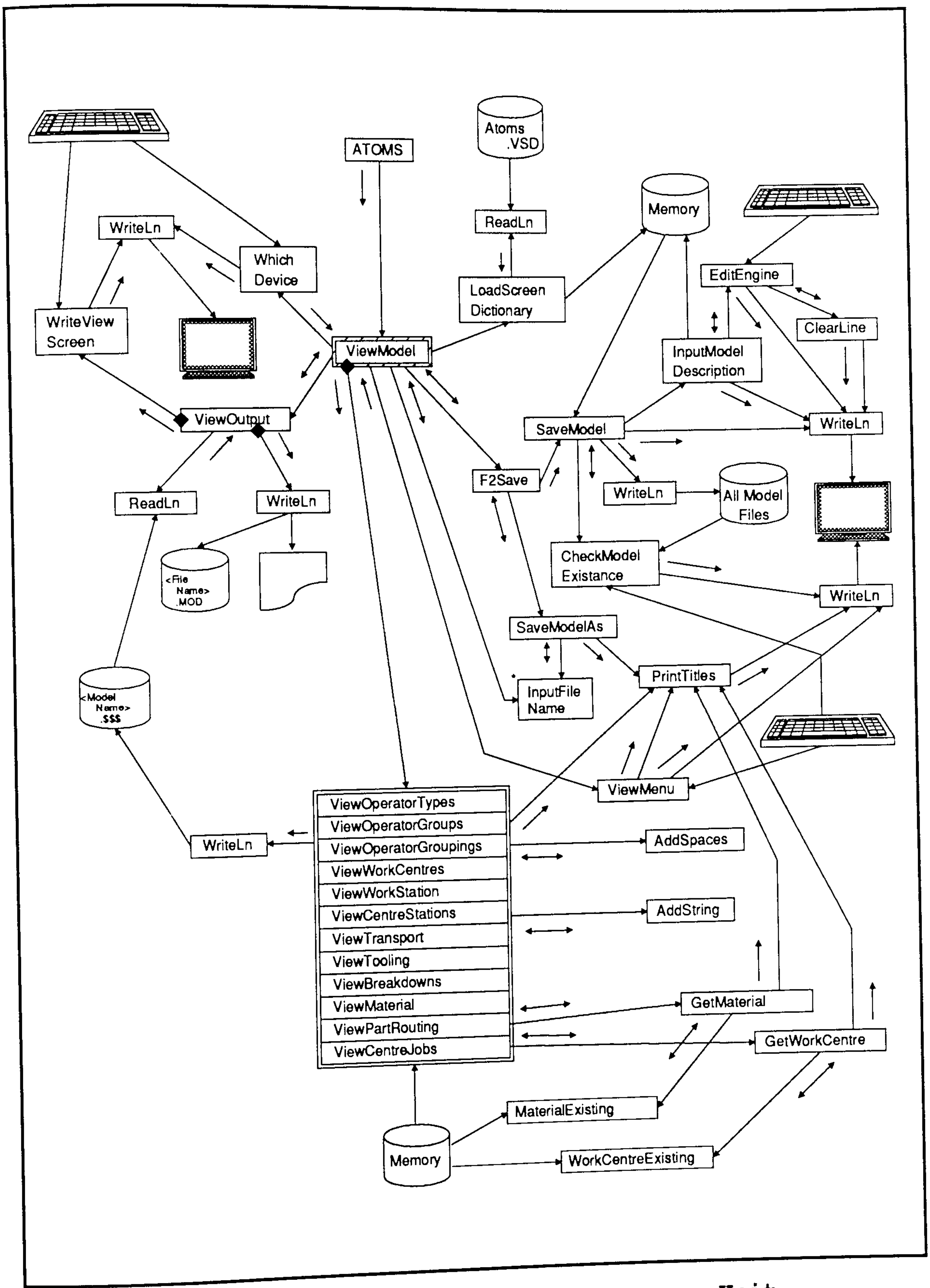


Figure D.45 ATOMS View Model Program Unit

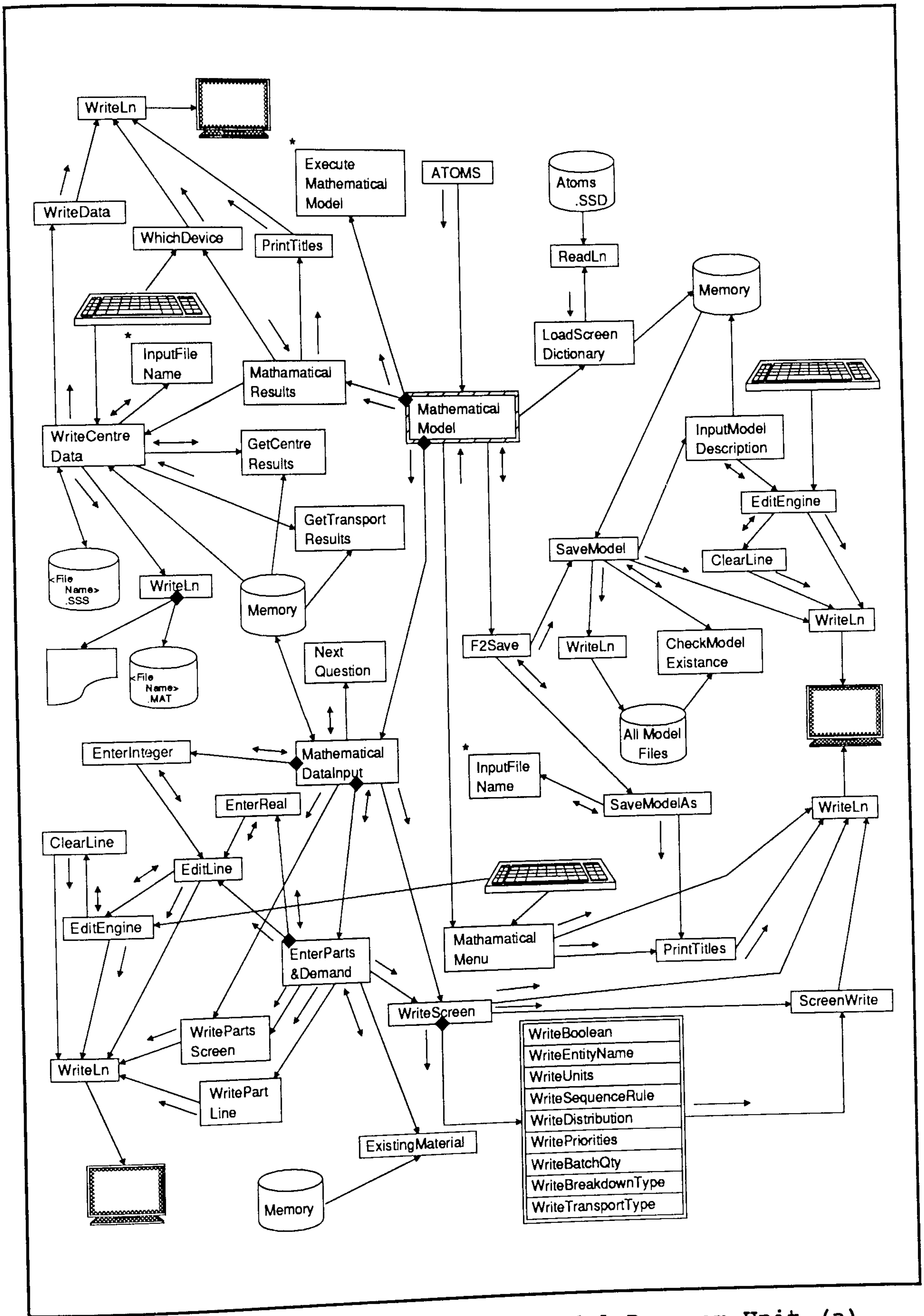


Figure D.46 ATOMS Mathematical Model Program Unit (a)

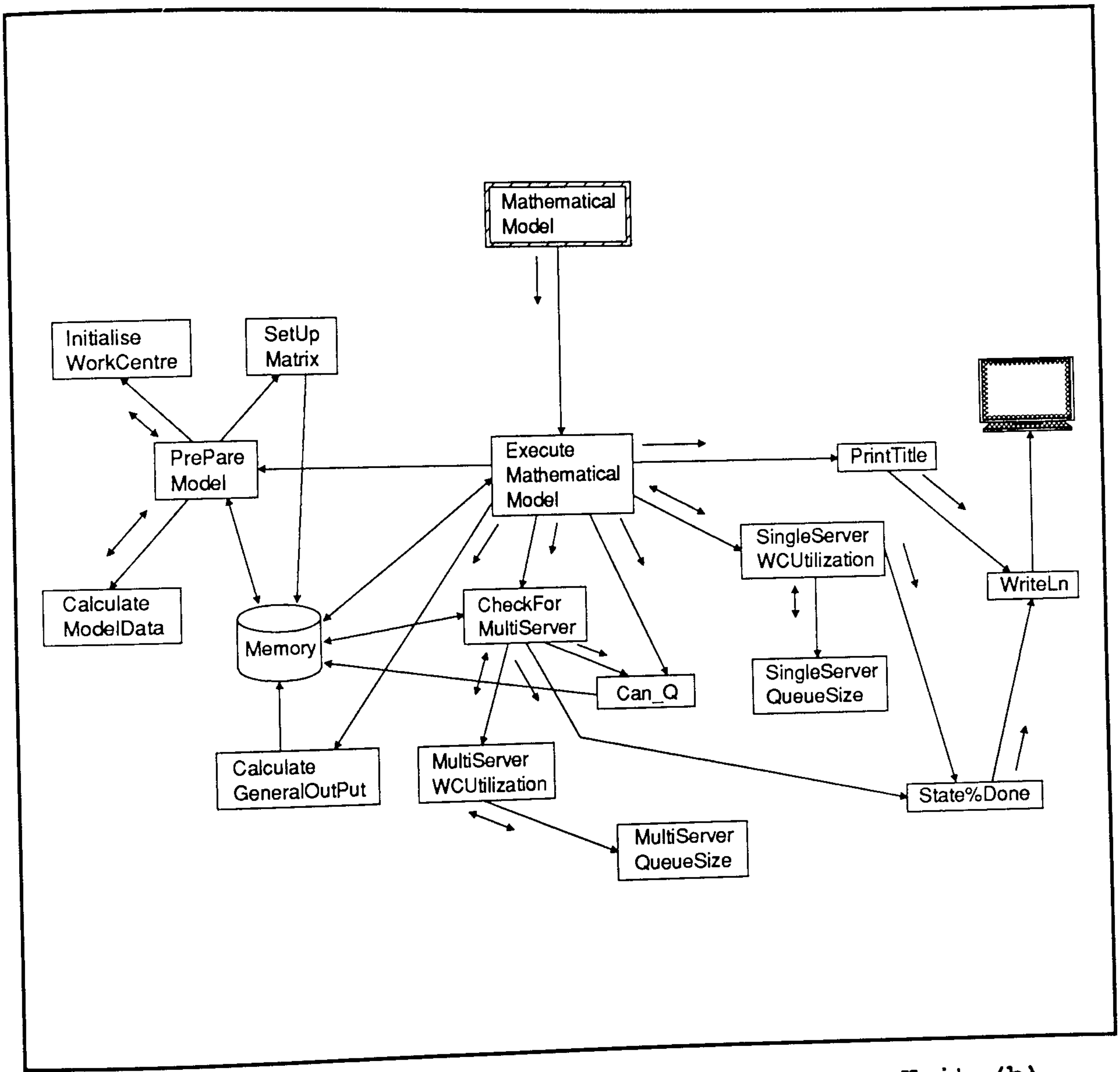


Figure D.47 ATOMS Mathematical Model Program Unit (b)

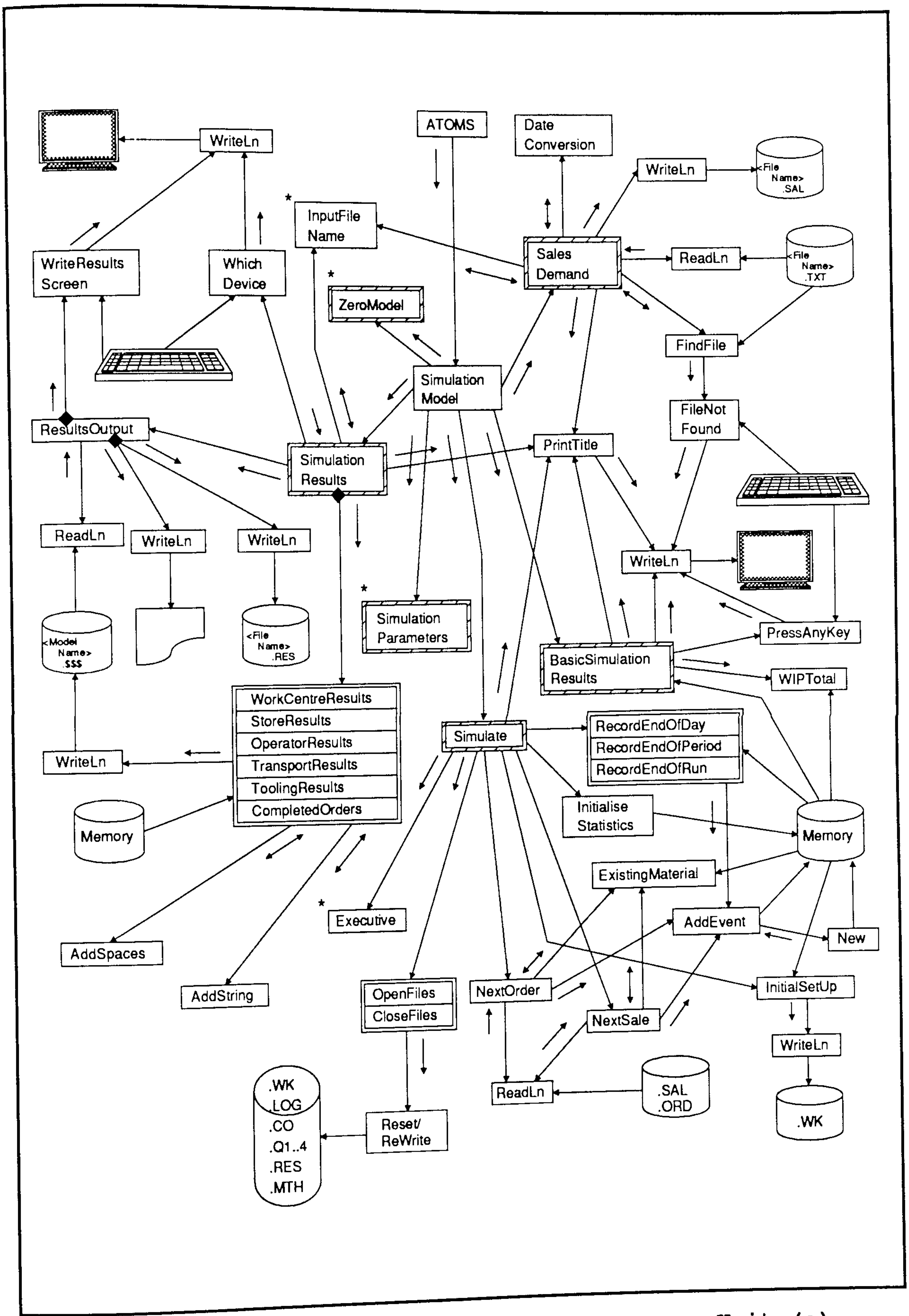


Figure D.48 ATOMS Simualtion Model Program Unit (a)

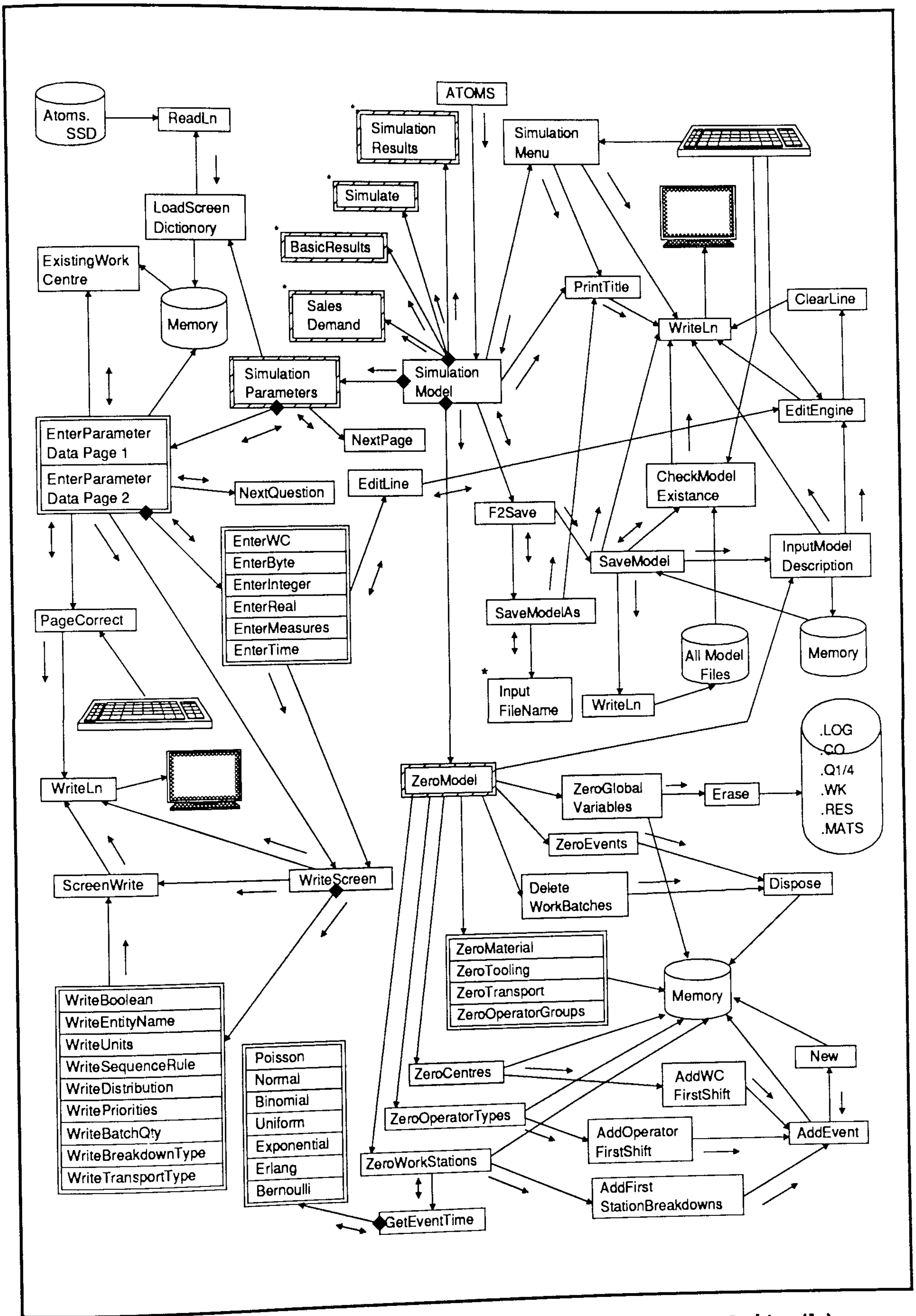


Figure D.49 ATOMS Simulation Model Program Unit (b)

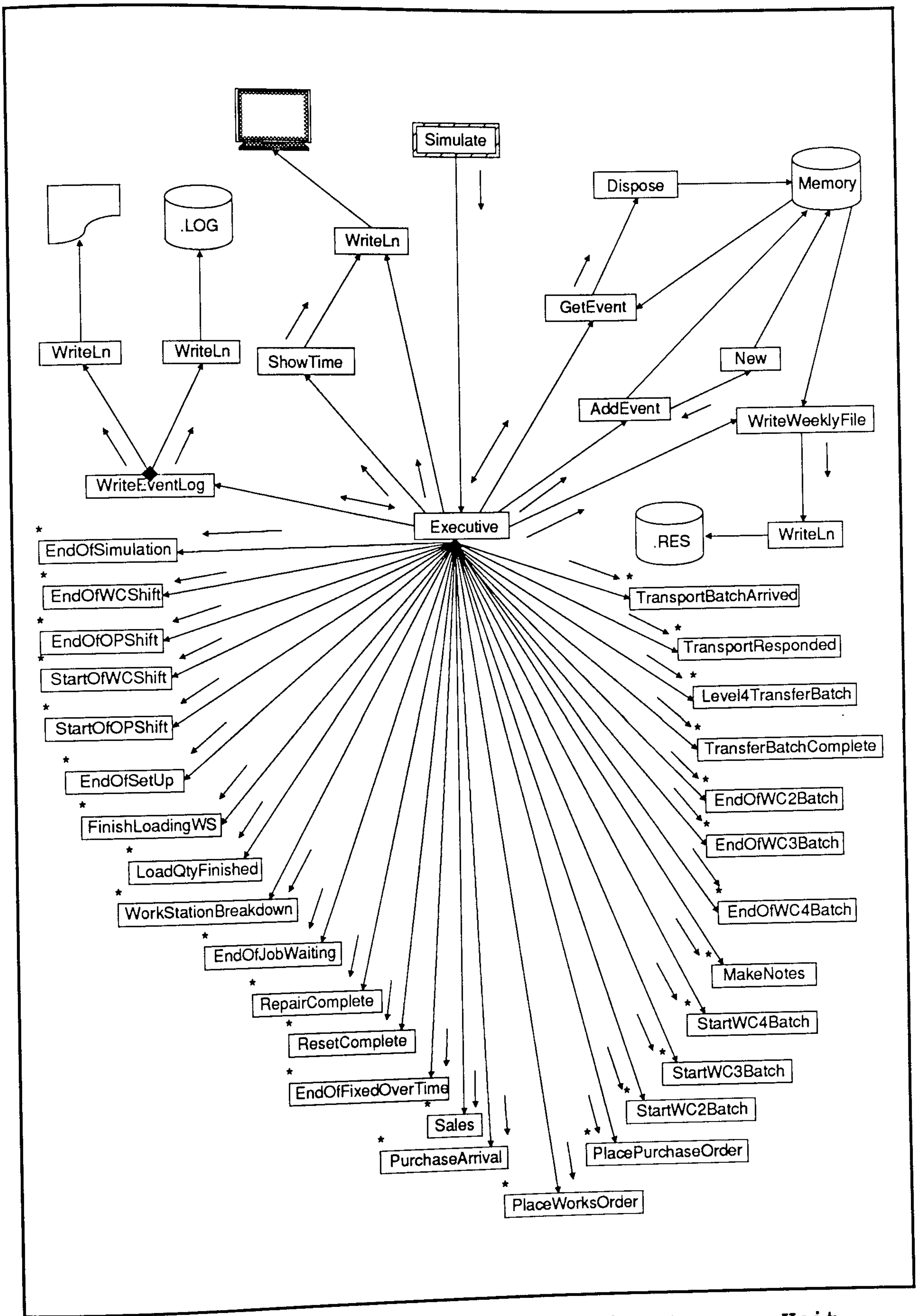


Figure D.50 ATOMS Simulation Executive Program Unit

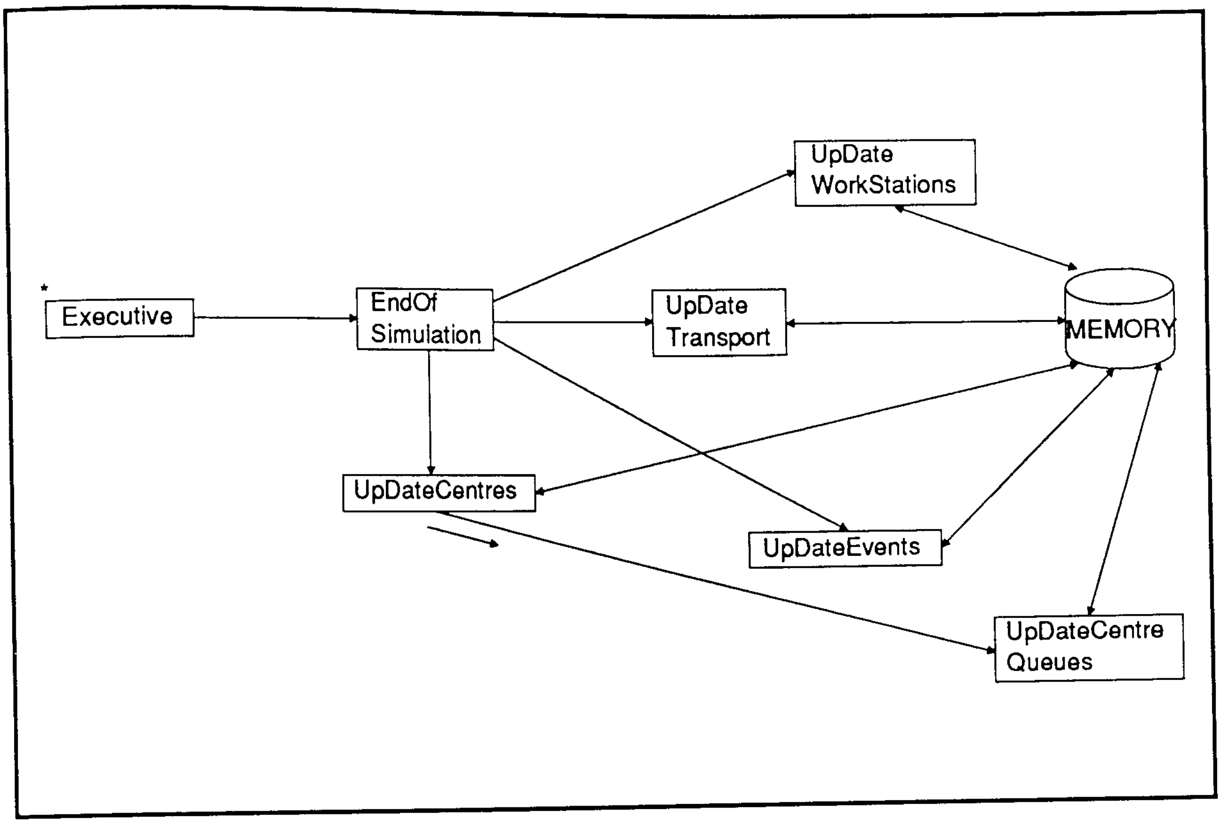


Figure D.51 ATOMS End of Simulation Event Program

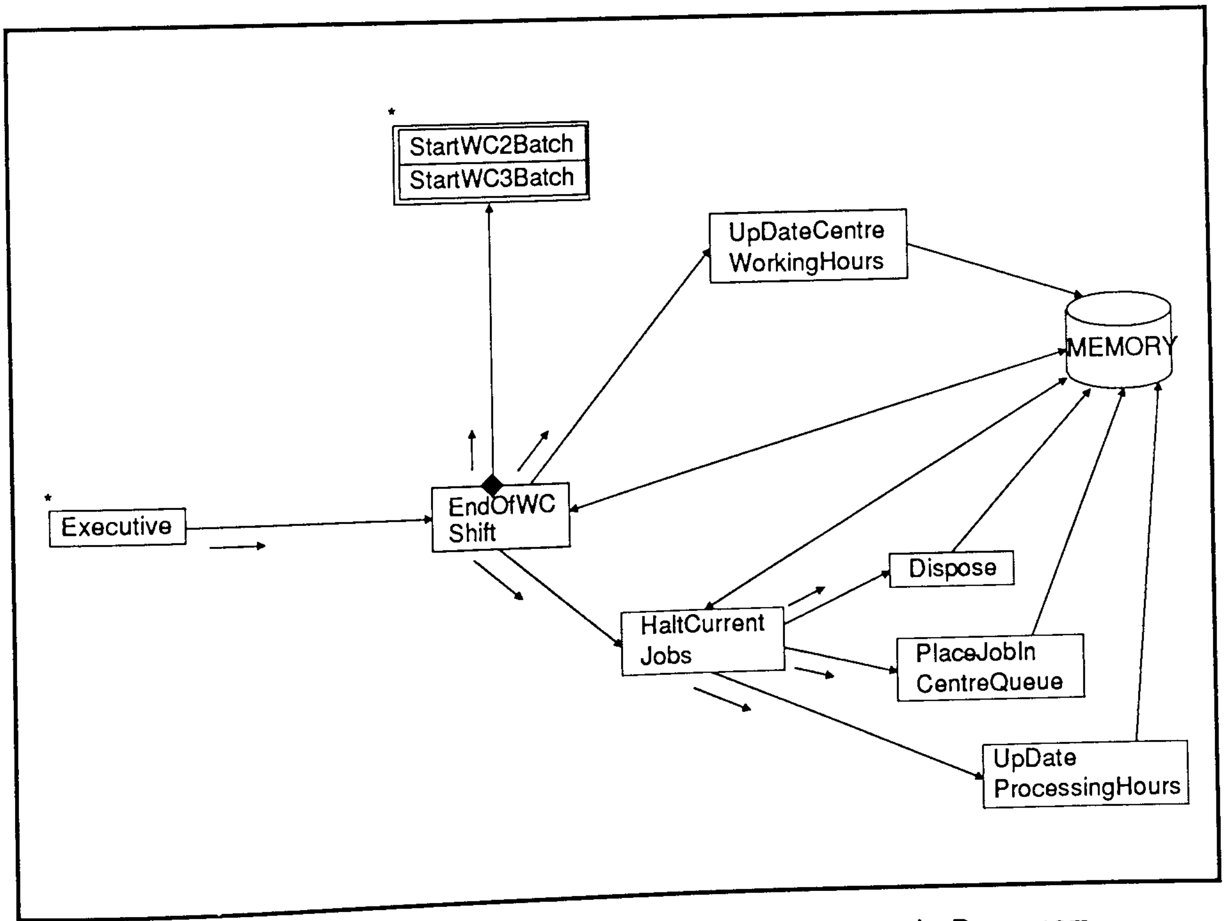


Figure D.52 ATOMS End Of W/C Shift Event Program

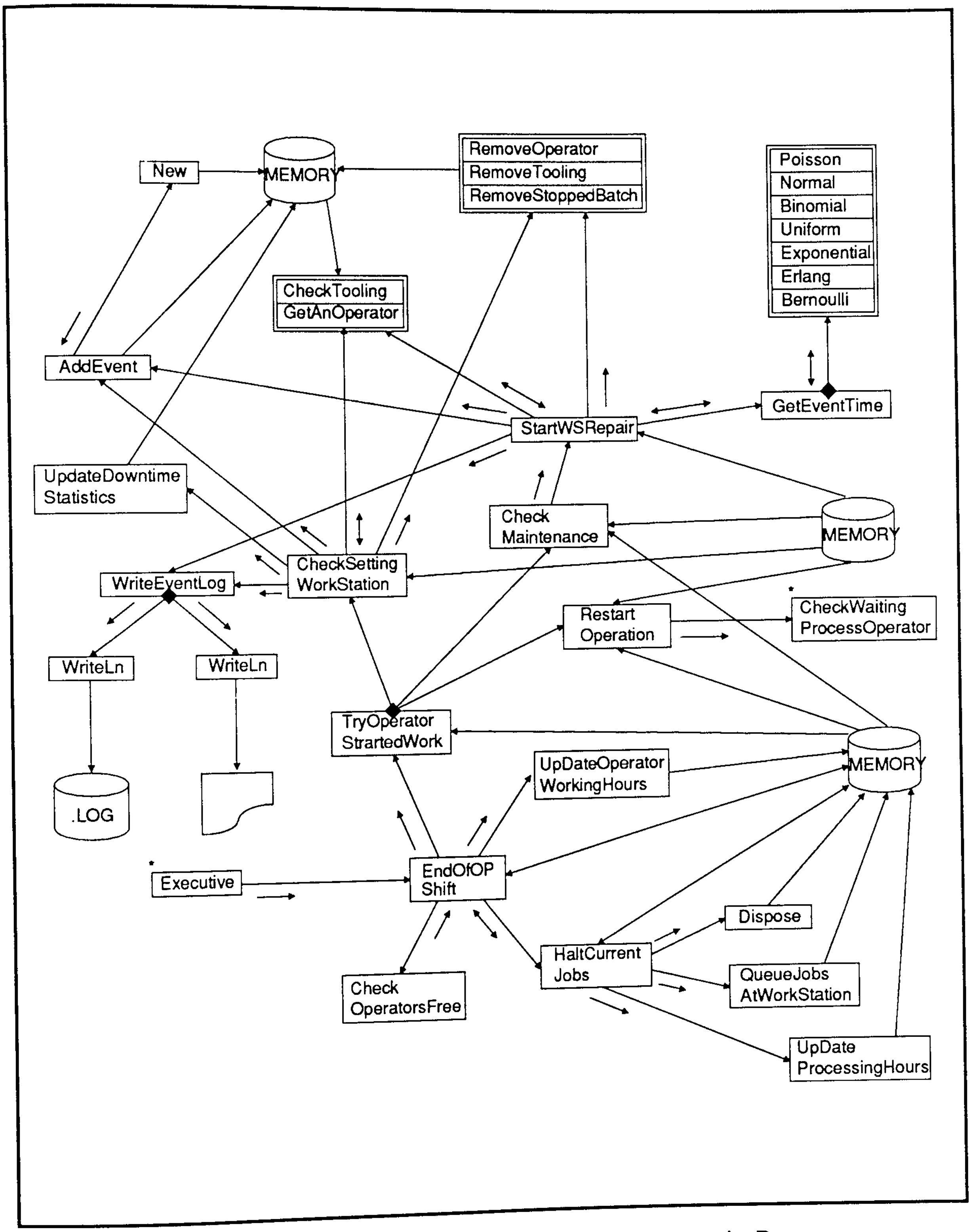


Figure D.53 ATOMS End of Op. Shift Event Program

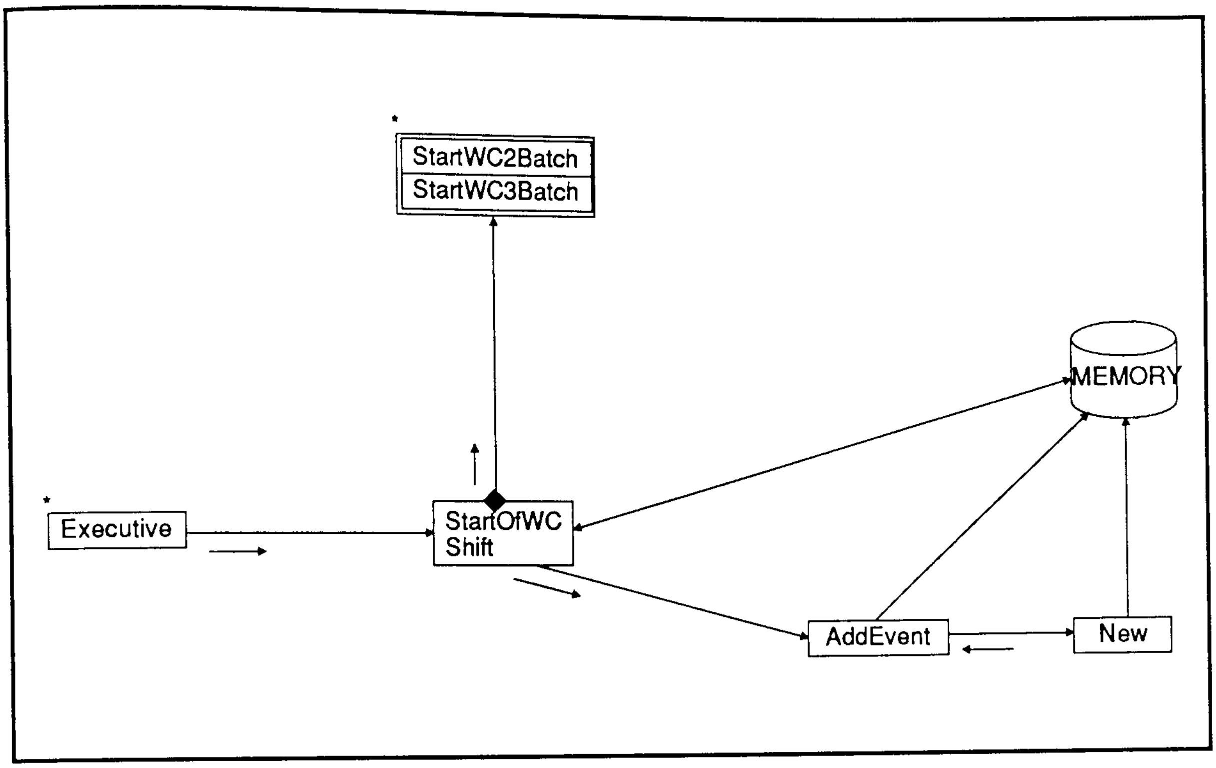


Figure D.54 ATOMS Start of W/C Shift Event Program

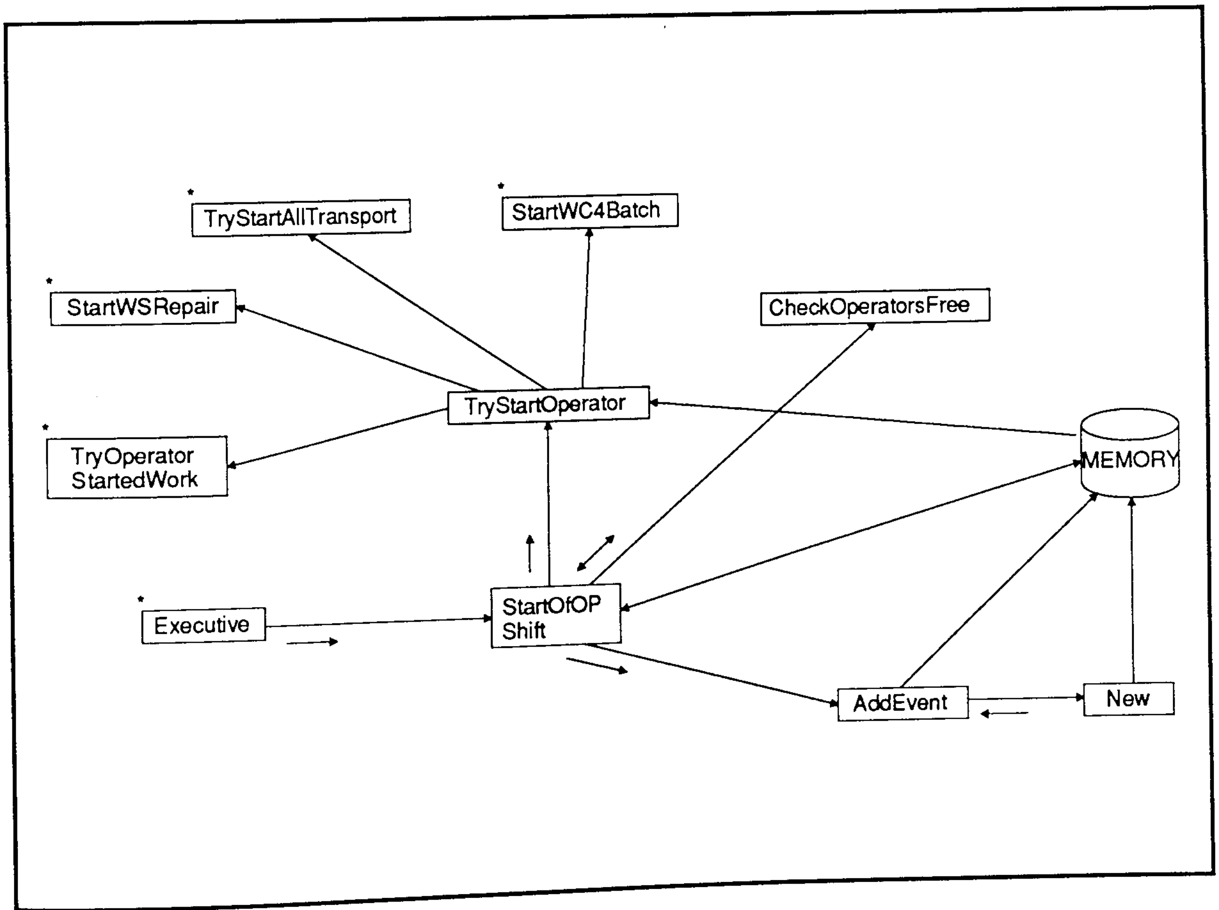


Figure D.55 ATOMS Start of Op. Shift Event Program

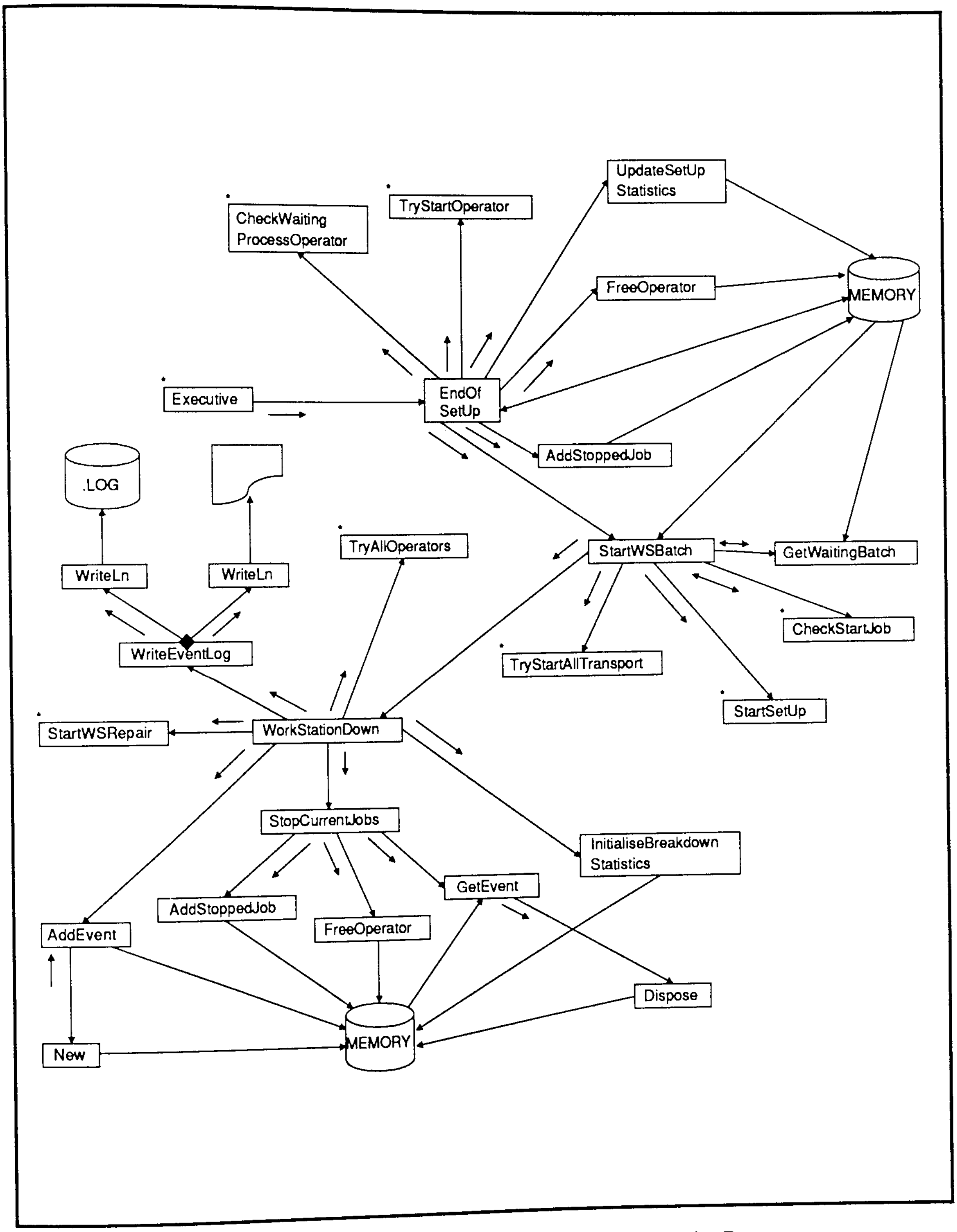


Figure D.56 ATOMS End of Set-up Event Program

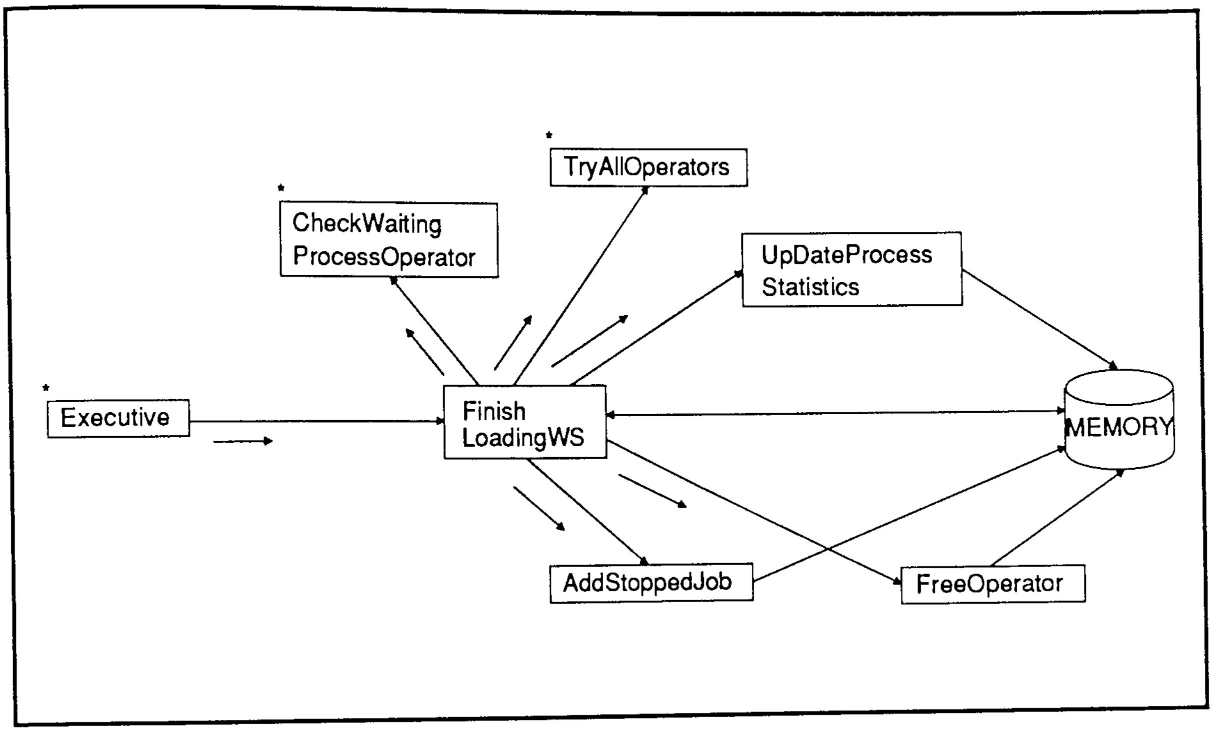


Figure D.57 ATOMS Finished Loading W/S Event Program

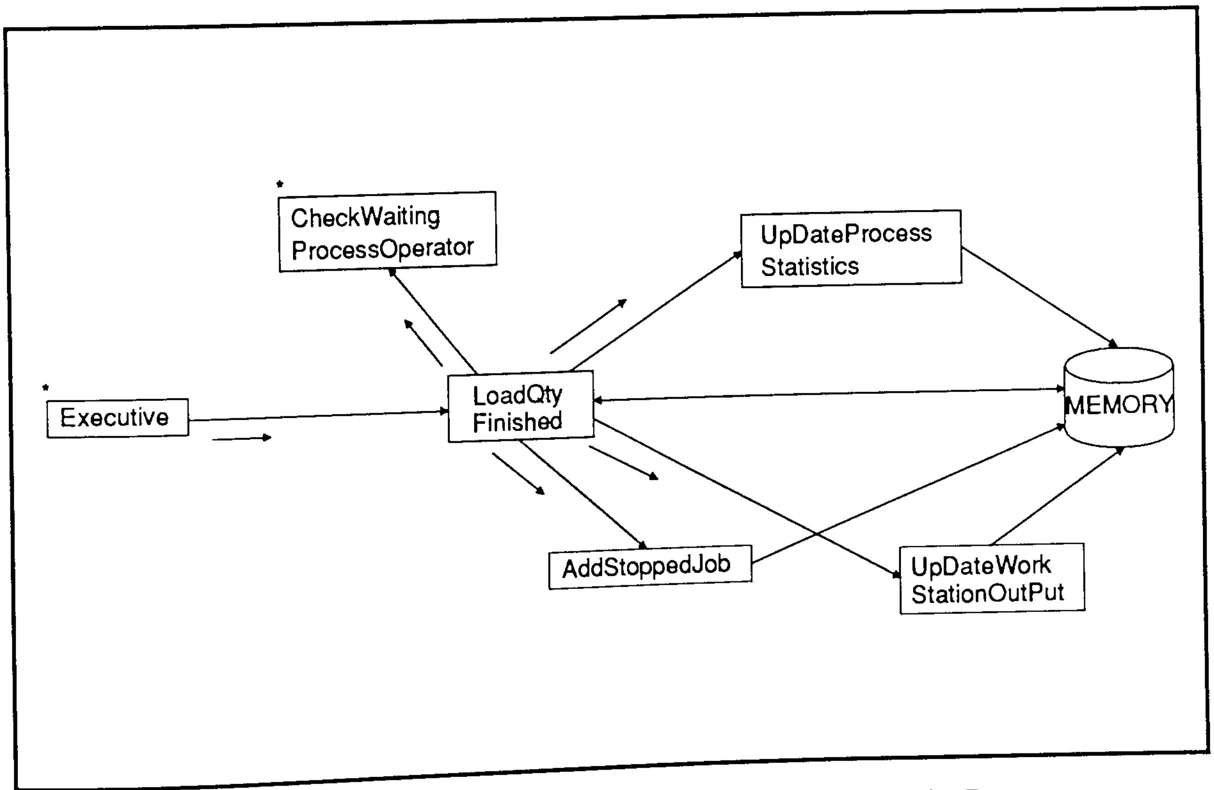


Figure D.58 ATOMS Load Qty. Finished Event Program

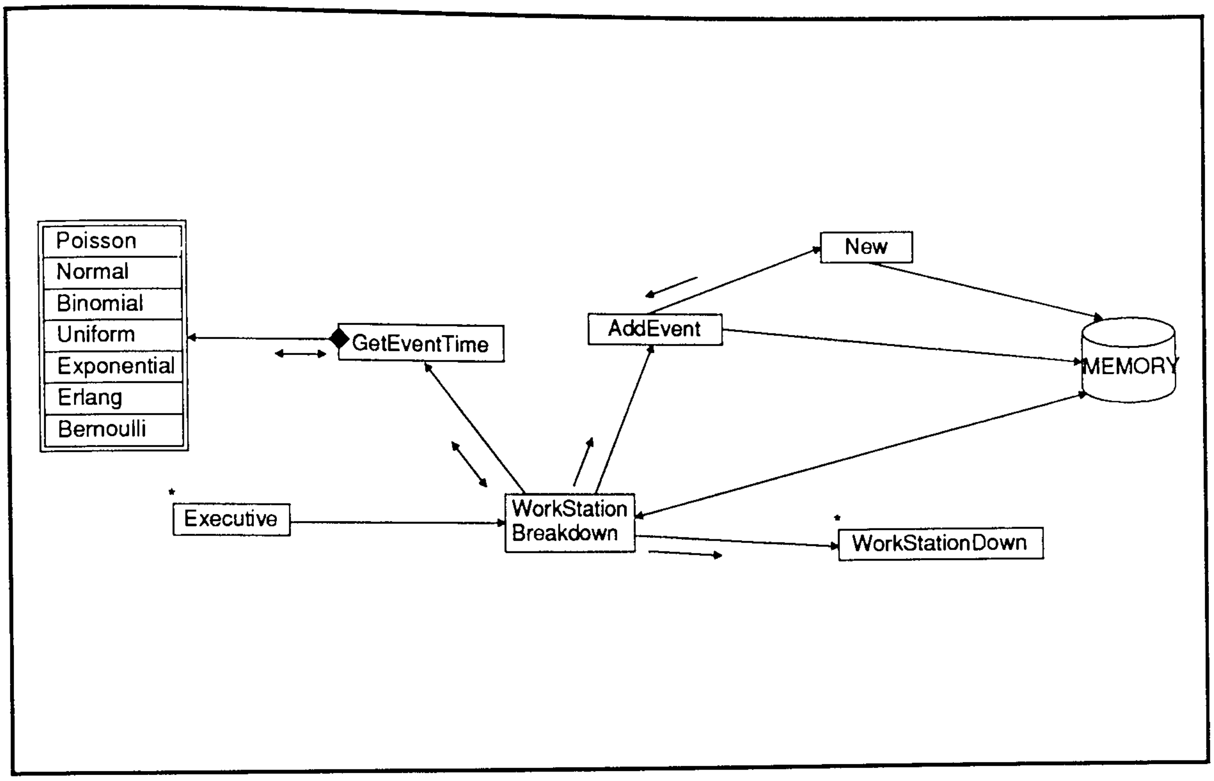


Figure D.59 ATOMS Work Station Breakdown Event Program

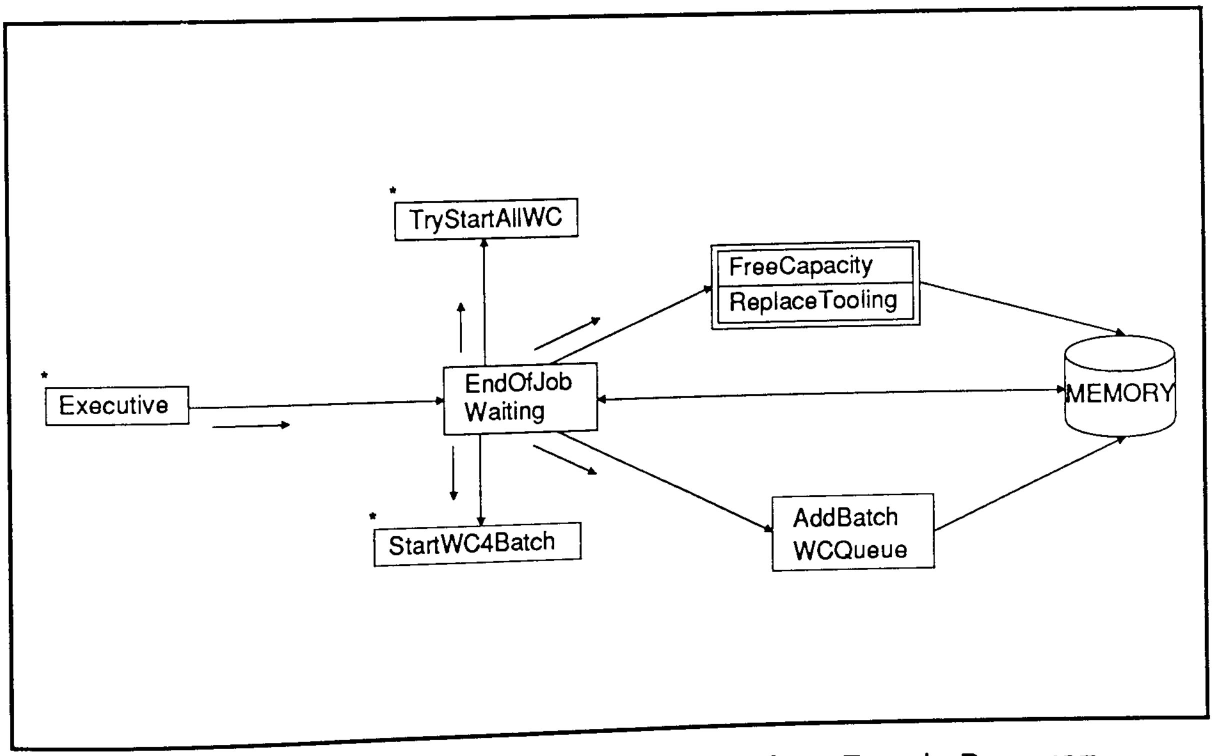


Figure D.60 ATOMS End of Job Waiting Event Program

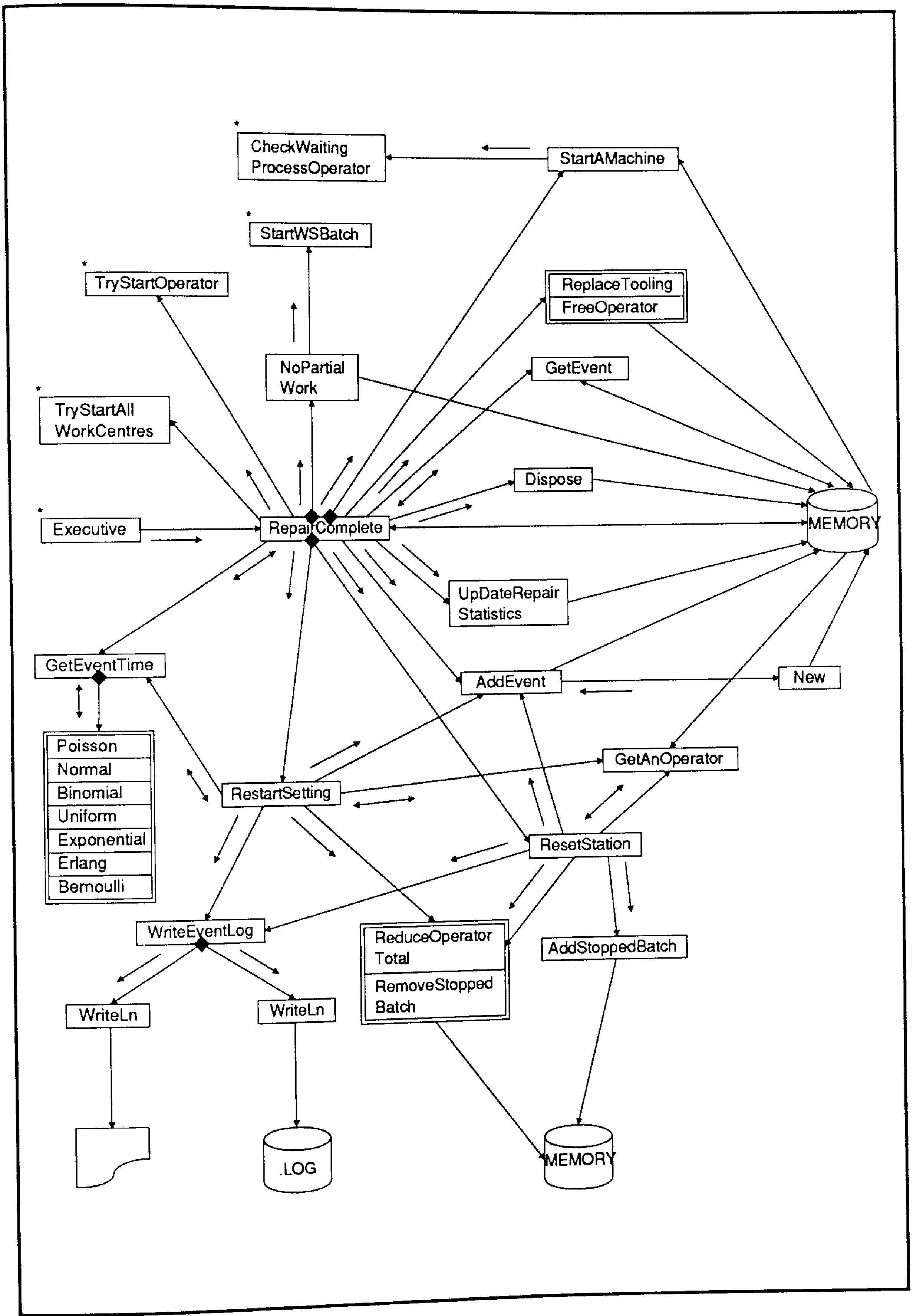


Figure D.61 ATOMS Repair Complete Event Program

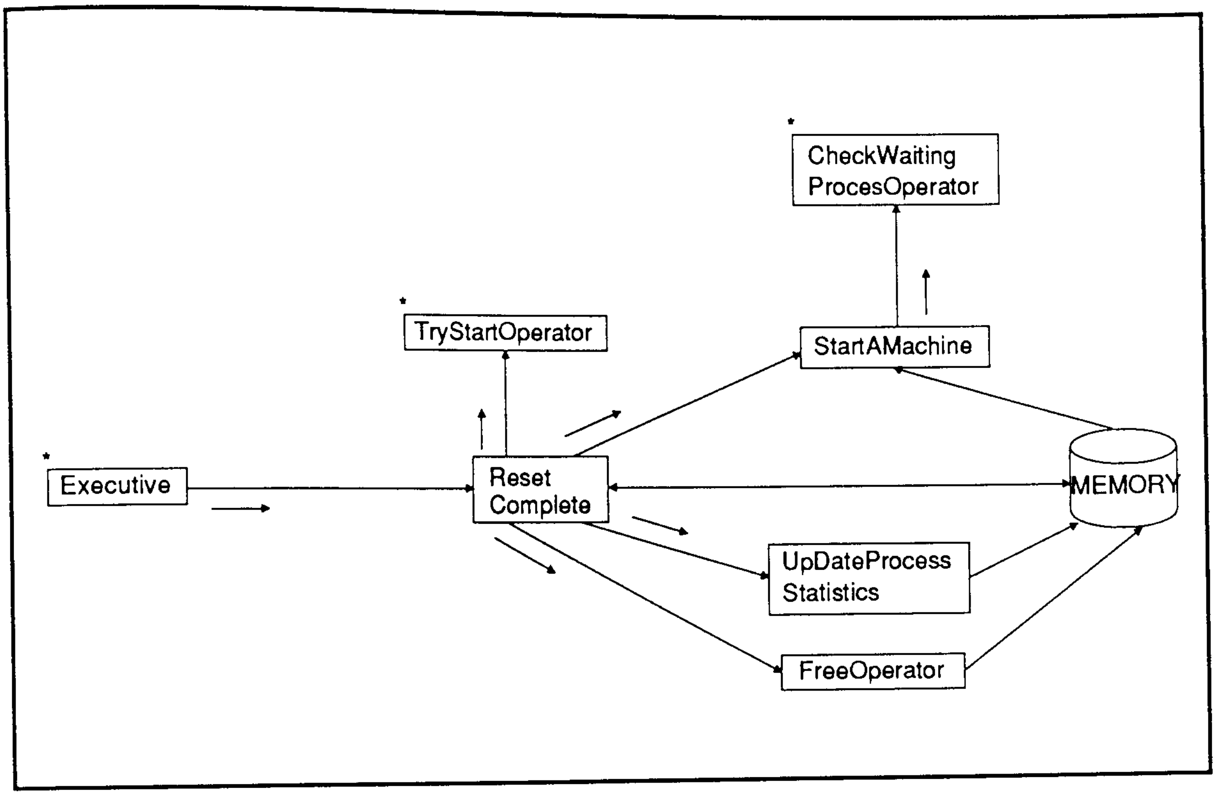


Figure D.62 ATOMS Reset Complete Event Program

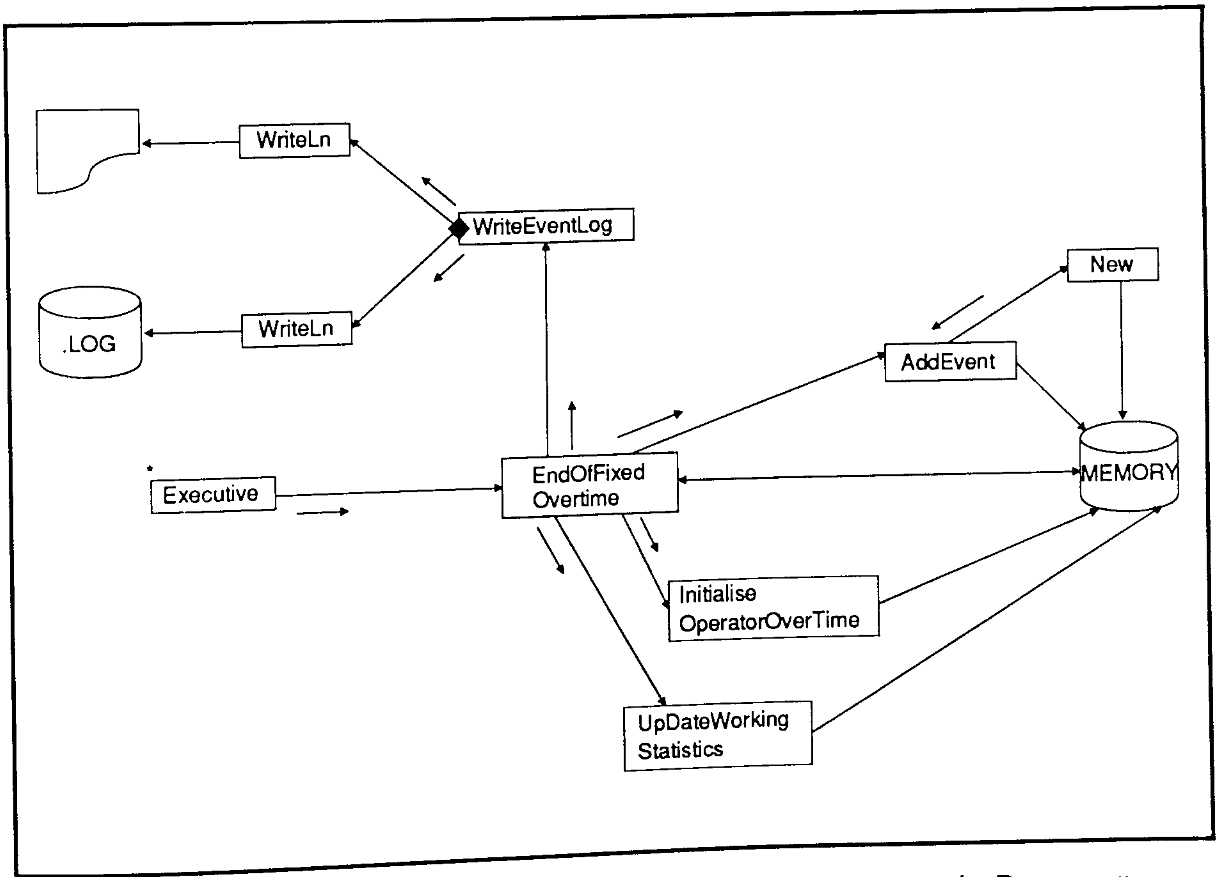


Figure D.63 ATOMS End of Fixed Overtime Event Program

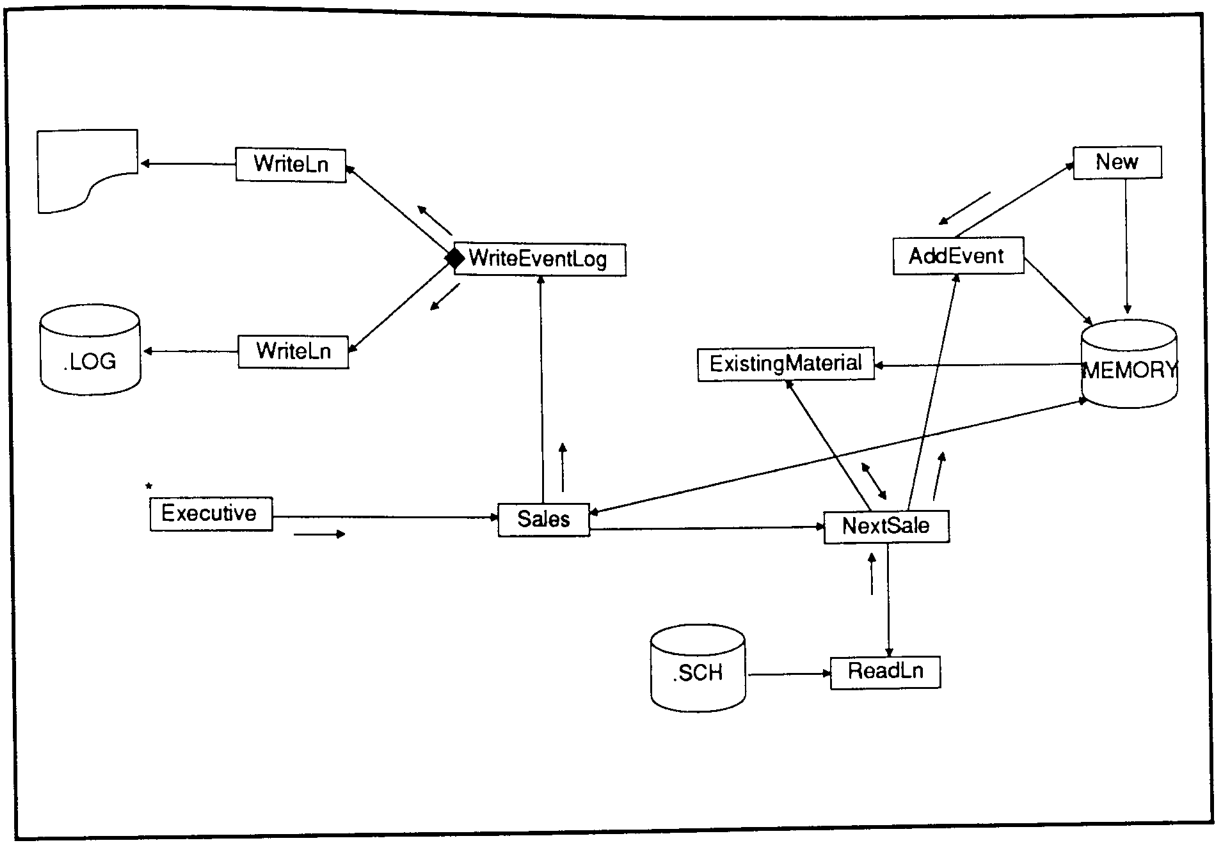


Figure D.64 ATOMS Sales Event Program

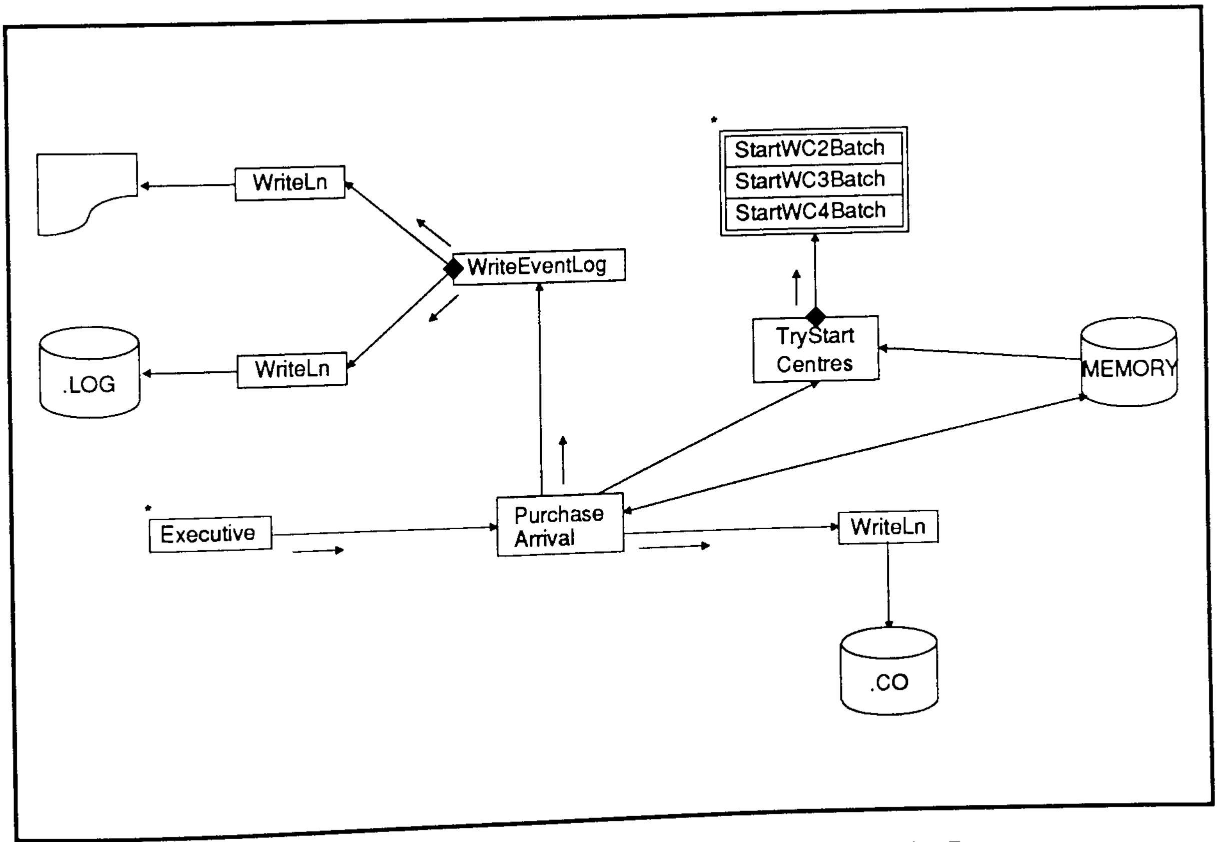


Figure D.65 ATOMS Purchase Arrival Event Program

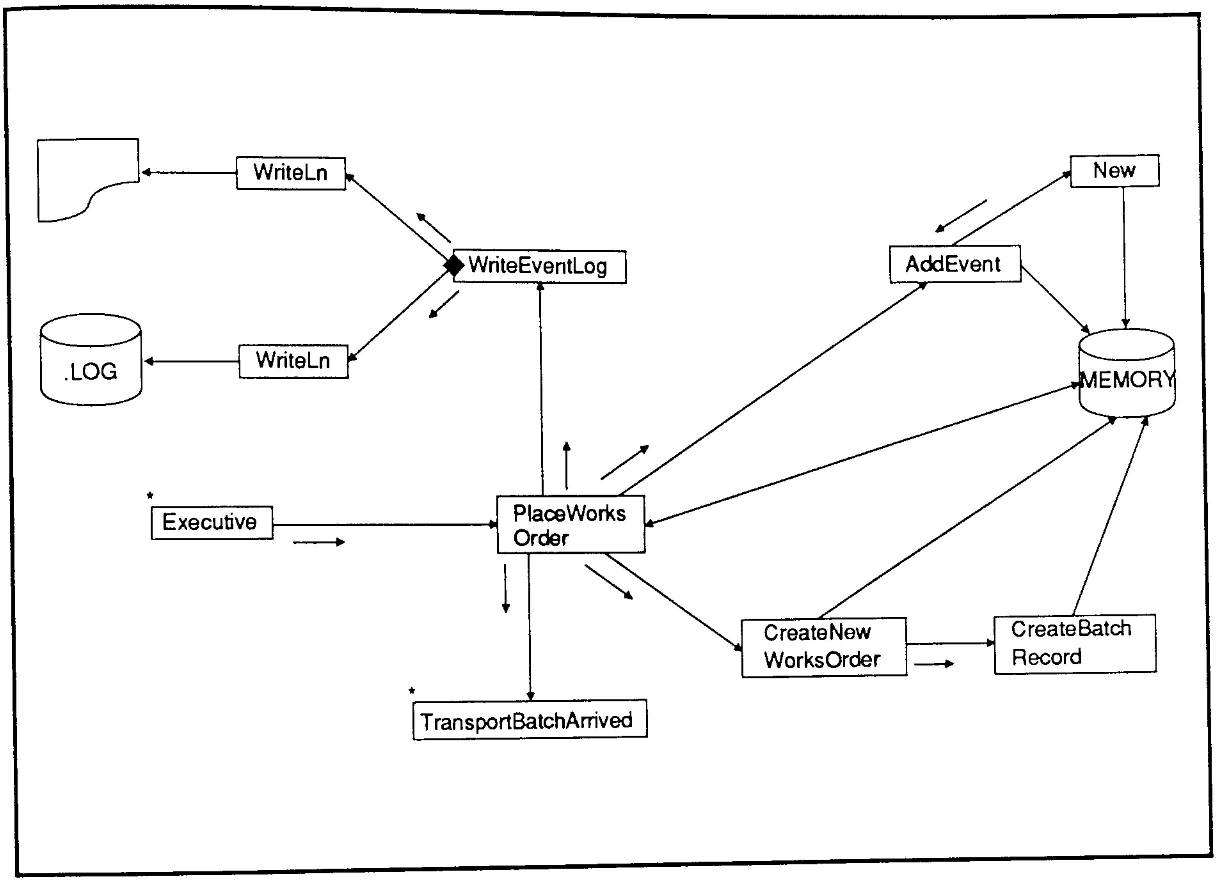


Figure D.66 ATOMS Place Works Order Event Program

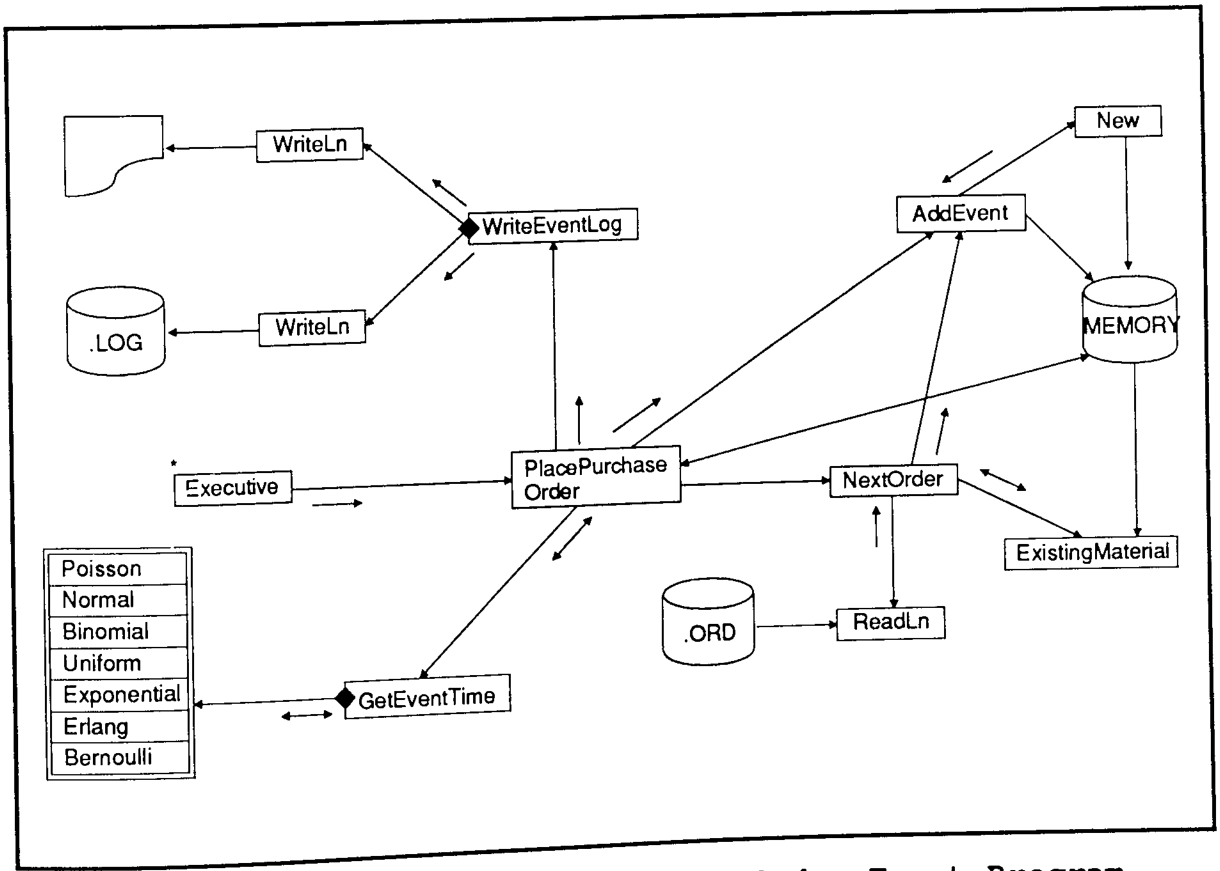


Figure D.67 ATOMS Place Purchase Order Event Program

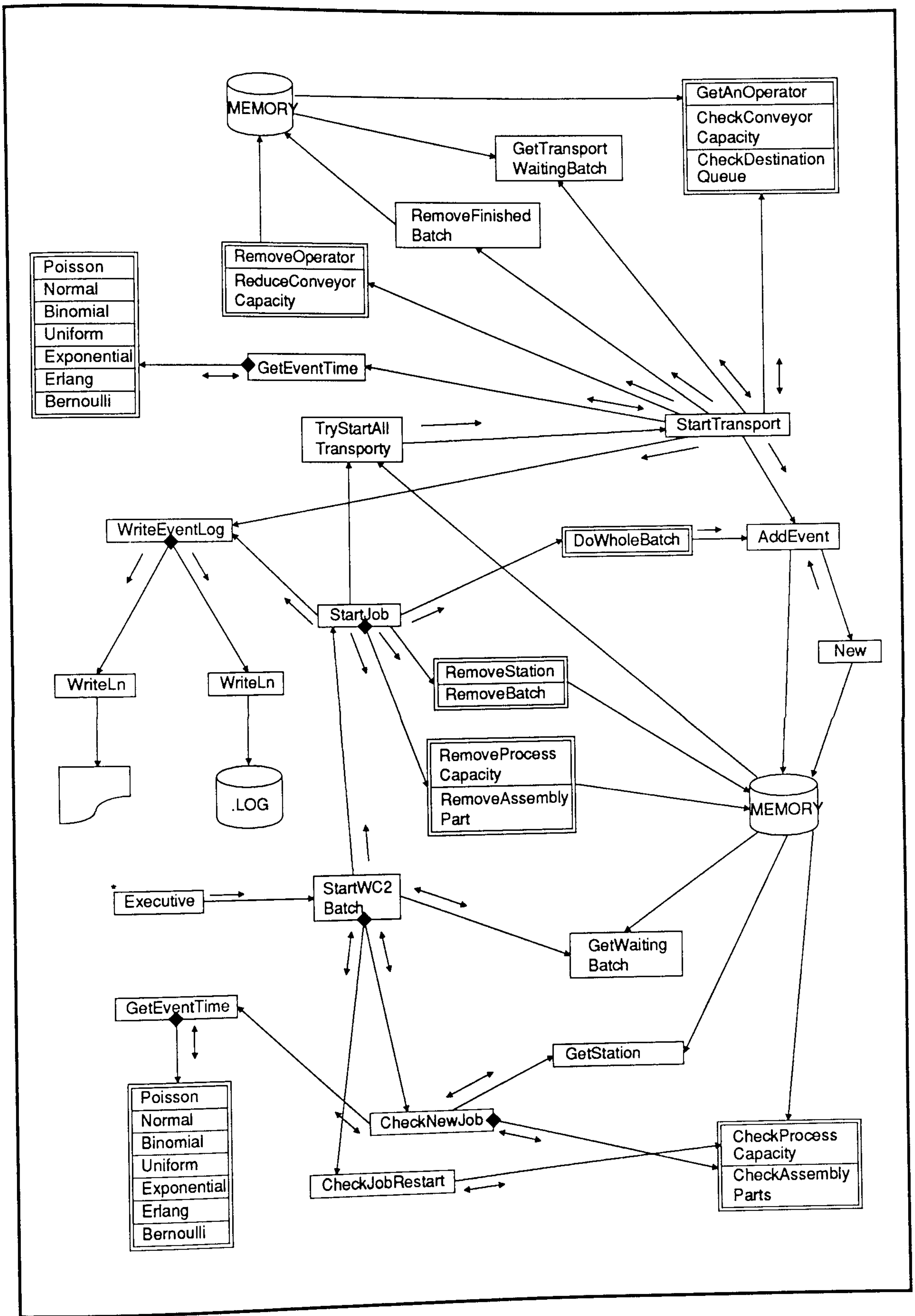


Figure D.68 ATOMS Start DEPARTMENT Centre Event Program

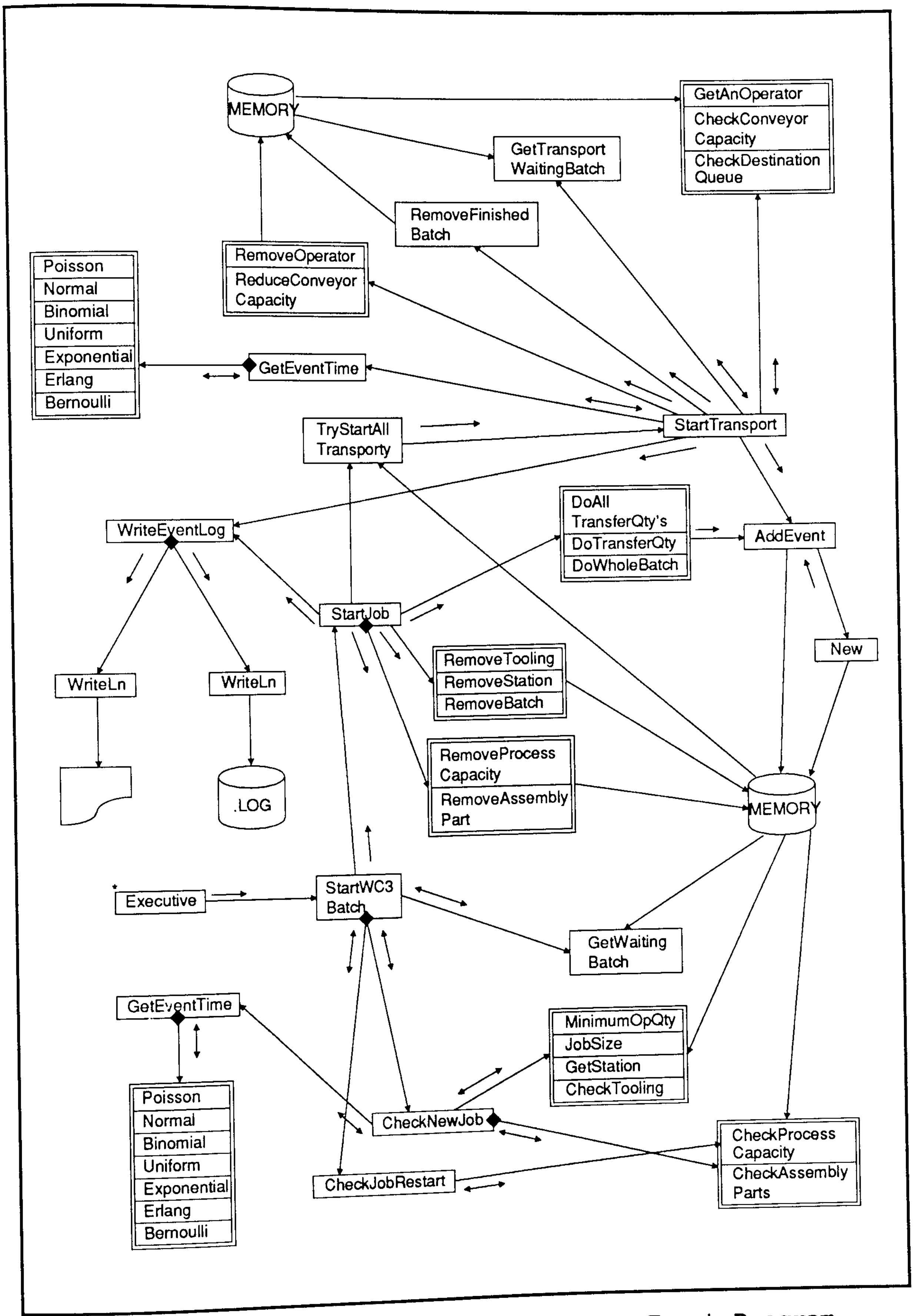


Figure D.69 ATOMS Start CENTRE Centre Event Program

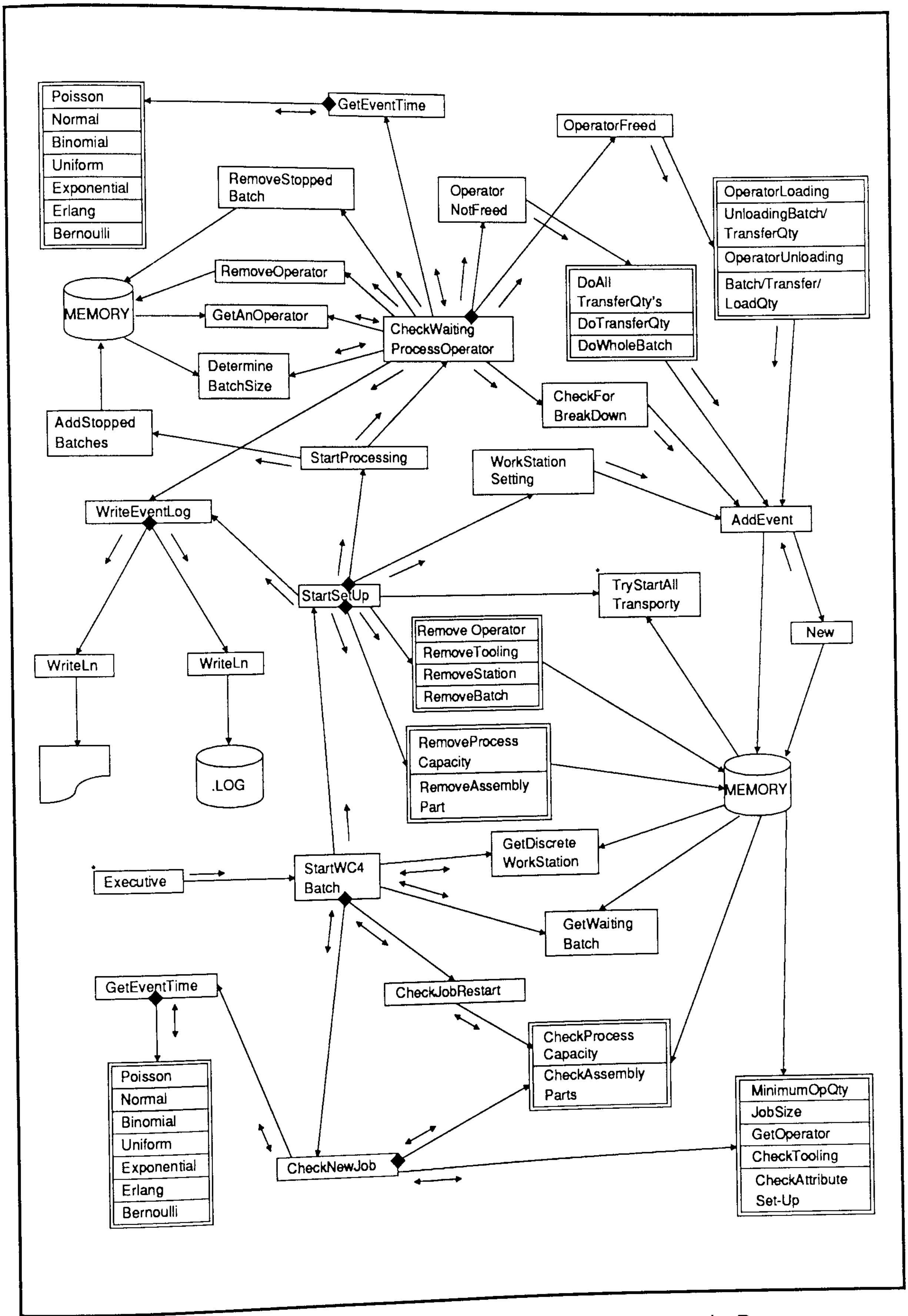


Figure D.70 ATOMS Start STATION Centre Event Program

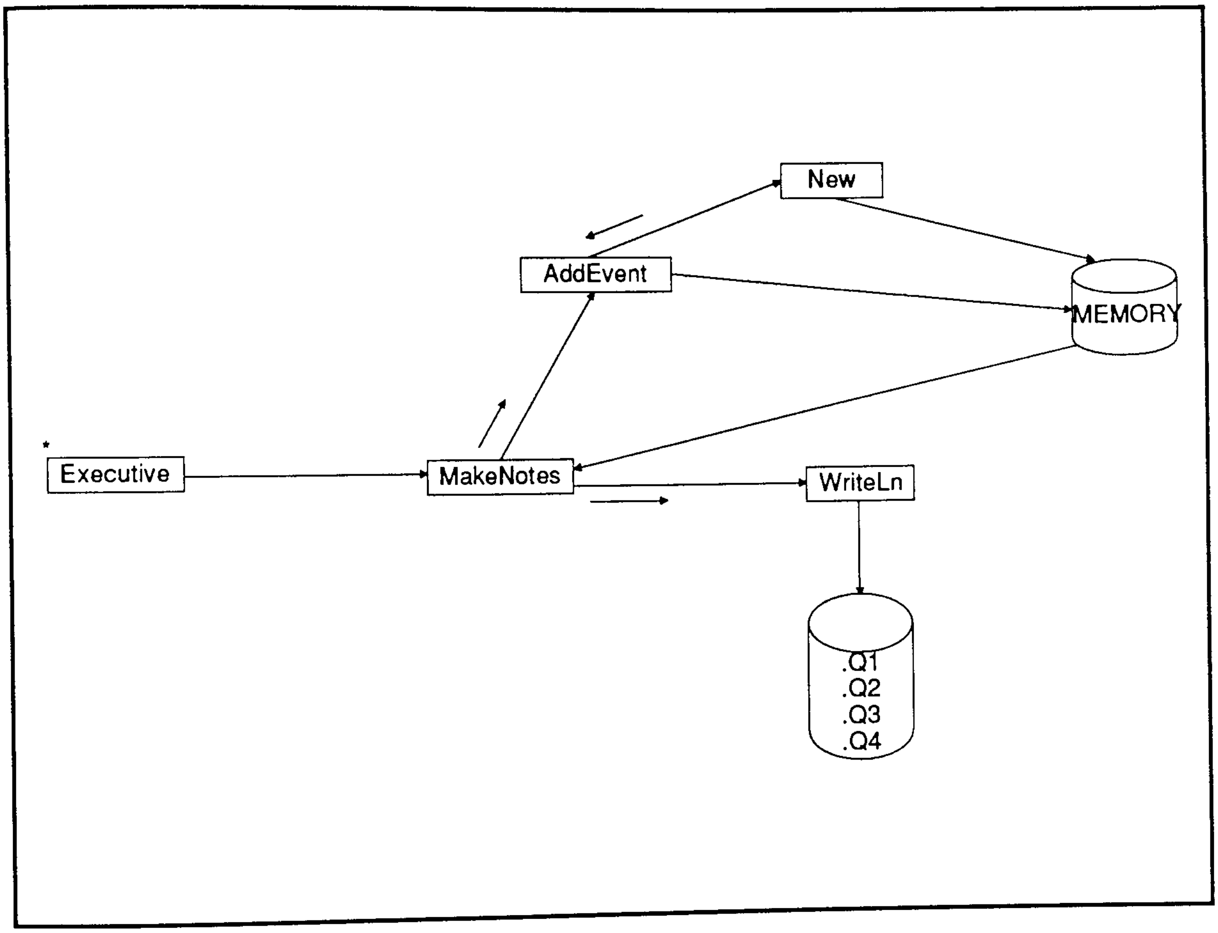


Figure D.71 ATOMS Note Queue Size Event Program

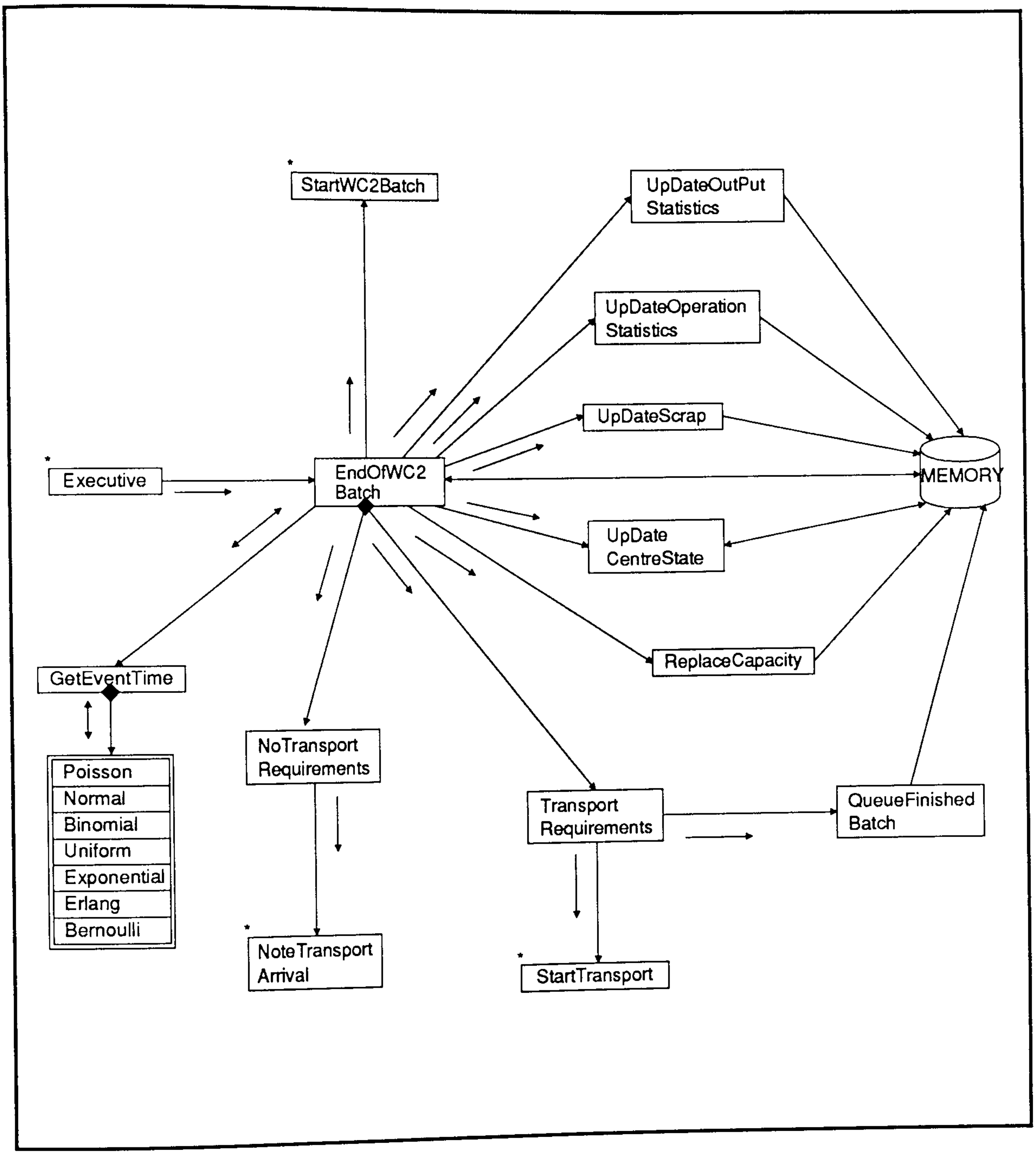


Figure D.72 ATOMS End of DEPARTMENT Job Event Program

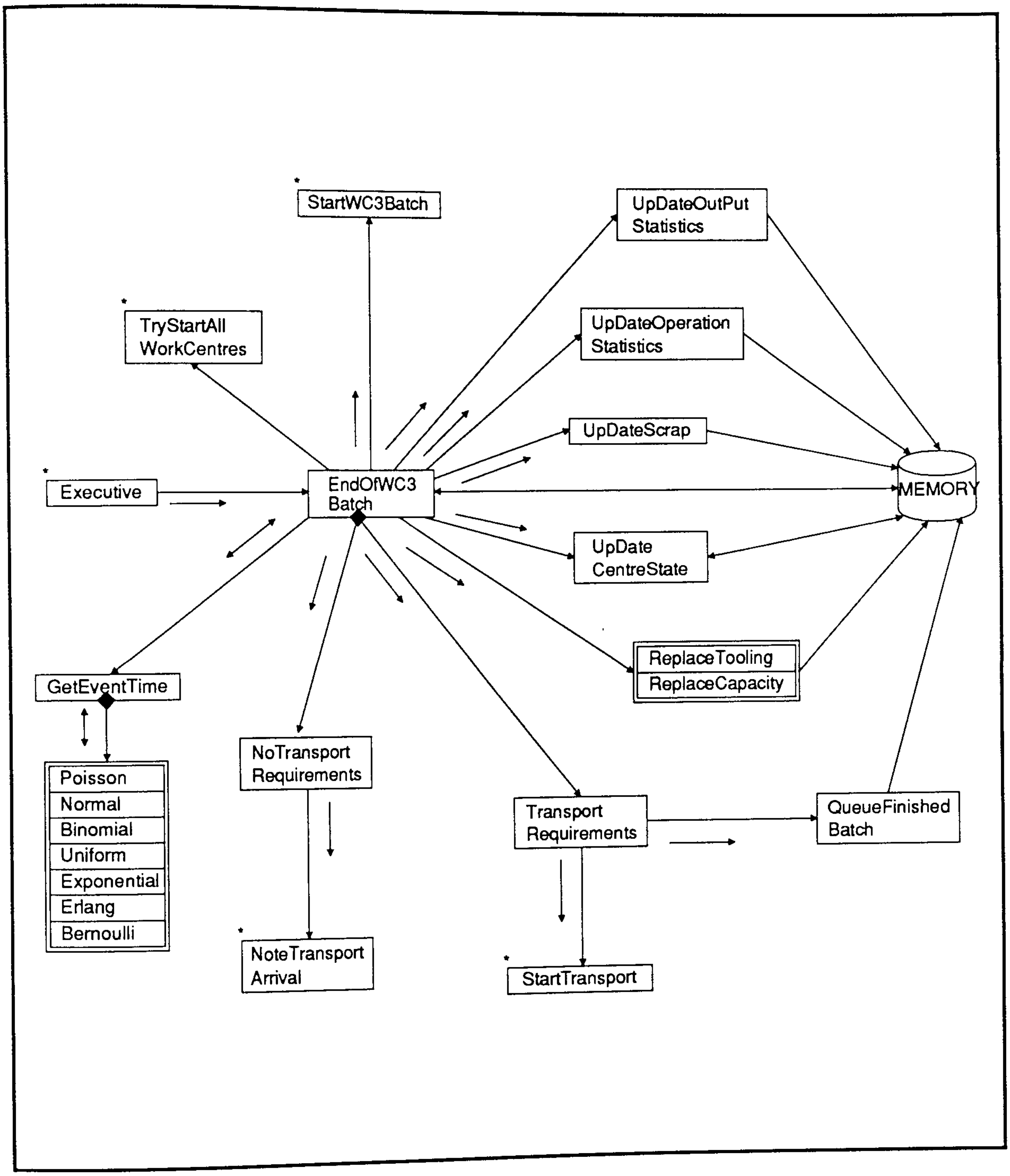


Figure D.73 ATOMS End of CENTRE Job Event Program

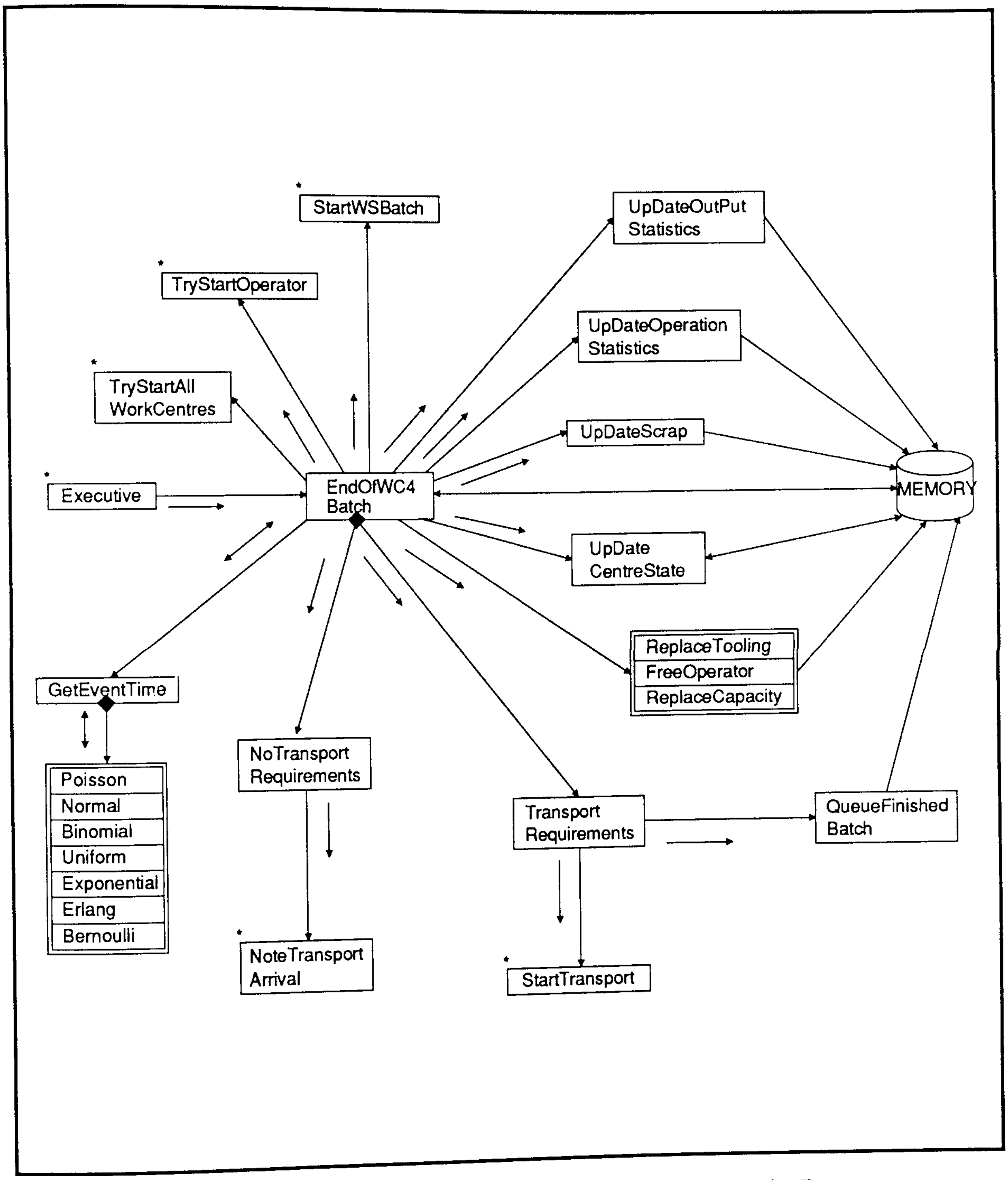


Figure D.74 ATOMS End of STATION Job Event Program

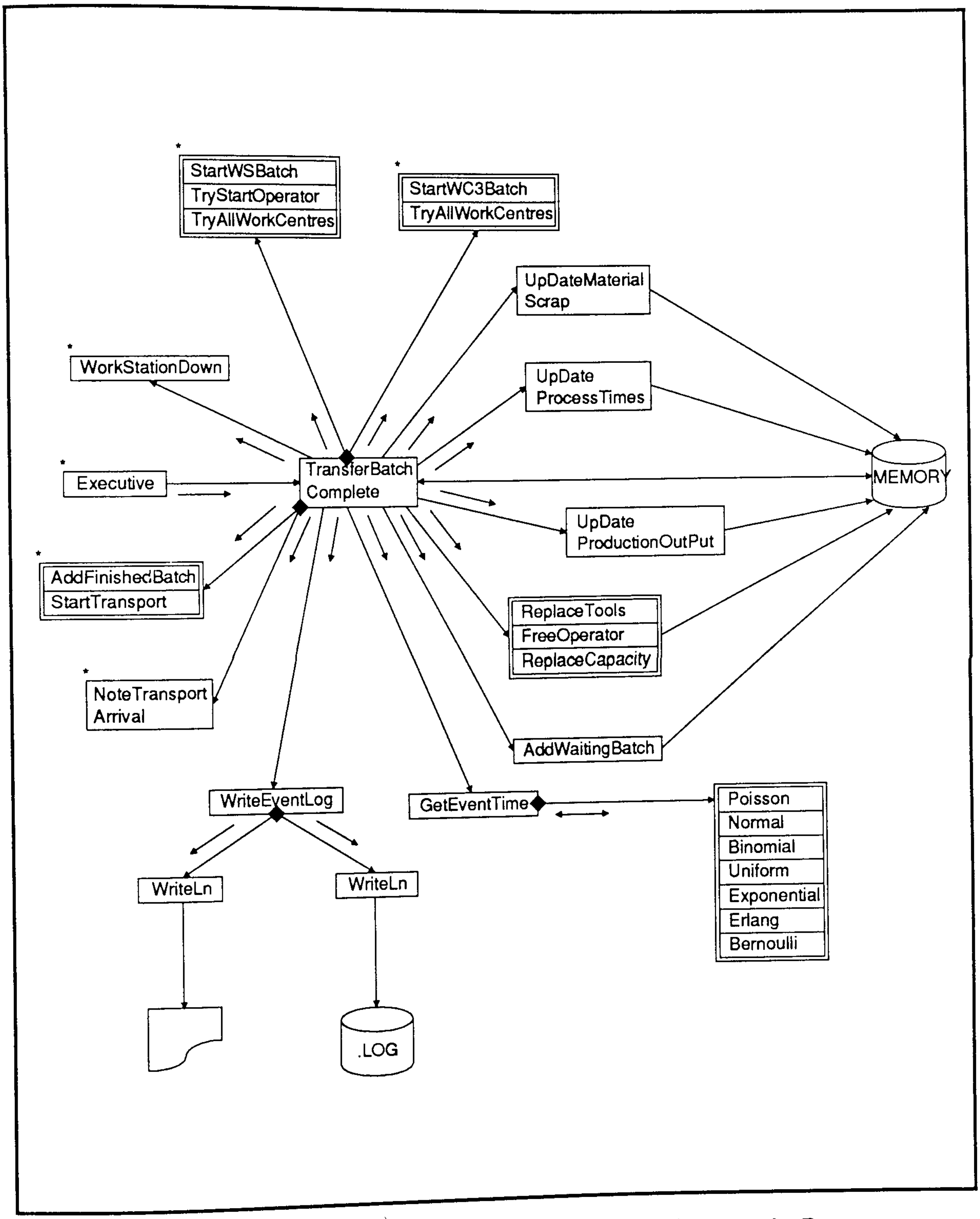


Figure D.75 ATOMS CENTRE Transfer Batch Event Program

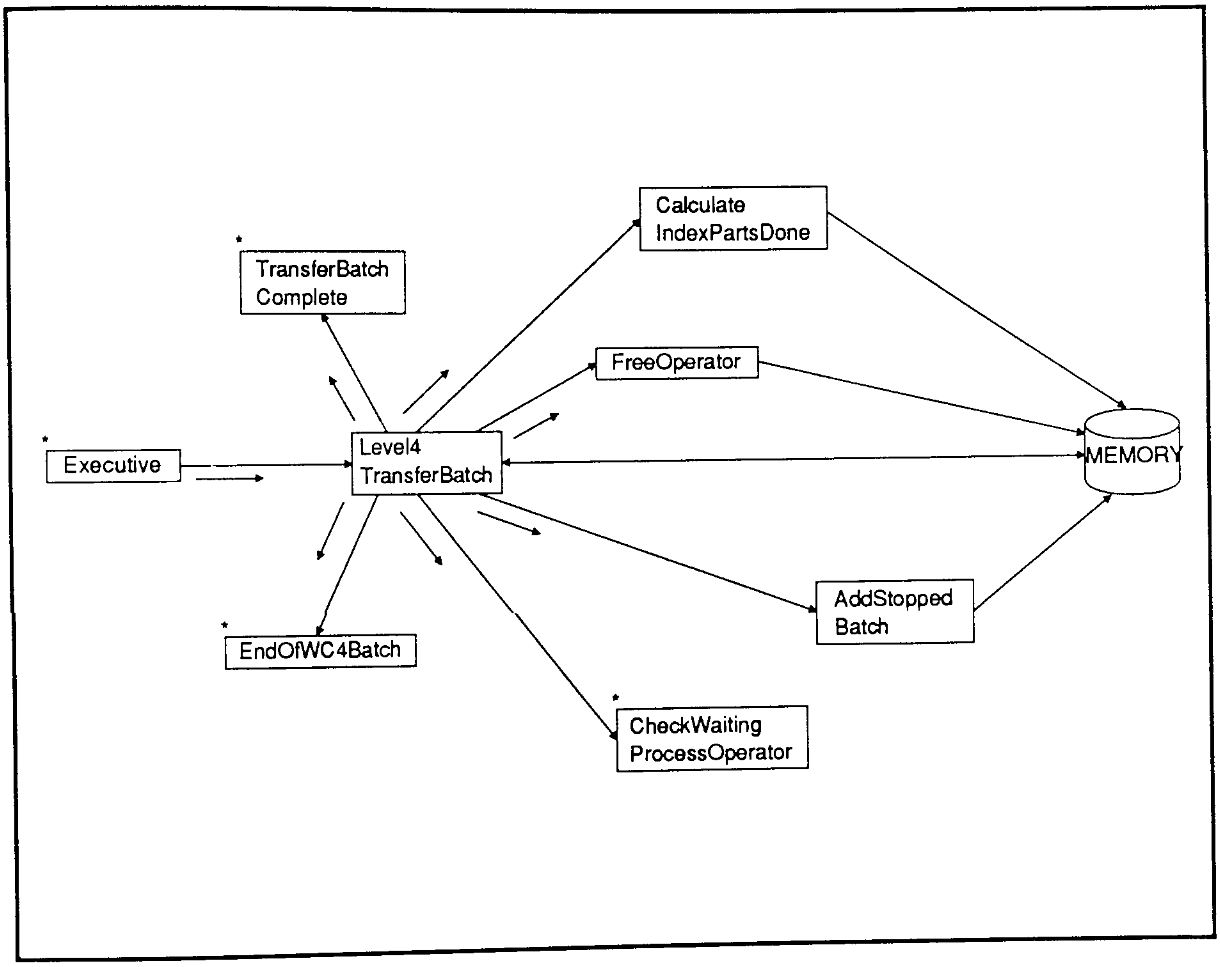


Figure D.76 ATOMS STATION Transfer Batch Event Program

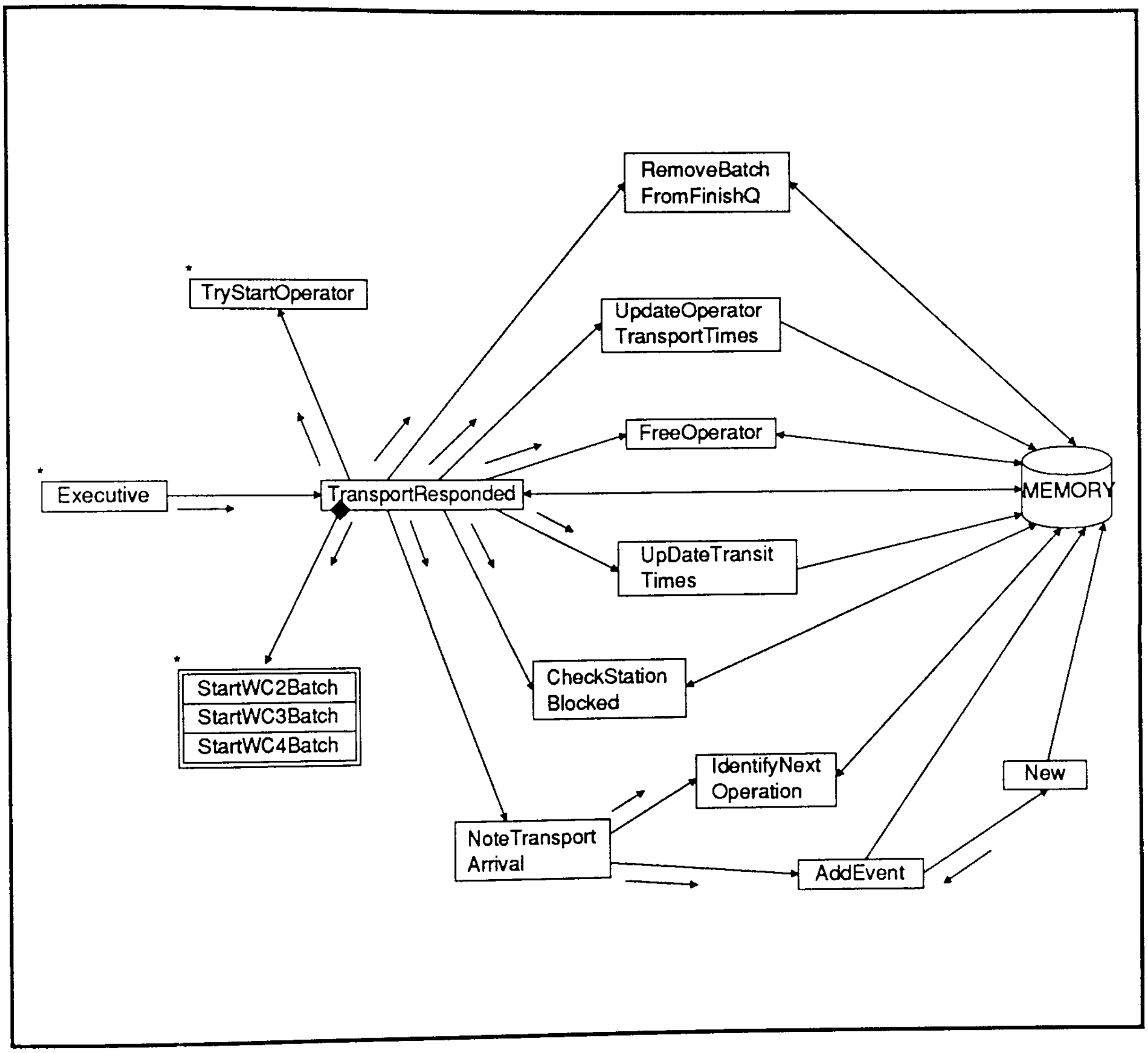


Figure D.77 ATOMS Transport Responded Event Program

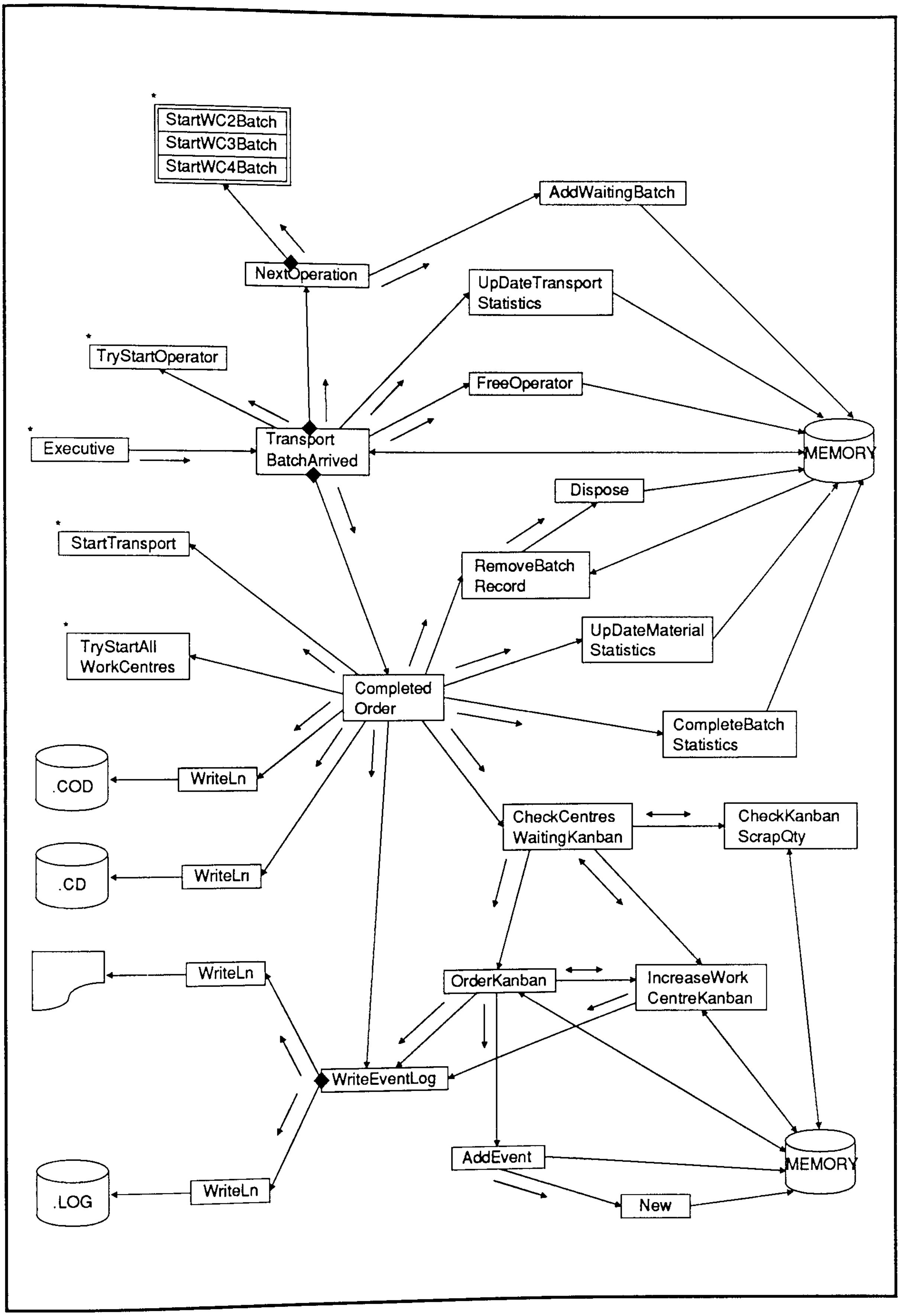


Figure D.78 ATOMS Transport Batch Arrived Event Program

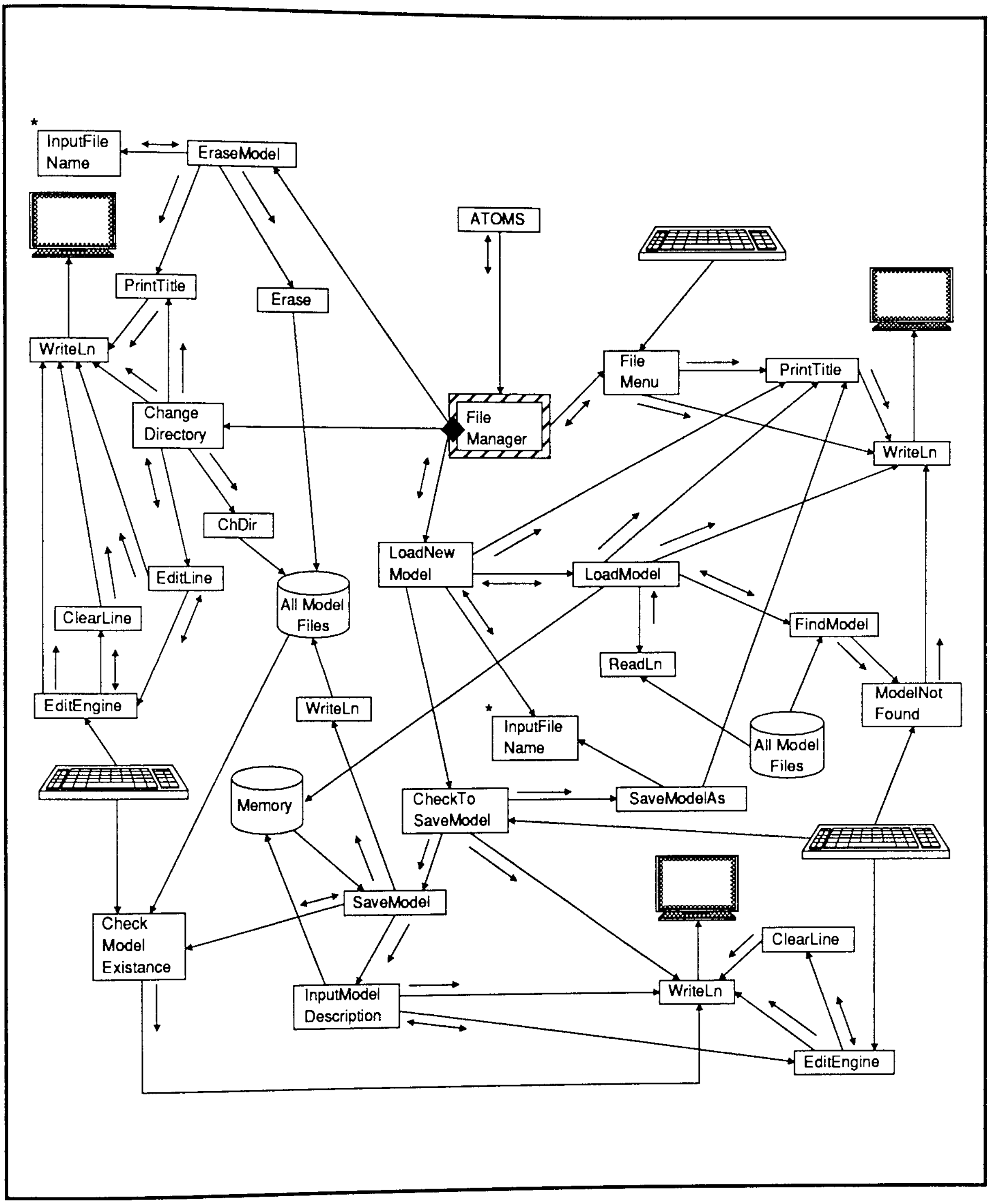


Figure D.79 ATOMS File Manager Program Unit

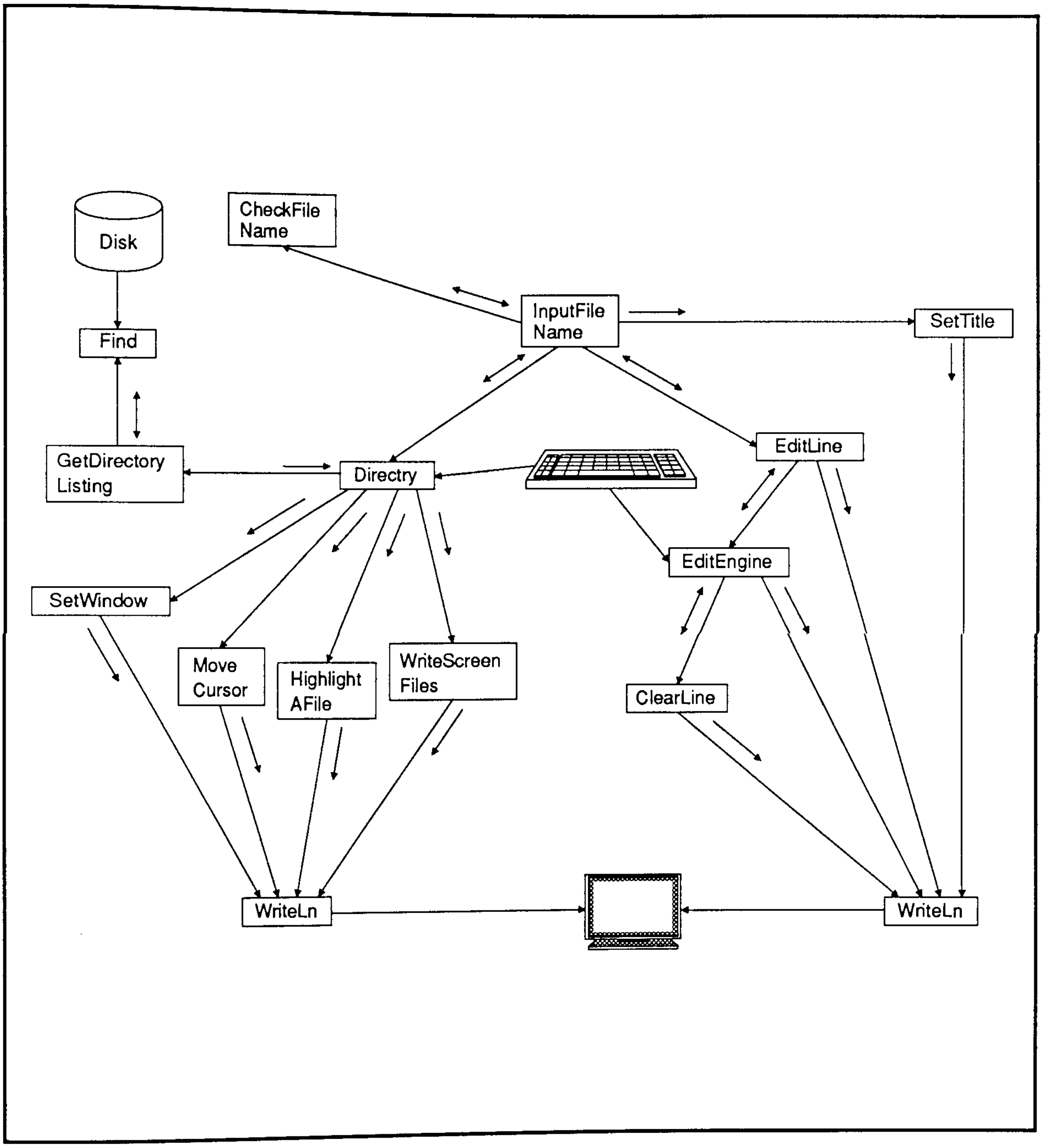


Figure D.80 ATOMS File Name Input Program Unit

Appendix E Cell 12 Station Level Model

Work Stations:

No.	Work Station Name	Type	Breakdowns 1	2	3	4	Associated WorkCentre	Associated Operator	Effi~
1	CMATIC211	Assembly	3	12	0	0	CMATIC-MAC	AUTO_OP_GR	90.0
2	CMATIC212	Assembly	3	12	0	0	CMATIC-MAC	AUTO_OP_GR	90.0
3	MILL213	Manual	5	15	0	0	FELL-MILL	MILL_OPS	100.0
4	MILL214	Manual	5	15	0	0	FELL-MILL	MILL_OPS	100.0
5	MILL215	Manual	5	15	0	0	FELL-MILL	MILL_OPS	100.0
6	MILL216	Manual	5	15	0	0	FELL-MILL	MILL_OPS	100.0
7	BROACH217	Manual	5	15	0	0	PER-BROACH	BROACH_OPS	95.0
8	BROACH218	Manual	5	15	0	0	PER-BROACH	BROACH_OPS	95.0
9	CMATIC203	Assembly	4	13	0	0	CMATIC-TRN	AUTO_OP_SP	95.0
10	CMATIC204	Assembly	2	11	0	0	CMATIC-TRN	AUTO_OP_SP	80.0
11	CMATIC205	Assembly	4	13	0	0	CMATIC-TRN	AUTO_OP_SP	95.0
12	HEAT-TR206	Manual	5	15	0	0	HEAT-TREAT	HT_OPS	95.0
13	GRIND207	Manual	1	10	0	0	GRIND	GRIND_OPS	85.0
14	GRIND208	Manual	1	10	0	0	GRIND	GRIND_OPS	85.0
15	GRIND209	Manual	1	10	0	0	GRIND	GRIND_OPS	85.0
16	GRIND210	Manual	1	10	0	0	GRIND	GRIND_OPS	85.0
17	PRESS219	Assembly	4	14	0	0	PRESS-12TN	PRESS_OPS	100.0
18	PRESS220	Assembly	4	14	0	0	PRESS-12TN	PRESS_OPS	100.0
19	INSP001	Manual	0	0	0	0	INSPECTION	INSPECTORS	100.0
20	INSP002	Manual	0	0	0	0	INSPECTION	INSPECTORS	100.0

Breakdowns:

No.	Type	Breakdown Interval	End Job	Repair Operator	Time	Number Tools	Wait Move
1	TIMEOUTPUT	6.0F	N	ENGINEERS	5.0F	0	60.0F
2	TIMEOUTPUT	8.0F	N	ENGINEERS	5.0F	0	60.0F
3	TIMEOUTPUT	12.0F	N	ENGINEERS	5.0F	0	60.0F
4	TIMEOUTPUT	16.0F	N	ENGINEERS	5.0F	0	60.0F
5	TIMEOUTPUT	20.0F	N	ENGINEERS	5.0F	0	60.0F
10	TIMEOUTPUT	50.0F	N	ENGINEERS	240.0F	0	0.0F
11	TIMEOUTPUT	100.0F	N	ENGINEERS	480.0F	0	0.0F
12	TIMEOUTPUT	150.0F	N	ENGINEERS	480.0F	0	0.0F
13	TIMEOUTPUT	200.0F	N	ENGINEERS	480.0F	0	0.0F
14	TIMEOUTPUT	200.0F	N	ENGINEERS	120.0F	0	0.0F
15	TIMEOUTPUT	300.0F	N	ENGINEERS	120.0F	0	0.0F

Work Centre: - Department

No.	Centre Name	Operation Type	Schedule	W/S Effi'	Number Shifts	Number Work Stations

Work Centre: - Centre

No.	Centre Name	Operation Type	Schd	Take Head	ReG Bch	Spl Bch	Eff~	Down Per%	Labour Losses	No. Shf	No WS

Work Centre: - Station

No.	Centre Name	Operation Type	Schedule	Take Head	Regroup Batches	Split Batches	Associated W/Stations
1	CMATIC-MAC	Assembly	FIFO	N	N	Y	CMATIC211
							CMATIC212
2	FELL-MILL	Manual	FIFO	N	N	Y	MILL213
							MILL214
							MILL215
							MILL216
3	PER-BROACH	Manual	FIFO	N	N	Y	BROACH217
							BROACH218
4	CMATIC-TRN	Assembly	FIFO	N	N	Y	CMATIC203
							CMATIC204
							CMATIC205
5	HEAT-TREAT	Manual	FIFO	N	N	Y	HEAT-TR206
6	GRIND	Manual	FIFO	N	N	Y	GRIND207
							GRIND208
							GRIND209
							GRIND210
7	PRESS-12TN	Assembly	FIFO	N	N	Y	PRESS219
							PRESS220
8	INSPECTION	Manual	FIFO	N	N	Y	INSP001
							INSP002

Operator Type:

No.	Operator Name	No. Shifts	Number Op'rs	Job Priorities Job 1	Job 2	Job 3	Job 4	% Eff
1	AUTO_OP_SP	2	2	OPERATION				100.0
2	HT_OPS	2	2	OPERATION				100.0
3	GRIND_OPS	2	4	OPERATION				100.0
4	AUTO_OP_GR	2	2	OPERATION				100.0
5	MILL_OPS	2	8	OPERATION				85.0
6	BROACH_OPS	2	4	OPERATION				100.0
7	PRESS_OPS	2	4	OPERATION				90.0
8	INSPECTORS	2	4	OPERATION	SETTING			60.0
9	CRAFTSMEN	2	6	SETTING	REPAIR			100.0
10	MTRL_HDLRS	2	5	MATERIAL				70.0

Operator Group:

Number	Operator Group Name	Associated Operator Types
1	SETTERS	CRAFTSMEN
2	HANDLERS	MTRL_HDLRS
3	ENGINEERS	CRAFTSMEN

Operator Type Allocation:

Number	Operator Type Name	Associated Operator Group	Associated Work Station
1	AUTO_OP_SP	----------	CMATIC203
		----------	CMATIC204
		----------	CMATIC205
2	HT_OPS	----------	HEAT-TR206
3	GRIND_OPS	----------	GRIND207
		----------	GRIND208
		----------	GRIND209
		----------	GRIND210
4	AUTO_OP_GR	----------	CMATIC211
		----------	CMATIC212
5	MILL_OPS	----------	MILL213
		----------	MILL214
		----------	MILL215
		----------	MILL216
6	BROACH_OPS	----------	BROACH217
		----------	BROACH218
7	PRESS_OPS	----------	PRESS219
		----------	PRESS220
8	INSPECTORS	----------	INSP001
		----------	INSP002
9	CRAFTSMEN	ENGINEERS	----------
		SETTERS	----------
10	MTRL_HDLRS	HANDLERS	----------

Material:

No.	Material Name	Scale	Routing Specified	Production Control	Store Qty	Purchase Lead Time
1	BAR_12MM	0.1	No	MRP	147.00	10.0F
2	BAR_14MM	0.1	No	MRP	508.00	10.0F
3	BAR_16MM	0.1	No	MRP	471.00	10.0F
4	BAR_18MM	0.1	No	MRP	438.00	10.0F
5	BAR_40MM	0.1	No	MRP	80.00	10.0F
6	BAR_45MM	0.1	No	MRP	270.00	10.0F
7	BAR_50MM	0.1	No	MRP	250.00	10.0F
8	BAR_55MM	0.1	No	MRP	250.00	10.0F
9	GEAR_A	0.1	Yes	MRP	0.00	1.0F
10	GEAR_B	0.1	Yes	MRP	6048.00	1.0F
11	GEAR_C	0.1	Yes	MRP	8320.00	1.0F
12	GEAR_D	0.1	Yes	MRP	0.00	1.0F
13	SPINDLE_A	0.1	Yes	MRP	0.00	1.0F
14	SPINDLE_B	0.1	Yes	MRP	6000.00	1.0F
15	SPINDLE_C	0.1	Yes	MRP	6000.00	1.0F
16	SPINDLE_D	0.1	Yes	MRP	3000.00	1.0F
17	SP_ASSY_A	0.1	Yes	MRP	9088.00	1.0F
18	SP_ASSY_B	0.1	Yes	MRP	35841.00	1.0F
19	SP_ASSY_C	0.1	Yes	MRP	31138.00	1.0F
20	SP_ASSY_D	0.1	Yes	MRP	28100.00	1.0F

Tooling:

Number	Tool Name	Tooling Quantity

Transport:

No.	Transport Name	Transport Type	Transport Quantity	Device Speed	Conveyor Capacity	Responce Time
1	TRUCKS	Discrete	2	10.0	0.0	4.0F

Routing: - General

GEAR_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

GEAR_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_40MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

GEAR_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

GEAR_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
GEAR_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_45MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
GEAR_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General
GEAR_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
GEAR_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_50MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
GEAR_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

GEAR_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

GEAR_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_55MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

GEAR_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SPINDLE_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

SPINDLE_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_12MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
SPINDLE_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General
SPINDLE_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
SPINDLE_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_14MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
SPINDLE_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General
SPINDLE_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
SPINDLE_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_16MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
SPINDLE_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General
SPINDLE_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
SPINDLE_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_18MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
SPINDLE_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General

SP_ASSY_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_A	1.000
					SPINDLE_A	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SP_ASSY_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_B	1.000
					SPINDLE_B	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SP_ASSY_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_C	1.000
					SPINDLE_C	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SP_ASSY_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_D	1.000
					SPINDLE_D	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Appendix F Cell 12 Centre Level Model

Work Stations:

No.	Work Station Name	Type	Breakdowns 1	2	3	4	Associated WorkCentre	Associated Operator	Effi~

Breakdowns:

No.	Type	Breakdown Interval	End Job	Operator	Repair Time	Number Tools	Wait Move

Work Centre: - Department

No.	Centre Name	Operation Type	Schedule	W/S Effi'	Number Shifts	Number Work Stations

Work Centre: - Centre

No.	Centre Name	Operation Type	Schd	Take Head	ReG Bch	Spl Bch	W/S Eff~	Down Per%	Labour Losses	No. Shf	No WS
1	CMATIC-MAC	Assembly	FIFO	N	N	Y	90.00	4.21	0.00	2	4
2	FELL-MILL	Manual	FIFO	N	N	Y	85.00	1.81	0.00	2	8
3	PER-BROACH	Manual	FIFO	N	N	Y	95.00	1.48	0.00	2	4
4	CMATIC-TRN	Assembly	FIFO	N	N	Y	90.00	3.68	0.00	2	6
5	HEAT-TREAT	Manual	FIFO	N	N	Y	95.00	1.47	0.00	2	2
6	GRIND	Manual	FIFO	N	N	Y	85.00	11.87	0.00	2	8
7	PRESS-12TN	Assembly	FIFO	N	N	Y	90.00	2.45	0.00	2	4
8	INSPECTION	Manual	FIFO	N	N	Y	60.00	0.00	0.00	2	4

Work Centre: - Station

No.	Centre Name	Operation Type	Schedule	Take Head	Regroup Batches	Split Batches	Associated W/Stations

Operator Type:

No.	Operator Name	No. Shifts	Number Op'rs	Job Priorities Job 1	Job 2	Job 3	Job 4	% Eff

Operator Group:

Number	Operator Group Name	Associated Operator Types

Operator Type Allocation:

Number	Operator Type Name	Associated Operator Group	Associated Work Station

Material:

No.	Material Name	Scale	Routing Specified	Production Control	Store Qty	Purchase Lead Time
1	BAR_12MM	0.1	No	MRP	147.00	10.0F
2	BAR_14MM	0.1	No	MRP	508.00	10.0F
3	BAR_16MM	0.1	No	MRP	471.00	10.0F
4	BAR_18MM	0.1	No	MRP	438.00	10.0F
5	BAR_40MM	0.1	No	MRP	80.00	10.0F
6	BAR_45MM	0.1	No	MRP	270.00	10.0F
7	BAR_50MM	0.1	No	MRP	250.00	10.0F
8	BAR_55MM	0.1	No	MRP	250.00	10.0F
9	GEAR_A	0.1	Yes	MRP	0.00	1.0F
10	GEAR_B	0.1	Yes	MRP	6048.00	1.0F
11	GEAR_C	0.1	Yes	MRP	8320.00	1.0F
12	GEAR_D	0.1	Yes	MRP	0.00	1.0F
13	SPINDLE_A	0.1	Yes	MRP	0.00	1.0F
14	SPINDLE_B	0.1	Yes	MRP	6000.00	1.0F
15	SPINDLE_C	0.1	Yes	MRP	6000.00	1.0F
16	SPINDLE_D	0.1	Yes	MRP	3000.00	1.0F
17	SP_ASSY_A	0.1	Yes	MRP	9088.00	1.0F
18	SP_ASSY_B	0.1	Yes	MRP	35841.00	1.0F
19	SP_ASSY_C	0.1	Yes	MRP	31138.00	1.0F
20	SP_ASSY_D	0.1	Yes	MRP	28100.00	1.0F

Tooling:

Number	Tool Name	Tooling Quantity

Transport:

No.	Transport Name	Transport Type	Transport Quantity	Device Speed	Conveyor Capacity	Responce Time
1	TRUCKS	Discrete	2	10.0	0.0	4.0F

Routing: - General

GEAR_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	1500	5.0FD	TRUCKS	0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_40MM	0.006

Routing: - Additional Detail

GEAR_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			
3	1		0		N			

Routing: - General

GEAR_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	1500	5.0FD	TRUCKS	0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_45MM	0.006

Routing: - Additional Detail

GEAR_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			
3	1		0		N			

Routing: - General

GEAR_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	1500	5.0FD	TRUCKS	0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_50MM	0.006

Routing: - Additional Detail

GEAR_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			
3	1		0		N			

Routing: - General

GEAR_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	1500	5.0FD	TRUCKS	0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_55MM	0.006

Routing: - Additional Detail

GEAR_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			
3	1		0		N			

Routing: - General

SPINDLE_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	1500	5.0FD	TRUCKS	0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	5.30F	10	1500	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

SPINDLE_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_12MM	0.020

Routing: - Additional Detail

SPINDLE_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			
3	1		0		N			

Routing: - General

SPINDLE_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	1500	5.0FD	TRUCKS	0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	5.30F	10	1500	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

SPINDLE_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_14MM	0.020

Routing: - Additional Detail

SPINDLE_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			
3	1		0		N			

Routing: - General

SPINDLE_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	1500	5.0FD	TRUCKS	0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	5.30F	10	1500	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

SPINDLE_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_16MM	0.020

Routing: - Additional Detail

SPINDLE_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			
3	1		0		N			

Routing: - General

SPINDLE_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	1500	5.0FD	TRUCKS	0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	5.30F	10	1500	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

SPINDLE_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_18MM	0.020

Routing: - Additional Detail

SPINDLE_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			
3	1		0		N			

Routing: - General

SP_ASSY_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_A	1.000
					SPINDLE_A	1.000

Routing: - Additional Detail

SP_ASSY_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			

Routing: - General

SP_ASSY_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_B	1.000
					SPINDLE_B	1.000

Routing: - Additional Detail

SP_ASSY_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			

Routing: - General

SP_ASSY_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	0.00

Routing: - **Operator/Assembly**

SP_ASSY_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_C	1.000
					SPINDLE_C	1.000

Routing: - **Additional Detail**

SP_ASSY_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			

Routing: - **General**

SP_ASSY_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	0.00

Routing: - **Operator/Assembly**

SP_ASSY_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_D	1.000
					SPINDLE_D	1.000

Routing: - **Additional Detail**

SP_ASSY_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2	1		0		N			

Appendix G Cell 12 Department Level Model

Work Stations:

No.	Work Station Name	Type	Breakdowns 1	2	3	4	Associated WorkCentre	Associated Operator	Effi~

Breakdowns:

No.	Type	Breakdown Interval	End Job	Operator	Repair Time	Number Tools	Wait Move

Work Centre: - Department

No.	Centre Name	Operation Type	Schedule	W/S Effi'	Number Shifts	Number Work Stations
1	CMATIC-MAC	Assembly	FIFO	86.21	2	4
2	FELL-MILL	Manual	FIFO	83.46	2	8
3	PER-BROACH	Manual	FIFO	93.59	2	4
4	CMATIC-TRN	Assembly	FIFO	86.69	2	6
5	HEAT-TREAT	Manual	FIFO	93.60	2	2
6	GRIND	Manual	FIFO	74.91	2	8
7	PRESS-12TN	Assembly	FIFO	87.79	2	4
8	INSPECTION	Manual	FIFO	60.00	2	4

Work Centre: - Centre

No.	Centre Name	Operation Type	Schd	Take Head	ReG Bch	Spl Bch	W/S Eff~	Down Per%	Labour Losses	No. Shf	No WS

Work Centre: - Station

No.	Centre Name	Operation Type	Schedule	Take Head	Regroup Batches	Split Batches	Associated W/Stations

Operator Type:

No.	Operator Name	No. Shifts	Number Op'rs	Job Priorities Job 1	Job 2	Job 3	Job 4	% Eff

Operator Group:

Number	Operator Group Name	Associated Operator Types

Operator Type Allocation:

Number	Operator Type Name	Associated Operator Group	Associated Work Station

Material:

No.	Material Name	Scale	Routing Specified	Production Control	Store Qty	Purchase Lead Time
1	BAR_12MM	0.1	No	MRP	147.00	10.0F
2	BAR_14MM	0.1	No	MRP	508.00	10.0F
3	BAR_16MM	0.1	No	MRP	471.00	10.0F
4	BAR_18MM	0.1	No	MRP	438.00	10.0F
5	BAR_40MM	0.1	No	MRP	80.00	10.0F
6	BAR_45MM	0.1	No	MRP	270.00	10.0F
7	BAR_50MM	0.1	No	MRP	250.00	10.0F
8	BAR_55MM	0.1	No	MRP	250.00	10.0F
9	GEAR_A	0.1	Yes	MRP	0.00	1.0F
10	GEAR_B	0.1	Yes	MRP	6048.00	1.0F
11	GEAR_C	0.1	Yes	MRP	8320.00	1.0F
12	GEAR_D	0.1	Yes	MRP	0.00	1.0F
13	SPINDLE_A	0.1	Yes	MRP	0.00	1.0F
14	SPINDLE_B	0.1	Yes	MRP	6000.00	1.0F
15	SPINDLE_C	0.1	Yes	MRP	6000.00	1.0F
16	SPINDLE_D	0.1	Yes	MRP	3000.00	1.0F
17	SP_ASSY_A	0.1	Yes	MRP	9088.00	1.0F
18	SP_ASSY_B	0.1	Yes	MRP	35841.00	1.0F
19	SP_ASSY_C	0.1	Yes	MRP	31138.00	1.0F
20	SP_ASSY_D	0.1	Yes	MRP	28100.00	1.0F

Tooling:

Number	Tool Name	Tooling Quantity

Transport:

No.	Transport Name	Transport Type	Transport Quantity	Device Speed	Conveyor Capacity	Responce Time
1	TRUCKS	Discrete	2	10.0	0.0	4.0F

Routing: - General

GEAR_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	Batch	5.0FD	TRUCKS	0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	Batch	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_40MM	0.006

Routing: - Additional Detail

GEAR_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

GEAR_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	Batch	5.0FD	TRUCKS	0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	Batch	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_45MM	0.006

Routing: - Additional Detail

GEAR_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

GEAR_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	Batch	5.0FD	TRUCKS	0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	Batch	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_50MM	0.006

Routing: - Additional Detail

GEAR_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

GEAR_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	Batch	5.0FD	TRUCKS	0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	Batch	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_55MM	0.006

Routing: - Additional Detail

GEAR_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

SPINDLE_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	Batch	5.0FD	TRUCKS	0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	Batch	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	5.30F	10	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

SPINDLE_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_12MM	0.020

Routing: - Additional Detail

SPINDLE_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

SPINDLE_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	Batch	5.0FD	TRUCKS	0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	Batch	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	5.30F	10	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

SPINDLE_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_14MM	0.020

Routing: - Additional Detail

SPINDLE_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - **General**

SPINDLE_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	Batch	5.0FD	TRUCKS	0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	Batch	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	5.30F	10	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - **Operator/Assembly**

SPINDLE_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_16MM	0.020

Routing: - **Additional Detail**

SPINDLE_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - **General**

SPINDLE_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	Batch	5.0FD	TRUCKS	0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	Batch	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	5.30F	10	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - **Operator/Assembly**

SPINDLE_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_18MM	0.020

Routing: - **Additional Detail**

SPINDLE_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

SP_ASSY_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	Batch	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD	TRUCKS	3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_A	1.000
					SPINDLE_A	1.000

Routing: - Additional Detail

SP_ASSY_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					

Routing: - General

SP_ASSY_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	Batch	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD	TRUCKS	3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_B	1.000
					SPINDLE_B	1.000

Routing: - Additional Detail

SP_ASSY_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					

Routing: - General

SP_ASSY_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	Batch	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD	TRUCKS	3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_C	1.000
					SPINDLE_C	1.000

Routing: - Additional Detail

SP_ASSY_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					

Routing: - General

SP_ASSY_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	Batch	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD	TRUCKS	3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_D	1.000
					SPINDLE_D	1.000

Routing: - Additional Detail

SP_ASSY_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					

Appendix H Cell 12 Factory Level Model

Work Stations:

No.	Work Station Name	Type	Breakdowns 1	2	3	4	Associated WorkCentre	Associated Operator	Effi~

Breakdowns:

No.	Type	Breakdown Interval	End Job	Operator	Repair Time	Number Tools	Wait Move

Work Centre: - Department

No.	Centre Name	Operation Type	Schedule	W/S Effi'	Number Shifts	Number Work Stations
1	CMATIC-MAC	Assembly	FIFO	86.21	1	2
2	FELL-MILL	Manual	FIFO	83.46	1	4
3	PER-BROACH	Manual	FIFO	93.59	1	2
4	CMATIC-TRN	Assembly	FIFO	86.69	1	3
5	HEAT-TREAT	Manual	FIFO	93.60	1	1
6	GRIND	Manual	FIFO	74.91	1	4
7	PRESS-12TN	Assembly	FIFO	87.79	1	2
8	INSPECTION	Manual	FIFO	60.00	1	2

Work Centre: - Centre

No.	Centre Name	Operation Type	Schd	Take Head	ReG Bch	Spl Bch	Eff~	Down Per%	Labour Losses	No. Shf	No WS

Work Centre: - Station

No.	Centre Name	Operation Type	Schedule	Take Head	Regroup Batches	Split Batches	Associated W/Stations

Operator Type:

No.	Operator Name	No. Shifts	Number Op'rs	Job Priorities Job 1	Job 2	Job 3	Job 4	% Eff

Operator Group:

Number	Operator Group Name	Associated Operator Types

Operator Type Allocation:

Number	Operator Type Name	Associated Operator Group	Associated Work Station

Material:

No.	Material Name	Scale	Routing Specified	Production Control	Store Qty	Purchase Lead Time
1	BAR_12MM	0.1	No	MRP	147.00	10.0F
2	BAR_14MM	0.1	No	MRP	508.00	10.0F
3	BAR_16MM	0.1	No	MRP	471.00	10.0F
4	BAR_18MM	0.1	No	MRP	438.00	10.0F
5	BAR_40MM	0.1	No	MRP	80.00	10.0F
6	BAR_45MM	0.1	No	MRP	270.00	10.0F
7	BAR_50MM	0.1	No	MRP	250.00	10.0F
8	BAR_55MM	0.1	No	MRP	250.00	10.0F
9	GEAR_A	0.1	Yes	MRP	0.00	1.0F
10	GEAR_B	0.1	Yes	MRP	6048.00	1.0F
11	GEAR_C	0.1	Yes	MRP	8320.00	1.0F
12	GEAR_D	0.1	Yes	MRP	0.00	1.0F
13	SPINDLE_A	0.1	Yes	MRP	0.00	1.0F
14	SPINDLE_B	0.1	Yes	MRP	6000.00	1.0F
15	SPINDLE_C	0.1	Yes	MRP	6000.00	1.0F
16	SPINDLE_D	0.1	Yes	MRP	3000.00	1.0F
17	SP_ASSY_A	0.1	Yes	MRP	9088.00	1.0F
18	SP_ASSY_B	0.1	Yes	MRP	35841.00	1.0F
19	SP_ASSY_C	0.1	Yes	MRP	31138.00	1.0F
20	SP_ASSY_D	0.1	Yes	MRP	28100.00	1.0F

Tooling:

Number	Tool Name	Tooling Quantity

Transport:

No.	Transport Name	Transport Type	Quantity	Device Speed	Conveyor Capacity	Responce Time

Routing: - General

GEAR_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	Batch	5.0FD		0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	Batch	5.0FD		0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD		0.00	0.00

Routing: - Operator/Assembly

GEAR_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_40MM	0.006

Routing: - Additional Detail

GEAR_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

GEAR_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	Batch	5.0FD		0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	Batch	5.0FD		0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD		0.00	0.00

Routing: - Operator/Assembly

GEAR_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_45MM	0.006

Routing: - Additional Detail

GEAR_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

GEAR_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	Batch	5.0FD		0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	Batch	5.0FD		0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD		0.00	0.00

Routing: - Operator/Assembly

GEAR_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Quantity
1				Batch	BAR_50MM	0.006

Routing: - Additional Detail

GEAR_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

GEAR_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	33.50F	150	Batch	5.0FD		0.00	0.00
2	FELL-MILL	15.0F	0.47F	1	Batch	5.0FD		0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD		0.00	0.00

Routing: - Operator/Assembly

GEAR_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Quantity
1				Batch	BAR_55MM	0.006

Routing: - Additional Detail

GEAR_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

SPINDLE_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	Batch	5.0FD		0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	Batch	5.0FD		0.00	0.00
3	GRIND	15.0F	5.30F	10	Batch	5.0FD		0.00	0.00

Routing: - Operator/Assembly

SPINDLE_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Quantity
1				Batch	BAR_12MM	0.020

Routing: - Additional Detail

SPINDLE_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

SPINDLE_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	Batch	5.0FD		0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	Batch	5.0FD		0.00	0.00
3	GRIND	15.0F	5.30F	10	Batch	5.0FD		0.00	0.00

Routing: - Operator/Assembly

SPINDLE_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Quantity
1				Batch	BAR_14MM	0.020

Routing: - Additional Detail

SPINDLE_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

SPINDLE_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	Batch	5.0FD		0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	Batch	5.0FD		0.00	0.00
3	GRIND	15.0F	5.30F	10	Batch	5.0FD		0.00	0.00

Routing: - Operator/Assembly

SPINDLE_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_16MM	0.020

Routing: - Additional Detail

SPINDLE_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

SPINDLE_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	15.20F	50	Batch	5.0FD		0.00	0.00
2	HEAT-TREAT	15.0F	5.77F	50	Batch	5.0FD		0.00	0.00
3	GRIND	15.0F	5.30F	10	Batch	5.0FD		0.00	0.00

Routing: - Operator/Assembly

SPINDLE_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	BAR_18MM	0.020

Routing: - Additional Detail

SPINDLE_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					
3			0					

Routing: - General

SP_ASSY_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	Batch	5.0FD		0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD		3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_A	1.000
					SPINDLE_A	1.000

Routing: - Additional Detail

SP_ASSY_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					

Routing: - General

SP_ASSY_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	Batch	5.0FD		0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD		3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_B	1.000
					SPINDLE_B	1.000

Routing: - Additional Detail

SP_ASSY_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					

Routing: - General

SP_ASSY_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	Batch	5.0FD		0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD		3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_C	1.000
					SPINDLE_C	1.000

Routing: - Additional Detail

SP_ASSY_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					

Routing: - General

SP_ASSY_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	Batch	5.0FD		0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD		3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_D	1.000
					SPINDLE_D	1.000

Routing: - Additional Detail

SP_ASSY_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1			0					
2			0					

Mathematical Model Data

Number Of WIP Items	1 to 55
Average Batch Size	1500
Number Of Transport	2
Average Transport Time	5.00 (Mins)
Speed Of Transport	1.00 (Distance Unit per Minute)

Material Demand

Part	Quantity
SP_ASSY_A	1872
SPINDLE_B	9048
GEAR_A	9048
SP_ASSY_B	9048
SPINDLE_C	8320
GEAR_C	8320
SP_ASSY_C	8320
SPINDLE_D	7800
GEAR_D	7800
SP_ASSY_D	7800
SPINDLE_A	1872
GEAR_A	1872

Appendix I Cell 12 Combined Level Model

Work Stations:

No.	Work Station Name	Type	Breakdowns 1	2	3	4	Associated WorkCentre	Associated Operator	Effi~
1	CMATIC211	Assembly	3	12	0	0	CMATIC-MAC	AUTO_OP_GR	90.0
2	CMATIC212	Assembly	3	12	0	0	CMATIC-MAC	AUTO_OP_GR	90.0
3	CMATIC203	Assembly	4	13	0	0	CMATIC-TRN	AUTO_OP_SP	95.0
4	CMATIC204	Assembly	2	11	0	0	CMATIC-TRN	AUTO_OP_SP	80.0
5	CMATIC205	Assembly	4	13	0	0	CMATIC-TRN	AUTO_OP_SP	95.0
6	GRIND207	Manual	1	10	0	0	GRIND	GRIND_OPS	85.0
7	GRIND208	Manual	1	10	0	0	GRIND	GRIND_OPS	85.0
8	GRIND209	Manual	1	10	0	0	GRIND	GRIND_OPS	85.0
9	GRIND210	Manual	1	10	0	0	GRIND	GRIND_OPS	85.0

Breakdowns:

No.	Type	Breakdown Interval	End Job	Repair Operator	Time	Number Tools	Wait Move
1	TIMEOUTPUT	6.0F	N	ENGINEERS	5.0F	0	60.0F
2	TIMEOUTPUT	8.0F	N	ENGINEERS	5.0F	0	60.0F
3	TIMEOUTPUT	12.0F	N	ENGINEERS	5.0F	0	60.0F
4	TIMEOUTPUT	16.0F	N	ENGINEERS	5.0F	0	60.0F
10	TIMEOUTPUT	50.0F	N	ENGINEERS	240.0F	0	0.0F
11	TIMEOUTPUT	100.0F	N	ENGINEERS	480.0F	0	0.0F
12	TIMEOUTPUT	150.0F	N	ENGINEERS	480.0F	0	0.0F
13	TIMEOUTPUT	200.0F	N	ENGINEERS	480.0F	0	0.0F

Work Centre: - Department

No.	Centre Name	Operation Type	Schedule	W/S Effi'	Number Shifts	Number Work Stations
1	PER-BROACH	Manual	FIFO	93.59	2	4
2	INSPECTION	Manual	FIFO	60.00	2	4

Work Centre: - Centre

No.	Centre Name	Operation Type	Schd	Take Head	ReG Bch	Spl Bch	Eff~	Down Per%	Labour Losses	No. Shf	No WS
1	FELL-MILL	Manual	FIFO	N	N	Y	85.00	1.81	0.00	2	8
2	HEAT-TREAT	Manual	FIFO	N	N	Y	95.00	1.47	0.00	2	2
3	PRESS-12TN	Assembly	FIFO	N	N	Y	90.00	2.45	0.00	2	4

Work Centre: - Station

No.	Centre Name	Operation Type	Schedule	Take Head	Regroup Batches	Split Batches	Associated W/Stations
1	CMATIC-MAC	Assembly	FIFO	N	N	Y	CMATIC211
							CMATIC212
2	CMATIC-TRN	Assembly	FIFO	N	N	Y	CMATIC203
							CMATIC204
							CMATIC205
3	GRIND	Manual	FIFO	N	N	Y	GRIND207
							GRIND208
							GRIND209
							GRIND210

Operator Type:

No.	Operator Name	No. Shifts	Number Op'rs	Job Priorities Job 1	Job 2	Job 3	Job 4	% Eff
1	AUTO_OP_SP	2	2	OPERATION				100.0
2	GRIND_OPS	2	4	OPERATION				100.0
3	AUTO_OP_GR	2	2	OPERATION				100.0
4	CRAFTSMEN	2	6	SETTING	REPAIR			100.0
5	MTRL_HDLRS	2	5	MATERIAL				70.0

Operator Group:

Number	Operator Group Name	Associated Operator Types
1	SETTERS	CRAFTSMEN
2	HANDLERS	MTRL_HDLRS
3	ENGINEERS	CRAFTSMEN

Operator Type Allocation:

Number	Operator Type Name	Associated Operator Group	Associated Work Station
1	AUTO_OP_SP	----------	CMATIC203
		----------	CMATIC204
		----------	CMATIC205
2	GRIND_OPS	----------	GRIND207
		----------	GRIND208
		----------	GRIND209
		----------	GRIND210
3	AUTO_OP_GR	----------	CMATIC211
		----------	CMATIC212
4	CRAFTSMEN	ENGINEERS	----------
		SETTERS	----------
5	MTRL_HDLRS	HANDLERS	----------

Material:

No.	Material Name	Scale	Routing Specified	Production Control	Store Qty	Purchase Lead Time
1	BAR_12MM	0.1	No	MRP	147.00	10.0F
2	BAR_14MM	0.1	No	MRP	508.00	10.0F
3	BAR_16MM	0.1	No	MRP	471.00	10.0F
4	BAR_18MM	0.1	No	MRP	438.00	10.0F
5	BAR_40MM	0.1	No	MRP	80.00	10.0F
6	BAR_45MM	0.1	No	MRP	270.00	10.0F
7	BAR_50MM	0.1	No	MRP	250.00	10.0F
8	BAR_55MM	0.1	No	MRP	250.00	10.0F
9	GEAR_A	0.1	Yes	MRP	0.00	1.0F
10	GEAR_B	0.1	Yes	MRP	6048.00	1.0F
11	GEAR_C	0.1	Yes	MRP	8320.00	1.0F
12	GEAR_D	0.1	Yes	MRP	0.00	1.0F
13	SPINDLE_A	0.1	Yes	MRP	0.00	1.0F
14	SPINDLE_B	0.1	Yes	MRP	6000.00	1.0F
15	SPINDLE_C	0.1	Yes	MRP	6000.00	1.0F
16	SPINDLE_D	0.1	Yes	MRP	3000.00	1.0F
17	SP_ASSY_A	0.1	Yes	MRP	9088.00	1.0F
18	SP_ASSY_B	0.1	Yes	MRP	35841.00	1.0F
19	SP_ASSY_C	0.1	Yes	MRP	31138.00	1.0F
20	SP_ASSY_D	0.1	Yes	MRP	28100.00	1.0F

Tooling:

Number	Tool Name	Tooling Quantity

Transport:

No.	Transport Name	Transport Type	Quantity	Device Speed	Conveyor Capacity	Responce Time
1	TRUCKS	Discrete	2	10.0	0.0	4.0F

Routing: - General

GEAR_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_40MM	0.006

Routing: - Additional Detail

GEAR_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1		0		N			
3			0					

Routing: - General

GEAR_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_45MM	0.006

Routing: - Additional Detail

GEAR_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1		0		N			
3			0					

Routing: - General

GEAR_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_50MM	0.006

Routing: - Additional Detail

GEAR_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1		0		N			
3			0					

Routing: - General

GEAR_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	0.00
3	PER-BROACH	30.0F	0.22F	1	Batch	5.0FD	TRUCKS	0.00	0.00

Routing: - Operator/Assembly

GEAR_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_55MM	0.006

Routing: - Additional Detail

GEAR_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1		0		N			
3			0					

Routing: - General

SPINDLE_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
SPINDLE_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_12MM	0.020
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
SPINDLE_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1		0		N			
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General
SPINDLE_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
SPINDLE_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_14MM	0.020
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
SPINDLE_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1		0		N			
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General

SPINDLE_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

SPINDLE_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_16MM	0.020
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

SPINDLE_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1		0		N			
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General

SPINDLE_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	0.00
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

SPINDLE_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_18MM	0.020
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

SPINDLE_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1		0		N			
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General

SP_ASSY_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD	TRUCKS	3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_A	1.000
					SPINDLE_A	1.000

Routing: - Additional Detail

SP_ASSY_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2			0					

Routing: - General

SP_ASSY_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD	TRUCKS	3.97	0.00

Routing: - Operator/Assembly

SP_ASSY_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_B	1.000
					SPINDLE_B	1.000

Routing: - Additional Detail
SP_ASSY_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2			0					

Routing: - General
SP_ASSY_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD	TRUCKS	3.97	0.00

Routing: - Operator/Assembly
SP_ASSY_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_C	1.000
					SPINDLE_C	1.000

Routing: - Additional Detail
SP_ASSY_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2			0					

Routing: - General
SP_ASSY_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	0.00
2	INSPECTION	2.0F	0.10F	1	Batch	5.0FD	TRUCKS	3.97	0.00

Routing: - Operator/Assembly
SP_ASSY_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1				Batch	GEAR_D	1.000
					SPINDLE_D	1.000

Routing: - Additional Detail

SP_ASSY_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1		0		N			
2			0					

Appendix J Cell 12 Station Level Model With No Breakdowns

Work Stations:

No.	Work Station Name	Type	Breakdowns 1	2	3	4	Associated WorkCentre	Associated Operator	Effi~
1	CMATIC211	Assembly	0	0	0	0	CMATIC-MAC	AUTO_OP_GR	90.0
2	CMATIC212	Assembly	0	0	0	0	CMATIC-MAC	AUTO_OP_GR	90.0
3	MILL213	Manual	0	0	0	0	FELL-MILL	MILL_OPS	100.0
4	MILL213	Manual	0	0	0	0	FELL-MILL	MILL_OPS	100.0
5	MILL214	Manual	0	0	0	0	FELL-MILL	MILL_OPS	100.0
6	MILL215	Manual	0	0	0	0	FELL-MILL	MILL_OPS	100.0
7	BROACH217	Manual	0	0	0	0	PER-BROACH	BROACH_OPS	95.0
8	BROACH218	Manual	0	0	0	0	PER-BROACH	BROACH_OPS	95.0
9	CMATIC203	Assembly	0	0	0	0	CMATIC-TRN	AUTO_OP_SP	95.0
10	CMATIC204	Assembly	0	0	0	0	CMATIC-TRN	AUTO_OP_SP	80.0
11	CMATIC205	Assembly	0	0	0	0	CMATIC-TRN	AUTO_OP_SP	95.0
12	HEAT-TR206	Manual	0	0	0	0	HEAT-TREAT	HT_OPS	95.0
13	GRIND207	Manual	0	0	0	0	GRIND	GRIND_OPS	85.0
14	GRIND208	Manual	0	0	0	0	GRIND	GRIND_OPS	85.0
15	GRIND209	Manual	0	0	0	0	GRIND	GRIND_OPS	85.0
16	GRIND210	Manual	0	0	0	0	GRIND	GRIND_OPS	85.0
17	PRESS219	Assembly	0	0	0	0	PRESS-12TN	PRESS_OPS	100.0
18	PRESS220	Assembly	0	0	0	0	PRESS-12TN	PRESS_OPS	100.0
19	INSP001	Manual	0	0	0	0	INSPECTION	INSPECTORS	100.0
20	INSP002	Manual	0	0	0	0	INSPECTION	INSPECTORS	100.0

Breakdowns:

No.	Type	Breakdown Interval	End Job	Repair Operator	Time	Number Tools	Wait Move

Work Centre: - Department

No.	Centre Name	Operation Type	Schedule	W/S Effi'	Number Shifts	Number Work Stations

Work Centre: - Centre

No.	Centre Name	Operation Type	Schd	Take Head	ReG Bch	Spl Bch	Eff~	Down Per%	Labour Losses	No. Shf	No WS

Work Centre: - Station

No.	Centre Name	Operation Type	Schedule	Take Head	Regroup Batches	Split Batches	Associated W/Stations
1	CMATIC-MAC	Assembly	FIFO	N	N	Y	CMATIC211
							CMATIC212
2	FELL-MILL	Manual	FIFO	N	N	Y	MILL213
							MILL214
							MILL215
							MILL216
3	PER-BROACH	Manual	FIFO	N	N	Y	BROACH217
							BROACH218
4	CMATIC-TRN	Assembly	FIFO	N	N	Y	CMATIC203
							CMATIC204
							CMATIC205
5	HEAT-TREAT	Manual	FIFO	N	N	Y	HEAT-TR206
6	GRIND	Manual	FIFO	N	N	Y	GRIND207
							GRIND208
							GRIND209
							GRIND210
7	PRESS-12TN	Assembly	FIFO	N	N	Y	PRESS219
							PRESS220
8	INSPECTION	Manual	FIFO	N	N	Y	INSP001
							INSP002

Operator Type:

No.	Operator Name	No. Shifts	Number Op'rs	Job Priorities Job 1	Job 2	Job 3	Job 4	% Eff
1	AUTO_OP_SP	2	2	OPERATION				100.0
2	HT_OPS	2	2	OPERATION				100.0
3	GRIND_OPS	2	4	OPERATION				100.0
4	AUTO_OP_GR	2	2	OPERATION				100.0
5	MILL_OPS	2	8	OPERATION				85.0
6	BROACH_OPS	2	4	OPERATION				100.0
7	PRESS_OPS	2	4	OPERATION				90.0
8	INSPECTORS	2	4	OPERATION	SETTING			60.0
9	CRAFTSMEN	2	6	SETTING	REPAIR			100.0
10	MTRL_HDLRS	2	5	MATERIAL				70.0

Operator Group:

Number	Operator Group Name	Associated Operator Types
1	SETTERS	CRAFTSMEN
2	HANDLERS	MTRL_HDLRS
3	ENGINEERS	CRAFTSMEN

Operator Type Allocation:

Number	Operator Type Name	Associated Operator Group	Associated Work Station
1	AUTO_OP_SP	----------	CMATIC203
		----------	CMATIC204
		----------	CMATIC205
2	HT_OPS	----------	HEAT-TR206
3	GRIND_OPS	----------	GRIND207
		----------	GRIND208
		----------	GRIND209
		----------	GRIND210
4	AUTO_OP_GR	----------	CMATIC211
		----------	CMATIC212
5	MILL_OPS	----------	MILL213
		----------	MILL214
		----------	MILL215
		----------	MILL216
6	BROACH_OPS	----------	BROACH217
		----------	BROACH218
7	PRESS_OPS	----------	PRESS219
		----------	PRESS220
8	INSPECTORS	----------	INSP001
		----------	INSP002
9	CRAFTSMEN	ENGINEERS	----------
		SETTERS	----------
10	MTRL_HDLRS	HANDLERS	----------

Material:

No.	Material Name	Scale	Routing Specified	Production Control	Store Qty	Purchase Lead Time
1	BAR_12MM	0.1	No	MRP	147.00	10.0F
2	BAR_14MM	0.1	No	MRP	508.00	10.0F
3	BAR_16MM	0.1	No	MRP	471.00	10.0F
4	BAR_18MM	0.1	No	MRP	438.00	10.0F
5	BAR_40MM	0.1	No	MRP	80.00	10.0F
6	BAR_45MM	0.1	No	MRP	270.00	10.0F
7	BAR_50MM	0.1	No	MRP	250.00	10.0F
8	BAR_55MM	0.1	No	MRP	250.00	10.0F
9	GEAR_A	0.1	Yes	MRP	0.00	1.0F
10	GEAR_B	0.1	Yes	MRP	6048.00	1.0F
11	GEAR_C	0.1	Yes	MRP	8320.00	1.0F
12	GEAR_D	0.1	Yes	MRP	0.00	1.0F
13	SPINDLE_A	0.1	Yes	MRP	0.00	1.0F
14	SPINDLE_B	0.1	Yes	MRP	6000.00	1.0F
15	SPINDLE_C	0.1	Yes	MRP	6000.00	1.0F
16	SPINDLE_D	0.1	Yes	MRP	3000.00	1.0F
17	SP_ASSY_A	0.1	Yes	MRP	9088.00	1.0F
18	SP_ASSY_B	0.1	Yes	MRP	35841.00	1.0F
19	SP_ASSY_C	0.1	Yes	MRP	31138.00	1.0F
20	SP_ASSY_D	0.1	Yes	MRP	28100.00	1.0F

Tooling:

Number	Tool Name	Tooling Quantity

Transport:

No.	Transport Name	Transport Type	Transport Quantity	Device Speed	Conveyor Capacity	Responce Time
1	TRUCKS	Discrete	2	10.0	0.0	4.0F

Routing: - General

GEAR_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

GEAR_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_40MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

GEAR_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

GEAR_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
GEAR_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_45MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
GEAR_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General
GEAR_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
GEAR_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_50MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
GEAR_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

GEAR_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

GEAR_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_55MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

GEAR_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SPINDLE_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

SPINDLE_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_12MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

SPINDLE_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General

SPINDLE_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

SPINDLE_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_14MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

SPINDLE_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General

SPINDLE_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
SPINDLE_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_16MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
SPINDLE_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General
SPINDLE_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
SPINDLE_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_18MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
SPINDLE_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General

SP_ASSY_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_A	1.000
					SPINDLE_A	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SP_ASSY_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_B	1.000
					SPINDLE_B	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SP_ASSY_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_C	1.000
					SPINDLE_C	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SP_ASSY_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_D	1.000
					SPINDLE_D	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Appendix K Cell 12 Station Level Model With No Breakdowns and Excess Labour Capacity

Work Stations:

No.	Work Station Name	Type	Breakdowns 1	2	3	4	Associated WorkCentre	Associated Operator	Effi~
1	CMATIC211	Assembly	0	0	0	0	CMATIC-MAC	AUTO_OP_GR	90.0
2	CMATIC212	Assembly	0	0	0	0	CMATIC-MAC	AUTO_OP_GR	90.0
3	MILL213	Manual	0	0	0	0	FELL-MILL	MILL_OPS	100.0
4	MILL213	Manual	0	0	0	0	FELL-MILL	MILL_OPS	100.0
5	MILL214	Manual	0	0	0	0	FELL-MILL	MILL_OPS	100.0
6	MILL215	Manual	0	0	0	0	FELL-MILL	MILL_OPS	100.0
7	BROACH217	Manual	0	0	0	0	PER-BROACH	BROACH_OPS	95.0
8	BROACH218	Manual	0	0	0	0	PER-BROACH	BROACH_OPS	95.0
9	CMATIC203	Assembly	0	0	0	0	CMATIC-TRN	AUTO_OP_SP	95.0
10	CMATIC204	Assembly	0	0	0	0	CMATIC-TRN	AUTO_OP_SP	80.0
11	CMATIC205	Assembly	0	0	0	0	CMATIC-TRN	AUTO_OP_SP	95.0
12	HEAT-TR206	Manual	0	0	0	0	HEAT-TREAT	HT_OPS	95.0
13	GRIND207	Manual	0	0	0	0	GRIND	GRIND_OPS	85.0
14	GRIND208	Manual	0	0	0	0	GRIND	GRIND_OPS	85.0
15	GRIND209	Manual	0	0	0	0	GRIND	GRIND_OPS	85.0
16	GRIND210	Manual	0	0	0	0	GRIND	GRIND_OPS	85.0
17	PRESS219	Assembly	0	0	0	0	PRESS-12TN	PRESS_OPS	100.0
18	PRESS220	Assembly	0	0	0	0	PRESS-12TN	PRESS_OPS	100.0
19	INSP001	Manual	0	0	0	0	INSPECTION	INSPECTORS	100.0
20	INSP002	Manual	0	0	0	0	INSPECTION	INSPECTORS	100.0

Breakdowns:

No.	Type	Breakdown Interval	End Job	Repair Operator	Time	Number Tools	Wait Move

Work Centre: - Department

No.	Centre Name	Operation Type	Schedule	W/S Effi'	Number Shifts	Number Work Stations

Work Centre: - Centre

No.	Centre Name	Operation Type	Schd	Take Head	ReG Bch	Spl Bch	Eff~	Down Per%	Labour Losses	No. Shf	No WS

Work Centre: - Station

No.	Centre Name	Operation Type	Schedule	Take Head	Regroup Batches	Split Batches	Associated W/Stations
1	CMATIC-MAC	Assembly	FIFO	N	N	Y	CMATIC211
							CMATIC212
2	FELL-MILL	Manual	FIFO	N	N	Y	MILL213
							MILL214
							MILL215
							MILL216
3	PER-BROACH	Manual	FIFO	N	N	Y	BROACH217
							BROACH218
4	CMATIC-TRN	Assembly	FIFO	N	N	Y	CMATIC203
							CMATIC204
							CMATIC205
5	HEAT-TREAT	Manual	FIFO	N	N	Y	HEAT-TR206
6	GRIND	Manual	FIFO	N	N	Y	GRIND207
							GRIND208
							GRIND209
							GRIND210
7	PRESS-12TN	Assembly	FIFO	N	N	Y	PRESS219
							PRESS220
8	INSPECTION	Manual	FIFO	N	N	Y	INSP001
							INSP002

Operator Type:

No.	Operator Name	No. Shifts	Number Op'rs	Job Priorities Job 1	Job 2	Job 3	Job 4	% Eff
1	AUTO_OP_SP	2	6	OPERATION				100.0
2	HT_OPS	2	2	OPERATION				100.0
3	GRIND_OPS	2	8	OPERATION				100.0
4	AUTO_OP_GR	2	4	OPERATION				100.0
5	MILL_OPS	2	8	OPERATION				85.0
6	BROACH_OPS	2	4	OPERATION				100.0
7	PRESS_OPS	2	4	OPERATION				90.0
8	INSPECTORS	2	4	OPERATION	SETTING			60.0
9	CRAFTSMEN	2	40	SETTING	REPAIR			100.0
10	MTRL_HDLRS	2	20	MATERIAL				70.0

Operator Group:

Number	Operator Group Name	Associated Operator Types
1	SETTERS	CRAFTSMEN
2	HANDLERS	MTRL_HDLRS
3	ENGINEERS	CRAFTSMEN

Operator Type Allocation:

Number	Operator Type Name	Associated Operator Group	Associated Work Station
1	AUTO_OP_SP	----------	CMATIC203
		----------	CMATIC204
		----------	CMATIC205
2	HT_OPS	----------	HEAT-TR206
3	GRIND_OPS	----------	GRIND207
		----------	GRIND208
		----------	GRIND209
		----------	GRIND210
4	AUTO_OP_GR	----------	CMATIC211
		----------	CMATIC212
5	MILL_OPS	----------	MILL213
		----------	MILL214
		----------	MILL215
		----------	MILL216
6	BROACH_OPS	----------	BROACH217
		----------	BROACH218
7	PRESS_OPS	----------	PRESS219
		----------	PRESS220
8	INSPECTORS	----------	INSP001
		----------	INSP002
9	CRAFTSMEN	ENGINEERS	----------
		SETTERS	----------
10	MTRL_HDLRS	HANDLERS	----------

Material:

No.	Material Name	Scale	Routing Specified	Production Control	Store Qty	Purchase Lead Time
1	BAR_12MM	0.1	No	MRP	147.00	10.0F
2	BAR_14MM	0.1	No	MRP	508.00	10.0F
3	BAR_16MM	0.1	No	MRP	471.00	10.0F
4	BAR_18MM	0.1	No	MRP	438.00	10.0F
5	BAR_40MM	0.1	No	MRP	80.00	10.0F
6	BAR_45MM	0.1	No	MRP	270.00	10.0F
7	BAR_50MM	0.1	No	MRP	250.00	10.0F
8	BAR_55MM	0.1	No	MRP	250.00	10.0F
9	GEAR_A	0.1	Yes	MRP	0.00	1.0F
10	GEAR_B	0.1	Yes	MRP	6048.00	1.0F
11	GEAR_C	0.1	Yes	MRP	8320.00	1.0F
12	GEAR_D	0.1	Yes	MRP	0.00	1.0F
13	SPINDLE_A	0.1	Yes	MRP	0.00	1.0F
14	SPINDLE_B	0.1	Yes	MRP	6000.00	1.0F
15	SPINDLE_C	0.1	Yes	MRP	6000.00	1.0F
16	SPINDLE_D	0.1	Yes	MRP	3000.00	1.0F
17	SP_ASSY_A	0.1	Yes	MRP	9088.00	1.0F
18	SP_ASSY_B	0.1	Yes	MRP	35841.00	1.0F
19	SP_ASSY_C	0.1	Yes	MRP	31138.00	1.0F
20	SP_ASSY_D	0.1	Yes	MRP	28100.00	1.0F

Tooling:

Number	Tool Name	Tooling Quantity

Transport:

No.	Transport Name	Transport Type	Transport Quantity	Device Speed	Conveyor Capacity	Responce Time
1	TRUCKS	Discrete	2	10.0	0.0	4.0F

Routing: - General

GEAR_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

GEAR_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_40MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

GEAR_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

GEAR_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
GEAR_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_45MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
GEAR_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General
GEAR_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
GEAR_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_50MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
GEAR_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

GEAR_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	CMATIC-MAC	240.0F	31.50F	150	1500	5.0FD	TRUCKS	0.00	Machine
2	FELL-MILL	15.0F	0.47F	1	1500	5.0FD	TRUCKS	0.00	Operator
3	PER-BROACH	30.0F	0.22F	1	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

GEAR_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_55MM	0.006
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

GEAR_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SPINDLE_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

SPINDLE_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_12MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

SPINDLE_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General

SPINDLE_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly

SPINDLE_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_14MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail

SPINDLE_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General

SPINDLE_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
SPINDLE_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_16MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
SPINDLE_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General
SPINDLE_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	CMATIC-TRN	240.0F	13.20F	50	1500	5.0FD	TRUCKS	0.00	Machine
2	HEAT-TREAT	15.0F	5.77F	50	1500	5.0FD	TRUCKS	0.00	Machine
3	GRIND	15.0F	4.70F	10	1500	5.0FD	TRUCKS	0.00	Machine

Routing: - Operator/Assembly
SPINDLE_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	BAR_18MM	0.020
2	SETTERS	Station	HANDLERS			
3	SETTERS	Station	HANDLERS			

Routing: - Additional Detail
SPINDLE_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	Y	2.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F
3	1	Y	0	100.0	N	Y	0.2F	0.4F

Routing: - General

SP_ASSY_A

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_A

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_A	1.000
					SPINDLE_A	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_A

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SP_ASSY_B

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_B

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_B	1.000
					SPINDLE_B	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_B

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SP_ASSY_C

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_C

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_C	1.000
					SPINDLE_C	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_C

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Routing: - General

SP_ASSY_D

Op. No.	Centre Name	Set Up Time	Job Time	Load Qty.	Trfer Qty.	Transport Time	Transport Device	Scrap	Group Perf'
1	PRESS-12TN	30.0F	0.24F	1	1500	5.0FD	TRUCKS	0.00	Operator
2	INSPECTION	2.0F	0.10F	1	1500	5.0FD	TRUCKS	3.97	Operator

Routing: - Operator/Assembly

SP_ASSY_D

Op. No.	Set Up Operator	Process Operator	Transport Operator	Kit. Qty.	Assembly Material	Assembly Quantity
1	SETTERS	Station	HANDLERS	Batch	GEAR_D	1.000
					SPINDLE_D	1.000
2	Station	Station	HANDLERS			

Routing: - Additional Detail

SP_ASSY_D

Op. No.	Min. Set Quantity	Set Up OnPart	W/S Index	Process Per%	Shift End	Op'r Freed	Load Time	Unload Time
1	1	Y	0	100.0	N	N	0.0F	0.0F
2	1	Y	0	100.0	N	N	0.0F	0.0F

Appendix L Cell 12 Weekly Order Input and Customer Demand

Weekly Order Input

The sequence is repeated every week with the period number, for both launch and due date, increasing each time by one.

Order Type	Launch Date Period	Launch Date Day	Launch Date Hour	Due Date Period	Due Date Day	Due Date Hour	Order Qty	Part Number	Works Order
WO	1	1	1	2	1	1	1872	SP_ASSY_A	SA/A-1
WO	1	1	1	2	1	1	9048	SPINDLE_B	SP/B-1
WO	1	1	1	2	1	1	9048	GEAR_B	GE/B-1
WO	1	1	1	2	1	1	9048	SP_ASSY_B	SA/B-1
WO	1	1	1	2	1	1	8320	SPINDLE_C	SP/C-1
WO	1	1	1	2	1	1	8320	GEAR_C	GE/C-1
WO	1	1	1	2	1	1	8320	SP_ASSY_C	SA/C-1
WO	1	1	1	2	1	1	7800	SPINDLE_D	SP/D-1
WO	1	1	1	2	1	1	7800	GEAR_D	GE/D-1
WO	1	1	1	2	1	1	7800	SP_ASSY_D	SA/D-1
WO	1	1	1	2	1	1	1872	SPINDLE_A	SP/A-1
WO	1	1	1	2	1	1	1872	GEAR_A	GE/A-1
PO	1	1	1	3	1	1	38	BAR_12MM	PO/BAR12/1
PO	1	1	1	3	1	1	181	BAR_14MM	PO/BAR14/1
PO	1	1	1	3	1	1	167	BAR_16MM	PO/BAR16/1
PO	1	1	1	3	1	1	156	BAR_18MM	PO/BAR18/1
PO	1	1	1	3	1	1	13	BAR_40MM	PO/BAR40/1
PO	1	1	1	3	1	1	61	BAR_45MM	PO/BAR45/1
PO	1	1	1	3	1	1	56	BAR_50MM	PO/BAR50/1
PO	1	1	1	3	1	1	52	BAR_55MM	PO/BAR55/1

Note: WO = Works Order, and
PO = Purchase Order.

Weekly Customer Demand

The sequence is repeated every ten weeks, the period number for due date, simply increasing each time by ten.

Due Date Period	Due Date Day	Hour	Part Number	Order Qty.
1	5	22	SP_ASSY_A	1816
1	5	22	SP_ASSY_B	8716
1	5	22	SP_ASSY_C	8245
1	5	22	SP_ASSY_D	7915
2	5	22	SP_ASSY_A	1750
2	5	22	SP_ASSY_B	8037
2	5	22	SP_ASSY_C	7589
2	5	22	SP_ASSY_D	7319
3	5	22	SP_ASSY_A	1809
3	5	22	SP_ASSY_B	8299
3	5	22	SP_ASSY_C	7779
3	5	22	SP_ASSY_D	7725
4	5	22	SP_ASSY_A	1735
4	5	22	SP_ASSY_B	8238
4	5	22	SP_ASSY_C	8337
4	5	22	SP_ASSY_D	7429

5	5	22	SP_ASSY_A	1809
5	5	22	SP_ASSY_B	8694
5	5	22	SP_ASSY_C	8363
5	5	22	SP_ASSY_D	7451
6	5	22	SP_ASSY_A	1791
6	5	22	SP_ASSY_B	8951
6	5	22	SP_ASSY_C	8697
6	5	22	SP_ASSY_D	7231
7	5	22	SP_ASSY_A	1765
7	5	22	SP_ASSY_B	9102
7	5	22	SP_ASSY_C	7990
7	5	22	SP_ASSY_D	7507
8	5	22	SP_ASSY_A	1789
8	5	22	SP_ASSY_B	8640
8	5	22	SP_ASSY_C	7820
8	5	22	SP_ASSY_D	7432
9	5	22	SP_ASSY_A	1821
9	5	22	SP_ASSY_B	8470
9	5	22	SP_ASSY_C	7938
9	5	22	SP_ASSY_D	7567
10	5	22	SP_ASSY_A	1786
10	5	22	SP_ASSY_B	8553
10	5	22	SP_ASSY_C	8247
10	5	22	SP_ASSY_D	7722

Appendix M Weekly Discrete Event Execution

M.1 Department Level Evaluation

At the department level, evaluation is simply concerned with the processing of whole work batches, there being no consideration of transfer quantities or discrete breakdowns. For each week of evaluation there are:

8 batches (i.e. GEAR_A/B/C/D and SPINDLE_A/B/C/D) are processed through 3 operations, and

4 batches (i.e. SP_ASSY_A/B/C/D) are processed through 2 operations,

therefore

(8 * 3) + (4 * 2) = 32 individual operations, and
32 individual transfer of batches between operations.

Consequently there are

64 discrete events per week of simulation.

M.2 Centre Level Evaluation

At the centre level, model evaluation considers transfer quantities and so the number of weekly events increases.

A type components are processed in 1872/1500 = 2 transfer quantities,

B type components are processed in 9040/1500 = 7 transfer quantities,

C type components are processed in 8320/1500 = 6 transfer quantities, and

D type components are processed in 7800/1500 = 6 transfer quantities.

Total = 21

For each product type therefore (i.e. gears, spindles and assemblies) there are 21 transfer quantities, as a batch of each component type is issued against each product per week. Hence in each week of evaluation there are:

42 transfer quantities processed through 3 operations,
and 21 transfer quantities processed through 2 operations,

therefore

(42 * 3) + (21 * 2) = 168 individual operations, and
168 individual transfer of batches between operations.

Consequently there are

336 discrete events per week of simulation.

M.3 Station Level Evaluation

In addition to considering transfer quantities, the station model also includes individual component loading and unloading of semi-automatic machines, as well as discrete breakdowns.

All operations consider work in transfer quantities of 1500, however the loading/unloading of individual components effects 3 types of operations, and are those performed at the semi-automatic CMATIC-MAC, CMATIC-TRN and GRIND work centres.

At CMATIC-MAC, 150 components/load, therefore each week there are:

1872/150 = 13 Gear_A loads/unloads,

9048/150 = 61 Gear_B loads/unloads,

8320/150 = 56 Gear_C loads/unloads, and

7800/150 = 52 Gear_D loads/unloads.

Total = 182.

At CMATIC-TRN, 50 components/load, Total = 542.

At Grind, 10 components/load, Total = 2705.

All other operations, being performed on manual machines, simply consider transfer quantities, hence 21 batches through each of the remaining 5 work centres per week.

Therefore

182 + 542 + 2705 + (21 * 5) = 3534 individual operations, and 168 individual transfer of batches between operations, as in the centre model.

The station model also includes discrete breakdowns. Assuming that each work centre processes a full schedule of type A, B, C and D components (i.e. 27040 part) per week then the number of weekly breakdowns are:

For CMATIC-MAC,

breakdowns occur every 12 and 200 hours of production, processing time is 31.5 minutes per 150 components,

therefore

$$\text{weekly production for GEAR\_A} = \frac{(1872/150) * 31.5}{60} = \frac{2 * 31.5}{60}$$

$$= 1.05 \text{ Hrs.}$$

$$\text{weekly production for GEAR\_B} = \frac{(9048/150) * 31.5}{60} = \frac{61 * 31.5}{60}$$

$$= 32.03 \text{ Hrs.}$$

weekly production for GEAR_C = $\frac{(8320/150) * 31.5}{60} = \frac{56 * 31.5}{60}$

= 29.40 Hrs.

weekly production for GEAR_D = $\frac{(7800/150) * 31.5}{60} = \frac{52 * 31.5}{60}$

= 27.30 Hrs.

Total weekly production = 89.78 Hrs.

Total production for the 30 week period = 2693.40 Hrs.

Number of breakdowns = $\frac{2693.4}{12} + \frac{2693.4}{200} = 224 + 13 = 237$

therefore

average weekly breakdowns = 237 / 30 = 7.9.

For FELL-MILL,

breakdowns occur every 20 and 300 hours of production,
processing time is 0.47 minutes per component,

therefore

average weekly breakdowns = 11.27.

For PER-BROACH,

breakdowns occur every 20 and 300 hours of production,
processing time is 0.22 minutes per component,

therefore

average weekly breakdowns = 5.23.

For CMATIC-TRN,

breakdowns occur on average every 13.33 and 166.67 hours of production,

processing time is 13.20 minutes per 50 components,

therefore

average weekly breakdowns = 9.63.

For HEAT-TREAT,

breakdowns occur every 20 and 300 hours of production,
processing time is 5.77 minutes per 50 components,

therefore

average weekly breakdowns = 2.77.

For GRIND,

breakdowns occur every 6 and 50 hours of production,
processing time is 4.7 minutes per 10 components,

therefore

average weekly breakdowns = 39.53.

For PRESS-12TN,

breakdowns occur every 16 and 150 hours of production,
processing time is 0.24 minutes per component,

therefore

average weekly breakdowns = 7.43.

INSPECTION incurs no breakdowns.

Therefore for breakdowns overall there are:

83.76 or 83 breakdowns a week on average, and
83 repair operations.

Consequently in the station model there are:

3534 + 168 + 83 + 83 = 3868 discrete events per week of simulation.

Appendix N Discussion of Multi-level Modelling Experiments

To investigate the differences in evaluation of a system at the various levels of approximation, the respective models were compared over a range of predicted manufacturing characteristics. The results from these studies are tabulated and discussed below.

N.1 Work Centre Utilization

One of the comparisons made between the various models was of predicted work centre utilization. This was based upon the number of set-up, standard and breakdown hours incurred at a work centre during a week (table N.1). Breakdown time at the factory, department and centre levels, along with the steady-state capacity model being taken into account by inflating the standard time by a certain percentage. However at the station level, discrete machine breakdowns were considered, with actual work station downtime being recorded. The basic comparison was between six models:

- four multi-level models; factory, department, centre and station,
- a combined multi-level model, and
- a steady-state capacity model.

In addition there was a "maximum" factory model (i.e. with 50 WIP batches) for further investigation into the mathematical model (section N.4).

A graph (figure N.1) of the predicted work centre utilization results, obtained from the six principal models, illustrated three main groupings. These were:

Group A - containing centre, station and combined models,
Group B - containing department and steady-state capacity models, and
Group C - containing the factory model.

	Spread Sheet	Factory Model	MaxFact'y Model	Depart Model	Centre Model	Station Model	Combined Model
MAC	78.03	79.78	91.02	78.59	87.99	89.65	88.85
FELL	65.28	55.82	63.69	66.87	65.98	66.24	67.34
PER	55.30	48.90	55.79	55.37	58.21	56.76	59.92
TRN	77.29	64.80	73.94	77.56	89.95	90.26	89.07
HT	75.36	50.64	57.78	75.27	76.25	76.05	75.60
GRD	81.95	68.72	78.41	82.31	82.07	83.58	81.29
PRESS	64.16	56.37	64.31	63.89	66.71	67.20	68.22
INSP	50.13	31.98	36.49	48.49	49.93	49.96	49.96

Table N.1 Average Weekly Work Centre Utilization (%)

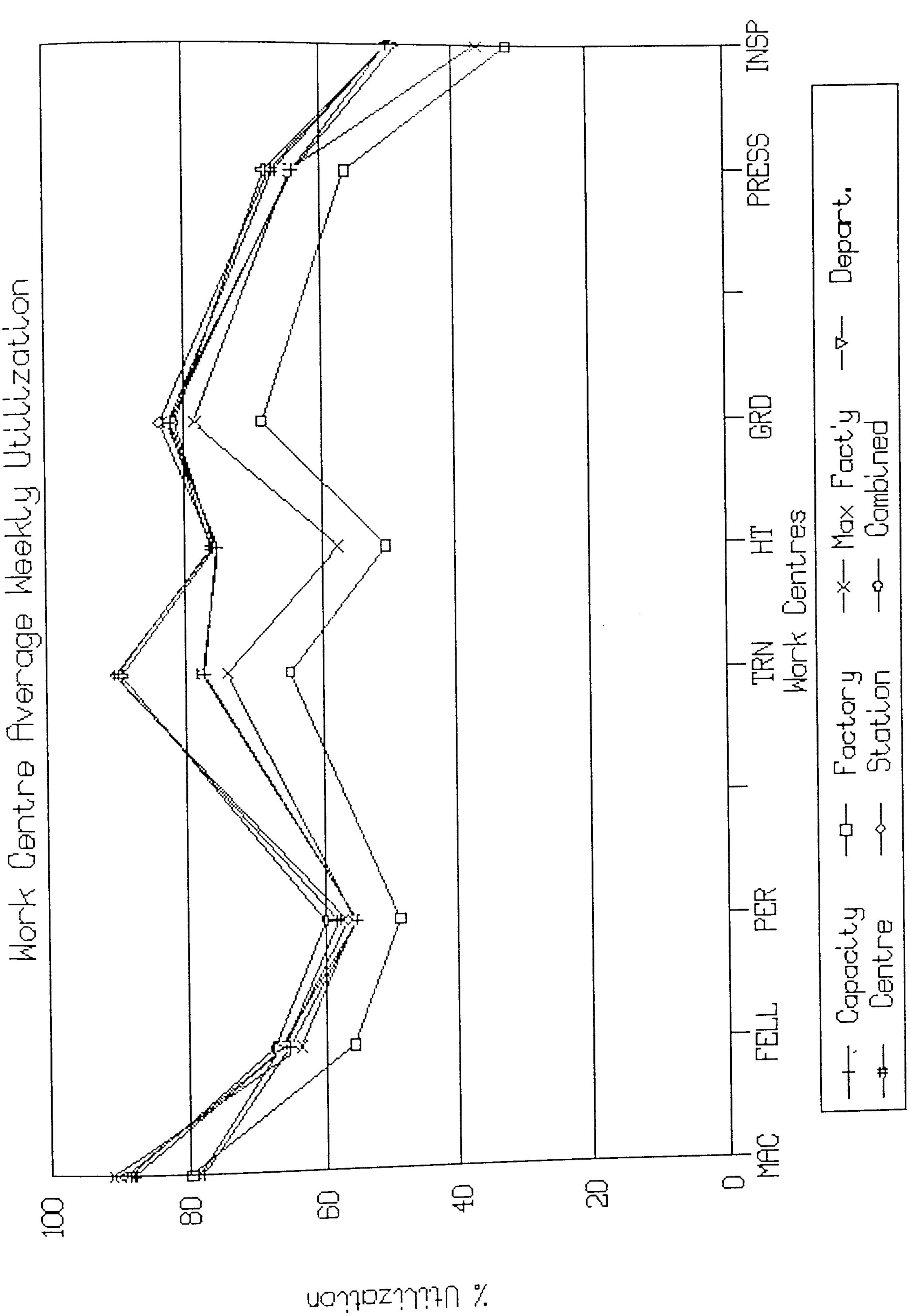


Figure N.1 Work Centre Utilization

The most noticeable contrast was between the factory and all other models. In the worst cases work centre utilization predicted by the factory representation differed by between 14 to 32% in comparison to the corresponding mean values, based upon the average result calculated across all models. The greatest divergence from the mean by a model other than the factory, being approximately 9% and this occurred simultaneously in three evaluations, the centre, station and combined. The validity of the results from the various simulation based models and steady-state capacity calculations being quickly accepted through verification of the evaluation process and a clear understanding of the underlying assumptions. However there was concern over the accuracy of the factory results because they did differ so dramatically from those obtained from other evaluations, and it was difficult to re-examine and question both the evaluation procedure and the included assumptions. The relevance of the factory model was further questioned when the results from the "maximum" model were considered (figure N.1) and seen to vary so significantly, both above and below the station results. The factory model was therefore viewed as inappropriate and the results ignored.

Importantly the comparison of work centre utilization clearly indicated that the combined model, containing department, centre and station elements did not significantly deviate from the pure station representation. The group B models however do highlight a difference in expected utilization, generally tending to underestimate those predicted by group A. In order to understand the difference in the results, the various elements of work centre utilization (i.e. set-up, standard and breakdown time) were considered.

The department, centre, station and combined models were compared on the basis of predicted total number of set-up (table N.2 and figure N.2) and standard (table N.3 and figure N.3) hours completed at a work centre over the 30 week period.

	Spread Sheet	Factory Model	MaxFact'y Model	Depart Model	Centre Model	Station Model	Combined Model
MAC				480.00	960.00	968.00	952.00
FELL				30.00	120.00	104.50	118.50
PER				59.00	239.00	126.50	292.50
TRN				480.00	1320.00	1316.00	1280.00
HT				30.00	45.00	34.25	56.00
GRD				29.50	104.50	119.25	112.25
PRESS				58.50	237.00	218.50	242.00
INSP				3.87	17.90	21.67	20.07

Table N.2 Total Work Centre Set-up Time (Hrs)

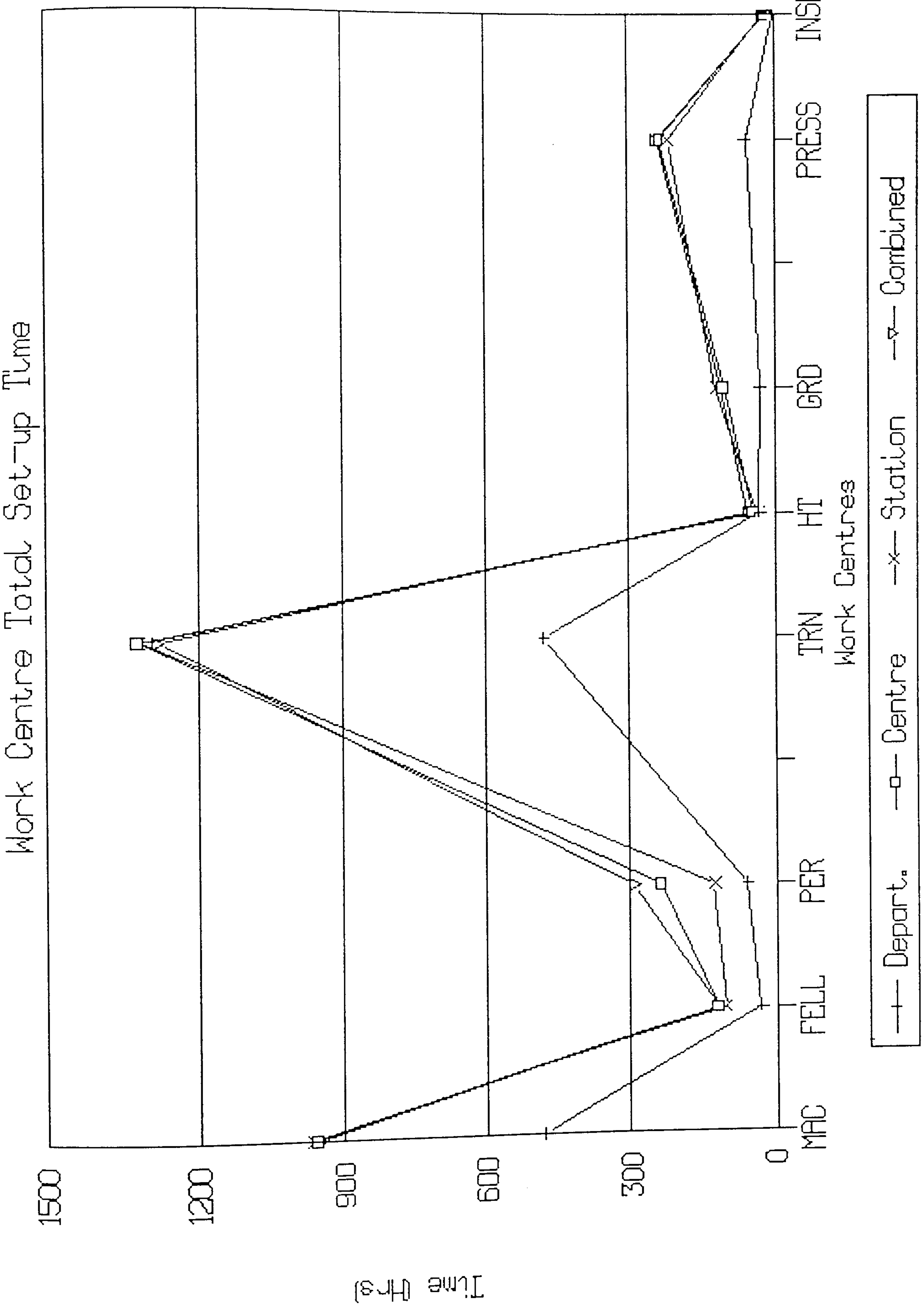


Figure N.2 Work Centre Set-up Time

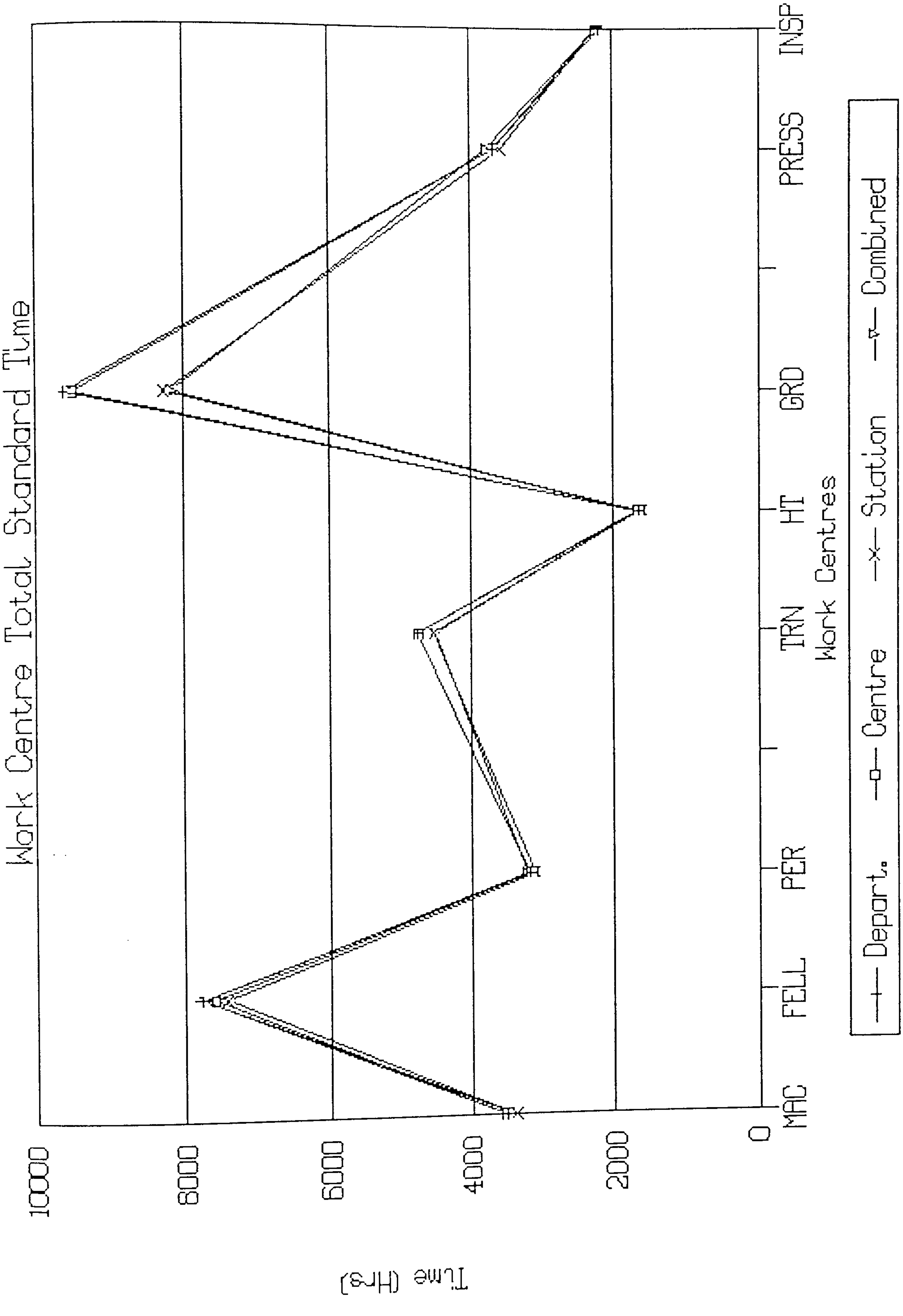


Figure N.3 Work Centre Standard Time

	Spread Sheet	Maths Model	MaxMath Model	Depart Model	Centre Model	Station Model	Comb. Model
CMATIC-MAC				3527.95	3527.99	3389.48	3388.58
FELL-MILL				7793.94	7599.72	7432.85	7760.55
PER-BROACH				3180.32	3166.23	3107.48	3212.75
CMATIC-TRN				4755.48	4751.75	4528.06	4503.14
HEAT-TREAT				1663.66	1670.53	1643.74	1644.95
GRIND				9600.79	9497.93	8270.93	8165.66
PRESS-12TN				3679.39	3665.48	3569.01	3748.59
INSPECTION				2178.22	2229.20	2226.47	2228.36

Table N.3 Total Work Centre Standard Time (Hrs)

The comparison of total set-up hours clearly highlighted that the department and steady-state models, quite significantly in cases, underestimated the number of hours completed, with the exception of HEAT-TREAT and INSPECTION. The fact that the results compared so favourable at INSPECTION with group A models was attributed to its relatively small set-up time (e.g. INSPECTION = 2 minutes, CMATIC-MAC = 4 hours). However the similarity of the results from both group A and B models for HEAT-TREAT provided a explanation for the differences in the predicted utilization of other centres. The correlation is due to only one work station available at HEAT-TREAT and therefore only one transfer batch can be processed at a time. However as other work centres contain two or more stations, a work batch can be split into transfer quantities and simultaneously processed on all available stations. Consequently at CMATIC-MAC, where there are four work stations, each one can be processing a transfer quantity from the same batch. The batch therefore incurring four set-ups instead of the one estimated by the department or stead-state capacity models. Due to this phenomena an additional experiment was performed. This compared the total set-up hours predicted by the department, centre and station models, when configured so that all batches were processed at only one work station and so expected to incur just one set-up.

A graph of the above experiment, illustrated in figure N.2, clearly shows the department model again generally underestimating set-up times, with the exception of first operation work centres. These latter work centres are operating as intended, with batches being processed at only one work station. Therefore depending upon the number of stations available at a particular centre, a number of different batches can be processed simultaneously. As a result, downstream work centres are continually receiving a mixture of different transfer quantities and hence have to alternate between different set-ups. Thus individual batches incur far more than one set-up per operation as estimated by the department model. In the first experiments the predicted number of set-ups between the department, centre and station models differed by only one or two depending on the number of available work stations, whereas in the additional experiment the differences are far more significant.

Furthermore in the additional experiments the department model actually overestimates, with respect to the station model, set-up time at CMATIC-TRN. This occurs because in reality at least one of the three available work stations is dedicated to a particular component and so does not incur any set-ups. The dedication of individual work stations not being taken into account in either the department or centre models.

Both the former and latter total set-up time experiments, indicated that in general the centre model overestimated, although by not as much as the department model underestimated. Any differences being primarily due to the fact that the current set-up of a work station is not recorded. Consequently all idle work stations incur a set-up irrespective of the last job they performed. Differences being most apparent therefore, when the supply of work to a work centre is not sufficient to keep the particular stations continually operating.

Comparison of predicted standard hours completed, illustrated in figure N.3, highlights a difference between the department and centre representations and that of the station model. Both the department and centre models predicting higher standard hours completed. This is directly related to the inclusion, within these models, of a percentage breakdown factor in the standard time. Therefore the more downtime incurred by work stations the bigger the difference in standard hours between department/centre and station models. Furthermore it should be remembered that a percentage factor only represents an expected average work station downtime. Hence differences in overall utilization can be related to the amount individual breakdowns, in the station model, vary from the mean.

Reasons, for any differences in predicted work centre utilization between the various multi-level models therefore, include:

set-up time variation, caused by

- using transfer quantities,
- dedication of work stations,
- inadequate supply of work, and
- duration of individual set-ups, directly effecting the significance of any differences;

standard time variation, caused by

- consideration of discrete stoppages (e.g. breakdowns);

breakdowns, caused by

- variation of individual discrete stoppages from the mean.

N.2 Work-In-Progress

Comparison of Work-in-progress (WIP) consists of weekly snap shots of all work present in the system, in terms of the total number of components (table N.4). In comparing predicted average WIP levels, four models were considered. These did not include the factory representation as WIP was not a predicted measure of performance but an actual input. The models considered were:

- three multi-level models; department, centre and station,
- a combined multi-level model.

To identify trends, the results from each model were compared graphically (figure N.4), and clearly highlighted a significant discrepancy between the department and other models, with the predicted level being at least doubled that of any of the other results. The cause of the difference being directly related to the specification of transfer quantities within the more detailed models. By working in transfer quantities, a batch passes quickly through a system, allowing as it does a number of operations to be performed on a batch simultaneously. In the department model however, a batch has to wait at each operation until the last component has been processed before it can move to the next operation. Consequently slowing down the progress of work through a system, resulting in greater WIP.

The WIP levels predicted by the centre model are a slight underestimation compared with the average suggested by the station evaluation. The differences here can be attributed to discrete stoppages, such as breakdowns. In the centre model which does not include any discrete breakdowns, work continually flows through the system uninterrupted. However the existence of discrete stoppages results in operations being continually disrupted, and hence stopping the flow of work through the system. This obviously leads to higher predicted average WIP levels, although at any instance the actual level could be much greater or less than the mean.

The combined model tends to fall between both the station and centre representations, as would be expected, incorporating as it does some operations which incur breakdowns and others which do not. In general the average WIP predicted by the combined model is only between 3-5% different than that indicated by the station evaluation.

Reasons for any differences in predicted average WIP levels between the various multi-level models therefore include:

- specification of transfer quantities,
- inclusion of discrete stoppages (e.g. breakdown),
- individual observations varying significantly from the mean.

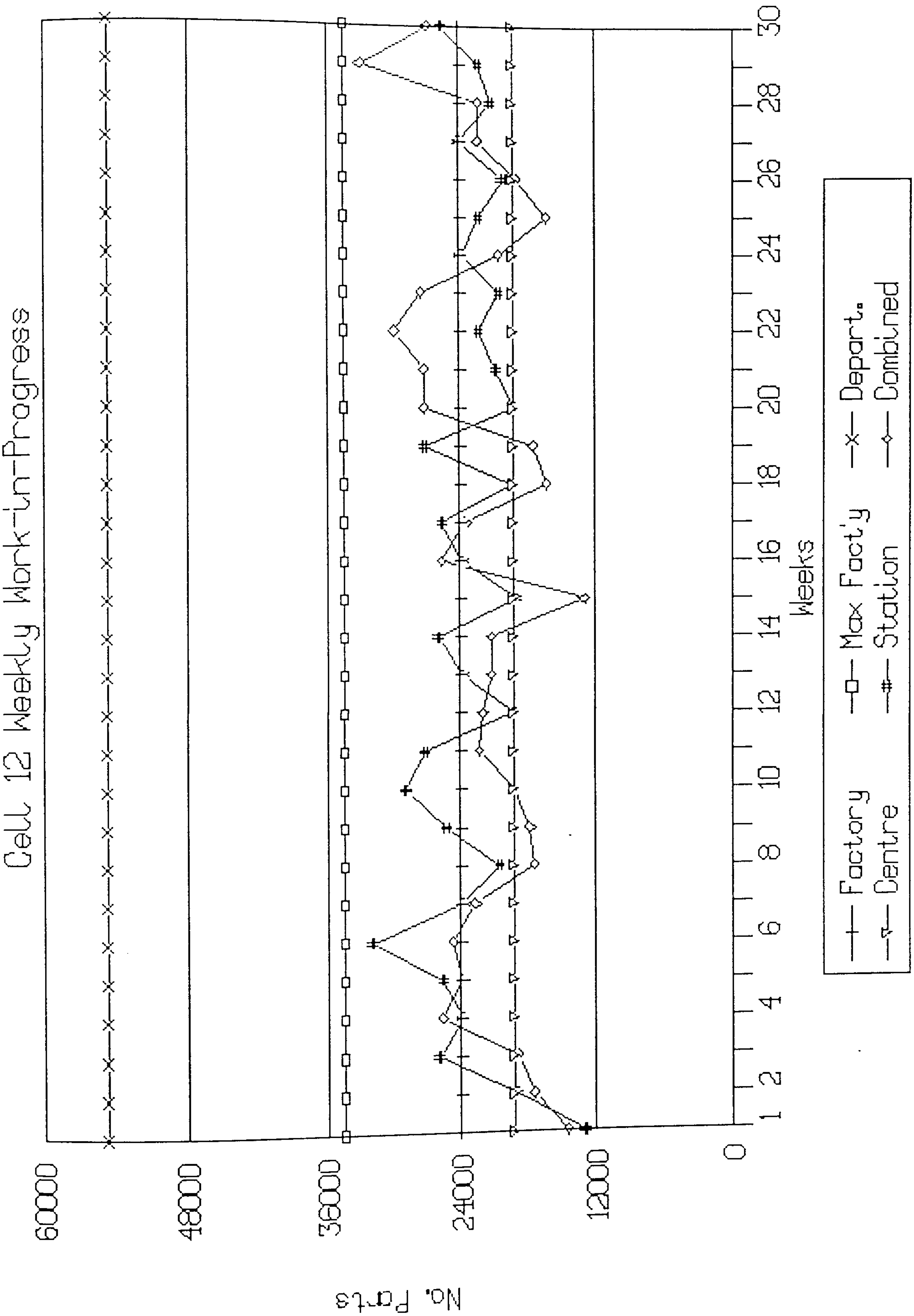


Figure N.4 System Work-in-Progress

Week	Spread Sheet	Factory Model	MaxFact'y Model	Depart Model	Centre Model	Station Model	Combined Model
		24000	34500	54704	19344	13044	14544
2		24000	34500	54704	19344	19044	17544
		24000	34500	54704	19344	26016	19044
4		24000	34500	54704	19344	23916	25716
		24000	34500	54704	19344	25716	23844
6		24000	34500	54704	19344	32016	24664
		24000	34500	54704	19344	23844	22716
8		24000	34500	54704	19344	20544	17472
		24000	34500	54704	19344	25344	17844
10		24000	34500	54704	19344	29016	19344
		24000	34500	54704	19344	27216	22344
12		24000	34500	54704	19344	19344	22044
		24000	34500	54704	19344	23844	21216
14		24000	34500	54704	19344	26016	21216
		24000	34500	54704	19344	19044	13044
16		24000	34500	54704	19344	23844	25716
		24000	34500	54704	19344	25716	23536
18		24000	34500	54704	19344	19416	16344
		24000	34500	54704	19344	27216	17544
20		24000	34500	54704	19344	19344	27216
		24000	34500	54704	19344	20844	27216
22		24000	34500	54704	19344	22344	29984
		24000	34500	54704	19344	20544	27516
24		24000	34500	54704	19344	23916	20544
		24000	34500	54704	19344	22344	16344
26		24000	34500	54704	19344	20164	19044
		24000	34500	54704	19344	24216	22416
28		24000	34500	54704	19344	21216	22344
		24000	34500	54704	19344	22344	32984
30		24000	34500	54704	19344	25716	26984

Table N.4 Work-in-Progress (in parts)

N.3 Component Output

This is the total number of components which complete manufacturing during a week and includes all gears, spindles and assembly components (table N.5). Predicted average component output for cell 12 was compared across five models:

- four multi-level models; factory (based on 19½ hrs. output per day), department, centre and station, and
- a combined multi-level model.

The results from each model were compared graphically (figure N.5). All models exhibited good correlation between each other, with the factory and department models differing the most (by approximately 5%). The average output for both the station and combined models slightly underestimated that predicted by the department and centre studies, due to the inclusion of discrete breakdowns. The inclusion of such stoppages resulting in predicted component output varying quite dramatically, with the graphs exhibiting a relatively

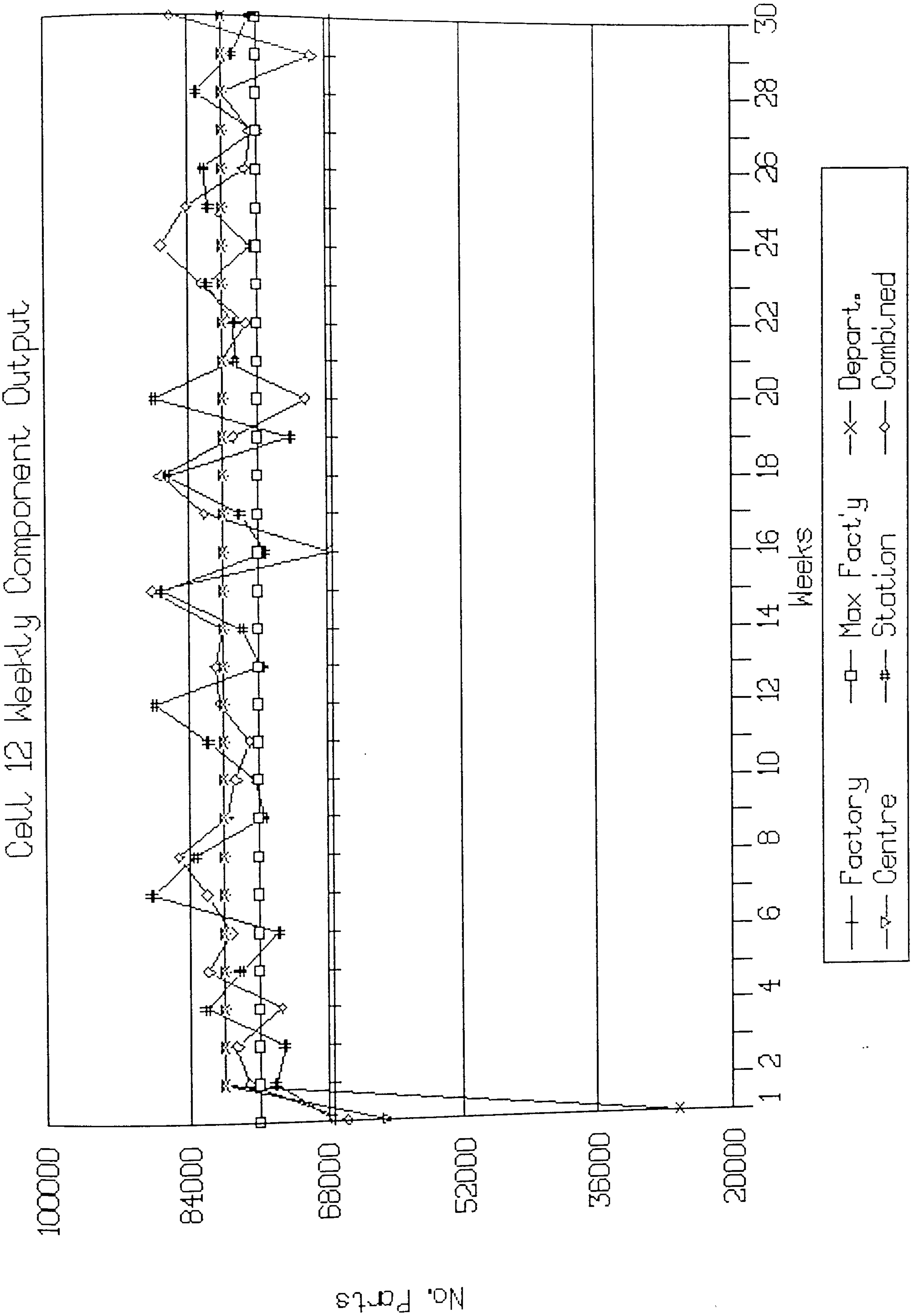


Figure N.5 System Component Output

Week	Spread Sheet	Factory Model	MaxFact'y Model	Depart Model	Centre Model	Station Model	Combined Model
		67275	76050	26416	61081	67261	65765
2		67275	76050	80047	80038	74158	77098
		67275	76050	80047	80038	73066	78598
4		67275	76050	80047	80038	82138	73366
		67275	76050	80047	80038	78238	81853
6		67275	76050	80047	80038	73738	79218
		67275	76050	80047	80038	88210	82047
8		67275	76050	80047	80038	83278	85224
		67275	76050	80047	80038	75298	79606
10		67275	76050	80047	80038	76366	78599
		67275	76050	80047	80038	81838	77038
12		67275	76050	80047	80038	87850	80340
		67275	76050	80047	80038	75598	80869
14		67275	76050	80047	80038	77866	80038
		67275	76050	80047	80038	87010	88151
16		67275	76050	80047	80038	75238	67486
		67275	76050	80047	80038	78166	82191
18		67275	76050	80047	80038	86338	87137
		67275	76050	80047	80038	72238	78898
20		67275	76050	80047	80038	87850	70426
		67275	76050	80047	80038	78538	80038
22		67275	76050	80047	80038	78598	77363
		67275	76050	80047	80038	81838	82413
24		67275	76050	80047	80038	76666	87010
		67275	76050	80047	80038	81610	84119
26		67275	76050	80047	80038	82191	77398
		67275	76050	80047	80038	76013	76727
28		67275	76050	80047	80038	83038	80050
		67275	76050	80047	80038	78910	69552
30		67275	76050	80047	80038	76666	85918

Table N.5 System Component Output (No. Parts)

significant transient effect. Consequently though the average for the station and combined models was less than that of the others, individual observations could be either much greater or less than the mean.

Reasons, for differences in predicted average component output between the various multi-level models therefore, include:

- specification of discrete stoppages (e.g. breakdown),
- individual observations varying from the mean.

N.4 Component Lead-times

This considered the average time taken to manufacture individual component work batches, from issue of the order to completion of the last component (table N.6). Predicted batch lead-times were compared over five models:

- four multi-level models; factory, department, centre and station, and
- a combined multi-level model.

The factory model however was quickly disregarded because it was unable to accurately reflect the given situation, the predicted batch lead-time figures differing quite significantly from all other models (figure N.6 to N.8). For in the system, orders were issued at the beginning of every week and therefore tended to accumulate at the first operations. As a consequence individual batches, depending upon their arrival at the operation, could incur an excessive amount of queuing time before the start of the first operation, which would have a sizeable effect on predicted lead-times. This is illustrated by the fact that a batch of 9000 GEAR_Bs can have a shorter lead-time than a batch of 1800 GEAR_As. Hence the lead-times are effected by the sequence in which work orders were launched and queue scheduling priorities. Neither of which the factory model could consider. Though the issues are relevant and need therefore to be examined, for in reality estimated batch completion dates are generally based upon the date the job is launch plus an average lead-time.

The comparison between the department, centre and station models highlights a high degree of consistency, with a very distinctive trend. It is generally the case that the department model overestimates lead-times, whilst the centre underestimates, with respect to the station evaluation. This results from a combination of factors which effect the flow of batches and, include transfer quantities and discrete breakdowns, both of which have previously been discussed. However the comparison further suggests that variation in the predicted average lead-time for component assemblies (e.g. SP_ASSY) is, to some extent, an accumulation of the inherent differences in the lead-times of the constituent parts. This is best illustrated by the results of the department model,

	Spread Sheet	Factory Model	MaxFact'y Model	Depart Model	Centre Model	Station Model	Combined Model
Gear A		43.71	55.07	135.00	134.00	139.00	135.00
Gear B		211.25	266.15	83.00	61.00	67.00	63.00
Gear C		194.25	244.73	107.00	93.00	100.00	94.00
Gear D		182.11	229.44	131.00	124.00	132.00	127.00
Spdl A		43.71	55.07	161.00	144.00	155.00	157.00
Spdl B		211.25	266.15	93.00	78.00	89.00	100.00
Spdl C		194.25	244.74	127.00	106.00	116.00	130.00
Spdl D		182.11	229.44	155.00	138.00	151.00	149.00
Assy A		43.71	55.07	201.00	161.00	177.00	174.00
Assy B		211.25	266.15	138.00	77.00	77.00	74.00
Assy C		194.25	244.73	164.00	104.00	104.00	103.00
Assy D		182.11	229.44	198.00	151.00	160.00	155.00

Table N.6 Component Lead Times (Hrs)

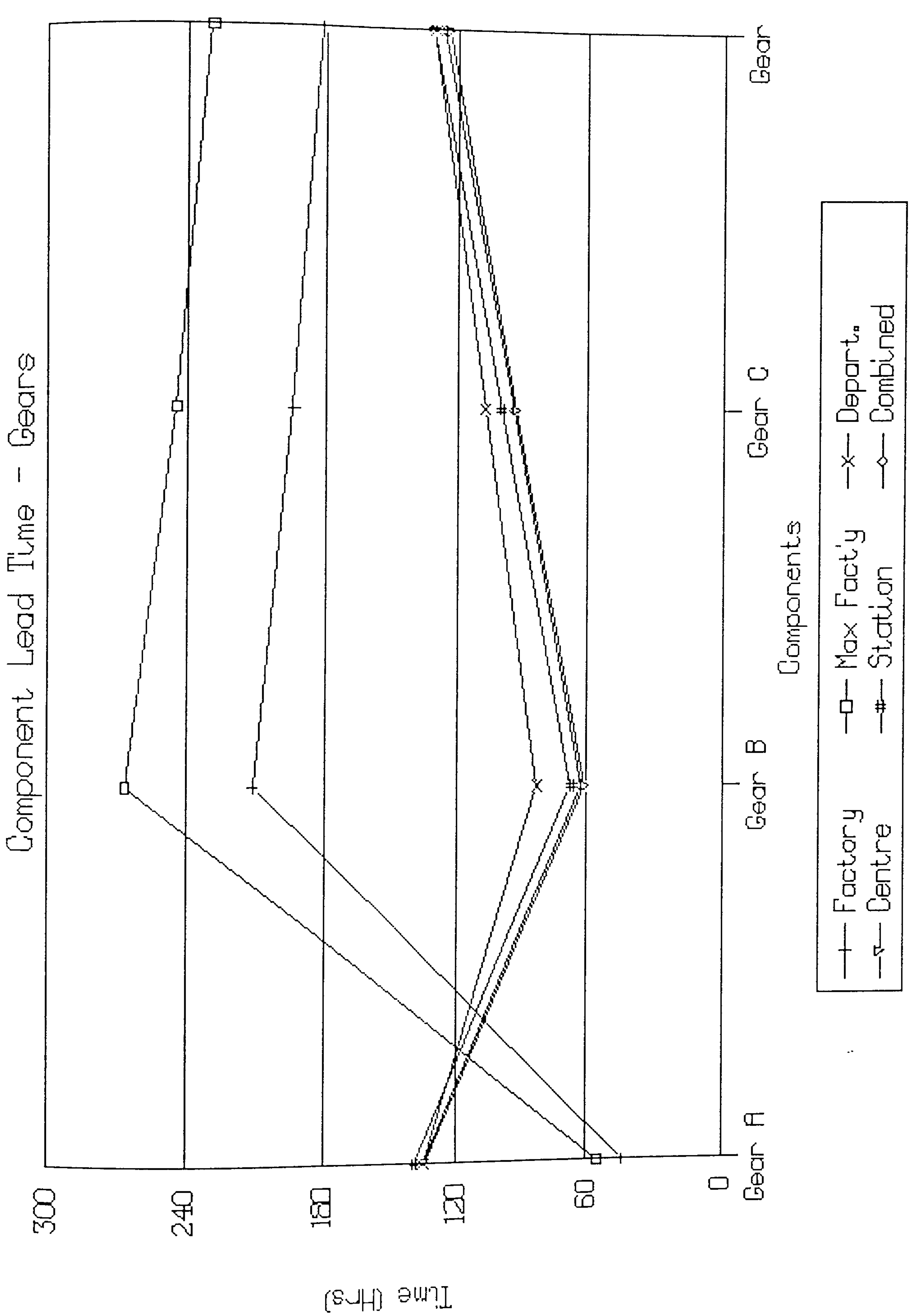


Figure N.6 Component Lead Time - Gears

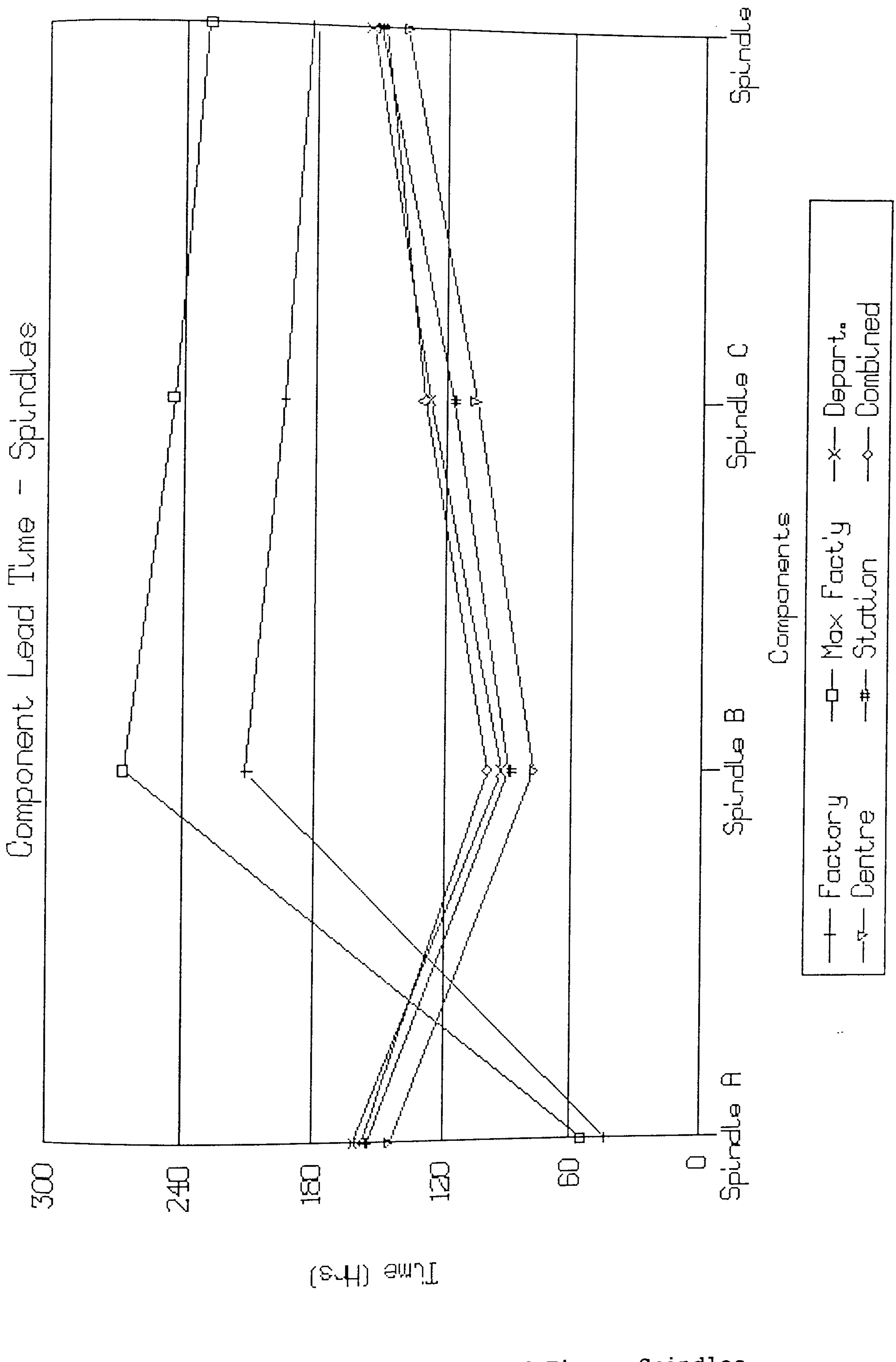


Figure N.7 Component Lead Time - Spindles

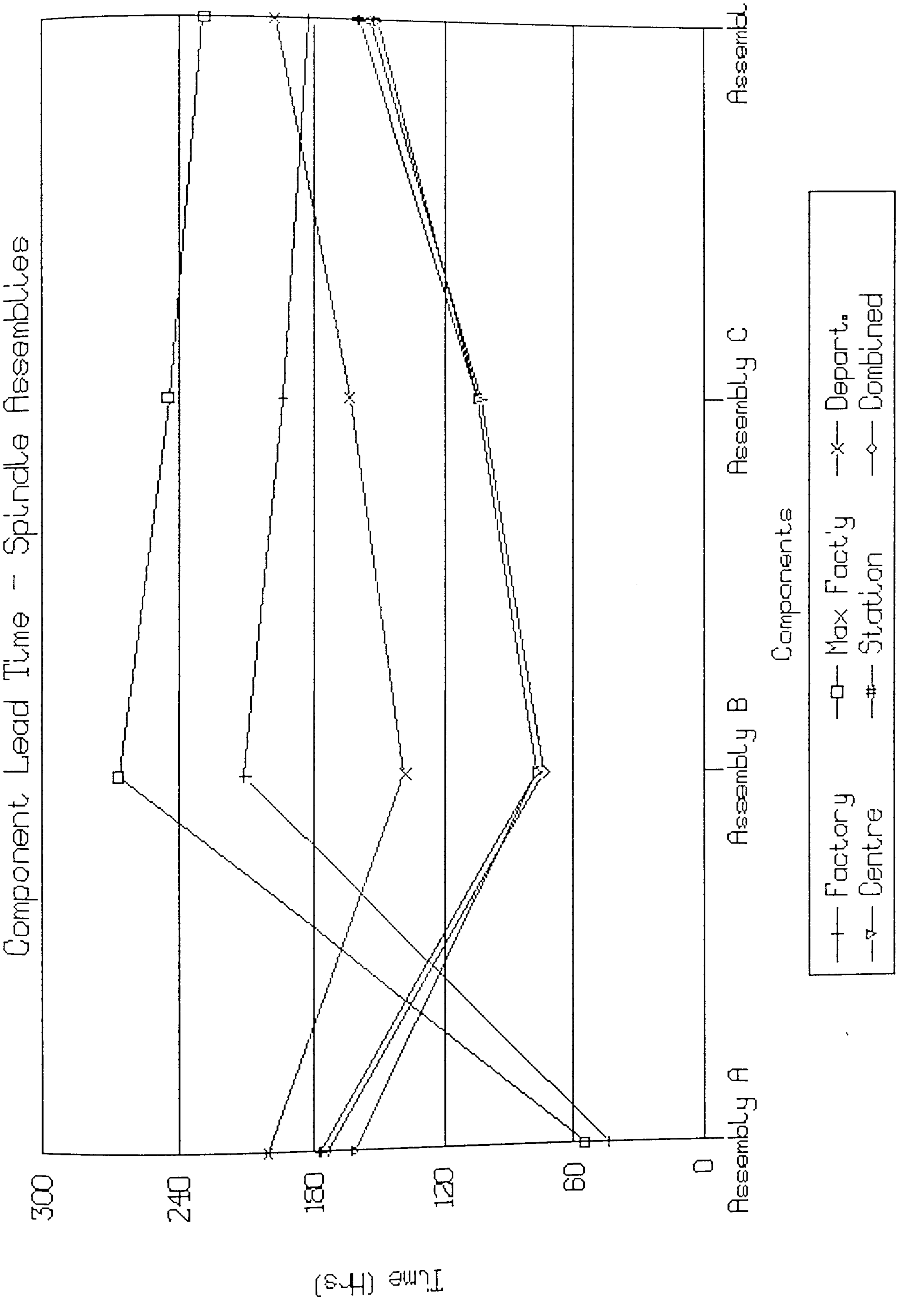


Figure N.8 Component Lead Time - Assemblies where the extended lead-times (with respect to other models) for both gears and spindles has a combined effect on component assembly lead-times, which can be double that predicted by other emulations. This effect only occurs because at the beginning of each week there is insufficient stock of gears and/or spindles to allow assembly operations to commence, and therefore have to wait for the weekly subcomponent orders to be completed. Hence assembly operations are dependent upon the delivery of manufactured components.

As with other measures of performance, the combined model closely reflects that predicted by the station representation.

Finally reasons for any differences in predicted average lead-times between the various models therefore, include:

- specification of job scheduling/sequencing rules,
- specification of transfer quantities,
- inclusion of discrete stoppages (e.g. breakdown),
- accumulation of differences in the lead-times of constituent components.

N.5 Work Centre Queue Size

This concerns the average and maximum number of components waiting to be processed at a particular work centre (tables N.7 and N.8). A comparison was made of the predicted work centre queue sizes obtained from five models (figures N.9 and N.10):

- four multi-level models; factory, department, centre and station, and
- a combined multi-level model.

Consistently the factory model underestimated average queue size for all first operation work centres. This can be attributed to the underlying mathematical model, upon which the factory representation is based. The mathematical model, being derived from closed-loop queuing network theory (section 8.3.1), assumes that all new work orders arrive only when an existing batch has been completed. However in the real system works orders are issued at the beginning of every week and accumulate at the first operation. This phenomena was highlighted by the average and maximum queue size figures from all models except those obtained from the factory. In effect the queue at a first operation is a "reservoir" of jobs with the work centre controlling the flow downstream. As a consequence downstream queues are much smaller and the predicted average queue size for these work centres across all models, including the factory evaluation, compare extremely well. This is with the exception of assembly operations, where the inability of the factory model to consider the availability of components causes more than a significant difference between it and other models in the predicted average queue size for the PRESS-12TN work centre.

The comparison of average queue size predicted by the department model with those of others (i.e. centre, station and combined) highlights an underestimation of first operation queues, with the except of PRESS-12TN and an overestimation of all other queues. The underestimation is as a result of batches being complete removed from queues at the beginning of

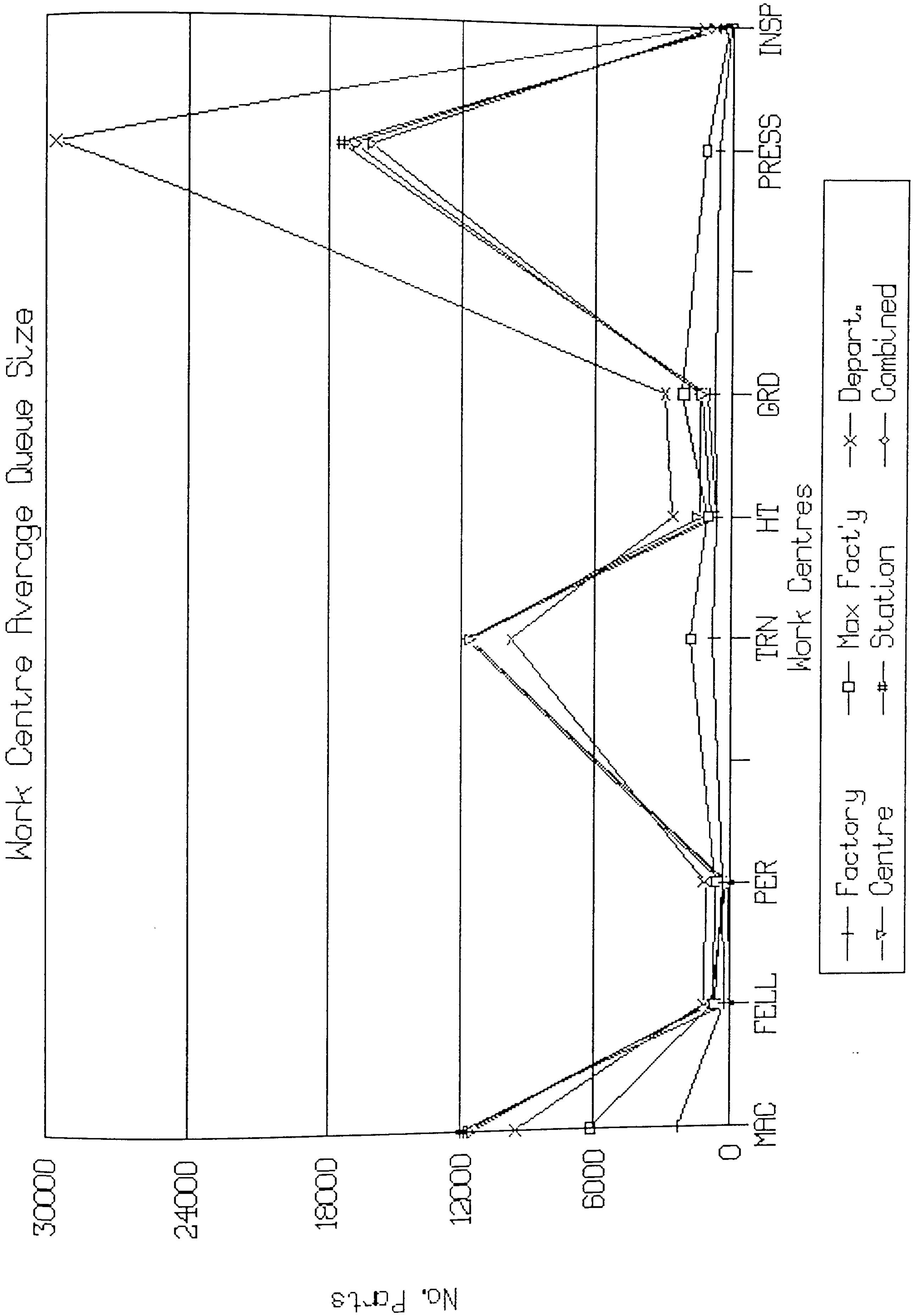


Figure N.9 Average Work Centre Queue Size

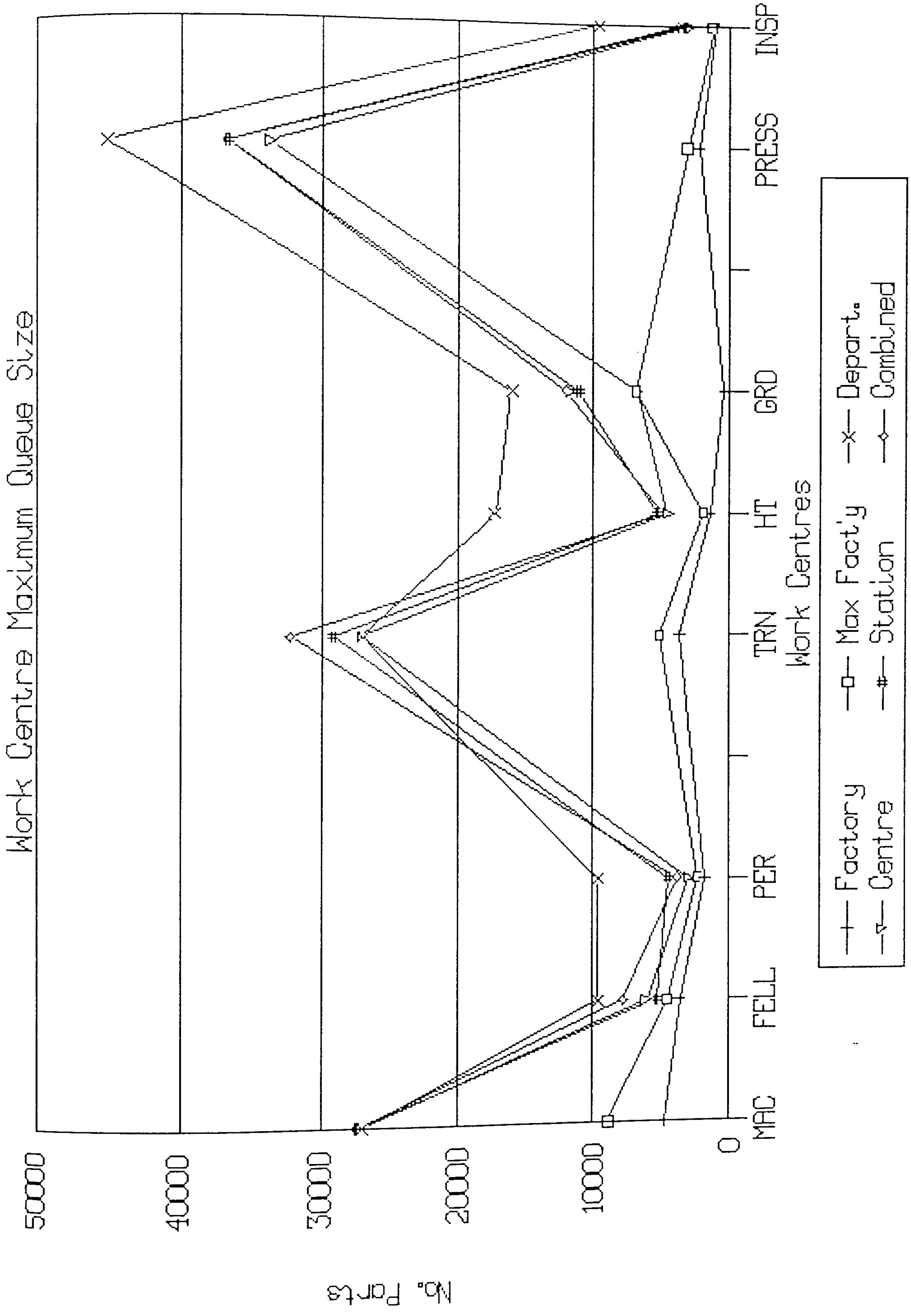


Figure N.10 Maximum Work Centre Queue Size

	Spread Sheet	Factory Model	MaxFact'y Model	Depart Model	Centre Model	Station Model	Combined Model
MAC		2385	6210	9560	11562	12007	11766
FELL		315	735	1210	875	119	760
PER		390	690	1172	229	152	421
TRN		810	1830	9793	11676	11644	11815
HT		690	1095	2642	1491	717	1006
GRD		825	2190	2979	1379	1105	1408
PRESS		630	1200	29548	16113	17444	16869
INSP		90	165	1287	957	358	619

Table N.7 Average Work Centre Queue Size (No.Parts)

	Spread Sheet	Factory Model	MaxFact'y Model	Depart Model	Centre Model	Station Model	Combined Model
MAC		4785	8940	27040	27040	27412	27412
FELL		3660	4560	9672	6048	5320	7800
PER		1845	2370	9672	3000	4500	3820
TRN		3720	5160	27040	27040	29212	32212
HT		1440	1965	17368	4548	5320	4800
GRD		495	6885	16120	6820	11172	11992
PRESS		2325	3120	45032	33712	36712	36712
INSP		1050	1260	9672	3000	3372	3820

Table N.8 Maximum Work Centre Queue Size (No. Parts)

an operation, and processed whole, whereas in other models, batches are split into transfer quantities and processed in smaller batches. The queues therefore being reduced quicker in the latter, than in the former models. The exception to this is the PRESS-12TN work centre, where all SP_ASSY components are assembled. The lack of an adequate store of assembly components (GEAR and SPINDLE) means that the press operations undertaken at the corresponding work centre are dependent on the delivery of manufactured components. As assembly components have longer lead-times in the department model (because of not including transfer quantities), then both predicted average and maximum queue size for the PRESS-12TN work centre are significantly higher than other models, because of the additional waiting time. Furthermore the overestimation of average queue size for work centres performing operations downstream from the first, is also due to transfer quantities. Downstream work centres, within the department model, receive the whole batch in one go and not in smaller, more frequent deliveries, as in other models. This is also the cause of the higher maximum queue size figures produced by the department model.

Generally the average queue sizes predicted by the centre model do not differ significantly with respect to that of the station. The only obvious variation occurring at the PRESS-12TN work centre and again is related to the availability of components, because predicted lead-times are less than those of other models. As a result the average queue size at the assembly operation is underestimated. This being directly due to the absence of discrete breakdowns, and is also responsible for the predicted maximum queue sizes, for all work centres being underestimated with respect to the station model.

There appears to be very little difference between station and combined models, in terms of both maximum and average queue sizes. The only significant difference being the maximum size for the CMATIC-TRN work centre caused by a combination of discrete breakdowns and the availability of the CRAFTSMEN to do the repairs. That is the availability of the CRAFTSMEN, at any given time, differs between the two models. Therefore for any breakdown, more or less downtime can be incurred by either model, depending upon the state of the systems. Furthermore, if less downtime is incurred, the stations will be able to process greater quantities and so may actually incur more breakdowns.

The main reasons for any differences in predicted average or maximum queue sizes between the various models, therefore are:

- specification of transfer quantities,
- assembly operations,
  i.e. component lead-times,
  kiting quantities.
- inclusion of discrete breakdowns,
- availability of resources to undertake work station repairs.

N.6 Batch Waiting Time

This concerns the average and maximum time a work batch has to wait before being processed at a particular work centre (tables N.9 and N.10). A comparison was made of the predicted queuing time obtained from four models, however this did not include a factory representation as queuing time was not a calculated measure of performance. The models were:

- three multi-level models; department, centre and station,
- a combined multi-level model.

A graphical comparison of both the average (figure N.11) and maximum (figure N.12) batch queuing time clearly illustrates a difference between the station and two less detailed department and centre models. The differences being attributable to a number of factors relating to the added detail of the station representation. One significant influence is the effect of discrete breakdowns on the flow of work through operations and has been discussed before. However a further element impinging upon queuing time relates to the operator/work station ratio. This effect was clearly illustrated by an additional experiment involving two further

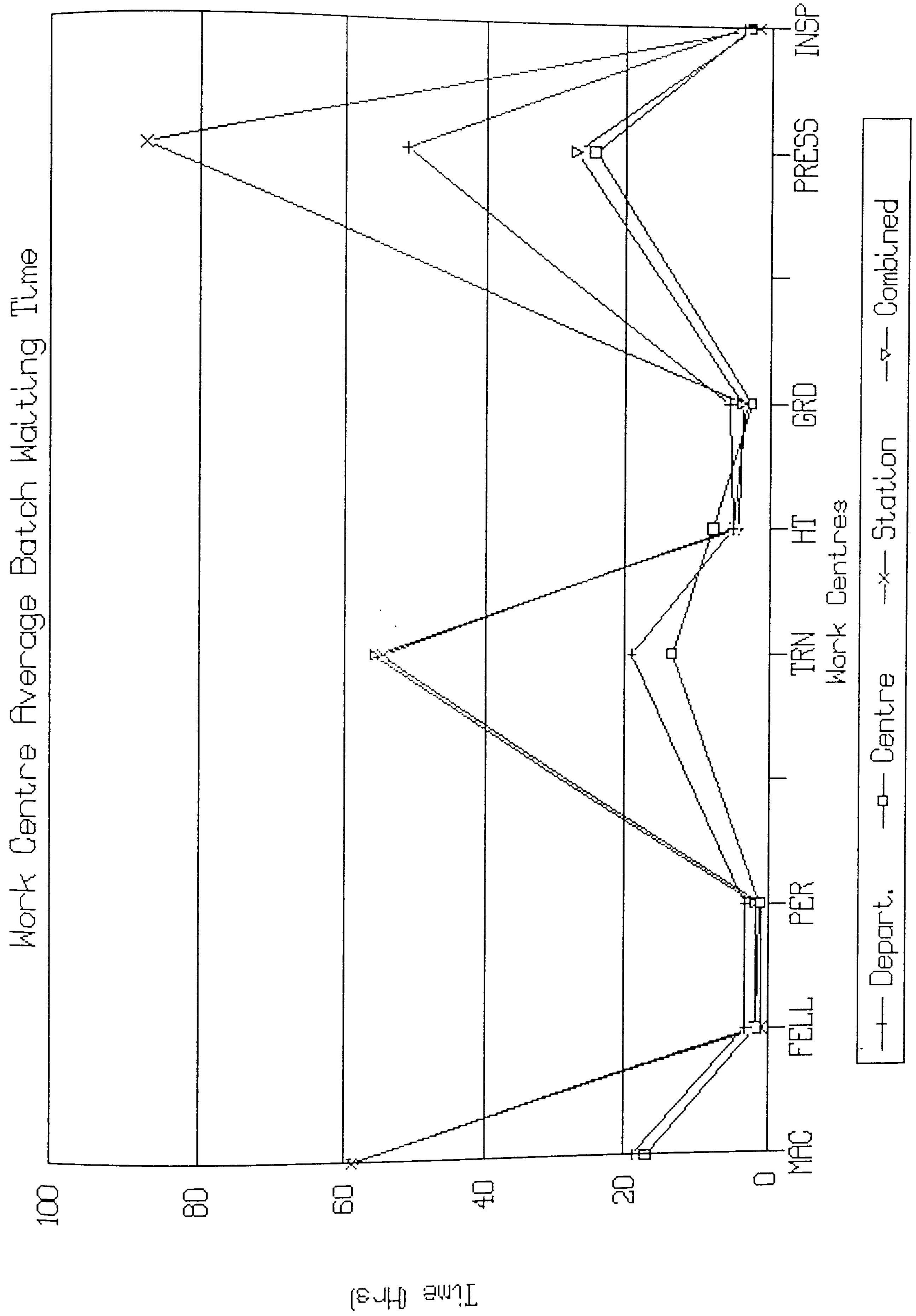


Figure N.11 Average Work Centre Batch Waiting Time

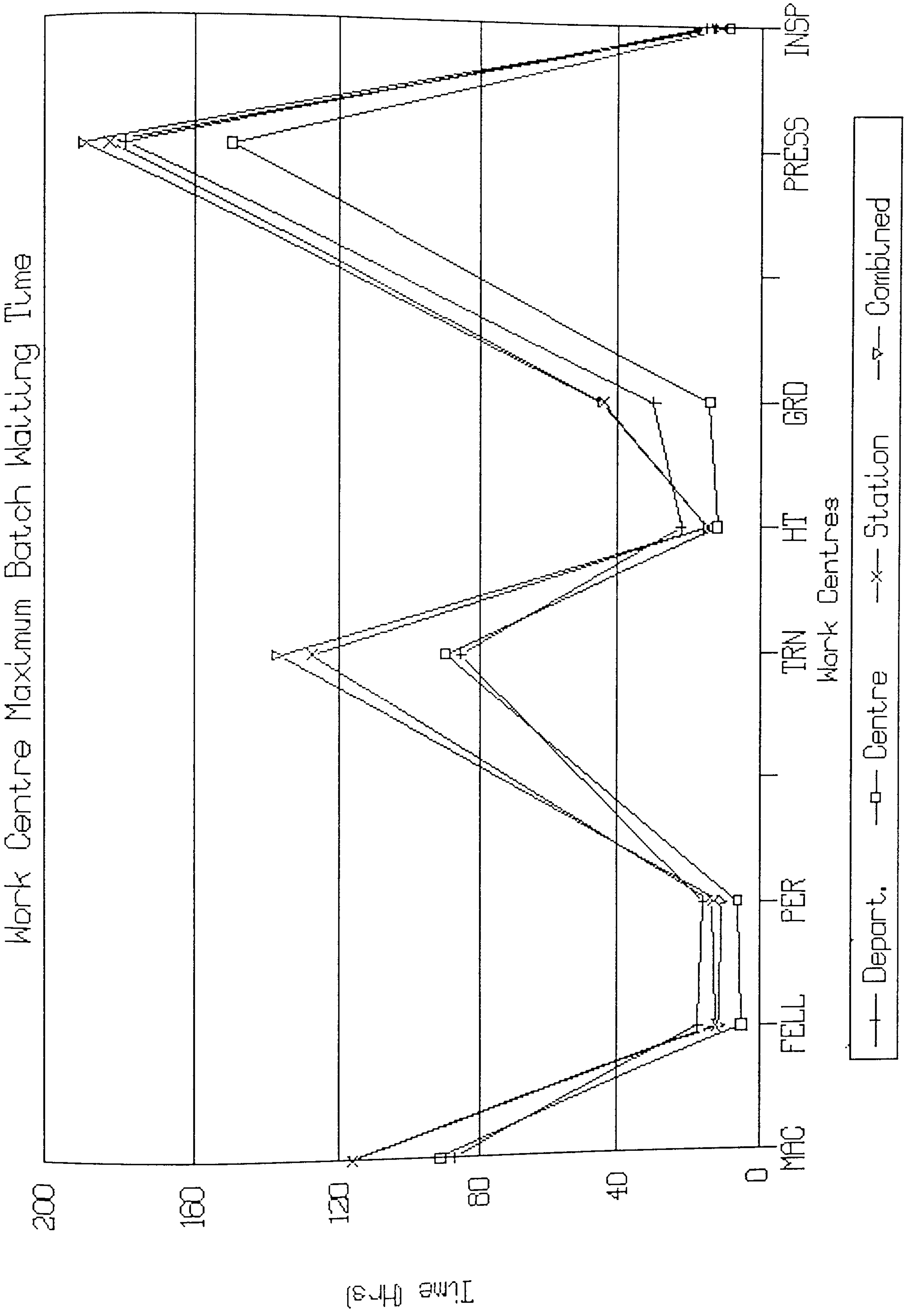


Figure N.12 Maximum Work Centre Batch Waiting Time

	Spread Sheet	Factory Model	MaxFact'y Model	Depart Model	Centre Model	Station Model	Combined Model
MAC				18.96	17.00	58.90	58.62
FELL				3.06	1.72	0.85	1.68
PER				3.20	1.12	1.04	1.71
TRN				19.16	13.52	54.73	55.90
HT				5.14	7.88	4.99	4.35
GRD				5.58	2.46	3.23	3.78
PRESS				51.46	24.47	87.15	27.17
INSP				3.88	2.68	1.59	2.30

Table N.9 Average Work Centre Batch Waiting Time (Hrs)

	Spread Sheet	Factory Model	MaxFact'y Model	Depart Model	Centre Model	Station Model	Combined Model
MAC				87.10	91.50	116.47	115.90
FELL				17.10	5.00	12.10	11.12
PER				15.67	5.93	12.73	10.49
TRN				85.60	90.00	127.73	136.92
HT				22.14	11.83	14.57	14.33
GRD				29.77	14.09	44.43	44.98
PRESS				178.39	149.50	182.58	189.59
INSP				15.23	8.50	10.89	12.48

Table N.10 Maximum Work Centre Batch Waiting Time (Hrs)

models of cell 12. They were station level models, one representing the standard configuration (Appendix J), the other with excess labour (Appendix K) and both without breakdowns. In comparing the various results (Appendix O) it was obvious that the predicted average (figure N.13) and maximum (figure N.14) batch queuing times were directly effected by labour restrictions.

Though on the whole the department and centre models were very similar, they did however differ significantly over the predicted maximum and average batch queuing times for the PRESS-12TN work centre (i.e. the assembly of manufactured components). This highlights the relatively long predicted component lead-times within the department model caused by failure to consider transfer quantities. This was also the reason for slight variation in other maximum and average predicted queuing times between the two models.

The combined model was extremely consistent with the station analysis over most work centres. The only area of any significant variation being in the predicted average batch queuing time at PRESS-12TN. This being attributed to the fact

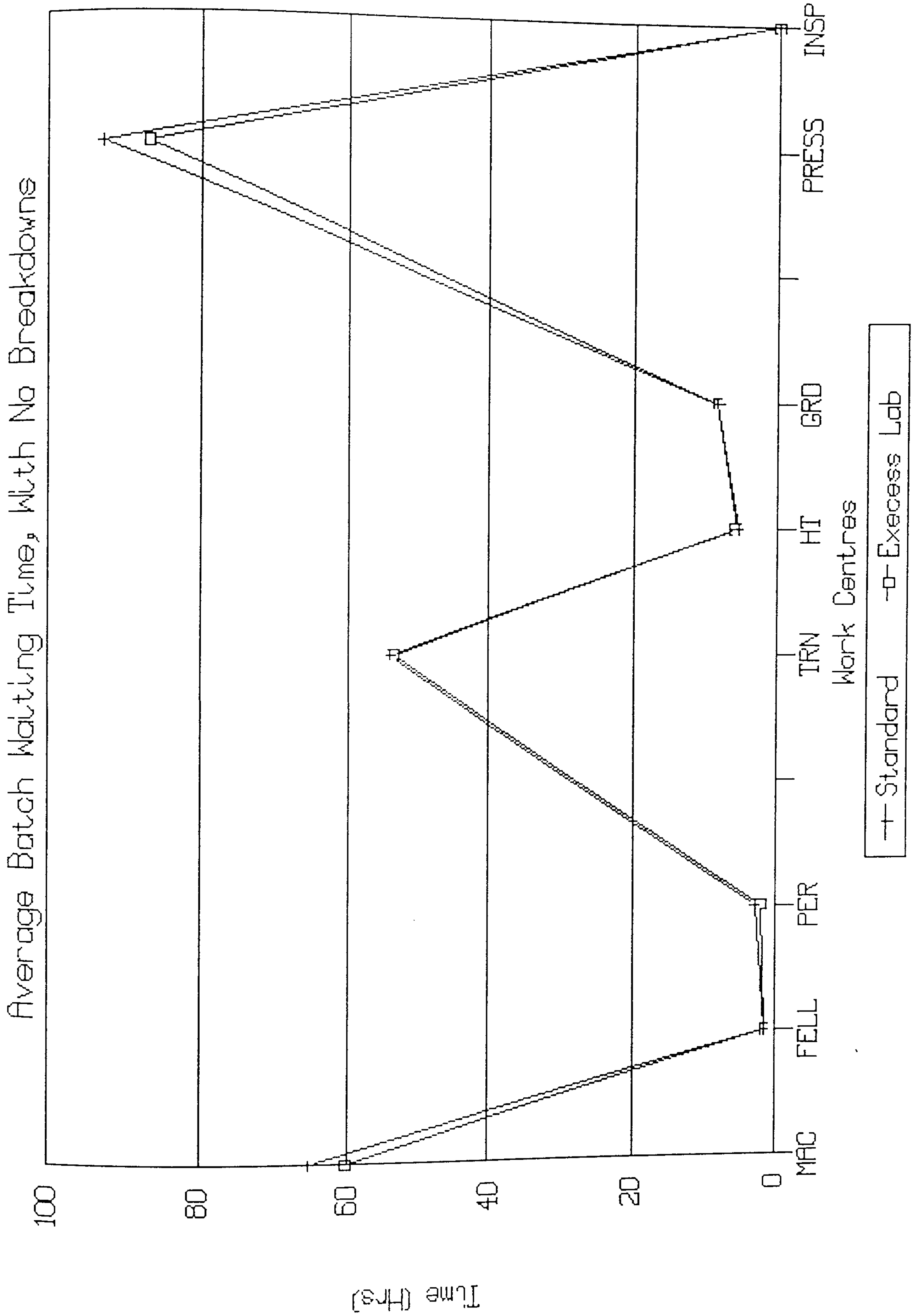


Figure N.13 Average Batch Waiting Time, With No Breakdowns

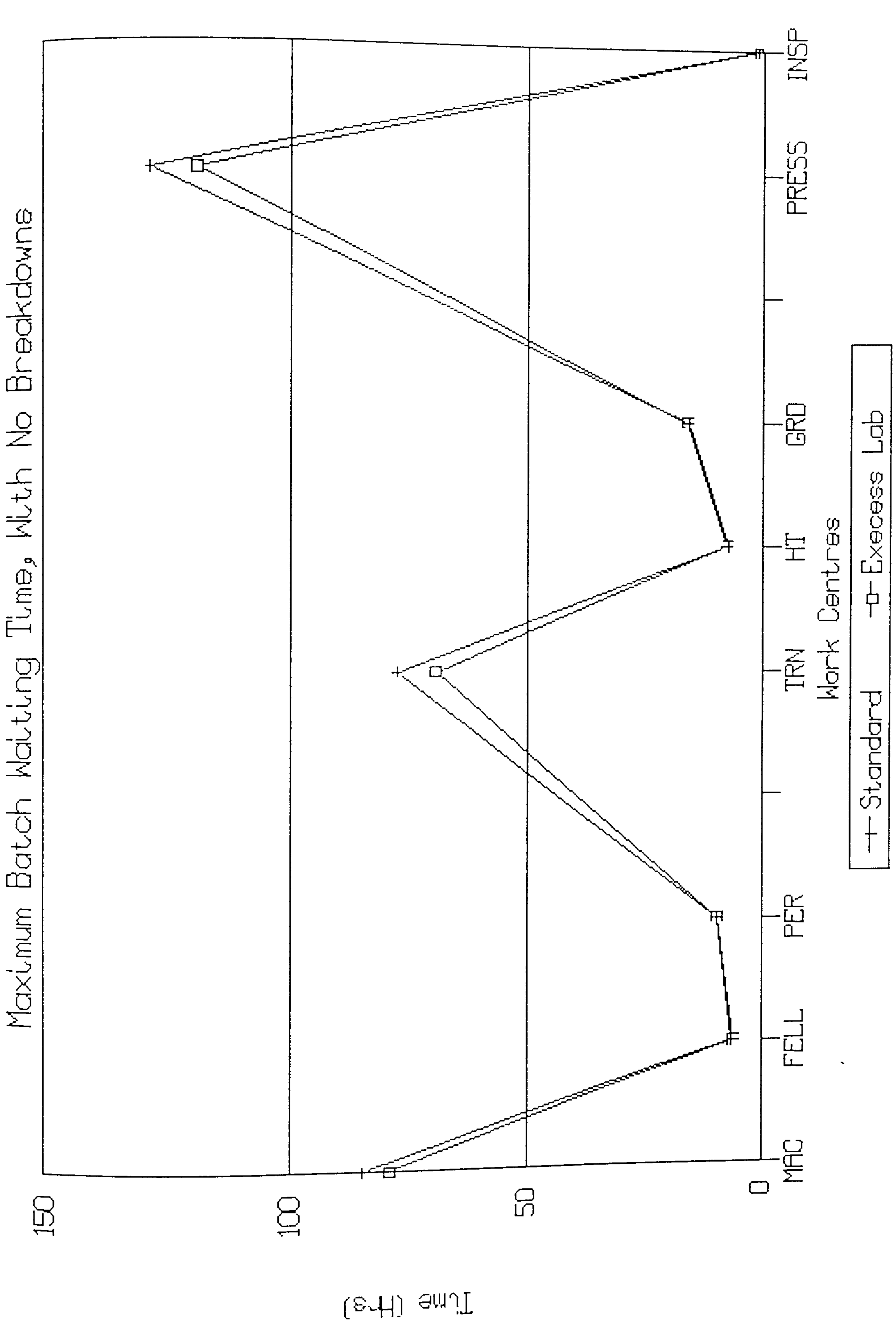


Figure N.14 Maximum Batch Waiting Time, With No Breakdowns that this particular work centre was emulated at the centre level, and corresponds to the results from the equivalent model. Although it must be noted that the maximum value was similar to that predicted by the station model. The average therefore being effected by the greater availability of the work centre because of considering only average percentage breakdowns, whilst the maximum time was due to availability of assembly components.

The main reasons for any differences in predicted average or maximum batch queuing time between the various models, therefore are:

- the operator/work station ratio,
- assembly operations,
  i.e. component lead-times, transfer quantities, discrete breakdowns.
- inclusion of discrete breakdowns,
- specification of transfer quantities.

Appendix O Cell 12 Results For 30 Weeks, With No Breakdowns

Average Waiting Time (Hours)

	Station Model	Station Model Excess Labour
CMATIC-MAC	65.35	60.17
FELL-MILL	1.56	1.52
PER-BROACH	2.80	1.96
CMATIC-TRN	54.18	53.58
HEAT-TREAT	5.57	5.75
GRIND	8.20	8.37
PRESS-12TN	92.79	86.67
INSPECTION	0.04	0.05

Maximum Waiting Time (Hours)

	Station Model	Station Model Excess Labour
CMATIC-MAC	85.02	79.47
FELL-MILL	6.25	6.17
PER-BROACH	9.79	9.57
CMATIC-TRN	78.06	69.64
HEAT-TREAT	7.54	7.54
GRIND	15.82	16.07
PRESS-12TN	128.50	119.03
INSPECTION	0.95	1.11