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A Model for Manufacturing Cell Job Redesign

APPENDICES

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APPENDIX A

RESEARCH METHODS

This appendix describes the underlying philosophical issues relating to research strategy development and research method selection and design. The use, advantages and disadvantages of the latter are described.

A1.1 Research Methodology and Strategy Development

Positivism and phenomenology are two contrasting research paradigms for social enquiry. They form the basis of any philosophical debate on research methodologies in the social sciences. The following sections discuss each in turn and establish the context for selecting an appropriate research strategy.

A1.1.1 Positivism

Positivism is a system of philosophy based on experience and empirical knowledge of natural phenomena, in which metaphysics and theology are regarded as inadequate and imperfect systems of knowledge. The doctrine was first called positivism by the 19th-century French mathematician and philosopher Auguste Comte as well as British philosopher David Hume, French philosopher Duc de Saint-Simon and German philosopher Immanuel Kant.

Natural scientists seek to establish cause and effect relationships between phenomena and embody them in scientific laws to aid the prediction of future events. These relationships are viewed as eternal and unchanging and are derived from rigorous measurement under controlled conditions. A positivistic view of the social sciences asserts that the scientific method of enquiry can be applied to the study of social behaviour based on the premise that social reality is comprised of causally linked phenomena such that if 'A happens, then B happens'. Reality is demonstrated to exist by reference to quantifiable observable evidence.

This approach is termed deductive in that hypotheses are confirmed or disproved according to statistically manipulated quantifiable data. Positivists advocate the use of operationalisation to break concepts down into measurable indicators of their existence. This allows reality to be conceived in terms of words and symbols to facilitate understanding and knowledge development.

A1.1.2 Phenomenology

Phenomenology is a 20th-century philosophical movement dedicated to describing the structures of experience as they present themselves to consciousness, without recourse to theory, deduction, or assumptions from other disciplines. The movement was founded by German philosopher Edmund Husserl in 1913.

Phenomenologists in the social sciences assert that social reality is consciously and actively created by individuals who attach meaning to things they do and to the behaviour of others. Positivists are criticised for their preconceived categorisations of reality during the process of operationalisation as they are not the product of understanding of the subjective aspirations, meanings, values and language that people possess in daily life. Phenomenology emphasises the role of the researcher to analyse the subjective accounts of people which are generated through social interaction and experience. This is the primary source of data.

Phenomenologists uncover reality as it is seen through the eyes of the individual by being receptive to their perceptions of the world as they see it. Laing (1967) emphasises this point and comments 'Human action has an internal logic of its own, which must be understood in order to make action intelligible. The researchers' role is to understand this internal logic...Social behaviour cannot be understood [therefore] in terms of causal relationships that do not account for the fact that human actions are based on...interpretations of events [and] social meaning, intentions, motives, attitudes and beliefs'. Hypotheses are the outcome of this inductive research activity - in contrast to the deductive approach.

Lincoln and Guba (1985) propose a range of characteristics of what they term 'naturalistic enquiry' which fall within the phenomenological paradigm. The approach shares many features of case study research. These encompass the study of natural research settings, people as the primary data-gathering instruments, the use of tacit knowledge, the use of qualitative methods because of their sensitivity, purposive rather than random sampling, inductive rather than deductive data analysis, grounded theory development, negotiated outcomes and tentative generalisation of theory to other domains. It may be asserted that this 'post-positivistic' data collection approach is more reflective of the world from which it is gathered.

A1.1.3 Research Strategy Design

Table A-1 compares the two research paradigms. A researcher must design a research strategy and select research methods to reflect the nature of the social settings as well as the objectives of the research. Practical research strategy designs, therefore, tend to be a combination or hybrid of the positivistic and phenomenological philosophies.

Table A-1 Comparison of Positivism and Phenomenology

Positivism	Phenomenology
Deductive	Inductive
Provide explanation through analysis of causal relationships	Provide explanation of subjective meaning held by subjects through understanding
Generate and use quantitative data	Generate and use qualitative data
Use physical and statistical controls to facilitate hypothesis testing	Minimise disruption into natural social settings to leave unchanged the reality under investigation
Use structured research methods to ensure reliability and validity of data	Minimise structure in research methods use to ensure the above

Research strategy refers to the general orientation or style adopted by an enquiry to address research questions and hypotheses. Research questions are the main drivers for undertaking research. Hypotheses may be viewed as early guesses, based on experience and theory, about what lies behind the 'how' in the research question. They may act as a bridge between research questions and the design of an enquiry. Designing a strategy for a piece of research is primarily concerned with transforming the research question into a coherent, structured research project. In general, the adopted research strategies must be appropriate for the questions to be answered by the research.

A research strategy enables an enquirer to undertake research in a systematic way and in doing so improve the general validity and reliability (quality) of accumulated data. The use of a research strategy introduces a logical justification to data collection, analysis and categorisation. In addition, the careful choice and design of a research strategy can help justify adopted data collection methods and any design modifications as well as helping allay methodologically based fears in the minds of sponsors, examiners and other interested parties. Also a well designed and justifiable research strategy help the latter assess the worthiness of the data collected and emerging theories and supports theory development through replication by other practitioners.

Research strategies can be classified broadly into qualitative and quantitative approaches. In the quantitative approach, the concepts and constructs are *predetermined* (positivistic and deductive) whereas in the qualitative approach they *emerge* from the data (phenomenological and inductive) and are grounded in empirical data collected through research. The research outlined in this thesis is qualitative and exploratory in nature where the outcome of the research was genuinely not certain. The selection of a research strategy and methods must tackle the methodological issues of research validity and reliability. As a consequence, the objectives and foreseeable difficulties involved in the research must be fully considered to minimise the many possible pitfalls.

Research strategies have traditionally tended to fall into three camps: experiments. surveys and case studies. These three strategies, however, are not exclusive and often it is more appropriate to adopt a hybrid or combined strategy building of the strengths of the three approaches.

A1.1.4 Case Study Methodology

Research can also be categorised in terms of its purpose - reflected and embodied in the research questions. This purpose may be exploratory, descriptive or explanatory. The research may be concerned with more than one purpose but usually one will predominate. Exploratory research seeks to find out what is happening, discover new insights, ask questions and assess phenomenon under research in a new light. Case studies tend to be appropriate for exploratory studies; surveys for descriptive studies and experiments for explanatory studies. Each strategy, however can be used for any or all purposes depending on the context. The research presented in this thesis is primarily exploratory but with descriptive and explanatory dimensions. The research question is a 'how' type to meet the objectives of the research in describing allocation of functions effects on the long term performance of Nagara cells. The research adopts a multiple case study approach. The notion of a case suits the self-contained and clearly identifiable nature of cellular manufacturing environments. as well as the exploratory nature of the research.

In a case study, a 'case' is the situation, organisation, group of people or whatever is the focus of the research. Robson (1993) defines case study as 'a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence'.

Case studies may be viewed as unscientific (in the philosophy of science sense) or unrigorous and so invalid as a form of enquiry because of the bias towards qualitative research methods. There is, however, no restriction to which research methods can and cannot be used. Also case study is sometimes considered as a 'soft option' or as a precursor to some more 'scientifically rigorous' experiment or survey. As Bromley (1986) points out that 'case studies are sometimes carried out in a sloppy, perfunctory...way.' These criticisms could, of course, be made about other research strategies. Case study is as scientific as any other research strategy in that what distinguishes scientific knowledge is not so much its logical status or quantitative and qualitative characteristics. as the fact that it is the outcome of a process of enquiry which is governed by critical norms and standards of rationality. To allay fears in the validity of this (largely) qualitative research approach, therefore, care must be taken to ensure that data collection, handling and analysis are carried out rigorous. This was facilitated in the multiple case study approach outlined in this report by giving particular attention to conceptual framework, research question and sampling strategy design as well as the formal selection and rigorous use of research methods. These issues are discussed and delineated in Chapter 4.

A1.2 Research Methods

The following sections outline the nature and salient issues of the main research methods not described elsewhere in the report.

A1.2.1 Semi-Structured Interview Method

Interviews aim to elicit views and opinions without imposition of the researchers' own conceptual framework. It is often used to identify both the range of features associated with a particular issue as well as respondents' perceptions of the relationships between features. Semi-structured interviews share the above objectives and ensure that particular issues are addressed by all respondents. In addition, their flexibility facilitates the elaboration of specific issues. In terms of tactics, interviewers have freedom in sequencing questions, in their exact wording and in the amount of time and attention given to specific issues.

The benefits of the approach, in contrast to structured interviews, are more consistent data sets are produced because informal, individual orientations are largely retained. In addition, it is easier to keep to areas of interest. The main disadvantage is that because of the inherent flexibility of the approach, the imposition of the researchers' conceptual framework may distort the perspectives of the respondents and miss aspects of importance. Sequencing and word flexibility may also result in the delivery of different questions with adverse implications for response comparability. Although quicker than structured interviews, the method is still time consuming for data collection as well as for data analysis.

A1.2.2 Self-Completion Questionnaires

Questionnaires can be used in a broad range of applications and are highly formalised methods of collecting data, although there is scope for including open-ended questions. Questionnaires can engender a wide range of responses including preference, dis/agreement, choice, opinion and attitude. They facilitate the direct probing of specific task details as well as examining the attitudes and feelings towards the tasks.

The questionnaire can produce a wealth of data, and therefore planning is essential. Questionnaires are rarely used in isolation and should be used as a means of gathering initial data to be complemented by follow-up questionnaires and interviews. Questionnaires are also useful in developing a 'situational setting' by revealing certain details that may be elaborated or focused upon in future interviews. Their main use is in the collection of specific data, and because of their economy in application, can be used to sample responses from a large sample of people. Coding can facilitate the generation of statistical data. Whilst questionnaires are inherently subjective, large amounts of data can be used to identify trends and inconsistencies.

Care must be taken to phrase questions to avoid ambiguity and foster consistent interpretation of questions in the way that was intended. Care must be taken to avoid leading, hypothetical.

vague, negative complex or double barrelled and 'could', 'should'. 'would' type questions. Also, jargon and loaded words that may cause offence and emotionally colour a question should also be resisted. Poor questionnaire design can also miss valuable data if the questionnaire firstly does not ask a full and representative range of pertinent questions to comprehensively characterise a given phenomenon and secondly, if the questionnaire does not allow the subject to elaborate upon an issue of specific importance to the research and the subject. The latter can lead to feelings of frustration in the recipients. The analyst must take great care, therefore, to ensure all necessary questions and question types are included in the questionnaire.

A1.2.3 Observational Methods

The actions of people are central to any enquiry. Observational methods provide formal ways of watching and recording what people do. The main advantages of observation as a technique are firstly the directness of data collection and secondly their usefulness in complementing questionnaire and interview data. The latter helping to ensure the validity and reliability of research data. The method is, however, criticised because of possible observer effects on a situation. This can be overcome by a combination of secret observation, at one extreme, and by complete familiarity with the observer. One, however, can never know what the behaviour would have been like if it had not been observed. Observational biases include selective attention to some aspects of the situation rather than others, selective encoding, selective memory and interpersonal factors. In addition, the method itself can be time consuming.

Observation may be used for a variety of reasons. It is often used in an unstructured form as an initial scanning or familiarisation method to find out what is going on in a given situation. Walk and talk throughs are also used for this purpose. These methods are useful in developing a vocabulary or common language between the researcher and participants during interviews. Observation data can be used to corroborate questionnaires and interview data as well as facilitating triangulation with other quantitative and qualitative data.

Methods for recording observations should reflect the nature and objectives of the research question. The two main methods are narrative accounts and coded schedules. The content of these methods depend on the degree of method formality. Informal methods are less structured and allow the observer much freedom in what and how data is recorded. Data of this kind is complex, unstructured difficult to synthesise. Formal methods are more structured and focus on pre-specified details. Although this facilitates data validity and reliability, the completeness and richness of the situation, achieved through the former, can be lost.

The role of the observer is central to the adopted recording method and focus. A participant observer seeks to become part of the observed group. This may be dichotomised in terms of a 'complete participant role' where the observer conceals that they are observing and attempts to infiltrate a group or, at the other extreme, the 'participant-as-observer role' where the observer is recognised as only being an observer within a group or social setting. The former

is, however, not generally acceptable for ethical reasons. With the latter. it is important that the observer establishes trust and a rapport with members. The dual role of participant and observer is not easy and the presence of the observer can have a significant disturbing effect on the group.

Another stance towards observation is the observer-as-participant role where the observer is recognised but distances themselves from the group or social setting. This is commonly aspired to by researchers who undertake systematic observation.

A1.2.4 Critical Incident Technique

The technique is useful in highlighting features of human behaviour that make a system vulnerable. It collects data on effective and ineffective behaviours central to meeting system objectives and attempts to record critical incidents that are memorable to those working in the system. It is can be used during the early stages of a project or as a 'trouble-shooter' tool because its strength lies in the rapid isolation of key problem areas. It is especially good at highlighting rare, extreme and critical events because of their ability to remain in people's minds. A representative set of responses from the critical incident technique interviews are tabulated in Appendix D1.4.4.

The questioning as well as the objective of the technique is open ended. Recipients are asked to describe in context effective and ineffective behaviours and relate them to overall system goals. Data may be collected in a variety of forms ranging from a semi-structured interviews with individuals or groups to self-completion questionnaires. The critical incident technique should not be used on its own as a way of collecting data about human behaviour because it only reveals atypical rather than everyday events. The method should, therefore, be used as one of a range of methods where the data can be used to support and corroborate other data.

Care must be taken to recognise and avoid rumours and anecdotes. The nature of the incidents themselves can compromise the respondents because they may potentially be sanctionable. A degree of rapport and trust, therefore, must be established between both parties.

A1.2.5 Hierarchical Task Analysis

Hierarchical task analysis (HTA) prompts the analyst to establish the conditions when various sub-tasks should be carried out to meet system objectives. HTA produces a hierarchy of operations, describing the basic things that people do to meet system goals, and plans which describe the necessary conditions required to undertake the operations. The method identifies how work should be done to meet system objectives in a way that links the activities of people directly to the requirements of the system. To illustrate the HTA technique used in the research, Appendix G2 contains the HTA diagrams to two levels of analysis for Cell A.

Since the resulting task description is hierarchical, the detail can be developed as much or as

little as necessary. The analysis begins by a statement of a goal. This is redescribed in terms of operations and sub-operations as well as related plans and sub-plans. At each level of the hierarchy, an operation is broken down into further sub-operations and further plans. Operations are synonymous with functions and can be described as a unit of behaviour. Tasks may be seen as trying to achieve system goals in a specific context by using facilities and resources whilst overcoming constraints. The task analysis process is, therefore, a process of critically examining task resources, constraints and preferences to establish how these influence operations in meeting system goals.

The Functional Analysis System Technique (FAST) is closely related to HTA and is useful in the early stages of system design. It focuses specifically on allocating functions between people and machines and looks similar to HTA diagrams. Functions (or operations with the HTA) are described in terms of an item, a verb and a noun. If the functions are modelled hierarchically, then for each function, 'how do I?' questions denote functions that appear underneath the current function being analysed. The 'why do I?' questions denote functions that appear above the current function. When the diagram is complete, having answered all how and why questions, then a coherent model of a system is produced along with the inter-functional relationships. Also AND and OR operators can be used to describe the latter.

The process of using either tool is complex and time consuming and should be carried out with the people working in the system to corroborate and modify, where necessary, the HTA description. The approach is best developed as a dialogue between the researcher and job incumbents to take into account the perceptions of the latter in operation and plan development. Data gathering is carried out using the critical incident technique, observation and walk-and-talk throughs. HTA is an effective way of organising information and provides a useful framework upon which other task analyses can be based.

APPENDIX B

ADOPTED RESEARCH PROTOCOLS

This appendix describes the protocols and codes of practice adopted for carrying out each research method. Their consistent use helps establish a sense of trustworthiness in the research, minimises validity and repeatability type research errors and fosters a representative and consistent set of data.

To facilitate the gathering of rich, detailed data over a long period it was essential to be immersed in the company and avoid complete detachment from the people. Excellent relationships were cultivated with the company before the research itself commenced over a period between February and November 1993. The adopted research strategy and data collection methods, therefore, were augmented with additional observation and unstructured interaction with participants which, in reflection, proved enlightening and of great value.

B1.1 Establishing Trustworthiness from the Research

It was essential that the research was conducted with an 'open mind...to avoid making assumptions' and to 'not take things for granted' (personal discussion with Lisl Klein, 1993). This is difficult to achieve because the experiences, preconceptions and beliefs that a person may possess colour the choice of problem and methods for research and analysis. These preconceptions and beliefs exist within a conceptual framework or paradigm advocated by the enquirer. The assumptions and presuppositions of the prevailing paradigm form part of an implicit framework which ultimately determines what questions are asked, what data are considered relevant and how data are gathered, analysed and interpreted. This describes the investigator paradigm effect.

Enquirers cannot carry out research without possessing some basic beliefs and assumptions about the subject of investigation. It is essential, therefore, that they have a thorough understanding of the state of knowledge related to the inquiry and subject as well as the ability to dismiss it if necessary. Although this itself is difficult to achieve, the author entered into the pilot study with a good understanding of cellular manufacturing and allocation of functions concepts; but also with a genuine lack of certainty as to the outcome of the research.

B1.2 Adopted Interview Protocols

Throughout the research, the author was conscious of the need to establish a friendly but business-like atmosphere during all data collection activities. This was especially important whilst conducting interviews. The majority of organised interviews were semi-structured because of the exploratory nature of the research. This proved useful for changing the order of questions and their exact wording as well as having the freedom to expand on particular details or to pay particular attention to a specific point.

The author was aware of the importance of guiding the direction of the interview whilst maintaining and developing the interest of the respondents as well as putting them at ease and allowing them to talk freely. The following sections outline issues considered important by the author for facilitating the above. No interviews were conducted during official work-breaks.

- *Location.* All interviews were conducted in locations familiar with the participants. Interviews with people from the training and personnel departments were carried out in their offices. In Division V, interviews were conducted in a small, internal room away from, but near-by the shop-floor. The room was regularly used for small group meetings and comprised of only a single large table with chairs. In Division C, interviews were conducted in the 'JIT-pit' located next to the Cells. The 'JIT-pit' is a clearly identifiable area of the shop-floor, designed and built by the employees, for eating, drinking and relaxing during official work breaks. The area is populated with permanent chairs and tables, a drinks and sandwich machine as well as basic washing facilities.

- *Seating.* All interviews were conducted with the author and participant facing each other across a table. This prevented the participants from reading the schedule or closely watching the answers being recorded which tended to maintain the spontaneity of responses.

- *Introductions and Preamble.* The author is conscious of the need to put the interviewee at ease. Interviews do not begin at question one and end with the last question. In all interviews (depending on levels of familiarity), the author introduced himself, his professional history, the objectives of the research as well as the purpose and content of the interview. It was stressed that all responses made by participants would remain confidential. In addition, it was found useful after a while to mention who was involved in the research, who else had been interviewed and the length of time the author had spent with the company. This helped put the interviewees at ease as well as adding an air of legitimacy and routine to the research.

- *Documents.* All documents were made ready before interviews. The number of papers were kept to a minimum because some people may have felt uneasy seeing large numbers of papers on the table before an interview. Typically, the interview schedule and a blank A4

pad were the only items of paper on the table.

Attention was given to preparing worksheets for interviews where the cell members were asked to draw and describe the Cells, confirm and discuss the functional descriptions of the Cells and take part in critical incident technique interviews. Concepts such as functional analyses and the critical incident technique were fully explained using prepared worksheets at the beginning of the interview.

- *Question Delivery.* The author is aware of the need to keep interviews progressing at a pace to suit the interviewee. In all cases this was facilitated through the use of a common language to improve understanding. The author was conscious that the participants were hearing the questions for the first time and so made an effort to allow interviewees time to think about the question which called for short periods of silence. Care was taken to speak clearly and not to use highfaluting or pretentious language. The author found the pilot study useful for improving his interviewing skills. It was found that the consideration of the above issues became more natural and automatic over time.

- *Recording Data.* Tape recorders were not used during the interviews even though the use of tape recorders was the preferred option. During the pilot study, however, it was found that the deep, bass noises of the factory tended to drown out the sound of the interviews. Consequently, interviews were recorded on written form. All data was recorded at the time of interview.

While these circumstances were not ideal, it was found that the slight pauses whilst writing did not feel unnatural. Care was taken not to draw the attention of the participant to the writing process by reading out written statements. The following coding method was used during the interview:

- ‘ ’ a verbatim quote.

- < > a précis of response or general opinion.

- ( ) an interviewer note or comment.

Responses were recorded and structured under the question headings specified on the schedule for each interview (refer to Appendix D1).

B1.2.1 Analysis of Findings

After every semi-structured interview, the responses of the cell members were grouped into categories corresponding to the specific questions asked within each feature. The responses within each category were subdivided into a range of representative responses. These are tabulated in Appendix D. For each Cell, the allocation of functions effects were determined using the following approach:

- To fully delineate the man-machine settings by describing the dependent features at the three levels of analysis.

- Data analysis by triangulation to identify allocation of functions effects at each level of analysis. The effects were identified from analysis of the categorised semi-structured interview data.

- To determine allocation of functions effects on the performance of the Cells, the analysis determined and mapped these effects as well as the effects of the other independent features at all levels of analysis. These effects were determined qualitatively from the systematic evaluation of the categorised data as well as from the experience of working in the company. The strength of the allocation of functions effects were not quantified. Qualitative measures were allocated to these features and were developed likewise from experience and through the evaluation of the collected data.

B1.3 Adopted Protocol for Observations

Convenient shopfloor locations were agreed with the cell members to avoid disrupting cell activities. There was no interaction with the cell members. Observation periods varied according to research requirements. Typically, the observation of cell activities was carried out for between fifteen to sixty minutes. The following coding method was used during the observations:

- ‘ ’ a verbatim quote from a cell member.

- < > summary of observed activity.

- ( ) an interviewer note or comment.

B1.3.1 Analysis of Findings

Observational data are represented by HTA diagrams and the Tables A1 to B4 (refer to Appendix G1) describing the influence of general system functions on features at the man-machine and job design levels of analysis. These mechanisms facilitate the analysis of observational data and is used to triangulate with other sources of data.

B1.4 Adopted Questionnaire Protocol

Questionnaires were conducted with all cell members individually or in pairs. They were completed by the cell members in the locations used during the pilot study and during the main research period for the semi-structured interviews. The semi-structured interview seating.

preamble and document protocols were adopted. The author was present at all times to answer any queries or to deal with any unforeseen problems. No other contact was made with the cell members whilst they completed the questionnaires.

B1.4.1 Analysis of Findings

The questionnaires described quantitatively features at the man-machine and job design levels of analysis. The scoring strategy for all questionnaires is outlined in Appendix E2. The mean score for all features were averaged over the whole research period for all cell members. These data described the nature of the Cells and provided a 'situation setting' for the semi-structured interviews. The interviews were consequently not conducted 'blind' but with an indication of the opinion of cell members. This helped focus the interviews. Comparisons of the individual scores highlighted the main disagreements between cell members. No further statistical operations were carried out on the data because of the small sample size. The questionnaires, therefore, fulfilled three objectives:

- *Generate descriptive data.* The data contribute towards developing a more detailed description of the four Cells by detailing the features at the three levels of analysis.

- *Generate quantitative data to facilitate data analysis by triangulation.* The questionnaires are part of the multi-method approach. They facilitate data analysis to improve the description and understanding of the work environments and ensure the representativeness of the data.

- *Provides a foundation for the interviews.* Questionnaire data helped develop a 'situational setting' for the semi-structured interviews.

Three self-completion questionnaires were submitted during the field research. A questionnaire was not devised for the socio-technical level of analysis because of the abstract nature of features at this level as well as difficulties in question design. Semi-structured interviews and observational methods were employed for data collection at this level. Not all features, however, were be detailed through interview. Consequently, features at the man-machine and job design levels of analysis supplemented the detailing of socio-technical features.

- The first questionnaire, the Job Diagnostics Survey (JDS) detailed characteristics of intrinsically motivating work. It was submitted once during the pilot study and once towards the end of the research period. This was done to identify any significant changes in job characteristics and psychological states of the cell members over the period of analysis.

The data rapidly help to generate a picture of the nature of work in the Cells and describes the social consequences of work upon the cell members.

- The second questionnaire was developed from the pilot study. The questionnaire on average took about thirty five minutes to complete and was submitted at the very start of the field research. Collected data describes cell layout, training and cell management issues central to the long term performance of the Cells.

- The third questionnaire was submitted twice during the research period - immediately after the second questionnaire and towards the end of the research period with the second submission of questionnaire one. The questionnaire generated quantitative data on features at the man-machine and job design levels of analysis. The questionnaire on average took about twenty five minutes to complete. These collected data formulated an initial detailed picture of the state of the research contexts and complemented the features studied in the semi-structured interviews.

APPENDIX C

PILOT STUDY METHODOLOGY AND FINDINGS

This appendix provides an overview of the pilot study methodology and contains the pilot study introductory and follow-up interview schedules and findings.

C1.1 Pilot Study Methodology

Each phase of the pilot study methodology is summarised below.

C1.1.1 Orientation and Familiarisation

At the beginning of the pilot study, no cells had been selected. The pilot study commenced with orientation activities which involved:

- *Health And Safety*
  An official health and safety course before having access onto the shopfloor.

- *Unstructured Interviews*
  Unstructured interviews and discussions were held with supervisors and managers encompassing:
  - Research requirements in terms of access to the shopfloor, people who would be interviewed and access to an interview room.
  - Foreseeable research activities and planned timing of research phases.
  - Major shopfloor developments and re-structuring activities.
  - Rules of conduct for moving around the shopfloor and for organising interviews with cell members.

- *Walk-And-Talk Throughs Around The Shopfloor With The Supervisors*
  These were general awareness activities where typically the history of the company, past changes, the role of the cells, individual personalities and future planned changes were discussed.

- *Cell Meetings*
  Two cell meetings in Division V were attended. The meetings proved to be a useful platform to rapidly 'get up to speed' on cell matters, to meet all the key people connected with cell operation and management and observe at first hand the social interactions between managers, supervisors and cell members. This was an excellent orientation activity which was used during the main research period.

C1.1.2 Initial Data Collection

For all Cells the supervisors introduced the author to the cell members and personally informed them about the purpose of the research. This happened in the cell environments. The author then elaborated on these details to the individual cell members to reaffirm the objectives of the research and verified to see if the cell members were willing to participate in the research. For each Cell, once the cell members were happy to participate in the research (no body refused to take part), the following data collection activities were carried out:

- *Walk-And-Talk Throughs Around The Cells With The Cell Members*
  The walk-and-talk throughs in the Cells were good mechanisms for quickly learning and understanding about 'what goes on in the cells' in a demonstrative and interactive question-and-answer manner. Brief notes were taken in the Cells. In all instances, the walk-and-talk throughs were followed by the introductory interviews described below. This method helped save time answering many basic questions, provided a foundation for subsequent interviews and contributed towards a common language for discussing shopfloor activities.

- *Semi-Structured Introductory Interviews*
  For Cells C and D, semi-structured interviews were conducted in a small private room away from but near-by the shopfloor. Appendix B outlines the interview protocols used throughout the research period. Appendix C outlines the interview schedule and findings. For Cells A and B, they were conducted in the 'JIT-pit'[1] located next to the Cells. The objectives of the semi-structured introductory interviews were:
  - To formally introduce the author and the objectives of the research to the cell members.
  - Obtain demographic data on cell members and fundamental cell details.
  - Develop a rapport and a degree of familiarity with the cell members.

  The interviews typically lasted sixty minutes and was structured as follows:

  - *Introductions Of Both Parties And General Preamble*

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[1] The 'JIT-pit' is a clearly identifiable area of the shopfloor, designed and built by the employees, for eating, drinking and relaxing during scheduled breaks in work. It is populated with permanent chairs and tables, a drinks and sandwich machine as well as basic washing facilities.

This was accompanied by a description of the need for the research. the research goals and the important role of the cell members in achieving these goals.

- *Semi-Structured Interviews*
  The semi-structured interviews comprised of two related parts. Firstly, the interview focused on basic cell design and operational details. The second part obtained demographic details of the cell members. The first part of the interview built upon experiences from the walk-and-talk throughs. Cell members were presented with pre-designed worksheets for them to sketch and label the cell and describe cell operations using pictures. In reflection, this proved invaluable in data collection terms and was a useful mechanism for encouraging participation from the cell members. The second part of the interview was allowed to drift where it was deemed advantageous for goodwill and elaborate reasons.

- *Self-Completion Questionnaire*
  A questionnaire was submitted for completion by the cell members on a separate occasion from the interviews. The cell members were asked to complete the Job Diagnostic Survey questionnaire developed by Hackman and Oldham (1980). Appendix E discusses the background to the tool, methods of application and research findings. It usually took about forty minutes to complete. The questionnaire was used to identify quickly, characteristics of the jobs in the cells and to gain an immediate insight into the opinions (attitudes) of the cell members towards their work. It was completed twice during the complete research period to record any changes that may have occurred in the attitudes of the cell members towards their jobs.

  Apart from its data collection function, the questionnaire had a number of methodological benefits early on in the research:
  - The questionnaire yielded valuable information which contributed towards a second, follow-up interview.
  - The questionnaire acted as a useful tool for creating a 'natural' end to the introductory interview.

C1.1.3 Follow-Up Interviews

Follow-up semi-structured interviews were conducted with the cell members. These built upon and were sensitive to the data already collected from the introductory interviews and questionnaires. Refer to Appendix C for the interview schedule and findings. The nature of the interviews were to ascertain opinion and factual details on cell issues. The interviews and subsequent qualitative categorisation of responses were based on related elements of the initial cell selection criteria. The interviews typically lasted for about sixty minutes.

C1.2 Analysis of Findings

The combined data from the questionnaires and interviews for all Cells facilitated the development of an overall picture of cell activity as well as the identification of factors affecting cell performance. The findings of the pilot study based on the features studied within the initial conceptual framework are summarised below.

- *Age of Cells*
  The age of the Cells tended to reflect their maturity in terms of how management treated the cell members as well as the number of 'teething' and basic layout problems experienced by the cell. The latter is true for Cells C and D. Cells A and B are the oldest. Their basic layout problems have been successfully tackled and more strategic improvements are being implemented encompassing communication mechanisms, devolution of planning responsibility and skills development.

  The age of the cell itself does, of course, not improve Cell development itself but is rather an indicator of how the Cells may have developed given an environment where continuous improvement is proactively encouraged.

- *Number and Types of Machine*
  From the pilot study, it was clear that the machines in the Cells influence skills use and requirements, the types and frequency of breakdowns, monitoring requirements, information needs and the overall role of people (these are not a remarkable findings). The allocation of functions is also affected by and reflects the nature of the technology used. Issues relating to this descriptor strongly influenced the selection of features for study during the main research period.

- *Cycle Times*
  Machine cycle times affect the pace and timing of work, the amount of slack between operations and the opportunities for the cell members to monitor the progress of machine operations. From the pilot study, these 'line balancing' issues tended to influence the content of work through the amount of effort required of the cell members to operate the Cells satisfactorily.

- *Size of Part Family*
  From the pilot study, the size of part family had little influence on the activities of the cell members and cell performance. All set-ups, changeover procedures and quality requirements are clearly and well documented for all parts.

- *Cell Loading*
  The cell loading varies between Cells. During periods of high cell loading (and when manpower issues allow) two people work in Cells A, B and D. This influences interaction and communication requirements. In addition, high production targets can affect the degree of urgency required to maintain correspondingly high production levels. Issues relating to

this descriptor influenced the selection of features for study during the main research period.

- *Skill Levels*
  From the pilot study it was clear that the skill levels of the cell members affect their abilities to cope with all forms of cell disruption. This has implication for the ability of the Cells to maintain production levels in the long term. The influences upon skills use and retention largely encompassed organisation training and education activities as well as the machines used. Issues relating to this descriptor influenced the selection of features for study during the main research period.

C1.3 Introductory Interview Schedule

The following interview schedule outlines the questions asked for data collection during the introductory pilot study interviews. Interviews typically lasted an hour.

Initial Pilot Study Interview

Date:
Time:
Location:
Participant:
Length of interview:

Preamble

Introductions
State objectives of interview
Question content and purpose
Probable length of interview
Seek permission for writing down responses

Issue Worksheet for Sketching Cell

Describe layout of sheet and ask cell members to sketch basic layout of cell.
Worksheet Diagram Here:

- Questions: Age of Cell
  "How old is the cell?"
  "How old is the cell in its present form?"
  <optional>

- Questions: Number and Types of Machine
  "What do the machines do?"
  "What are they called?"
  "How old are they?"
  "How does work flow around the cell?"
  <optional>

- Questions: Cycle Times
  "What are the approximate cycle times for each machine and for first offs?"
  <optional>

- Questions: Size of Part Family
  "How many products does the cell make?"
  "What do the parts you make do?"
  <optional>

- Questions: Cell Loading
  "Typically what is the level of cell loading?"
  "Do levels of cell loading change much?"
  <optional>

- Questions: Skill Levels
  "How many people work in the cell?"
  "What do they do?"
  "At what skill level are you?"
  <optional>

Preamble - Demographic Interview
Introduce new subject - moving away from cells onto personal details

- Questions: Demographic
  "How long have you been with the company?"
  "Apart from the cells you work in now, where else have you worked?"
  "What other previous industrial experience have you had?"
  "What education and training have you had before and in the company?"
  <optional>

Preamble - Questionnaire
Introduce and submit questionnaire
Read through instructions with cell members
Check for any problems
Move away from recipient but remain in room in case of any problems

Round-up

Thank cell members for their input and time.
For courtesy, walk back to the cell with them.
Evaluate data collected.

C1.3.1 Pilot Study Findings: Demographic Findings

Key demographic details of the cell members are:

	Cell A 3 Cell Members	**Cell B 2 Cell Members**	**Cell C 4 Cell Members**	**Cell D 2 Cell Members**
Age / Years	1) 26 2) 27 3) 27	1) 26 2) 27	1) 23 2) 27 3) 29 4) 52	1) 26 2) 30
Length of Time in Company / Years	1) 7.2 2) 4.8 3) 8.5	1) 6.0 2) 5.4	1) 4.2 2) 3.0 3) 5.4 4) 10.2	1) 6.5 2) 9.0
Skill Level	All Operator-Setters	All Operator-Setters	All operators	1) SS3 2) Operator-Setter

C1.4 Follow-Up Pilot Study Interview

The content of the follow-up semi-structured interviews were based on related elements of the initial cell selection descriptors. Interviews typically lasted sixty minutes. The questions presented here were developed from and were sensitive to earlier data collection activities during the pilot study. From these experiences, the author became aware of the sensitivity of some of the questions which would (and in retrospect did) result in some revealing, interesting and detailed responses.

C1.4.1 Interview Schedule

The following interview schedule outlines the questions asked for data collection during the follow-up pilot study interviews. Interviews typically lasted an hour.

Follow-Up Pilot Study Interview

Date:
Time:
Location:

Participant:
Length of interview:

Preamble
Introductions
State objectives of interview
Question content and purpose
Sate probable length of interview
Seek permission for writing down responses

- Questions: Age of Cell
  "Looking back over the time you have worked in the Cell, in what ways has the Cell changed?"
  "In the Cell, what things have improved?"
  <optional>
  "What things have got worse?"
  <optional>

- Questions: Number and Types of Machine
  "In what ways do the machines influence the nature of your work in the Cell?"
  "Thinking about your work in the Cell, what would you say is your main role?"
  "Looking back over the time you have been working in the Cell, what things can go wrong with the machines?"
  "What sort of things does the company do to minimise and prevent machine breakdowns?"

- Questions: Cycle Times
  "How would you describe the pace of work in your Cell?"
  "What ways can you control the pace and timing of work yourself?"
  "Typically, do you have time to monitor the progress of the machines?"
  "In your Cell, what do you usually do between operations?"

- Questions: Size of Part Family
  "Does the number of components that your Cell makes affect your work in any way?"
  <prompts: workflow control procedures, quality issues, planning requirements>
  "Thinking back over the past month, how often did you need to perform a tool changeover?"

- Questions: Cell Loading
  "Thinking back over the past year, how have customer demands fluctuated?"
  "When the Cell is heavily loaded, how does this affect the way you work?"
  <prompts: activities, repetition, monotony, slack time, busy, free time and levels of concentration>
  "What typically happens to your work when demand is low?"

"How often do you get to talk to other people in your work, who are they and under what circumstances?"

- Questions: Skill Levels
  "What skills and abilities do you usually use when you work in the Cells?"
  <prompts: problem solving, decision making, inter-personal, planning, machine operation, craft and engineering skills>
  "What opportunities does the company offer you to improve your skills?"
  "How do you think the company would benefit from having a highly skilled workforce?"
  "How do you think you would benefit from improving your skills?"
  "When things go wrong in the Cell, for example, when an important machine breakdowns, what usually happens?"

Round-up
Thank cell members for their input and time.
For courtesy, walk back to the cell with them.
Evaluate data collected.

C1.4.2 Pilot Study Findings: Follow-Up Interviews

The following two dimensional matrix represents a data reduction of the responses from the follow-up interviews based on the above schedule. All cell members in the four Cells were interviewed. The content of the matrix are quotes from the cell members and are representative of the range of responses.

	Cell A	Cell B	Cell C	Cell D
Skill Levels ***"What skills and abilities do you usually use when you work in the Cells?"***	• 'A lot of the time is spent on the machines operating and inspecting the work ...planning work with assembly is a nice break.' • 'Don't get to use a lot of my skills...I've done a four year craft apprenticeship and don't really use it here.'	• 'Most of the skills used are similar to what we did before the cells.' • 'Not everyone can operate the VM mill ...you need to know what to do when things go wrong.' • 'We do everything - operate machines, inspect work, do the SPC stuff, plan most work, changeovers, set the machines...most things.'	• 'Mostly working the Fanucs and the Takisawa...' • 'Mostly operating the machines and the PreCom...we also need to watch quality and gauge the work ourselves.' • 'I'm happy with what I'm doing..it's a bit boring but the people are good here...'	• 'You don't really do much for most of the time...anyone could do it.' • 'We have to operate all machines...set all tools and change tool bits... usually sort out what needs to be done with the supervisors.' • 'I think I'm losing my edge...and may need a top up soon.'
Skill Levels ***"What opportunities does the company offer you to improve***	• 'They're going for the Total Quality thing at the moment. I've been on a Total Quality Speed and Set-up course.' • 'They're usually well done but are not followed through to the shop.' • 'It helped with	• 'Quite a few courses ...everyone goes on the courses...whether they're a good thing is debatable.' • 'It would be good if what we learnt could change what we do ...sometimes I think we just go up there to keep the company happy.'	• 'There's lots of Total Quality Management courses. The last one was a Total Quality Speed course...doesn't really change my work though.' • 'The training's a waste of half a day...we go up then we come back and get on with our work.'	• 'Quite a few courses on continuous improve-ment... and there's lots of things on Total Quality and team-working.' • 'The training department is getting everyone up to speed with Total Quality and cells... there's meant to be another follow up

	Cell A	Cell B	Cell C	Cell D
your skills?"	knowing about cells generally...and about teamworking...and I know it helped a few people out with writing and reading skills which [the company] had never done before.'	• 'The courses are good. Most of the quality things we use in the shop...like gauging, responsibility for quality, minimising waste.'	• 'The courses are good ...and well run...but the management don't seem to know what in them.' • 'We all go on courses ...we never get to use what we've learnt...we don't need the training that they give us.'	course soon...probably more of the same.' • '...they're quite good but I don't see the point in them if we don't do what they show us down here.'
Skill Levels ***"How do you think the company would benefit from having a highly skilled workforce?"***	• 'We're pretty highly skilled now...we're good at working on our own which is good for the supervisors.' • 'We can work anywhere on the shop-floor...'	• 'It's good for the company because they can move us where they like.. sometimes that's quite good.' • 'When people are off, supervisors move people around to other cells.'	• 'It would probably help the company if we were more skilful but things are o.k...we do what needs doing.' • 'Don't know really, perhaps it'd help to move onto different cells...they'd just get you to work harder.'	• 'I'd be better for them if we could work more on our own.' • 'Flexibility is important if you need to move things around the shop-floor.'
Skill Levels ***"How do you think you would benefit from improving your skills?"***	• 'At the moment there's no point...I don't think I'm paid enough for our skills now compared with others.' • 'I can't really improve my skills more unless I get a promotion...I'm losing them if anything ...things need changing if I'm going to do that.' • 'There's no point in developing more skills if I don't really use the ones I have now...it makes no sense...'	• 'I do nearly all things already. I could go for supervisors job but that's a few years away yet.' • 'I don't think I need to ...we don't get enough [money] for what we do now in my opinion ...we get about the same as blokes to just operate the machines.'	• 'Too old now to learn new skills...learn things from the setters when they come round. I like to do that.' • 'Not much point in training because you don't get much more money...no incentive really, can just get the setter to do what needs doing.' • 'Not everyone can be operator setters it'd be too expensive.' • 'I wouldn't really benefit because the money's not good...I would have more to do.'	• 'I don't think I've got the ability really to become a full setter-operator...the supervisors keep onto me to apply.' • '...probably get us to do more work...I'd like to become a full setter-operator...the money's not much better than for operator or SS3 - only £11 more per week for all that effort.'
Skill Levels ***"When things go wrong in the Cell, for example, when an important machine breakdowns, what usually happens?"***	• 'We sort out most things between us. The supervisors are told when big things go wrong...most of the time we fix most things.' • 'The supervisor gets the mechanical engineers in to fix the [Primary Machine] when it goes wrong ...they made a big mistake getting that ...given it a coat of paint to make it look new but it keep breaking down.'	• 'We deal with all machine breakdowns unless its really bad.' • 'Changes in orders are usually dealt with by us and the supervisors...it depends...say on whether we have the capacity in the cell.' • 'Bad breakdowns may last for weeks...we sometimes have a cell meeting to plan what needs doing.'	• 'I go get the supervisor and he tends to sort things out with the other supervisors and the setters.' • 'For most small things I get the setters...like with worn tooling and the PreCom not working properly.'	• 'I can sort out most things like tooling...the setters come in and fix the major stuff... supervisors usually leave it to us if it can be sorted quickly.' • 'I do all my tool changes... I deal with most things.'

	Cell A	Cell B	Cell C	Cell D
Cell Loading ***"Thinking back over the past year, how have customer demands fluctuated?"***	• 'Pretty constant.' • 'The cell is in arrears at the moment...probably for the next one and a half years.'	• 'Haven't changed a lot ...still have the same customers.' • 'At the moment things are quiet...but things look like picking up.'	• 'Quite steady ...increasing demand at the moment.' • '...cell in arrears at the moment.'	• 'Fluctuates a lot...the cell takes on overspill and late work from other cells.' • '...make changeovers whenever late batches need finishing.'
Cell Loading ***"When the Cell is heavily loaded, how does this affect the way you work?"***	• 'The cell is always heavily loaded.' • 'Things need to keep moving... the [Primary Machine] must be kept running.'	• 'When things pick up, two of us have to work in the cell...' • 'Daily targets are always set at the start of each shift so you just need to meet them.'	• 'Things don't change much anyway...you can't go any faster than the machines...' • 'I suppose it's heavily loaded all the time...I just operate the machines and it doesn't change much.'	• 'When work comes over from other cells someone else operates the other Fanucs.' • 'Two people need to work in the cell when all machines are used.' • 'You can't really work faster than the machines.'
Cell Loading ***"What typically happens to your work when demand is low?"***	• (See above, question not asked)	• '...in that case only one person needs to work in the cell...the pace of work is pretty well controlled by the machines...but you can take it a little easier sometimes.'	• (See above, question not asked)	• 'The work doesn't change...there's no difference because how hard you need to work is controlled by the cycle times.' • '...only one person is in the cell.'
Cell Loading ***"How often do you get to talk to other people in your work, who are they and under what circum-stances?"***	• 'Really often when two of us are in the cell...the supervisors come around during the day.' • 'Get to talk to others on the floor...things are pretty flexible.' • '...when we have cell meetings.'	• 'Sometimes with two in the cell...cell is quite big and so don't really chat much especially with the noise.' • 'I sometimes talk with people from other cells when I need a break.' • '...when there's a meeting, we all meet with the supervisors...'	• '...supervisors come around to the cell.' • '...sometimes go across to other cells.' • 'mostly talk to mates during breaks.'	• 'With two of us in the cell, things are o.k... supervisors come around sometimes.' • '...sometimes go to other cells to see mates when I need a break ...thing can be pretty flexible, it depends on how busy you are.'
Age of Cell ***"Looking back over the time you have worked in the Cell, in what***	• 'Just the position of the stillages...some old measuring equipment has been taken out.' • 'All tooling that we need are in the cell on the painted, labelled board...that's good.'	• 'We built the stairways and platforms which you've seen...sorted out the problem with moving parts between ops. by building that trolley runway thing ...the kanban system ...that was at the start.' • 'Quality issues have	• 'The position of the lighting has changed...' • '...the deburring booth has moved...the PreCom has moved three times...managers can't get it right...we are not listened to.'	• 'The [lathes] have been converted to dedicated machines...the Fanucs are used as auxiliary machines.' • 'Some improvements suggested by us have been implemented ...like with the chuck changeovers and

	Cell A	Cell B	Cell C	Cell D
ways has the Cell changed?"		got much tighter.'		locating the parts in the washer.'
Age of Cell ***"In the Cell, what things have improved?"***	• 'Communication's better...the notice board is good for logging fault with tooling and machines...things are more visual and you get more information on what customers think...' • 'The old measuring equipment has been scrapped...'	• 'We know exactly what needs to be done.' • 'Communication is better...we know what [the customers] want because we get the faxes sent to us...that's really good.'	• 'Nothing much.' • 'Things are still being changed.' • 'Its quite good to work on more than one machine...not much has improved.'	• (See above, question not asked)
Age of Cell ***"What things have got worse?"***	• 'The [Primary Machine] hasn't got better...' • 'Not much has got worse really.' • 'Too many cell meetings.'	• 'Some cell meetings aren't really needed...' • 'Don't like the pay changes...it doesn't seem fair to me.' • 'We seem to need to work harder in the cell...just because we work in the cell, we still need to work hard for eight hours a day.'	• 'Need to work really hard...this is one of the worst cells to work in...' • 'The training courses sort of raise your hopes really...that's not good.' • 'We have to fill in those production charts.'	• 'Nothing really.' • 'Things haven't really got worse which doesn't necessarily mean things were great in the first place... I think there are too many meetings we don't need them.' • 'The charting's always been a bad idea...'
Size of Part Family ***"Does the number of components that your Cell makes affect your work in any way?"***	• 'The cell only manufactures two different parts...you don't need much planning.' • '...workflow is controlled by whoever is working in the cell ...its not complicated ...if there're any problems the supervisors help to sort out things.'	• 'The cell has eight products...The flow of work doesn't change.' • 'Changeovers are no problem...everything has been simplified.' • 'We need to change more than others because we make more different part than in other cells.' • '...quality is not affected because all procedures are written down...we know exactly what to check...all work is inspected anyway.'	• '...the cell makes four variations...the workflow does not change...the quality checks are the same for all parts.' • 'No. The parts are basically the same...the tooling doesn't change much either...gauging changes slightly but nothing complicated.'	• 'the workflow is not affected at all...two basic part are made with four variations each...the machines are the same, the only things that change are the computer programmes and tooling.' • 'Quality procedures are similar for all parts...there's little variation between parts.' • 'Changeovers are clearly written down...I change the tooling but the setters re-set the machine and the computer programme..'
Size of Part Family ***"Thinking back over the past month, how often did you need to perform a tool changeover?"***	• '...changeovers aren't that often. Last month we made only two changeovers.'	• '...anything up to once a day...typically once every four days or so...it depends.'	• 'Changeovers are done by the setters...this doesn't happen often...perhaps three times a week sometimes less.'	• 'Changeovers vary from say once a day to once a week...it depends on what's going on around the shop.'

	Cell A	Cell B	Cell C	Cell D
Cycle Times ***"How would you describe the pace of work in your Cell?"***	• '...not that fast...the [Primary Machine] sets the pace of work and the cycle time for that is about a minute.' • 'If you're not on the [Primary Machine] then you deburr the work...and have time to move around the cell ...the pace of work is not that bad.'	• '...steady...quite hard...' • '...need to run more than one machine at a time so that pace is high to keep these machines running.'	• '...really fast...hardly any time to think.' • 'Few people like to work in the cell because of the pace of work...its hard work compared with other cells.'	• 'Quite relaxed...the line balancing is not good.' • '...it gives me time to sort things out in the cell, monitor machines and think a lot...'
Cycle Times ***"What ways can you control the pace and timing of work yourself?"***	• 'The machines do it...if you want to slow down then you can of course but then you won't make what you need to.' • 'The way you load the machines...'	• '...the speed which you load and unload work from the machines affects the timing...' • 'The procedures for running the cell for one person and for two have been worked out ...the only way to change this is to slow down feeding the machines.'	• 'I've got to run more than one machine at a time...I can affect the number of parts made by basically slowing down...I would get into trouble though...' • 'If you work hard, then you can keep the machines running nearly all the time and make a few more parts an hour...'	• '...not really...line balancing is slack and you don't really save time if you make a real effort to quickly unload and load the machine.'
Cycle Times ***"Typically, do you have time to monitor the progress of the machines?"***	• '...quite a lot of time to monitor the [Primary Machine]...it gets very boring...'	• (see above, question not asked)	• '...sometimes between operations but I'm usually busy.' • 'If I'm not working on the Fanucs and Lathe then I'm on the PreCom...'	• (see above, question not asked)
Cycle Times ***"In your Cell, what do you usually do between operations?"***	• (see above, question not asked)	• '...there is rarely any time to do anything...' • '...machines are run in parallel and so there's no time to stand around.'	• '...if I've got time I smoke my pipe...' • '...it depends...I go to find more trolleys for the pallets or tidy up a bit.'	• (see above, question not asked)
Number and Types of Machine ***"In what ways do the machines influence the nature of your work in the***	• '...the [Primary Machine] is very important to the cell...we have to keep this machine running as much as possible.' • '...work tend to be loading and monitoring work most of the time ...unless the machines breakdown...' • '...I feel like I'm glued to the machine.'	• 'I feel like I'm running around after the machines most of the time...' • 'I don't really get to use all my skills...and my brain that much.' • '...it's a change when a machine breaks down or when a changeover is ordered.'	• (See above, question not asked.)	• 'Most of the time you spend operating the lathes...you need to keep the second lathe running as much as possible because its got a longer cycle.' • 'I set all the machines and change tool tips ...wash the work and check the dimensions on the Pre-Com...'

	Cell A	Cell B	Cell C	Cell D
Cell?"				
Number and Types of Machine ***"Thinking about your work in the Cell, what would you say is your main role?"***	• '...machine operator.' • '...maintain machines and keep things running smoothly, sort out any problems in the cell.' • '...improve cell operations...'	• '...keeping the machines running and balanced...' • 'Making sure the work is made to the right tolerances and keeping production levels high.' • 'improve the cell whenever possible.' • '...meet customer requirements.'	• '...check work quality ...keep machines running...produce as many parts as possible.' • 'Maintain machines and work area.'	• 'Check the quality of the work is o.k.' • 'Make sure the work is cleaned and made to tolerance.' • 'when possible, carry out improvements to the cell.'
Number and Types of Machine ***"Looking back over the time you have been working in the Cell, what things can go wrong with the machines?"***	• '...tools hitting the work, running out of tool bits...' • 'Pneumatic and electrical failure on the [Primary Machine].' • 'Worn out and broken tools.'	• 'Common problems are with worn out tools, broken tools and missing equipment.' • 'The tooling on the VM mill hardly ever needs changing.' • '...sometimes the tools collide with the work and the shear pins go.'	• 'The offsets don't always work.' • ...tool wear, the PreCom rigging sometimes needs rebuilding...' • 'Sometimes the tooling hits the work.'	• 'Sometimes machines don't start because the safety guard contacts are faulty.' • '...tool collisions.' • '...missing tool bits.'
Number and Types of Machine ***"What sort of things does the company do to minimise and prevent machine breakdowns?"***	• '[Primary Machine] checked by mechanical engineers every few months...we replace all tooling and often inspect machine for any wear...it is a very complicated machine so a lot can go wrong.'	• '...monthly capability tests.' • 'We take part in machine overhauls every few months ...automatically check machines when we set the up.'	• 'Capability tests every month.' • 'Machines overhauled about every three months.' • 'Setters check for wear on machine spindles etc.'	• 'Capability tests are often conducted every few months ...sometimes by visiting students on placement.' • 'Machines stripped down every three months.'

APPENDIX D

OVERVIEW OF MAIN RESEARCH PERIOD AND FINDINGS

This appendix firstly gives an overview the research methodology for the main research period. Secondly, the schedules and condensed findings for the man-machine, job design and socio-technical semi-structured interviews with the cell members are reproduced. Finally, qualitative data for all four Cells are discussed based on these findings.

D1.1 Overview of Main Research Methodology

D1.1.1 Sampling Strategy

The sampling strategy was contingent upon the state of the shopfloor environment and focused on fulfilling the planned research methods for each case. The research schedule was situation dependent and flexible. Because of the uncertain nature of the research environment, plans for conducting the various research methods with the cell members, supervisors and management could not be rigidly set for more than a couple of days in advance. The supervisors clearly communicated the breadth of scope and rules for access to the shopfloor. Data collection was carried out within these rules based on data requirements and what was politically reasonable and when production allowed.

Cell activities were observed whenever necessary but was particularly useful during busy periods when access to the cell members for interviewing was not possible. To minimise variability whilst collecting data, the same research methods was conducted for as many cell members and supervisors as possible. For example, all cell members in a particular Cell completed questionnaires which were followed by interviews. This helped the researcher establish a rhythm with managing and conducting the research as well as systematically developing a picture and facilitating data analysis using like data. Towards the end of the research, this approach became less feasible and necessary reflecting the requirement to complete 'pockets' of missing data.

D1.1.2 Field Research

In total, four months were spent with the company over a period of thirteen months. Each visit lasted a period of no more than three weeks which allowed for a significant period of data collection but was short enough to allow for a degree of detachment from the company for data analysis and reflection. All quantitative and qualitative research methods were conducted with the cell members commonly working in the Cells. Research was carried out with all day and night shifts which facilitated the generation of a representative set of data for each cell by overcoming the situation were some informants may be entirely unrepresentative of other, perhaps less candid participants.

A sequence was established for conducting the various data collection methods based on the advantages and disadvantages of the research methods. It intuitively provided a way of systematically building a clear, detailed picture of the work situations was inherently flexible. The duration of individual research methods varied according to the state of the shopfloor and the individual characteristics of people.

As well as providing a number of methodological benefits, the pilot study highlighted the importance of people in sustaining the performance of the Cells irrespective of the technology employed.

D1.1.2.1 Research Methods Overview

The description and analysis of the features at the three levels of analysis is an objective of the research. All cell members and supervisors involved with Cell production were involved in the research. The research methods used encompass self-completion questionnaires, semi-structured interviews, critical incident technique interviews and periods of observation on the shopfloor.

The four main research methods are summarised below within the research strategy framework. For each method, the summary places into context alongside the other methods the use, timing and methodological benefits of each. Appendix A2 further describes the methodological use, advantages and disadvantages of each research method. Appendix B profiles the adopted research protocols to enhance repeatability and to safeguard against inconsistencies within each method.

Self-Completion Questionnaires

- *Method Characteristics*
  - Easy to submit and manage.
  - Rapidly describes a wide range of Cell characteristics.

- *Data Characteristics*

- Quickly generates quantitative data on job characteristics, cell members' perceptions of their work, features at the man-machine and job design levels of analysis.
- No extensive statistical analysis was made of the data because of small sample sizes.

- *Relationship With Other Methods*
  - Data analysis identifies salient issues for further exploration during the semi-structured interviews.
  - Triangulated with interviews responses.
  - Generates a 'situation setting' for carrying out interviews.

- *Timing*
  - Questionnaires submitted before all related semi-structured interviews.
  - Initial submissions were carried out at the start of the analysis for each case.
  - The maximum time for questionnaire completion was no longer than fifty minutes.

- *Methodological Comments*
  - In general, questionnaire data are not without their methodological difficulties. The questionnaires yielded descriptive data but did not identify the relationships between features. This latter point, the inherent threat of respondents not truthfully recording their opinions as well as dangers of 'socially desirable response' bias (people responding in a way that shows them in a good light) emphasises the need for the use of qualitative research methods to facilitate triangulation and the collection of 'rich', descriptive data.

Critical Incident Technique

- *Method Characteristics*
  - Interviews are focused and semi-structured.
  - Method identifies and describes in context effective and ineffective behaviours.

- *Data Characteristics*
  - Identifies characteristics of an 'ideal' cell member for the Cells.
  - Data delineated the nature of work methods.

- *Relationship With Other Methods*
  - Triangulates with other data sources.
  - Generates 'situation setting' for carrying out semi-structured interviews.

- *Timing*
  - Interviews were conducted immediately after the questionnaires.
  - The interviews commonly lasted twenty minutes.

- *Methodological Comments*
  - The method rapidly gave an insight into the nature of work in the Cells and what the cell members perceived as being the 'ideal' characteristics and abilities of people to work in

the Cells.

- The process of using this method was enlightening. In general, the 'ideal' characteristics of people to work in the Cells, as described by the cell members in Cells A, B and D, were far less skilled, had fewer employment aspirations and could cope with the repetitive nature of work far better than the cell members themselves.
- Section D1.2.4.4 outlines the schedules for the critical incident technique interviews and tabulates a representative qualitative sample of the responses from the reduction of interview data.

Semi-Structured Interviews

- *Method Characteristics*
  - Focuses the line of enquiry and allow for elaboration on specific points of interest and relevance.

- *Data Characteristics*
  - Generates rich, detailed qualitative data of the features at all levels of analysis.

- *Relationship With Other Methods*
  - Triangulates with questionnaire, observation and critical incident technique interview data.

- *Timing*
  - Interviews varied from thirty minutes to commonly no longer than seventy minutes.
  - Interviews were conducted after the related questionnaires and in parallel with observation methods and critical incident technique interviews.

- *Methodological Comments*
  - Man-machine and job design interviews were conducted after both submissions of the JDS, man-machine and job design questionnaires. This facilitated the comparison of features between submissions and illustrated how opinions and features evolved during the research period.
  - Socio-technical level interviews were merged with the job design interviews. Interviews lasted typically half an hour with supervisors.
  - Additional interviews were conducted where previous interviews overran or to clear up specific outstanding matters. As with the pilot studies, the responses for the interviews were recorded by hand. Although this was not ideal, any pauses proved to not significantly influence the rapport between interviewer and recipient. All cell members participated fully in the interviews and paced their responses accordingly to facilitate data collection.
  - Section D1.2 outlines the schedules for the semi-structured interviews and tabulates a representative qualitative sample of the responses from the data reduction of all interview data.

Observation

- *Method Characteristics*
  - Cell activities on the shopfloor and cell meetings were observed.
  - Allows one to view activities at first hand in light of previously collected data.

- *Data Characteristics*
  - Helps develop a vocabulary for describing the social and physical settings.
  - Describes features at all levels of analysis as well as work in functional terms.

- *Relationship With Other Methods*
  - Complements the semi-structured interviews to detail features at the socio-technical level of analysis.

- *Timing*
  - The duration of the observational methods varied from fifteen to sixty minutes.
  - Variable scheduling depending on the state of the Cells and also when required to establish a picture of cell activities throughout a working day.

- *Methodological Comments*
  - Periods of observation were carried out in all cells. Access to the shopfloor for observation was not constrained and commonly lasted between fifteen to sixty minutes depending on the purpose of the observation and the state of the cell.
  - Unobtrusive locations in each cell were agreed upon with the cell members. Observation was carried out for three reasons, combining for convenience and for practical reasons data collection for the description of features at the three levels of analysis, data collection for a functional analysis, for clarification of important and outstanding issues.
  - A functional analysis was carried out by observing Cell activities to provide a basic understanding of what people do and what machines do in the four Cells. The Hierarchical Task Analysis (HTA) method was used to graphically represent the allocation and content of functions in the four Cells (refer to Appendix G). This method breaks down the functional descriptions into levels of detail - from 'high level', broadly defined functions to 'low level', more detailed functions. The HTA diagrams were explained to and reviewed by the cell members to confirm their validity and representativeness.
  - These methods fully describe the allocation of functions in the cells and their influence upon features at the man-machine and job design levels of analysis. This process was not undertaken for socio-technical features because they could not be described in functional terms.
  - The HTA findings were invaluable for data analysis and developed a basis upon which the research was founded.
  - Observation data elaborated upon dependent features at the three levels of analysis and helped develop a common vocabulary to aid the interview process.
  - Sources of variance, task inter-dependence and mechanisms for coping with variances

were observed in the four Cells. The latter feature was also observed during cell meetings. In total, five cell meetings were attended. They proved invaluable for observing interactions between all supervisors and cell members as well as for learning at first hand short and long term organisation and political issues affecting Cell performance.

D1.1.3 Analysis of Data

Quantitative and qualitative data were analysed to identify the dominant features at each level of analysis describing factors influencing the design of 'whole' jobs. Data were analysed throughout the research period. The qualitative semi-structured interview data were central to fulfilling this objective. Additional quantitative and qualitative data facilitated the development of representative contextual descriptions, aided the interviews process and helped validate the findings.

Triangulation was aided by the wide range of quantitative and qualitative data - generated from the use of the various research methods. This helped guard against the generation of fabricated findings resulting from the adoption of only a single approach and the partiality of any one method of data collection. It should be noted, however, that in no way does this approach, like any other multiple-method strategy, generate an 'objective' truth since the '...accuracy of a method comes from its systematic application, but rarely does the inaccuracy of one approach to the data complement the accuracies of another' (Fielding and Fielding, 1986).

Triangulation was used to make better sense of data from the various sources and highlighted the commonalties and discrepancies between them. In addition, the use of a multi-method approach enabled the responses from the semi-structured interviews to be interpreted against the context described by the questionnaire, observational and critical incident technique data. This is fundamental to the interactionist approach (refer to Appendix A) where the social context of, say, an interview is intrinsic to understanding any data that are obtained. Consequently, the triangulation method and data proved invaluable for determining 'why' type questions specifically relating to explaining allocation of functions effects. Appendix B outlines the approach used for data analysis.

The following sections reproduce the semi-structured research findings, summarise the responses and provide an analysis of these findings.

D1.2 Semi-Structured Interviews

The following sections outline the main research findings from semi-structured interview data collection methods. Semi-structured interviews were conducted with all cell members from both Divisions on the features at the man-machine and job design levels of analysis. Two

distinct interviews were conducted for each of these levels.

Data reduction was performed as soon after the interview as possible - anything from immediately after the interview to typically by the end of the day. From the interview scripts, all comments made by recipients were divided up and grouped according to the features identified at the three levels.

D1.2.1 Interview Schedule for the Man-Machine Level

The following interview schedule outlines the questions asked for data collection at the man-machine level of analysis. Interviews typically lasted about forty minutes.

Man-Machine Level Interview

Date:
Time:
Location:
Participant:
Length of interview:

Preamble

Introductions
State objectives of interview
Question content and purpose
Probable length of interview
Seek permission for writing down responses

- Questions: Transparency
  "What are the main things that you are aware of which affect your work in the Cells?"
  <prompt: suppliers, customers, supervisors, management, other shop-floor workers, breakdowns, meetings, training programmes>
  "Taking all these things into account, are you usually able to form a clear picture of how these things affect your work?"
  <prompt: 'how aware', 'how knowledgeable', 'how informed', 'understanding'>
  "Within the company, who is dependant upon your work. For example when you work well or when the output of the Cell drops off, whose work is affected?"
  "Thinking about working in the Cells, are you able to form a clear picture of the progress of the machines?"
  <prompt: 'what the machines are doing at any given time or moment')
  <optional>
  "In the Cells, when things go wrong, can you usually identify what the problem is?"
  <optional>

- Questions: Technical Coupling
  "In the Cells, how much freedom do you have to vary the order of the tasks you perform?"
  <prompt: 'the main factors that determine the pace and timing of your work in the Cells')
  "How much do the tasks you perform vary from day-to-day?"
  <prompt: 'prescribed', 'predetermined', 'fixed', 'rigid', 'variable', 'flexible')
  "What is critical for maintaining production in the Cells?"
  <prompt: machines, people, quality issues, decisions)

- Questions: Nature of Operator Loading
  "In your work, how much of the time are you basically carrying out physical activities?"
  <prompt: 'ask for examples', frequency, 'how physically tiring?', cognitive functions>

- Questions: Adaptive Allocation of Functions
  "In the Cells, are you able to override the machines and carry out tasks manually?"
  "Are there any operations in the Cells which you usually perform manually that you can let a machine carry out if required?"
  <optional>
  "In the past, have any functions that you have carried out been given to machines to perform?"
  <prompt: vice versa, 'tasks'>

- Questions: Decision Authority and Competence
  "What decisions do you usually need to make whilst working in the Cells?"
  "What decisions relating to the Cell do other people make?"
  <prompt: supervisors, setters, managers>
  <optional>
  "Are you usually able to implement and act upon the decisions that are make by yourself and by others relating to the Cell?"
  "In the Cells, what manufacturing decisions are made by the machines"
  <optional>

Round-up
Thank cell members for their input and time.
For courtesy, walk back to the cell with them.
Evaluate data collected.

D1.2.2 Interview Schedule for the Job Design Level

The following interview schedule outlines the questions asked for data collection at the job design level of analysis. Interviews typically lasted an hour.

Job Design Level Interview

Date:
Time:
Location:
Participant:
Length of interview:

Preamble
Introductions
State objectives of interview
Question content and purpose
Probable length of interview
Seek permission for writing down responses

- Questions: Skills Use and Retention
  "Thinking about your work in the cell, using examples, what skills do you usually use?"
  <prompt: 'craft skills', 'interpersonal skills', 'analytical skills'>
  "What opportunities do you have for using your problem solving and analytical (mental) skills?"
  <prompt: 'arithmetic skills', 'mental skills', 'structured methods', 'creativity'>
  <optional>
  "How well do you think you have kept (or maintained) the skills that you have gained?"
  <prompt: 'give examples'>
  <optional>

- Questions: Task Flexibility
  "How often do you rotate between jobs (cells)?"
  "Do you have any say in when you rotate between cells?"
  <optional>
  "Comparing your experiences with a process focused and a product focus factory, what extra tasks do you now carry out that you didn't have to do in the past?"

- Questions: Interaction Requirements
  "When do you need to interact (talk) with other people?"
  <prompt: 'communicate', 'mechanisms', 'ask to give examples'>
  "How often do you come into contact with other people?"
  <optional>

- Questions: Experienced Responsibility From Work
  "In the cell what are your main responsibilities?"
  <prompt: production, quality, decisions, improvements>
  "How have your responsibilities changed since working in the cell?"
  <prompt: 'ask for examples'>
  <optional>
  "How do you feel about having this amount of responsibility?"

- Questions: Process Feedback
  "In what ways do you find out how well you are doing in your job?"
  <prompt: people, machines, mechanisms, meetings>
  "Are you happy with the amount of feedback you get on how well you are doing?"
  "What information do the machines provide you with to let you know how well you are doing?"
  <prompt: 'ask for examples'>

Round-up
Thank cell members for their input and time.
For courtesy, walk back to the cell with them.
Evaluate data collected.

D1.2.3 Interview Schedule for the Socio-Technical Level

The following interview schedule outlines the questions asked for data collection at the socio-technical level of analysis. Interviews typically lasted an hour.

Socio-Technical Level Interview

Date:
Time:
Location:
Participant:
Length of interview:

Preamble
Introductions
State objectives of interview
Question content and purpose
Probable length of interview
Seek permission for writing down responses

Cell Members:
- Questions: Sources of Variance
  "Thinking about you job, what are the main things that can go wrong?"
  <prompt: equipment, 'inside the physical cell', 'outside the physical cell'>
  "When these things go wrong, how are they dealt with?"

Supervisors:
- Questions: Boundary Regulation Activities
  "What are your main responsibilities towards each Cell?"
  <prompt: 'ask for examples'>

"When dealing with each Cell, what activities are involved?"
<optional>

Round-up
Thank cell members for their input and time.
For courtesy, walk back to the cell with them.
Evaluate data collected.

D1.2.4 Responses From Semi-Structured Interviews

The following two dimensional matrix represents a data reduction of the responses from the semi-structured interviews based on the above schedules. All cell members in the four Cells were interviewed. The content of the matrix are comments from the cell members and are representative of the range of responses.

D1.2.4.1 Man-Machine Level of Analysis

	Cell A	Cell B	Cell C	Cell D
Transparency ***"What are the main things that you are aware of which affect your work in the Cells?"***	• '...The [Primary Machine] causes a lot of grief with breaking down a lot...' • 'The supplier situation has improved a lot ...poor casting quality can stop work in the cell for up to two weeks...it depends.' • 'The supervisors deal with the suppliers and delivery stuff.' • 'If operators or someone doesn't come in then sometimes I might be moved to another cell...' • 'Any complaints from the customers...are posted up on the notice board and if necessary procedures are changed or more quality checks are used until the problems are sorted.' • '...shop meetings and cell meetings help everyone understand how well the cells and the company is doing.' • 'I don't really get involved in matters outside the cell but quite a lot of information comes from management...so I	• '...we follow what the [downstream assembly cell] requires on a daily and weekly basis.' • 'The suppliers deliver castings on time but the quality varies a lot ...this obviously affects what we can make.' • '...we get to hear from the customers what's right and what's wrong because all faxes...are pinned up on the notice board by the cell. • 'Manning and quality and production issues are usually sorted out during cell meetings or simply by talking to the supervisors.' • 'The communication of things that affect the cell, like suppliers and money, is done through the notice board, cell meetings and shop meetings...its much better but sometimes there's far too much talk and we aren't getting things done.' • 'When things are busy, the supervisors do most cell improvements.' • 'I don't really know about things outside the	• 'The supervisors and setters mostly deal with things off the shopfloor.' • 'I don't meet with the assembly shop workers ...the supervisors handle work loads and quality issues between shops...we don't get on well with them anyway.' • 'I just concentrate on the work in the cell and let the setters and supervisors do their job ...I'm happy with just getting on with the job of operating.' • 'There are too many cell meetings...they are a waste of time because we aren't listened to much...not much gets done from the meetings ...we get to hear about how the company is doing from the shop meetings.' • 'Most of the problems are sorted out by the supervisors...I just do what I'm told to.' • 'I don't know about who does what with the suppliers or customers ...but anyway I don't	• 'I find out what things are like in the shop through talking with supervisors when they come to the cell...the monthly cell meetings and the shop meetings are good for finding out and discussing things but we could do with less cell meetings.' • 'I don't talk to the assembly shop workers because I'm too busy.' • '...when [the assembly cell] was moved into the machine shop I could see things better...it didn't work well though because its a different culture between the shops and we don't get on that well.' • 'I help the supervisors plan work in the shop when things go wrong with other cells...that way I get to know what things are right and wrong in the shop.' • 'Most of the time I get on with the work I need to do in the cell ...the supervisors sort things out to help me.' • 'The managers and

	Cell A	Cell B	Cell C	Cell D
	feel I know how well the cell and the company is doing.' • 'I don't know anything about ordering [work] or working out quantities...management deal with that.'	cell... I only do stuff linked with production and the maintenance of the machines and the quality of the work.'	need to know...I concentrate on working the machines and the supervisors and managers deal with what they should do.'	supervisors deal with the company problems and leave us to get on with the shopfloor work.'
Transparency ***"Taking all these things into account, are you usually able to form a clear picture of how these things affect your work?"***	• '...it's difficult to really get involved with [the above issues] because of the work I need to do.' • 'With the planning side of things I can understand what problems are faced by the supervisors...I know how important this is and who will be affected if its not done right.' • 'I don't know what the customers are really like but of course I've got my own picture ...some people have actually visited their factory.' • 'I think I know what's going on in the company but whether its accurate or not I'm not sure...I know about the assembly cell and things on the shopfloor connected with the cell but its difficult to understand things I don't come into contact with outside the cell.'	• 'I'm not that close to how [the company] gets on with [the customers] but we get an idea from the shop meetings...' • 'Its hard to understand really how everything affects the cell...I know about most of the shopfloor things that affect the cell and the assembly cell ...planning the work with [the people in this cell] helps me understand customer and supplier issues.' • 'Cell meetings help me learn about what's going on around the shopfloor...and with customers.' • 'There's a lot going on around the shop...its difficult to paint a clear picture of everything that's going on mainly since I'm usually really busy...cell meetings help though.'	• 'I don't know really what's going on off the shopfloor...I pick up a lot of information from [others] on the shopfloor...I'm not really bothered about that stuff...' • 'I get on with my work and don't really understand what the supervisors do or anything like that...I like it like that.'	• 'I can understand the problems the supervisors face with machine breakdowns around the shopfloor ...the cell is used to take on extra work from [these cells]...' • 'My job is not connected with dealing with suppliers and customers...I only get to hear [about them] when things go wrong...its difficult to get a picture of everything that's going on.' • 'Cell meetings help with understanding the pressures on supervisors and other cells.
Transparency ***"Within the company, who is dependant upon your work..?"***	• 'The main customers [outside the company] are dependent upon my work.' • 'We get to know what the customer think of our work because the supervisors tell us and post up the faxes on the board.'	• 'An assembly cell in the shop is dependent upon the parts made in the cell...work is planned between the cells to sort loading requirements.'	• 'The assembly cell is the customer for the cell...all work goes to the assembly shop.' • 'The supervisors co-ordinate the flow of parts between cells.'	• 'The cell manufactures parts for an assembly cell in the other shop.' • '[The assembly cell is] directly affected by the performance of the cell.' • 'I don't deal directly with the [assembly cell]...things are co-ordinated by the supervisors.'
Transparency ***"Thinking about working in the Cells, are you able to form a clear picture of the***	• '...I can't really tell what the [Primary Machine] is doing once it is started...' • 'I do know what the [Primary Machine] does and I know about the different cutting operations but it is difficult to know exactly what's going on when it's running.'	• 'All [cell members] know what the machines do in theory...its difficult to know exactly what's happening when the things are running because there's no way to see...we're usually very busy anyway to try and work it out.' • 'I can tell what the VM	• 'No. I'm very busy. If I had the time, I couldn't see what cutting stages the machines are at anyway...because of the coolant all over the place.' • 'I basically know what cutting operations are performed...if something went wrong though, I could	• '...I usually have time to check on the progress of the machines because of the gap between cycles.' • 'I'm familiar with the cutting ops. that the machines carry out ...the only way to tell on the progress of the machines is to stare

	Cell A	Cell B	Cell C	Cell D
progress of the machines?"	• 'The [Primary Machine] is very complicated.' • 'Most of the other operations are easy to understand...they're very basic...its obvious what's going on.' • 'I don't understand everything about the equipment that I use ...but I know enough to be able to cope with the most common problems.'	mill is doing because of the glass surrounding the work area and the monitor showing the NC codes...I don't usually have much time to check on the work.' • 'The machines are all pretty old...they don't help me understand what they are doing...if you asked me, I could probably tell you what cutting stage a machine was at but without really monitoring the machine I couldn't be sure of being totally right...that's not the case with the 'Splitter' and VM mills.'	probably tell you what had gone wrong if it wasn't too complicated ...I don't have much time to check on the machines because other machines usually need seeing to.'	through the clear guard...' • 'I've been working with the machines for a long time now and I've come to know about how the machines work...'
Transparency ***"In the Cells, when things go wrong, can you usually identify what the problem is?"***	• (see above, question not asked)	• '...usually...' • 'All [cell members] are well trained and are skilled to maintain the machines...its quite difficult though to predict when things may go wrong...we can deal with most problems without much help from the supervisors or engineers.' • 'Each machine fails in its own way...we get to learn this over time.'	• '...I get the setters to sort any machine problems out.' • 'I can sometimes identify what the problem is because I've worked with the machines for a long time...I advise the setters on what I think the problem is from what my last actions were...'	• 'I've worked with the machines long enough to know what usually goes wrong with them.' • 'The setters deal with most breakdowns... although if they're busy I can sometimes fix the machines on my own...its difficult to tell sometimes why a breakdown happened.'
Technical Coupling ***"In the Cells, how much freedom do you have to vary the order of the tasks you perform?"***	• 'The tasks are set by [the company]...they're all fixed...the steps are all written down and pinned up on the board.' • 'All tasks in the cell has been standardised so everything is done the same...all jigging and set-ups are fixed.' • 'I know exactly what to do and how long things should take.'	• 'The tasks that each person carries out and the order that the tasks are carried out are clearly described and are on the notice board.' • 'There is no freedom ...if I changed the order I would get in trouble... everything is fixed...' • '...everything in the cell has been fine tuned to produce the maximum output.'	• 'Very little freedom...I do everything in a fixed way.' • 'I know exactly what to do...the order of operations are set by the machines and don't change...unless a Fanuc breaks down then the order changes a little' • '...there's little variety in what I do...I'm a machine operator.'	• 'What I do in the cell varies little from day to day...tasks are set and cannot be changed.' • '...for each part, the order of work is fixed and cannot be changed...even when we need to do work for other cells, all procedures are fixed...and do not vary.'
Technical Coupling ***"How much do the tasks you perform vary from***	• (see above, question not asked)	• 'If two people are working in the cell then the tasks set for these are different than if only one person worked in the cell.' • 'The tasks in both cases are described on diagrams pinned to the board.'	• (see above, question not asked)	• 'Things can vary a lot when things break-down around the shopfloor...the production, set-up and changeover tasks are still fixed and do not change.'

	Cell A	Cell B	Cell C	Cell D
day-to-day?"				
Technical Coupling ***"What is critical for maintaining production in the Cells?"***	• '...the [Primary Machine] must be kept going...the work in the cell will stop if it goes down.' • 'The other operations are important of course but not as much as the [Primary Machine]...it does most of the cutting operations.'	• 'All the mills are critical to the production in the cells...the VM has the longest cycle time and must be run constantly.' • 'You need to run more than one machine to keep production levels high...'	• 'The two [mills] must be kept running to feed the [lathe]...the lathe is critical...when this goes down the cell goes down.' • 'The lathe is critical. If a [mill] breaks down we can get by on one [mill] and one lathe.' • 'The [mills] must run in parallel to keep work at the right levels for the [lathe].'	• 'Both machines are important.' • 'Both lathes run in parallel...depending on what the cell is used for all machines are critical to the cell.'
Nature of Operator Loading ***"In your work, how much of the time are you basically carrying out physical activities?"***	• 'Almost all the time.' • 'Most of what I do in the cell is physical ...including machine maintenance and inspection...pulling work from stores and packing parts in the boxes for shipping.'	• 'Most of the time with breaks for meetings and training courses... machine maintenance and planning workloads with the [assembly cell].'	• 'All the time...I just operate the machines.' • 'I need to walk 'round the shopfloor sometimes to find pallets from the assembly shop...that's annoys me...if I need help on anything I find a setter.'	• 'Most of the activities are physical...I plan workloads with the supervisors when breakdowns happen in other cells.' • 'Once the machine are set, most of my time of course spent operating them...'
Adaptive Allocation of Functions ***"In the Cells, are you able to override the machines and carry out tasks manually?"***	• 'No. The [Primary Machine] is not designed for manual override.' • '...there is no option, either the [Primary Machine] carries out the operations or it doesn't. It isn't designed for people to operate.'	• 'None of the mills can be manually overrided.' • 'The operations carried out by the machines cannot be overrided by [the cell members] and the operations carried out by [the cell members] cannot be automated.'	• 'No. All cutting operations are automated and can't be done manually.'	• 'None of the machines can be overrided...' • 'In the cells, the tasks that I do cannot be automated.'
Adaptive Allocation of Functions ***"Are there any operations in the Cells..?"***	• (see above, question not asked)	• (see above, question not asked)	• 'No, the tasks that the machines carry out can only be done by the machines...and the same is true for [the cell members].'	• (see above, question not asked)
Adaptive	• 'I can't think of anything...the machines	• 'No...they haven't changed since the cell	• '...nothing has changed...the only	• '[The cell members] have always carried out

	Cell A	Cell B	Cell C	Cell D
Allocation of Functions ***"In the past, have any functions..?"***	in the cell now were there at the start [when the cell was first implemented].'	was first formed...I don't think any changes are planned either.'	things that have changed are the positions of the machines...cell layout... and the lighting has been improved.'	the tasks that they carry out now...nothing has changed.'
Decision Authority and Competence ***"What decisions do you usually need to make whilst working in the Cells?"***	• '...usually not many...' • '...but can involve me deciding on when to replace tooling.' • '...the size of buffer stock between operations and when to shut down a machine before it breaks down or for safety reasons.'	• '...the main decisions are made when planning cell workloads.' • 'I need to decide when to replace tool tips, when things need repairing...whether to shut a machine down for maintenance reasons...and whether to rework work or reset the machines if quality isn't right.'	• 'Not many...I get given work and I follow what's required of me.' • 'If the PreCom isn't working right, I need to decide if it needs recalibrating or just rebuilding...if I'm not sure I get the setters...I recalibrate the jigs if I need to.'	• 'Most of the decisions that I make are made during the planning tasks with the supervisors.' • 'If necessary I may choose to re-set the machines...I change the tooling and tool tips when required.'
Decision Authority and Competence ***"What decisions relating to the Cell do other people make?"***	• '...the supervisors make decisions on part batches...what needs to be made next ...improving cell ops. and procedures...' • 'Managers sort out long term orders...and decide on who works in what cell.' • '...supervisors arrange cell meetings when they need to ...they have the final decision on all cell improvements and who goes on what course...things like that.'	• '...planning workloads is done by supervisors and [cell members] ...the decisions made in the [assembly cell] affect what we make in the cell...batch sizes, part numbers, due dates etc.' • 'We get moved around the floor to other cells...' • 'Supervisors decide when machines need inspecting...when quality practices need checking...making final cell improvement decisions.'	• 'A lot of things...what part numbers are needed on schedule sheets...when to have cell meetings...and what is talked about at the meetings.' • '...when breakdowns happen in other cells ...supervisors move people 'round the shopfloor to other cells...they do all the work planning based on the state of the [assembly cell]...I don't do any of it.'	• '...supervisors move [cell members] to the cell when finishing off overflow work...' • 'Supervisors plan work schedules and timing...' • 'Cell meetings and shop meetings are set by management ...which cell improvements are made to the cell are decided by management.' • '...supervisors decide on changes to the cell when parts from other cells need attention...'

	Cell A	Cell B	Cell C	Cell D
Decision Authority and Competence ***"Are you usually able to implement and act upon the decisions that are make by yourself and by others relating to the Cell?"***	• '...mostly yes... improvements are done by [the cell members] or the supervisors...we know what can be done.' • '...supervisors make decisions that they know we can act upon ...its a bad decision otherwise...'	• 'We make decisions and plan...on what we are able to do and what the cell can produce.' • 'Of course, we make decisions based on how things are in the cell...' • 'We need to work hard to meet some of the planned targets...its never unrealistic...'	• 'I need to work hard in the cell...its the worst cell to work in...cell improvement decisions are sometimes carried out by the setters...I can cope with most things.' • 'The supervisors know what can and can't be done...'	• 'When I plan the work for the cell, I know and the supervisors know what can be done...' • 'Its unpractical to make a decision that nobody can act upon ...everyone in the shop knows roughly what can be achieved...and the abilities of everyone.'
Decision Authority and Competence ***"In the Cells, what manu-facturing decisions are made by the machines"***	• 'None really...the [Primary Machine] uses the MARPOSS system to set offsets on the tooling...based on 100%...measurements of the finished parts.'	• 'The machines don't make any...they're not clever enough...'	• 'They don't make any ...all decisions are made by me, setters and supervisors.'	• 'None. The machines aren't intelligent ...humans make all the decisions...'

D1.2.4.2 Job Design Level of Analysis

	Cell A	Cell B	Cell C	Cell D
Skills Use and Retention ***"Thinking about your work in the cell, using examples, what skills do you usually use?"***	• 'The main skills I use ...is connected with operating the machines...there's not much skill in that...I use my skills when things go wrong or when there's a change in work schedule.' • '...the way you carry out all of the tasks is set and cannot be changed...I don't use any craft skills its mostly just following procedures...' • 'When the machines are down we need to assess what's wrong with them...experience helps...we strip down the machines and fix them.' • 'I set and calibrate all the machines which is quite a skilled job.' • 'I've got a lot of experience from working in cells ...working with more than one machine...new quality procedures and cell meetings...' • 'I try to think about how the cell can be improved...usually for making machine operations better and to solve quality problems ...I put forward ideas at the meetings...'	• 'The skills I use in the cell aren't much different than before we worked in cells.' • 'The skills you need for one machine are about the same for all the others...the VM cannot be operated by everyone...you need to go on a three day course ...its not the operation but you need to know what to do when it goes wrong.' • 'I've learnt how a kanban works...about cells, what the parts are used for, new quality procedures...and what continuous improvement is.' • 'I don't use many of my craft skills that I learnt when I was an apprentice...its mostly just machine operation tasks on a number of machines in parallel...my planning skills and the way I talk with people I think have improved...the cell meetings allow for discussion about cell activities...there's not always much time for improvement tasks.'	• 'I operate the machines most of the time...I'm just following the procedures set down by [the company].' • 'Mostly I load and unload work, I operate the PreCom and read the screen to see if the work is within the tolerance limits...I don't use any craft skills because the tasks are all automated...' • 'I don't say much during the cell meetings...that's the same I think for all operators...' • '...the planning is done by the setters and supervisors...' • 'I don't use many...I don't see the point in going on training courses...I pick things up from the setters and others...so I don't keep on having to stop work and wait for setters to fix a problem...I like working in the cell, you get to learn how to operate more than one machine...' • 'I set the offsets on the machines...I pull work from stores depending on the schedule.'	• '...I don't use many of the skills I have...I think I'm losing my edge...I think I'll need to go on a refresher course soon...' • 'I haven't yet learnt to set the machines but I change all tooling, chucks...programmes and set offsets to compensate for tool wear.' • 'I plan work with the supervisors which gets complicated some-times...' • 'I know a bit about the machines...I do the front line maintenance when I can...I've made improvements to the washer...and the changeover procedures for the two lathes...' • 'I've mostly learnt about cells generally, how different machines work...and a lot of new manufacturing methods ...even if I don't always have time to make use of what I've learnt.' • 'I need to think about when to changeover and remember what I've made...so I need to keep track of things ...that means writing keeping a record...'
Skills Use and Retention ***"What opportunities do you have for using your problem solving and analytical (mental) skills?"***	• 'Working out quantities and daily workloads for the cell ...all tasks are very clearly defined and everything is quite easy to follow with a bit of experience...' • '...there's not much call for the use of mental skills...except with cell improvement tasks.'	• 'The main times I think are when identifying improvements, planning the work for the cell and working out what is wrong with equipment when it fails.' • 'The kanban system is easy to use...you don't need to think hard to be able to use it...that's the whole point of the system.'	• 'I keep a log of what has been made...and what need doing...that means being able to read the schedules and read the machining charts.'	• '...the planning tasks which I carry out anything from twice a day to twice a week ...there's no pattern...' • 'Sometimes I think of an improvement to the cell...which I tell the supervisors at the cell meetings...that's the proper time to debate improvement tasks.' • 'When machines go down I can fix a lot of the faulty equipment or replace it.'
Skills Use and Retention	• 'I've not been able to use any of my [craft] skills at all...I do more than a lot of the others	• (see above, question not asked)	• 'I'm at the operator skill level...I operate the machines so I use my skills all the time.'	• (see above, question not asked)

	Cell A	Cell B	Cell C	Cell D
"How well do you think you have kept (or maintained) the skills that you have gained?"	in other cells like setting machines, maintenance, changeovers, planning... rigging and carrying out improvements...' • 'I need to do a lot of things in the cell but most of what I do, except for the planning, meetings and the kanban, I did before the cells...I don't use my apprenticeship skills at all...'		• 'I've just learnt how to operate [the machines] and so I haven't lost any skills because I use them all the time...'	
Task Flexibility ***"How often do you rotate between jobs (cells)?"***	• 'Two people usually work in the cell...I've also worked on my own...it depends on who's in the shop.' • 'There's job rotation between four people... we're in pairs and swap between day and night shifts every fortnight.' • 'In the cells we decide on who does what...' • '...supervisors sometimes get us to work in other cells...sometimes for a day sometimes for longer...it changes.'	• 'Typically two people work in the cell to get the most out of it...there used to be three but we improved the way things were done...' • '...jobs are rotated between six people. We swap between day and night shifts on a fortnightly basis...we need to be flexible.' • '...it depends...I may be asked to move to another cell in the shop.'	• 'I work in a pair...I work on my own in the cell for one week and then change over...I go and work in another cell ...every two weeks we swap with another pair to the night shift and back again.' • 'I get to work in other cells...the supervisors decide...I can change cells sometimes twice a week.'	• 'It depends on what the cell is doing ...operators can be brought in to cope with overspill work...' • '...usually there's job rotation between four people fortnightly, day and night shift basis.' • 'Other [people] work in the cell...its not fixed...everyone is flexible and needs to be sometimes.'
Task Flexibility ***"Do you have any say in when you rotate between cells?"***	• 'No. The decision is made by the supervisors...we don't know what's going on the shopfloor...we need to get on with our work, it's the supervisors job.'	• 'It's not for me to decide who works in which cell.' • 'The supervisors sort all that out...' • 'We know in which cell we're going to work in advance ...unless unknown things happen.'	• '...I work where I'm asked.' • 'The supervisors decide on who is needed in which cell.' • 'Unless things change we usually know where we will work from week to week.'	• 'There's no way I decide on where I work in a shift...we get told where we're going to work...its important to be flexible.'
Task Flexibility ***"Comparing your experiences with a process focused and a product focus factory..?"***	• 'Working in the cell doesn't really help you develop new skills ...the main changes are with communicating ...cell meetings, notice boards, faxes, problem charts...the cell meet-ings can be a waste of time sometimes...but not always...I need to speak out and some-times present my ideas for improvements...I never had to do that before.' • 'I'm now involved with a product from the beginning...but the tasks themselves are no different really than before the cells.' • 'Quality is a real issue now and is more	• '...I work on more than one machine but the skills needed for one is the same for all of them.' • 'There are quite a few differences like with changes in quality procedures, cell meetings...before I never had to speak up in meetings, in fact we never had meetings...' • 'We never used to talk to people to sort out production levels... because of piece rate...' • 'There's more of a teamworking atmo-sphere here...I've learnt what its like to be in a group or team ...I've got to read a lot more as	• 'Not really...it's better that you have to work on more than one machine...you get to learn a lot more.' • 'I've learnt to operate more than one machine...I don't mind if I just work on one machine or more than one...the skills needed are the same.' • 'I'm using a computer ...with the PreCom. but if it goes wrong then I'm in trouble...' • 'I don't feel I'm in a team...there's a lot of talk about it ...there's a lot of talk about a lot of things' • 'The cell meetings don't get anything done...I	• '...a lot was promised from the training courses but still there's an atmosphere of them and us.' • 'Because the machines are brought together, of course you find yourself operating all of them...management have stressed skilling, quality...teamworking, meetings and improvement...I think they've been quite successful ...I haven't improved my communication skills...the meetings don't help.' • 'I'm more aware of quality issues...than before and I operate the

	Cell A	Cell B	Cell C	Cell D
	controlled...'	well...charts, diagrams, faxes...'	don't feel anyone will listen to me.'	PreCom computer...I make a whole part from start to end.'
Interaction Requirements ***"When do you need to interact (talk) with other people?"***	• 'I often talk to whoever is in the cell ...the cell is not big ...we talk about many things like how things are going with the machines...about quality...' • 'I usually talk with the supervisors at the start of the shift, when things go wrong ...during cell meetings and at various stages in the day...I can go off and talk to others on the shopfloor if I need to...and anyone can come into the cell to see me if they need to.' • '...when the [Primary Machine] breaks down for example I interact with the supervisors and engineers...' • '...supervisors don't interfere that much ...they allow us to get on with work...I prefer that...I work better that way.'	• 'I get to see people in other cells at the beginning of the shifts to plan workloads...I see supervisors during the day, for planning and when any machines are down.' • 'It's difficult to interact with [people] in the cell because the cell's quite big and we're usually busy. When things do slow down we can check to see if things are o.k...of course we can shout across to each other above the noise.' • 'I don't see the supervisors much during the day if there' no meeting...they know they can trust us to get on with work...' • '...not including breaks from work, I meet with people mostly when I leave the cell for meetings, training courses and planning tasks.'	• 'I talk with the supervisors as little as possible...usually they check up on work and output...' • 'I get to be with the setters and supervisors when there's a cell meeting...setters check to see if the machines are o.k. sometimes too.' • 'I don't really have time to leave the cell during working hours ...except to get a new stillage from stores or going to search for some trolleys around the shopfloor.'	• 'The main reasons why I need to talk with people is either when things go wrong or when we talk about cell output.' • 'The supervisors don't bother me that much...they come 'round from time to time to check up on things...they leave me to get on.' • 'Cell meetings are good for meeting setters and the supervisors...usually they talk to us and not the other way 'round...' • 'We don't see the assembly workers much...except when the assembly cell was located in the machine shop for a short time.' • 'I sometimes have a short chat with others around the shop between cycles if its o.k.'
Interaction Requirements ***"How often do you come into contact with other people?"***	• 'Of course it depends but I usually see the supervisors a three or four times a day...with cell meetings I see everyone...they're set whenever we need them but usually one a month or so...' • '...I chat and talk with colleagues throughout the day.'	• 'I see the supervisors several times in a day ...it varies...at the start of a shift, during cell meetings...organised whenever they are needed...once every one or two months...' • 'I see [assembly cell workers] at least once a day...and other colleagues anytime during the day.'	• (see above, question not asked)	• (see above, question not asked)
Responsibility ***"In the cell what are your main responsib-ilities?"***	• 'I'm responsible for most things...all inspection and part quality...removing burrs, surface finish, threads and part dimensions...planning, boxing the work up ...change all tooling, maintaining all machines...implem-enting changes okayed by the supervisors.' • 'We organise cell meetings when we need them...and fully manufacture all parts ...washing the work,	• 'Everything in the cell ...all aspects of making a part...making sure it is made within quality limits and in the right quantities...' • '...keeping the machines running...tool changes, coolant... lubrication...and front line maintenance. Even though there's not much time we are encouraged to suggest cell improvements...the supervisors also make them too.' • 'We plan workloads	• 'Operating the machines...' • '...changing offsets ...operating the PreCom...gauging all threads.' • 'I have to make sure the work is made in the right quantities to the right quality.' • 'I change the coolant and do all the housekeeping tasks.'	• 'Machine operation...a bit of machine maintenance, tool and chuck changes...' • '...I ensure that work is made to the right standards...the quality of work is my responsibility...' • 'I wash the work, operate the PreCom system...set the machines, carry out front line maintenance tasks...' • '...when disruptions happen, planning is carried out with

	Cell A	Cell B	Cell C	Cell D
	checking the quality of all work, packaging and marking it...' • 'When there's time, we are expected to make suggestions for cell improvements...'	with assembly and do the changeovers...'		supervisors...at random times...its difficult to predict when...'
Responsibility ***"How have your responsibilities changed since working in the cell?"***	• '...before, I was just operating a machine for most of the day ...when we were paid by piece-rate...' • 'There was no such thing as continuous improvement or Total Quality...or cell meetings...also quality was not as tight.'	• 'The main difference I think is the responsib-ility for the full production of a part.' • 'Quality is really pushed now...and multi-skilling as well.' • 'Communication has also got better like with cell meetings...' • '...its important now to think of quality as well as just work on the machines.'	• '...a bit...I have to operate more than one machine which I didn't do before...as well as having to ensure quality and keeping the workplace and machines clean.' • 'I now have to think about the quantities and quality of the work I produce, not just the quantity as before...'	• '...since I improved my skills and started work in the cells, I'm doing more with more machines and not only just operating them.' • '...communications between management is better...' • 'I make a whole product now unlike before...and have to think about planning work, improvements and the quality of work.'
Responsibility ***"How do you feel about having this amount of responsib-ility?"***	• '...it's not really fair because of the pay...we get paid about the same as other workers...who don't have as much responsibility, like the operators...the setters do everything for them ...if things go wrong they just stop work and wait for a setter...'	• 'How we get paid for what I do in comparison with others in the shop is, I personally think, not fair...because all the operators have to do is run the machines...we have to do a lot more and I don't think we are rewarded right.'	• 'Its o.k., I can cope...its not much more difficult than before.'	• '...I see little point in going for an operator-setter job because the pay isn't worth it...it's too much effort for [a few] more pounds a week...the amount of responsibility I have now is enough for the pay...operators get a good deal...'
Process Feedback ***"In what ways do you find out how well you are doing in your job?"***	• '...from the supervisors really...and letters and faxes from customers.' • 'The machines don't let me know...I can see how well I'm doing from inspecting the work...and from the measurements equipment and hand gauges.'	• '...the supervisors give us feedback in cell meetings...based on production output and the satisfaction of our customers' • '...communications from customers are pinned up on the board.' • '...to maintain quality... we know when to replace tools from inspection and gauging tasks...'	• '...from the supervisors during cell meetings ...and during the day.' • '...the PreCom tells me the state of the tools...so I can set offsets.'	• 'I get information from supervisors...mostly during cell meetings.' • 'The PreCom checks the quality of the work I produce...this affects tool changes and offsets...'
Process Feedback ***"Are you happy with the amount of feedback you get on how well you are***	• 'I can tell how well I am doing in the cell ...it's good to know what the customers think.' • 'The supervisors let us get on with work...the cell meetings are timetabled for when we need them...there are not that many interruptions which I like.'	• 'I think the level of feedback is fine...' • 'The notice board is useful...we are allowed to get on with the work.' • 'Yes, I'm happy with it...supervisors give me feedback on the floor and in cell meetings.' • '...shop meetings are a waste of time.'	• 'I think there are too many cell meetings.' • 'I just want to get on with my work...I get a lot of feedback from the supervisors...they usually leave me alone to get on...'	• 'Management tell me how well I'm doing during cell meetings and sometimes during the shift...it depends.' • 'There are too many cell meetings...I think we could do with less.'

	Cell A	Cell B	Cell C	Cell D
doing?"				
Process Feedback ***"What information do the machines provide you with to let you know how well you are doing?"***	• '...none really...the MARPOSS system [on the Primary Machine] links the measurement equipment to the tooling offsets...but it's old equipment.'	• 'The VM is the most advanced and newest machine...it shows the cutting stages and tool paths on a screen...I get feedback from the supervisors, the customers and from what I make.'	• 'The machines don't tell me how well I am doing.'	• '...feedback comes from the supervisors and the number and quality of work...the machines don't tell me.'

D1.2.4.3 Socio-Technical Level of Analysis

	Cell A	Cell B	Cell C	Cell D
Sources of Variance ***"Thinking about you job, what are the main things that can go wrong?"***	• 'Oh, lots of things ...usually its the [Primary Machine] that goes down...everything can go wrong...the washer motor goes from time to time...I replace the drill bits and the brushes and any tools that need it.' • 'One of the stages on the [Primary Machine] may go...we can usually take care of it, the problem is is when the pneumatics go or there's a big collision ...a milling tool gets jammed or something' • 'The [Primary Machine] is the main problem...other things like poor supplier performance or when people don't come to work are a real problem.'	• '...things can go wrong on all the machines...' • '...tooling can break, parts sometimes go missing but not always and of course machines fail but the preventative maintenance programme reduces the likelihood that machines will fail ...this definitely has improved' • 'Because our customers are [the neighbouring assembly cell] what goes on there affects what we need to produce and how many people are in the cell...the customers sometimes can't make their mind up...at the moment orders are pretty constant.' • '...machines can go wrong anywhere at any time...capability tests and checking tooling when setting up does help...but you can't ever be sure.' • '...suppliers have really messed up recently ...which stopped work in the cell...'	• '...chucks on the Fanucs can hit the work...sometimes drilling bits get stuck and snap off...the PreCom rigs may need completely rebuilding.' • '...the switches and contacts around the [safety] doors sometimes go...the machines are really old and been reconditioned twice probably already.' • '...trolleys go missing around the shopfloor and I need to go off and look for them...the [PreCom] computer can go a bit strange.' • '...machines breakdown all over the shop just like in this cell...we work them hard, its not really surprising.' • '...assembly cell demand has been steady for a while and orders are pretty high at the moment.' • '...what goes on the assembly shop, I suppose, affects what we make...'	• '...oh lots...mostly machine breakdowns in this cell and in other cells...when things go badly wrong [in other cells] my work is affected...I might need to reset the machines to make all these other parts.' • '...machines are quite reliable...we can monitor the machines during set ups...and capability testing...the setters also check the machines.' • '[The assembly cell] affects what we make because they're my customers...' • '...the [PreCom] rigging can go and need rebuilding which can take an hour.'
Sources of	• '...whoever's working in the cells deals with tool changes as far as it goes...anything too	• 'The VM mill doesn't fail that often, the tooling's high quality and only needs	• '...I don't get involved with the fixing...the setters deal with collisions and	• '...Cell meetings are used to discuss issues about the shopfloor and changes in cell

Variance ***"When these things go wrong, how are they dealt with?"***	major and [the engineers] or supervisors have a look.' • '...planning issues are sorted during the cell meetings...' • '...the supervisor stuck a flip chart up in the cell...you write problems and solutions on it when they happen ...its a good record of what can go wrong ...small things really, to do with equipment.' • 'All things that have gone wrong with the parts are written on charts on the notice board.'	replacing once a year ...a few of us are trained to change the tooling and most things that can go wrong...' • 'A lot of issues are sorted out during cell meetings...we discuss planning issues, breakdowns...forms of equipment failure...cell improvements...' • '...we carry out front line maintenance procedures...we sort out most problems in the cell.'	breakdowns and the PreCom rigging.' • 'Sometime the engineers or outside contractors come in to fix the Fanucs or [Lathe]...that can take quite a time...up to three or four weeks or more.' • 'We're not involved or consulted with these things during cell meetings...they talk about improvements, repairs and preventative issues at the meetings we don't attend.'	workloads...also work planning...' • '...some of the breakdowns I can deal with...but the setters are usually the ones to fix the major breakdowns or even outside engineers.' • '...my skills have got better and so I feel more confident to sort things out on my own ...although I can't fix a lot of things, I don't need to bother [others].'

Boundary Regulation Activities ***"What are your main responsibilities towards each Cell?"***	• '...keeping everybody happy...customer, suppliers and [cell members]...its very difficult...I wouldn't like to do their job ...I've got to help keep things moving whilst thinking about the people side of things.' • '...above all keeping production moving but not like before...things tend to be done in teams with a bit more planning and structure to what's done...' • 'I talk directly to suppliers and customers...we all now attend cell meetings to discuss all aspects of cell life...problems, costs...improvements and people issues...communications better and I thing relationships are overall better than before.' • '...its ultimately my responsibility for the quality of output and meeting targets...that's basically what I need to ensure but of course to achieve this, with things breaking down and people not turning up all over the place that's pretty complicated and can really take it out of you...there's a stronger slant towards people issues which goes along with the continuous improvement and Total Quality programmes...also the emphasis of training and meeting skills...' • 'We all try to reduce what can go wrong in the cells by making the effort to get [the cell members] to suggest improvements...and we produce drawings and diagrams showing exactly what needs doing, in what order and with what tools...this way operations never vary...this is supported by flip charts and component diagrams showing clearly all the things that have gone wrong in the past with the components and what was done to sort it...we don't fill them in [the cell members] do.'	• '...it can vary but overall to ensure customer orders are met in all the machine cells...' • '...specifically monitoring production levels...the quality of work...and other things like how [the cell members] are...even not saying 'hello' to someone can put them off for the whole day ...you've got to treat everyone individually...also I make sure suppliers deliver on time, I talk to customers, plan work loads and generally make sure things run smoothly.' • 'I need to be a very versatile...dealing with breakdowns around the shop whilst keeping production levels as high as possible and keeping the people happy...including training...and the continuous improvement scheme going.' • '...we always encourage [the cell members] to go on training courses but its not always easy...and can be frustrating...you see work has become a lot easier since the cellular approach in many ways...but things are always busy, things always go wrong or people are away or suppliers don't deliver...cell have simplified a lot of things but I'm not a psychologist and I need to deal with a lot more 'people' issues now...and getting on top of all that will take time.'
Boundary Regulation Activities ***"When dealing with each Cell, what activities***	• '...well they can range from talking to [the cell members] from time to time...usually at the start of the shifts to ensure a smooth changeover...to being the chairman of cell meetings...to even simply waving and saying 'good morning' to someone so you know they're going to work well for the day.' • '...activities are broadly connected with different forms of communication...this can be with the cell members by talking with them...with suppliers via computer or phone/fax...customers through phone usually and fax...cell meetings are very good for quickly sorting things out with [cell members] ...charts on the notice board, which are used a lot	• '...there are the formal ways of doing things and the informal which involves talking in the cells or wherever on the shopfloor...the chief formal method is the cell meeting. These were arranged every month but are now every two months...they were just too frequent...we didn't need them.' • '...cell meetings and more commonly discussing planning, maintenance and other issues with [the cell members] on their own or with the setters there as well.' • 'The suppliers and the 'customers', which are the [assembly cells] in the assembly shop, I deal with. Sometimes I go and visit them, sometimes they come here...of course we use the phones and the fax

are involved?"	now, are good ways of keeping track of cell problems and solutions to problems.' • '...all I need to do is go to the cell and talk to [the cell members] whenever I need to...if its something to do with component quality and can wait, I post it on the board and alert their attention to it or I book a meeting.'	machines.' • '...its all about communication, if I need to juggle cells around to make different parts from other 'down' cells, I need to move people around as well ...this needs to be done carefully and with tact. I find I need to be a good communicator, a diplomat, a counsellor manager and an engineer all rolled into one.'

D1.2.4.4 Critical Incident Technique Interview Results

The following table contains a reduced data set representative of the data collected from the critical incident technique interviews.

	Cell A	**Cell B**	**Cell C**	**Cell D**
Effective Behaviours	• Identify what is wrong with the [Primary Machine] if it fails. • Have the dexterity to effectively handle the work. • Plan and reschedule cell loads. • Understand and effectively use the kanban. • Have the confidence to organise cell meetings, present ideas and propose improvements.		• To be able to do the same basic activity well for a long period of time. • Reschedule cell loads.	
	• Possess the skills to operate all the machines. • Operate more than a single machine in parallel. • Be flexible and willing to work anywhere in the shop. • To be able to do an activity well for a long period of time. • To be able to 'turn off' and get on with the work.			
Ineffective Behaviours	• Not coping with the repetitive nature of work. • Not taking part in cell meetings. • Not willing or able to present ideas or improvement proposals. • Dropping or mishandling work. • Not matching the line balancing requirements and slacking off.			

D1.3 Description of Qualitative Findings For the Four Cells

The following sections discuss the findings from the main research period.

Throughout the discussion, Cell pairs A and B, and C and D will be discussed separately. They are located in different company Divisions - Divisions C and V respectively. These pairs experience common supervisory styles, manufacturing traditions and culture, maturity of training programmes and job rotation methods.

Task and role type functions are identified in the research. Task functions are comprised of interactive and enabler functions. Interactive functions are physical and encompass basic machine operating functions. Enabler functions embrace functions essential for sustained machine operation and high component quality. They include housekeeping, quality assurance, storage, machine setting and maintenance functions as well as organising cell meetings and implementing cell improvements. Their allocation fosters autonomy and is strongly mediated by machine design and reflect company job enlargement and Cell design strategies.

Role functions encompass cognitive and decision making functions. Their allocation reflects human-centred manufacturing and job enrichment policies and is dependent upon strategic choices within boundaries defined by machine design, management style, industrial relations and the abilities of the cell members. The scope for job enrichment in the four Cells vary widely as well as the potential for further change.

Factors of the working 'environments' encompass customer requirements, supplier performance, supervisory and management styles, the state of industrial relations and the technology employed. These factors influence the state of the dependent features at the three levels of analysis. In the following sections, the features describe how these environmental factors influence the ability of the Cells to self-regulate, the organisation of work and the way in functions are carried out by the cell members. For each feature, the discussion is structured as follows:

1) Re-statement of feature characteristics,

2) Identification of the research methods used to study, analyse and describe each feature,

3) A statement of the changing state of the feature during the research period,

4) Identification of the effects on and state of each feature within the framework of the proposed model.

Tables G1.1, G1.3, G1.5 and G1.7 (refer to Appendix G) summarise the state of the features at the man-machine level of analysis for the main task and role functions in each Cell. Tables G1.2, G1.4, G1.6 and G1.8 likewise summarise features at the job design level. These tables complement the detail in the following sections.

D1.3.1 The Number and Types of Machines

Product quality and the minimisation of all sources of waste are assured through the standardisation and clear display of changeover, set-up, housekeeping, machine operation and quality assurance procedures. These methods as well as their significance to production are promoted by comprehensive, company wide education courses and directed training methods. All cell members in the company are responsible for these aspects of Cell operation. Although the responsibility for carrying out these basic functions have changed due to the transition to

cellular manufacturing, the individual machines remained largely the same. This aspect, more than any other, constrains the scope for allocating interactive functions between people and machines. Consequently, the allocation of these functions as well as the underlying nature of work in the four Cells is similar.

Many of the machines are over forty years old and have received numerous refittings and overhauls. The majority of machines (except for the CNC machine in Cell B and the Primary Machine in Cell A) were used in a process focused factory environment. The company originally used machines that were designed to satisfy large batch requirements and relocated them into cells with the transition to a product focused factory.

The scope for allocating role functions encompassing decision making and cognitive requirements for machine operation is narrow. The nature of the equipment limit opportunities to intervene and make process decisions during machine operation. This is the case whether the machines are in isolation or are organised into Cells and so have not varied by adopting cellular manufacturing methods. The influence of individual machines are described by features at the man-machine and job design levels of analysis.

From the perspective of a 'whole' manufacturing process, however, the emergent properties of arranging the machines into Cells provides greater scope for allocating role functions between people. These properties, described by features at the job design and socio-technical levels of analysis do, however, influence the effectiveness as well as the opportunity to carry out enabler and role functions. Unlike the nature of task functions, the ability of the Cells to self-regulate, the manner in which work is carried out by the cell members and the effectiveness of system improvement and development activities differ from Cell to Cell.

The following sections detail the above issues and describe the effects of environmental factors in terms of the state of features, relating to the 'number and types of machines' descriptor (cf. original cell selection criteria), at the man-machine and job design levels of analysis.

D1.3.1.1 Adaptive Allocation of Functions

Adaptive functions refer to interactive functions that are allocated dynamically between people and machines as well as enabler and role functions that are likewise allocated between people. Dynamically allocated functions are carried out by either people or machines according to the state of the Cells, the need to avoid overloading and under-loading people, functional criticality, health and safety issues and the decision making capabilities of people and machines.

The allocation of adaptive interactive functions are meditated by the design and functionality of the man-machine interface. The machines in all Cells have no decision making capabilities and so the scope for adaptive allocation of interactive functions is narrow. The only adaptable functions are the washer, drilling and deburring functions. These, if necessary, could be undertaken by the cell members. There is, however, wide scope for strategic choice in

adaptively allocating enabler and role functions between cell members and supervisors. Enabler functions such as housekeeping, storage and quality assurance functions are statically allocated to the cell members. The allocation of role functions between the cell members and supervisors is mediated by the skill levels of the cell members, the state of industrial relations as well as management and supervisory styles.

Adaptive allocation of functions was studied by walk and talk throughs and periods of observation on the shopfloor. Functional analyses of the Cells using the hierarchical task analysis (HTA) technique was carried out to formally describe which functions and under what circumstances these functions are carried out by the cell members. The HTA findings were discussed with the cell members to finalise their content.

The functional analyses are summarised in Tables G1.1 to G1.8. Tables G1.1 and G1.2 correspond to Figures G1.1 to G1.10 which demonstrates the relationship between the HTA diagrams and the summaries (refer to Appendix G). During the research period, the adaptive allocation of task functions between the cell members and supervisors remained unchanged. Throughout the research period, the execution of role functions varied depended on cell loads, the state of the shopfloor and the need to maintain high output levels. In Cell D, the cell members who successfully completed skills development courses experienced an increase in enabler and role functions.

D1.3.1.1.1 Cells A and B

The allocation of role functions in both Cells is flexible. Under 'normal' operating conditions, when cell loads are high the supervisors may take over daily production planning and Cell improvement functions. During the research period cell loads for Cell A remained high because the Cell was in arrears. In Cell B, however, varied widely but remained high for the majority of the research period.

High levels of allocation flexibility, facilitated by good communication mechanisms and good industrial relations, enables the supervisors and cell members respond to and cope with production uncertainties.

D1.3.1.1.2 Cells C and D

The allocation of role functions between supervisors and cell members in both Cells is static. This is also the case with the more highly skilled cell members in Cell D. The cell members participate in production planning and (re)scheduling activities alongside the supervisors when disruptions affect production and for planning daily loads. The cell members never schedule work on their own. This is reflective of the supervisory and management styles towards these Cells.

Because of the low skill levels of the cell members and relative young age of the Cells,

management maintains control of the production planning, control and development activities. In addition, all final improvement decisions are made by the setters, supervisors and management. These characteristics of the working environment did not help to foster good industrial relations or provide an incentive for the cell members to participate in and accept changes in working practices. In time, however, it was clear from the mood of the company that the practices will mature and change with the help of the experience and expertise of the other Divisions.

D1.3.1.2 Decision Authority and Competence

Decision authority refers to the decision making capabilities of machines and their ability to facilitate decision making processes in the Cells. Competence refers to the ability of the cell members to act upon decisions made by themselves, supervisors and machines. The latter relates to the skill levels of the cell members and the resources available to them.

Decision authority and competence was studied by interviewing cell members and supervisors, walk and talk throughs in the Cells and periods of observation on the shopfloor. In all Cells, the machines have no decision making capabilities. During the research, decision authority remained unchanged because no new machines were introduced into the Cells and no existing machines were modified. This reflects the un-adaptive allocation of task functions and the limited opportunities for carrying out decision making functions during machine operation.

The competence of the cell members to act upon decisions also largely remained the same during the research period. This is because the skill levels of the cell members (except for two cell members in Cell D) also remained unchanged. The ability for the cell members to competently act upon their decisions is supported by company wide education and training courses to develop presentation, teamworking and technical skills and to improve the understanding of cellular manufacturing and total quality concepts.

The 'low tech' nature of the equipment requires the cell members and supervisors to carry out all decisions. This is characteristic of Nagara cells. The authority to carry out these decisions as well as the degree of allocation adaptivity varies from Cell to Cell. The latter is influenced by the skill levels of the cell members, cell loads, the 'maturity' of the Cells themselves as well as industrial relations.

D1.3.1.2.1 Cells A and B

Cell members in both Cells have the authority for making daily production decisions encompassing daily production planning, machine resetting and re-calibration, tool and coolant replacement and intra-Cell job rotation decisions. Daily planning activities are typically scheduled for five minutes at the start of each shift and are often carried out in the absence of the supervisors. In addition, the cell members decide setting offsets to compensate for tool wear, whether to discard or rework out-of-tolerance parts, liaise with other parties to settle

potential uncertainties and, in Cell B, to check-up on the performance of the downstream assembly cell. Under 'normal' condition, the cell members are, therefore, highly autonomous. The number of these decisions are constrained by the standardisation and clear display of set-up, changeover, inspection and machine operating procedures.

The cell members also have the authority for making long term decisions relating to maintaining production. These encompass continuous improvement, maintenance and long term production planning decisions. These decisions are made jointly between the supervisors and cell members. For example, under disruptive conditions, decisions relating to the allocation of responsibilities and functions to restart production after mechanical breakdowns or the delivery of sub-standard castings are made by the supervisors and cell members.

The supervisors possess invaluable expertise and experience, and prefer to remain fully aware of the state of the Cells. This allows the supervisors to maintain a clear picture of the status of the whole Division which maintains the quality of boundary regulation activities and decisions. All cell members are fully competent to act upon their decisions. All but the most severe machine and component problems are rapidly dealt with by the cell members because of their high skill levels and experience.

D1.3.1.2.2 Cells C and D

The skill levels of the cell members in Cell C and half of those in Cell D are low and are classified as 'operators'. These cell members have the authority to carry out a basic set of daily production decisions common throughout the company. These encompass when to pull work from stores, when to replace coolant, whether to discard or rework out-of-tolerance parts and what machine offsets are needed to compensate for tool wear. The cell members notify setters to change tooling, to reset machines, to rebuilding and re-calibrating the PreCom rig and when any machines or tools fail. Under disruptive conditions, therefore, the cell members do not experience much autonomy and rely heavily on the setters and supervisors to rectify even the smallest mechanical disruption. The supervisors and setters make many of the production decisions when disruptions occur. Problems are brought to their attention by the cell members.

In addition to the basic decisions outlined above, the more highly skilled cell members in Cell D have the authority to and are competent in carrying out daily production decisions encompassing machine resetting and re-calibration and tool replacement decisions. Also, the supervisors involve the cell members in daily production planning activities.

In both Cells, the cell members are not involved in decision making relating to maintenance and long term production planning activities. They do take part in the continuous improvement programme but are not involved with final improvement decisions. As with Cells A and B, because the machines have no decision making capabilities, the degree of decision making authority reflects the skill levels of the cell members. Consequently, they are capable of acting upon their decisions.

D1.3.1.3 Technical Coupling

The degree of technical coupling in a system may be viewed as the extent to which the physical and cognitive activities of the cell members are prescribed by the technology employed. Technical coupling is affected by the design of the machines, line balancing requirements and cell loads. Where the activities of the cell members are prescribed too rigidly (i.e. if technical coupling is high) their flexibility for coping with variations in the manufacturing operations, their ability to move within the Cells to perform other functions as well as the opportunity for the cell members to implement system improvements and use a broad range of skills is constrained. In addition, high technical coupling demotes the cell members to the role of merely 'feeding' the machines with components which in turn promotes boredom and a lack of interest in the work itself.

Independent features such as the design of the machines, cell loads and line balancing requirements configure the nature of technical coupling in the Cells. High technical coupling is characteristic of the largely repetitive nature of work in all Cells. Under 'normal' conditions, the cell members are required to carry out task functions for the majority of each shift. Role functions are allocated to the more highly skilled cell members in Cells A, B and D to foster long term autonomy, flexibility, workplace ownership and a more motivated workforce. Because technical coupling is high, the effectiveness and opportunities for the cell members to carry out role functions is constrained. Consequently, their intended consequences are not always realised.

In all Cells, the pace and timing of work as well as skills requirements are technologically mediated. Under 'normal' conditions, however, the output levels of the Cells varied according to who was working in the Cell. The motivation and directed effort of the cell members significantly influenced output levels even with highly standardised and technologically mediated task methods and tight line balancing. For example in Cell C, under comparable conditions, output levels varied from twenty parts an hour to twenty-eight an hour. This difference is reflected in the long term and is characteristic of the individual cell members.

Technical coupling is technologically and commercially determined. Motivational aspects, however, are characteristic of a much wider range of more fundamental and complex organisational, social and political issues. These are difficult to account for and engineer into the design of cell jobs. The company has adopted more human-centred manufacturing methods in an attempt to intrinsically motivate the cell members through job design. The implementation of these methods vary between Divisions, Cells and individual cell members. The underlying characteristics of the work in the Cells and the nature of human-centred methods, however, tend to conflict and is a frequent source of contention between the shopfloor and management. For example, high technical coupling and high commercial pressures constrain opportunities for the more highly skilled cell members to carry out continuous improvement and long term production planning functions. The nature of work, described in terms of technical coupling is, therefore, one of a large number of organisational, commercial and social issues that affect the effectiveness, execution and intended outcomes of

allocating role functions to the cell members.

Technical coupling in the Cells was studied by observing Cell activities on the shopfloor and by conducting interviews with the cell members. The critical incident technique proved useful in obtaining a description of how technology affects the activities of the cell members through the description of effective and ineffective actions. Throughout the research period, technical coupling in the Cells remained largely static because the machines, manufactured components, cycle times and production sequences remained unchanged. In addition, cell loads were typically high in all Cells.

D1.3.1.3.1 Cells A and B

In both Cells technical coupling is high. All task methods are predetermined reflecting un-adaptive allocation of task functions, the machine and equipment design and the standardisation of set-ups, changeovers, inspection and machine operating procedures. All work procedures are clearly defined. High technical coupling constrains opportunities for the cell members to structure the pace and order of their work. The flow of work in both Cells is rigidly prescribed by line balancing considerations, the design of the machines and machine cycle times. The influence of the former is significant in Cell B because of the need to operate machine in parallel.

The main cutting operations are performed by the Primary Machine in Cell A and the four mills in Cell B and are critical for maintaining production. Cell production levels reflect the utilisation of these machines. When these machines fail, production in the Cells stop once buffer stock in the Cells has been processed.

Under 'normal' operating conditions, the Primary Machine constrains physical movement around the Cell by requiring the cell members to continuously 'feed' the machine with work. Physical movement of the cell members around Cell A is constrained because of short cycle times (about one minute) and the requirement to keep the machine running. The pace and timing of work is pre-determined by the machine. During a cycle the following activities are typically carried out: finished work is visually inspected, stillages of raw castings are loaded next the machine, the progress of the machine is monitored, the dimensions and finish of parts are measured when required and, if two people work in the Cell, there is a lot of informal 'chat'. In general, however, the attending cell member has little to do between cycles. Consequently, it was common to find him pacing around the Cell.

In Cell A, the technical coupling for the deburring, drilling, washing and quality functions is low and are not critical in line balancing terms and for Cell production levels. Automation for the deburring, drilling and washing functions is low. With the deburring and drilling functions, the pace of work is determined by the condition of the work itself. For the washing function, the pace of work (for loading, unloading and preparation activities) is determined by the cell members. With the quality function the cell members prepare the work for measurement. The pace of the work is dictated by the condition of the components and the skill of the cell

members.

Production levels in Cell B depend on the utilisation of the four mills. At any time, the cell members (irrespective of the number of people working in the Cell) operate on at least two machines in parallel. The pace of work is determined by the cycle times and tight line balancing which tends to constrain physical movement around the Cell. For example, the cycle times for the 'Cincinatti' and 'Kingsbury' mills in Cell B are both around twenty seconds. The cell members working on these machines are kept busy operating both in parallel for batches of typically two hundred. Cell B is divided into two sub-cells. The cell member in the sub-cell containing the CNC mill must continuously be aware of the state of this machine. The CNC mill has the longest cycle time and so must be kept running continuously and in parallel with other machines. When the cycle on the CNC mill is complete, the cell member must stop his current activity to attend the machine. The remaining operations in Cell B are not critical in line balancing terms or to Cell production levels. They encompass the vibro, washer, bolt-rig and chamfering functions. In all cases, technological complexity is low and the pace and timing of work is determined by the cell members.

Under 'normal' conditions, the activities of the cell members are determined by the design of the machines, predefined work procedures and commercial pressures. The degree of technical coupling in the Cells are symptomatic of these features and tend to limit opportunities for the cell members to undertake and effectively carry out role functions. The intended effects of allocating role functions to the cell members, reflecting their high levels of skill and experience, are often not realised.

D1.3.1.3.2 Cells C and D

Technical coupling in the Cells is high. All task methods are prescribed and the pace and timing of work is determined by the NC lathes and Fanuc drills in both Cells. These machines are critical to Cell production levels.

The line balancing in Cell C is tight. The two Fanuc NC drills each manufacture three components in parallel for finishing on the NC lathe. The cycle times for the Fanucs are 6.3 minutes and for the lathe 1.1 minutes. Under 'normal' conditions, the cell members focus on keeping the lathe running constantly. Cell members operate the three machines in parallel. In Cell C, the lathe process is critical. If this machine goes down, production stops. If one Fanuc goes down, production levels will roughly halve and the tight line balancing disappears. The cell members, therefore, monitor the lathe closely for visual and audible signs of breakdown. Formal preventative maintenance methods carried out by external parties help predict disruptions before they occur.

The line balancing in Cell D under 'normal' operation is not tight. There is a difference in lathe cycle times of one and a half minutes. In this time, the cell members have time to monitor the machines and informally talk with other parties as well as carry out inspection and housekeeping functions. If either of the lathes fail then production stops. The pace and timing

of work is determined by the lathes. The work itself is, as a cell members put it, 'not very strenuous'.

When Cell D is used to finish off overspill or rush jobs from other cells, production plans considering production priorities, the current state of the Cell, tooling requirements, the timing of changeovers and production targets are jointly determined by the more highly skilled cell members and supervisors. Depending on the situation, the other Fanucs in the Cell may need to be set and tooled up. In addition, a cell member from the shop will be required to operate them. These latter decisions are carried out by the supervisors based on the state of the whole shopfloor. Under these conditions, line balancing may vary. In all cases, however, task methods are still predetermined because of standardised working practices.

D1.3.1.4 Transparency

There are two elements of transparency: 'cell' and 'machine'. Machine transparency refers to the ability of the cell members to form a clear picture of an individual machine process. Machine transparency is influenced by man-machine interface design which affects the amount, timing, type, correctness and relevance of any feedback as well as the allocation of task and role functions for machine operation; cell loads and line balancing requirements which affects the ability of cell members to closely monitor machine operations.

Cell transparency refers to the ability of the cell members to form a clear picture of not only low level technological issues but also more high level organisational and commercial issues (i.e. a 'whole' production system) at any given time. Cell transparency is influenced by levels of machine transparency; the quality and use of communication mechanisms between Cells as well as between the shopfloor and management; the skill levels and experience of the cell members and industrial relations.

High levels of transparency enables cell members to predict and identify system failures and to learn about and develop an understanding of a system or individual process. Transparency was studied by interviewing the cell members. During the research period, levels of machine transparency varied little in all Cells because machines, work procedures and line balancing requirements remained unchanged. Cell transparency improved in Cells A, B and D. In Division C, improved communication mechanisms were implemented by the supervisors in both Cells. This facilitated the communication of production problems and solutions between shifts and between supervisors and cell members. Cell and machine transparency improved for two cell members in Cell D who successfully completed skills development courses. They became competent setters and involved with short term production planning issues.

D1.3.1.4.1 Cells A and B

The transparency of the main machining operations in both Cells is low. In Cell A, the Primary Machine is about twelve years old, is very complex and tends to break down about two to four

times a year. Machine transparency is low and cell members are unable to predict and identify machine failures. This is because of an incomplete understanding of the pneumatic, mechanical and electrical components; the lack of opportunity to allocate role functions for machine operation; no facility to intervene in the cutting processes; poor informational feedback on machine status, tool wear and material condition; and poor visibility of the manufacturing operations because of safety guards and spraying coolant.

The same is true for the mills in Cell B. As well as the factors affecting the Primary Machine, machine transparency is constrained by high cell loads and tight line balancing requirements. These factors reduce the ability of cell members to closely follow and evaluate the state of the machines and constrains their ability to predict, identify and rectify machine failures or propose machine improvements. The commercial pressures require the cell members to focus on maintaining high production levels. The interactive nature of the allocated functions for machine operation characterises the nature of work in the Cells.

With the CNC machine in Cell B, cell members are able to intervene during operation where necessary based on informational feedback from a VDU. This is particular useful in diagnostic terms for first offs and when starting new material batches. Under 'normal' conditions, however, the benefits of this feature is constrained by high cell loads and the need to operate machines in parallel. The cell members have good transparency and control over the deburring and washing operations in Cell A as well as the vibro, chamfer, bolt-rig and washing operations in Cell B. These tend to be low-tech, fully understandable and involve significant amounts of manual interaction. The cell members determine the pace and timing of the work and inspect all components after deburring. Transparency is poor for the quality operations in both Cells. This is because of the 'black box' and highly technical nature of the surface measuring processes. The cell members impose a degree of control through standardised preparatory and set-up activities.

Cell transparency is facilitated by highly skilled (polyvalent) cell members, good industrial relations as well as good communication mechanisms. The former reflects the allocation of enabler and role functions and enhances the understanding and awareness of the shopfloor issues affecting long term Cell performance. The latter facilitates the effective sharing of product, manufacturing and commercial information between the cell members, supervisors and, in Cell B, with the downstream assembly cell. The cell members are responsible for all daily production needs and long term Cell development activities. The latter is facilitated by good cell transparency but is constrained by high commercial pressures and poor machine transparency.

D1.3.1.4.2 Cells C and D

In Cell C and D, the age and characteristics of the machines, commercial pressures and line balancing requirements are comparable to Cell B. As a consequence, the nature and effects of machine transparency are like those experienced in Cell B.

For the low skilled cell members in Cell C and D, cell transparency is constrained by low skill levels and the state of industrial relations. These combined features narrow the scope for allocating role functions to the cell members and tend to hinder effective communication between the shopfloor and management. The lack of in-depth involvement in technological, commercial and long term cell development issues as well as the lack of production responsibilities distances the cell members from the main issues affecting Cell performance. In addition, it offers them little incentive to take an interest in their work and issues affecting the company itself.

In Cell D, cell transparency is greater for the more highly skilled members who play a greater role in production planning during periods of disruption as well as carrying out setting and basic maintenance functions. Consequently, they are more aware of the technical and commercial factors that may affect Cell performance.

As with Cells A and B, under 'normal' conditions, high technical coupling and high cell loads constrain machine and cell transparency. To combat poor cell transparency, the communication mechanisms in Division C facilitate effective information sharing between the cell members and supervisors during periods of high cell loads. Unlike Cells A and B, however, the communication mechanisms are less effective in Cells C and D and the cell members have fewer skills. Cell transparency is consequently good for the setters and supervisors who tackle their boundary regulation activities as well as most mechanical disruptions and production problems in the Cells.

D1.3.1.5 Nature of Operator Loading

The nature of operator loading represents the proportion of physical and cognitive tasks required by the cell members to fulfil manufacturing objectives and reflects the allocation of task and role functions as outlined below. In all Cells the nature of operator loading is primarily physical where the cell members are largely constrained to carrying out task functions. Under 'normal' conditions, task functions are typically carried out for between 60% to 85% in Cell A, 50% to 80% in Cell B and 60% to 85% in Cells C and D of the total working time.

The opportunity and need to carry out high level, cognitive functions is constrained by high cell loads and high technical coupling. The nature of the work, therefore, does not facilitate the maintenance of a wide range of high and low level skills and learning from the work itself. This is in contrast with the manufacturing philosophy of the company which aims to develop a highly skilled and flexible workforce. The mismatch between the nature of work and the human-centred manufacturing oriented objectives of the company is a source of contention between the shopfloor and management. Skills development, for example, is actively promoted by the supervisors. They encourage people to go on company-paid training and education courses. These additional courses complement the general company wide programmes which cover total quality, cellular manufacturing, just-in-time and continuous improvement issues. The reasons for the lack of motivation for taking advantage of the free training courses are

many. The most prevalent are the perceived lack of financial incentive (i.e. increase in salary) for completing the courses, the perception that more skills will lead to more work and the lack of confidence, amongst cell members in Cells C and D. in their ability to successfully complete the courses. The company are experiencing great difficulties in overcoming these issues in the long term.

The nature of operator loading was evaluated by interviewing cell members and supervisors, walk and talk throughs as well as periods of observation on the shopfloor. Throughout the research period, the nature of operator loading did not change for the cell members in Cells A, B and C. In Cell D, however, the proportion of cognitive and physical loading changed for the two cell members who completed training courses. Additional cognitive functions include some production planning activities as well as additional responsibilities for deciding how and when to (re)set and maintain equipment.

D1.3.1.5.1 Cells A and B

Under 'normal' conditions, cell members carry out few cognitive (role) functions and many physical (interactive and system) functions in both Cells. The allocation of role functions is open to wide strategic choice. The maturity of the Cells, high skill levels and good industrial relations facilitates the allocation of role functions to the cell members. The opportunity to effectively carry them out, however, are constrained by high cell loads and high technical coupling.

D1.3.1.5.2 Cells C and D

In Cells C and D, the cell members carry out mostly physical functions. The low skilled cell members in Cells C and D, are allocated few role functions. The more highly skilled cell members in Cell D, however, are involved with planning functions with the supervisors when disruptions occur. The relatively young age of the Cells and in some cases poor industrial relations and low skill levels constrain the scope for allocating role functions. Consequently, in both Cells, the majority of role functions are allocated to the setters and supervisors.

D1.3.1.6 Process Feedback

Process feedback from the work itself and from others help cell members evaluate their own performance, implement corrective measures, learn from the working environment and propose system improvements. Feedback from equipment is strongly mediated by man-machine interface design. In addition, cell members learn to interpret audible and visual feedback from the machines.

Formal mechanisms to provide feedback from other cell members and supervisors include monthly Cell meetings, quarterly Divisional meetings. notice boards and 'key organisation

statistic' (KOS) charts displaying key Divisional performance measures. There is considerable room for choice in implementing these mechanisms. Over twenty five KOS statistics are clearly displayed in each Division in the form of coloured bar charts and are good indicators of overall trends in Divisional performance. They are of limited value, however, to the cell members because they show macro statistics and bear no relation to the performance of individual Cells. In addition, for some measures, there are criticisms of their internal validity as well as methods for data gathering.

The content and forms of feedback were evaluated by interviewing cell members and supervisors and by periods of observation on the shopfloor. The characteristics of machine feedback changed little throughout the research. In Division C, formal mechanisms for communication and feedback between cell members, supervisors and management improved during the research period.

D1.3.1.6.1 Cells A and B

Process feedback from the three mills in Cell B and the Primary Machine in Cell A is low. The cell members can estimate the progress of an operation through experience and from audible cues. The Primary Machine in Cell A provides corrective feedback through a system called MARPOSS to compensate for tool wear. The system forms a closed loop with measurement equipment and calculates offsets on the appropriate tooling to ensure future work is cut to the specified dimensions. This facilitates the replacement of tools but does not provide information on the status of the cutting operations. Information feedback from the CNC machine in Cell B is high and is in the form of a VDU which displays G-codes and shows tool paths and cutting sequences. This facilitates good transparency and control over the cutting process.

Feedback from the work itself on their performance of the cell members is primarily in the form of the number and quality of finished components. This is determined through the use of manual inspection and dimensional measurement equipment (pre-calibrated rigs for automated measuring, surface measurement devices, hand gauges for checking threads and hole depths) in Cells A and B as well as SPC tools in Cell B.

Informational and corrective feedback takes a variety of forms. These encompass Cell meetings, quarterly Divisional meetings, notice boards and flip charts. Cell meetings are often scheduled by the cell members when the need arises to discuss cell improvements, cost reduction activities, manufacturing problems and Cell performance issues. This is accompanied by much informal discussion on the shopfloor. Quarterly Divisional meetings are held to present and answer questions on the performance of each Division and the company as a whole. Notice boards were set-up to for displaying component details, operating procedures, machining problems along with solutions as well as customer queries, complaints and general communications. They are there for the cell members to read and, where necessary, act upon them. In addition, the supervisor located flip charts in the Cells for the cell members to rapidly record production problems and solutions. This facilitates the communication of these issues

between shifts and between the shopfloor and management. The method is particularly useful when cell loads are high. In addition, it facilitates the continuous improvement process by clearly highlighting any outstanding problems.

The good communication mechanisms provide corrective and informational feedback to the cell members. This facilitated good cell transparency and, when time is available, the effective execution of role functions.

D1.3.1.6.2 Cells C and D

All the machines are numerically controlled but do not explicitly furnish cell members with informational or corrective feedback on cutting sequences and tool wear. The PreCom equipment, hand gauges and visual inspection provide feedback on the quality of the products. Supervisors often give feedback on Cell production levels and overall work quality. Formal mechanisms for feedback between cell members, setters and supervisors involves the use of cell meetings to discuss cell improvements, manufacturing problems and Cell performance issues. They are organised approximately the same time each month. Unlike Division C, the cell members are not present at cost reduction and key cell improvement meetings. Customer communications with the company relating to the Cells are not formally forwarded to the cell members.

Quarterly Divisional meetings are also held as with Division C. Notice boards were set-up for formal and informal notices relating to production as well as the activities of social organisations within the company.

At the beginning of the research period the company adopted charting methods in both Cells to record hourly production rates. The charts were imposed by management to keep a record of not only production levels for each cell members but also for assessing machine utilisation and efficiency levels. This was almost universally unpopular amongst the people working throughout the shopfloor and with some managers. The cell members were required to note their own hourly production rates. The record charts enabled the supervisors to quickly assess the progress of each cell member in the Cells. Feedback from the supervisors to the cell members tended to rely on the content of the record charts. There were widespread fears for possible 'discretionary' uses of the charts by management and irritation in the way the charts were implemented. The use of the charts stopped after about eight months because of their contentious nature, dubious accuracy and limited use.

The charting method was used as a substitute for effective face-to-face communications and high levels of trust between the shopfloor and management. This reflects the state of industrial relations and the relatively young age of the Cells. Cell members primarily get feedback from the setters and supervisors. Cell transparency is poor and reflects the nature of the communication methods as well as machine design.

D1.3.2 The Skill Levels of the Cell Members

The skills and abilities of the cell members encompass their craft, inter-personal, teamworking skills and mental abilities for decision making and problem solving. Skills development is actively promoted by the company because highly skilled cell members are more autonomous, flexible and can be relocated in other cells on the shopfloor.

High skill levels promote the allocation of role functions to the cell members, although their use is affected by the underlying physical nature of the work in the cells, industrial relations and commercial pressures. The following sections detail the above issues and describe the effects of independent features in terms of the state of features, relating to the 'skill levels of the cell members' descriptor (cf. original cell selection criteria), at the job design level of analysis. Their effects upon allocating and the ability to effectively carry out functions is described along with the effects of allocating functions between people and machines.

D1.3.2.1 Skills Use and Retention

Skills maintenance, in general terms, is promoted through their frequent use. The regular use of a broad range of physical and cognitive skills facilitates learning from the work itself and provides opportunities for personal development. The highly skilled cell members in Cells A, B and D, are invaluable to the company because they allow the supervisors to deal with 'boundary' activities, reduce the need for setters and, when disruptions occur, can rapidly cope with and rectify most forms of disruption. Their multi-skilling allows them to be allocated all necessary task and role functions. The underlying physical and repetitive nature of work in the Cells, however, provide few opportunities to use the wide range of their high and low levels skills during 'normal' operation and has caused many cell members to 'loose their edge' as well as becoming de-motivated and uninterested in their work.

Also, many of the skills developed and promoted during the company wide education programmes were not followed up and used on the shopfloor. Many of the cell members consequently failed to appreciate the need for the training courses and, in Division V, tended to view them merely as time away from the shopfloor when they could be getting on with working in the Cells. The mismatch between the nature of the courses and opportunities for the cell members to exercise or put into practice what they had learnt was of great concern for the company. This tends to hamper the adoption of and general interest in human-centred manufacturing methods and moves to more decentralised forms for work organisation.

Many issues tended to hamper the adoption of human-centred methods. Industrial relations and the internal politics tied to the way these methods were implemented was a significant factor. In addition, changes in the payment structure significantly and overtly influenced the acceptance and enthusiasm for current and future changes.

Skills maintenance and use was studied by interviewing the cell members and changed little throughout the research. The responses from earlier interviews also proved invaluable. The

use of high level skills, however, varied according to uncertainties in the Cells. Two cell members in Cell D completed skills development courses. Their newly acquired skills embraced enabler functions. Because of the nature of the work and management style, they were not given the opportunity to carry out a wide range of higher level skills.

D1.3.2.1.1 Cells A and B

In both Cells, the cell members are highly skilled - half have completed four year craft apprenticeships. Under 'normal' conditions, low level skills involving physical, interactive functions are typically carried out for between 60% to 80% in Cell A and 50% to 80% in Cell B of the total working time. Under 'normal' conditions in Cell B, daily planning activities can last between five to twenty minutes at the start of a shift or changeover. Daily planning often involves liaising with the downstream assembly cell and supervisors. These activities and the need to occasionally sort out queries with the kanban system take up a proportionally greater amount of time than in Cell A. In Cell A, planning is often more rapid because of a smaller product range and the continuous and steady demand for parts. Also the Cell does not experience the complexity and problems arising from meeting the requirements of a number of internally dependent customers. The content of the planning activities are often rudimentary during periods when the Cells are in arrears; but can be complicated by machine failures in the Cell and other cells, greater manufacturing priorities elsewhere in the shop, late material supplies, poor quality materials and changing customer demands.

Role functions are, however, used more during periods of disruption and during cost reduction, improvement and long term production planning meetings than for daily production planning and general Cell problem solving. The discretionary use of high level skills is constrained by high cell loads, machine design and, in Cell B, tight line balancing requirements. This reflects the high levels of technical coupling, the nature of operator loading, low transparency and the un-adaptive allocation of interactive functions. Under 'normal' conditions, in the short term, there are few opportunities to use role functions, the priority being to manufacture the work to meet business goals. Continuous improvement issues, even in the long term, tend to take second place when the Cells are both in arrears. During the second half of the research period this was the case for both Cells. Under these conditions, the supervisors took over the role of implementing improvements and improving communication mechanisms between themselves and the cell members.

D1.3.2.1.2 Cells C and D

The nature of work in both Cells provides few opportunities to use a broad range of high and low level skills. In both Cells, under 'normal' conditions, task functions are typically carried out for between 60% to 80% of the total working time. Opportunities for carrying out role functions is constrained by high technical coupling, low transparency, high cell loads, un-adaptive allocation of task and role functions for machine operation as well the low skill levels of the cell members themselves.

The lower skilled cell members in Cell C and D are classified as 'machine operators'. Because of the nature of the work in the Cell, the retention of these low level skills is good. All discretionary and role functions are carried out by the setters and supervisors. In Cell C, overall machine utilisation can drop to around 30% due to the need to re-calibrate and re-build the PreCom rig or to wait for a setter to re-set a machine. There is little scope and there are few opportunities for the cell members to use their initiative. In addition, few operational and continuous improvement decisions are made by the cell members.

The more highly skilled cell members in Cell D are classified as either 'SS3s' or 'setter-operators'. The SS3 level lies between an operator and a full setter-operator. A setter-operator can fully set and operate all machines as well as replace all tooling and perform basic front line maintenance tasks. Cell members at an SS3 skill level cannot fully set a machine but can replace all tooling. Overall, the cell members are more flexible than in Cell C and are consulted more on continuous improvement and daily production planning matters. Planning activities involving the cell members are carried out during period of disruption and when required by the supervisors. They may last from between one to fifteen minutes but are frequently brief, informal and modest in their content.

D1.3.2.2 Task Flexibility

Task flexibility is broken down into job rotation, enlargement and enrichment dimensions. These dimensions refer to elements of job design which seek to extend the scope and variety of work through movement between different jobs as well as the horizontal and vertical integration of tasks. There is room for strategic choice in implementing all three dimensions.

Inter-cell job rotation is practised in both Divisions. Overall, the cell members value this because it helps relieve boredom and the monotony of work. In the long term, however, this tends not to be eliminated because, under 'normal' conditions, the minimum length of time required to work in a Cell is about two weeks. This does, however, help to establish a sense of ownership for the workplace. Due to typically high cell loads in both Divisions, job rotation activities are strictly adhered to but may change according to the state of the shopfloor.

Cellular manufacturing, as a form of work organisation, promotes job enlargement by providing an environment where people, to varying degrees, operate a 'whole' system comprising a range of different machines and techniques. Job enlargement is fostered by eliminating full-time unskilled labourers from the shopfloor and allocating their functions to the cell members.

In all Cells, the job enrichment characteristics of job design vary between Cells. The room for strategic choice in designing and implementing these characteristics is constrained by high technical coupling and low transparency as well as the skill levels of the cell members, the age of the Cell, management style and industrial relations. High technical coupling, low cell transparency and high cell loads, however, limit opportunities to effectively carry out a wide range of high level skills. Job enrichment and enlargement decisions reflect attempts to

decentralise decision making (in Division C) and foster autonomy in all Cells. Whilst it is the policy of the company to promote these features in line with human-centred manufacturing concepts, the nature of work in the Cells as well as industrial relations and internal politics strongly influenced how these policies were embodied in reality and accepted at the shopfloor.

Task flexibility was studied by interviewing cell members and supervisors. In general, the policies and content of the three task flexibility dimensions varied little during the research period. In Division V, the allocation of task and role functions is un-adaptive. In Division C, the allocation of task functions is static, reflecting machine design and the job enlargement strategy, whilst the allocation of role functions is flexible depending on the state of the shopfloor.

D1.3.2.2.1 Cells A and B

Job rotation is fostered between and within Cells A and B. When two people work in either of the Cells, it is the responsibility of the cell members to allocate tasks between themselves. The high skill levels of the cell members give the supervisors the flexibility to locate them in any cell on the shopfloor. Under 'normal' conditions, inter-cell job rotation on a fortnightly basis is typical. Job enlargement is fostered throughout the company by allocating all interactive and enabler functions to the cell members and eliminating the need to employ casual labour.

Job enrichment is fostered by high skill levels (polyvalence), good industrial relations and adaptive allocation of role functions. The opportunity to carry out role functions and experience high levels of autonomy is constrained by the nature of work - high technical coupling, low cell transparency and high cell loads. The Division is experiencing great difficulty in overcoming the mismatch between the implementation of new forms of work organisation, the nature of the jobs themselves and the abilities and aspirations of the cell members. This is a major hurdle to nurturing enthusiasm and support at the shopfloor for existing and future organisational change.

D1.3.2.2.2 Cells C and D

The cell members work in Cell C for typically two weeks at a time. When not working in the Cell, the cell members work in other cells on the shopfloor including Cell D. Under disruptive conditions when the Cell is used to manufacturing overspill or late work from other cells, the cell members work in Cell D under the direction of the more highly skilled cell member. Cell members in Cell D also work in Cell C when conditions dictate.

In both Cells, job enrichment concepts are limited. They reflect the skill levels of the cell members as well as management perceptions of their abilities, management style, moderate levels of industrial relations and the need to retain control of all aspects of Cell production. The lack of unwillingness to decentralise decision making activities (allocate role functions) to the shopfloor is a source of contention that does nothing to foster enthusiasm towards existing

and future organisational change. This unwillingness is, however, exacerbated by low skilled cell members and their reluctance to improve their skills because of the perceived lack of financial incentive.

D1.3.2.3 Experienced Responsibilities

The amount of responsibility allocated to people is dependant upon strategic choices made by management. These choices reflect the skill levels of the cell members, the complexity of the working environment, industrial relations and the allocation of task and role functions. They impact upon supervisory style, workplace flexibility, the autonomy of the cell members and is a potential source of intrinsic motivation.

Degrees of control over fulfilling production responsibilities is strongly influenced by the design of the machines themselves. For example, poor machine transparency reduces the degree to which people have control over product quality and the individual cutting operations. The allocation of responsibilities for the long term operation and maintenance of the Cells is, however, dependant upon strategic choice, as outlined above.

Changes in the payment structure is a source of contention for the more highly skilled cell members. It makes company efforts to promote multi-skilling and the allocation of responsibilities to the shopfloor (in line with the adoption of human-centred manufacturing methods) more complex and difficult. The transition towards a flat rate pay structure decreases the number of pay levels from over one hundred to just five. Consequently, the financial differentiation between job grades has decreased dramatically. The more highly skilled cell members in Cells A, B and D regard their levels of responsibility, in addition to carrying out basic task functions, as an added burden because of changes in pay. The perceived lack of differentiation between those cell members with high levels of responsibility and those without is not an incentive for the lesser skilled cell members in Cells C and D to complete training courses. This is the case even though many realise the organisational benefits of a more flexible and skilled workforce.

Experienced responsibilities were studied by interviewing cell members and supervisors as well as by periods of observation on the shopfloor. The experienced responsibilities of the cell members remained largely static throughout the research period. The cell members in Cell D, however, who completed company training courses experienced an increase in responsibility for maintaining, setting and operating Cell equipment.

D1.3.2.3.1 Cells A and B

Cell members in Cells A and B have many responsibilities. They are solely responsible for part quality, pulling work from stores, maintaining the workplace and housekeeping, setting dates for and organising Cell meetings, determining intra-cell job rotation, front line maintenance as well as maintaining, setting and operating the machines and, in Cell B, maintaining the kanban

system with the downstream assembly cell. The responsibility for daily and more long term production planning and proposing and implementing improvements is shared between the cell members and supervisors depending on cell loads and the state of the shopfloor.

The relatively high levels of responsibility allow the cell members to work autonomously releasing the supervisors to deal with boundary regulation activities. The responsibility for fulfilling the role functions allocated to the cell members reflects the amount of trust and good industrial relations between the supervisors and cell members. The cell members, however, expressed feelings of inequity with the differentiation in pay between themselves and colleagues with fewer responsibilities.

Feelings of unfairness towards pay fostered reservations towards existing and future plans for change. Although not unique in industry, this situation was a significant hurdle for developing a working culture compatible with cellular manufacturing practices. The responsibility of the cell members to assure part quality in Cell A is constrained by the design of the Primary Machine. In Cell B, this is also the case with the three mills. In both Cells, low machine transparency, high technical coupling and typically high cell loads constrain the ability of the cell members to fulfil production responsibilities.

D1.3.2.3.2 Cells C and D

The low skilled cell members in Cells C and D, are solely responsible for part quality, operating machines, pulling work from stores, housekeeping and proposing Cell improvements. Machine setting, tool (re)calibration, machine failures and disruptions to the schedule are dealt with by setters and supervisors. As with Cells A and B, low machine transparency, high technical coupling and typically high cell loads constrain the ability of the cell members to fulfil and be in full control of meeting production responsibilities. In addition, high cell loads limit opportunities for the cell members in both Cells to undertake improvement activities.

In addition to the experienced responsibilities in Cell C, the more highly skilled cell members in Cell D share the responsibility with the supervisors for production planning during periods of disruption and whenever supervisors require assistance. The cell members are solely responsible for (re)setting the machines, tool (re)calibration and front line machine maintenance. Under 'normal' conditions, the allocated responsibilities allow the cell members to experience high levels of autonomy and enables the supervisors to focus more on boundary regulation issues. The attitudes of the cell members in Cells C and D towards skills development and the perceived lack of financial recognition for improvement is the same as for the cell members in Cells A and B.

D1.3.3 The Number of People in the Cells and Cell Loads

The following sections discuss the state and contribution of features relating to the number of

people and cell loads on the performance of the Cells and the cell members.

The number of people in a cell at any time depends on the number of machines in a cell, cell loads, the overall state of the shopfloor and on strategic choice. High cell loads require a Cell to be fully manned and tends to place great pressure upon the cell members to maintain high production levels. The former is, however, not always the possible since the supervisors need to consider the requirements and priorities of all Cells in a Division. In all Cells, during periods of high cell loading, continuous improvement activities by the cell members are severely constrained.

The number of people in a cell affects the need to consider the way cell members interact and co-ordinate their activities to maintain high production levels and also influences the opportunity for intra-Cell job rotation.

D1.3.3.1 Boundary Regulation

Boundary regulation refers to the activities of the supervisors in dealing with Cell matters not directly associated with production on the shopfloor. The content and style of these supervisory activities are dependant upon the age and 'maturity' of the Cells, industrial relations and the skill levels of the cell members. The allocation of role and enabler functions reflects the above issues. In both Divisions, the supervisors distance themselves from the Cells during 'normal' periods of operation. In Division V, there are more reasons for the setters and supervisors to intervene in Cell production because the cell members have few skills and are allocated fewer responsibilities and role functions.

The supervisors in all Cells, and in the case of Division V, the setters are required for trouble-shooting, regulating, information sharing and Cell improvement activities. In Cells C and D, the setters and technicians intervene to deal with mechanical disruptions to release the supervisors for boundary regulation activities. The more highly skilled cell members in Cells A, B and D resolve the majority of Cell disruptions. In all Cells, therefore, the supervisors are able to focus on and deal with more organisational issues. These encompass Cell and shopfloor improvements, assembly shop requirements, health and safety, training, capacity problems, absenteeism, industrial disputes, long term production planning and dealing with suppliers and customers. Although this is the case, because the setters and technicians are not always available in Division V, the supervisors need to do a lot of fire-fighting and assesses production priorities to reallocate resources amongst the cells.

Boundary regulation was studies by interviewing the supervisors and by observing activities in the Cells. Supervisory style changed little throughout the research period.

D1.3.3.1.1 Cells A and B

Under 'normal' conditions, the boundary regulation activities of the supervisors typically

encompass the organisational issues described above. Supervisors distance themselves as much as possible from direct Cell production because of high levels of confidence in the abilities of the cell members as well as the well established and proven nature of operating procedures.

The supervisors primarily liaise with the cell members when disruptions interfere with the execution of task and role functions. When this happens, the two parties meet informally on the shopfloor or formally in Cell meetings to exchange production, supplier and customer information and to plan activities to rectify the immediate problem. They evaluate whether the problem may be resolved by the cell members or with external help. If the breakdown cannot be resolved using front line maintenance skills, mechanical engineers and technicians rectify the problem. This, however, may take time because the required people may need to be subcontracted into the company. Under these conditions, the supervisors relocate the cell members in other cells.

D1.3.3.1.2 Cells C and D

Under 'normal' conditions, the boundary regulation activities of the supervisors typically encompass the organisational issues described above. Supervisors distance themselves as much as possible from direct Cell production. The setters and supervisors, however, tend to keep tabs on Cell activities because of the cell members not highly skilled, the relatively young age of the Cells and management requirements to closely monitor and maintain control of Cell design and working practices. The latter reflects the state of industrial relations between the shopfloor and management and is characteristic of their lack of confidence in the abilities of the cell members.

With the low skilled cell members in Cells C and D, under disruptive conditions the supervisors and setters deal with individual machine, material and quality issues - many are delegated to the setters and where necessary, to mechanical engineers or technicians. If these parties setters are busy, however, this can delay or reduce production for anything up to a month. The setters share much of the Cell liaison role and are also closely involved with shopfloor and individual Cell improvements.

The company have experienced an upturn in orders are experiencing the benefits of coming out of the recession. When cells go down, therefore, the supervisors have to deal with under capacity problems and often need to 'juggle' work between Cells to maintain production levels. Under these conditions, a highly skilled, flexible workforce is essential to help the supervisors with this task, but is not always available as discussed earlier. Cell D is used for this purpose when other cells go down. The supervisors and the more highly skilled cell members determine and plan production activities. During the research period, this occurred one to two times a month.

D1.3.3.2 Task Inter-Dependence and Sources of Variety

Task inter-dependence refers to the synergy established between people using various procedures and technologies to undertake a set of related tasks. Tasks are dependent upon each other in terms of the flow of work and information. The tasks in all Cells are sequentially related and are oriented towards a common manufacturing objective. Critical tasks are easily identifiable due to the sequential nature of work. Sequential task inter-dependence allows one to clearly identify critical tasks and the interdependencies between all tasks makes the consequences of carrying out all tasks easily understandable and predictable. This improves the ability of the cell members to regulate, co-ordination and cope with Cell disturbances before they affect neighbouring cells or operations. This is facilitated by the standardisation of all operations and dedicated machinery.

The sequentially dependent machine operations reflects the flow-line characteristics of the Cells. Under these circumstances, people 'down the line' can identify and give immediate feedback on poor quality work. This is embodied within the total quality management approach, formal and informal activities to eliminate all forms of waste as well as giving responsibility for part quality to the cell members. The combination of small batch sizes and the continuous inspection of all work helps minimise the need for re-work.

Sources of variance encompass those disturbances that arise from within the Cells themselves, from the organisation as a whole or from outside the organisation itself. Disruptions not emerging from the former source are outside the scope of all the cell members and are dealt with by management. Under 'normal' conditions, task methods in all Cells are prescribed and rigidly followed. To resolve Cell disruptions, the cell members need to be highly skilled, exhibit high levels of flexibility and have the opportunity to use their initiative and high level skills. The resolution of disruptions is facilitated through teamworking and good communications between themselves and supervisors. This situation is, however, not always organisationally or politically feasible or achievable.

Task inter-dependence and sources of variance were studied by interviewing cell members and supervisors, from periods of observation on the shopfloor as well as walk and talk throughs in the Cells. During the research, task inter-dependencies were unchanged because no Cell was fundamentally redesigned. Sources of variety and the timing of disruptions, however, were unpredictable. A wide range of commercial, technical and organisational disruptions adversely affected production in the Cells over the research period. Methods for their resolution varied according to the state of the shopfloor and the type of disruption.

D1.3.3.2.1 Cells A and B

In Cell A, the Primary Machine is the main source of internal mechanical disruption and is the critical operation. The machine is very complex and is prone to breaking down two to four times a year. The cause of a breakdown is often difficult to identify and ultimately to repair

because of its complexity and age. The Primary Machine broke down twice during the research period, in each case for about ten working days. This reduces the autonomy of the cell members since engineers and technicians are often needed to intervene to fix the machine. In the past when this has happened, production was stopped for around one to four weeks.

The four mills in Cell B are all critical operations. During the research period, none of the machines broke down. Even though it is difficult for the cell members to predict when a machine was going to fail, major breakdowns were prevented by monthly capability tests and preventative maintenance activities based on experience and statistical measures. Also, during the Autumn, the company has a planned shut-down. All machines are stripped-down and refitted.

The tasks in both Cells are sequentially related by a single flow-line 'pull' system where downstream tasks are dependant upon all preceding tasks. Task are inter-dependent in terms of material flow and part quality. There is no flow of information between machines. The flow of materials is controlled through standardised work procedures. Because of high technical coupling and un-adaptive task allocations, all machine operations are critical and highly inter-dependent. In the case of the latter, the cell members rigidly adhere to work practices requiring 100% inspection of all batches to minimise the transfer of errors between machine operations and Cells.

Organisational disruptions encompass feelings of inequity fostered by changes in the payment structure, the requirement to attend Total Quality refresher courses, 'juggling' people around the shopfloor by the supervisors according to production priorities as well as becoming familiar with improvements proposed and implemented by supervisors. In addition, production requirements and cell loads in Cell B are shaped by disruptions in the 'downstream' assembly cell. The purpose and rationale behind all of these issues and how they relate to Cell production was always formally or informally communicated with the cell members. Under these circumstances, the supervisors and all cell members meet to reschedule work and plan corrective activities. Because of their high skill levels, the cell members can be moved into any cell on the shopfloor and can autonomously fulfil their responsibilities.

The main source of external variety encompassed poor supplier performance. Because many companies were emerging from the recession, individual suppliers were experiencing difficulties with meeting a rapid increase in orders for castings. Batches of castings for both Cells occasionally suffered from porosity and could not be used. This delayed work in the Cells for anything up to five days. The supervisors communicated with the suppliers. Depending on the state of the shopfloor, the cell members were relocated elsewhere in the shop after using existing stock.

D1.3.3.2.2 Cells C and D

In both Cells, the Fanucs and lathes are critical operations and are the main sources of mechanical disruption. One Fanuc was down in Cell C twice during the research period and

roughly halved production in total for four weeks. Throughout the research period, none of the lathes in either Cell broke down and proved to be highly reliable. In addition, both Cells experience problems with the PreCom measurement equipment. The rigging, about once every two months, needed to be dismantled, rebuilt and calibrated by the setters. This would stop production until the setters were available to carry out the tasks and has held up production for up to half a day whereas the task itself took only a hour to complete.

As with Cells A and B, tasks are sequentially linked and task dependencies are clear. This makes the consequences of carrying out production tasks easily understandable and predictable and facilitates learning of these consequences from the work itself. As in Division C, the transfer of errors between processes and cells is minimised by 100% work inspection. Tasks are dependent upon each other in terms of work flow and work quality. All machines in both Cells are, therefore, critical for maintaining production. This criticality is exacerbated by the design of the machines themselves which foster un-adaptive allocation of task functions, poor machine transparency and high technical coupling. The setters and supervisors provide the support to maintain production. Variances beyond the shopfloor boundary of the Cell (i.e. beyond the influence of the cell members) are also dealt with by the supervisors. In addition, sources of organisational variety were similar to those experienced in Division C.

D1.3.3.3 Independence of System

The regulation of disturbances at their point of origin is essential for the independence of the Cells and ensures disturbances are not transferred in an unpredictable way from one cell to another. The ability of the Cells to self-regulate in the long term is dependent upon the ability of the cell members and supervisors to eliminate, predict and rectify organisational, technical and commercial disruptions. Continuous improvement activities help minimise and eliminate sources of variance. These activities, however, are often of secondary importance because of short term production and commercial pressures.

Predicting disruptions is more effective than merely being in a position to identify and rectify them once they have occurred. The ability of the cell members to predict cell disruptions is facilitated by sequential task interdependence, an autonomous and flexible workforce as well as effective communication between management and the shopfloor. This is characteristic of Cells A and B and is fostered by good industrial relations, highly skilled cell members effective communication mechanisms and allocating responsibilities and role functions to the cell members. In all Cells, however, the opportunity and ability of the cell members to predict disruptions is strongly constrained by the nature of the work itself, machine design and high cell loads.

Dealing with cell disruptions once they have occurred is again facilitated by the capabilities of the cell members and the use of effective communication mechanisms between supervisors and the shopfloor. Where setter, engineers or technicians are required to resolve disruptions, cell production may be suspended for anything up to four weeks if these parties are busy elsewhere in the company or if they need to be sub-contracted from outside the company. When this

happens, supervisors minimise the negative impact on production by assessing manufacturing priorities, rescheduling production and 'juggling' people and products between cells.

The independence of the Cells was studied by periods of observation on the shopfloor, attending cell meetings, interviews with supervisors and walk and talk throughs in the Cells. The responses from earlier interviews and the characteristics of dependant variables at the three levels of analysis were invaluable for describing the ability of the Cells to maintain its independence. The ability of the Cells to self-regulate and methods for pre-empting disruptions remained unchanged during the research period. Mechanisms for coping with disruptions varied according to their severity and type.

D1.3.3.3.1 Cells A and B

All but the most severe machine, material and product variances are dealt with by the cell members. When disruptions occur, the supervisors and cell members plan rectifying activities. Company or outside engineers and technicians are used where the front line maintenance skills of the cell members are insufficient to deal with a disruption.

The autonomy of the cell members is constrained by machine design, commercial pressures and the nature of the work itself. Poor machine feedback, high cell loads, high technical coupling and low machine and system transparency provides few opportunities for the cell members to learn from the work itself and predict when production disruptions will occur. In addition, the requirement for the cell members to carry out largely interactive functions under 'normal' operating conditions does not foster the maintenance of high level skills as well as enthusiasm and interest in the work itself. These issues constrain the ability of the cell members to predict internal-cell disruptions rather than the communication of and the ability to deal with the disruptions once they have occurred.

Cell meetings are good mechanisms for long term planning, cell improvement and problem solving activities. Long term maintenance through continuous improvement activities and being able to predict internal-cell disruptions are, however, constrained by machine design, commercial pressures and the nature of work itself, as outlined above. The remaining activities maintain performance by fostering the effective rectification of internal-cell disruptions. The company maintenance programme facilitates long term cell performance by maintaining machines and pre-empting mechanical failures.

To compensate for the mismatch between the 'interactive' and repetitive nature of work and adopting human-centred manufacturing methods the company fosters, in various forms, effective communication mechanisms, preventative maintenance methods and continuous improvement activities. The cell members, however, have few opportunity to undertake the latter. During periods of low production or when production is disrupted, however, the cell members have time to propose, plan and implement cell improvements. Under 'normal' operating conditions the supervisors tend to proactively implement improvements whilst the cell members are busy. As well as cell meetings, the supervisors use notice-boards and

flip-charts in the Cells to foster the communication of Cell problems and solutions between cell members, supervisors, customers and shifts. The cell members use these tools to communicate Cell and product manufacturing difficulties and solutions. During periods of high cell loading, solutions are implemented by either supervisors or mechanical engineers and often affect working procedures.

The preventative maintenance activities and communication mechanisms are, therefore, key to sustaining cell performance in the long term. Continuous improvement activities, also help minimise sources of production uncertainty. In addition, the polyvalence of the cell members enable them to take part in front line maintenance activities, when failures do occur, to rapidly recommence production.

D1.3.3.3.2 Cells C and D

For the low skilled cell members in Cells C and D, setters and technicians assess and rectify all machine failures. During the research period, long delays have occurred of up to two weeks where these parties were busy on other jobs. In Cell D, the cell members replace and (re)calibrate tooling. The more highly skilled cell members use their front line maintenance skills to deal most mechanical breakdowns. In both Cells, preventative maintenance activities minimise and pre-empt machine failures.

As with Cells A and B, the work in Cells C and D conflicts with the human-centred manufacturing philosophy and skills development objectives of the company. The flat pay structure was viewed by all cell members as a disincentive to skills development.

Cell meetings for both Cells are useful for formal communication and feedback between supervisors and cell members but are also a source of contention. The initiative to suggest cell improvements often had to come from the cell members. Improvements were often proposed before quite a confrontational audience of supervisors and management. All the cell members found this quite daunting. All the final continuous improvement decisions are made without the cell members present, with the supervisors and setters acting as intermediaries between management and the shopfloor. Much of the feedback from the Cell on production levels and prospective improvements is in the form of accumulated data from the charting method imposed upon the Cells in October 1993. The scheme was later removed in at the start of 1995. Final improvement and cost reduction decisions are often based on the charting data and also on that provided by the supervisors and setters. Primarily because of the low skill levels of the cell members in Cells C and D and, management do not involve the cell members in these decisions. The cell members consequently feel little sense of 'workplace' ownership because changes in working conditions and operational procedures tend to be management imposed.

To illustrate this point, the deswarfing booth in Cell C was moved three times before its final position. Conflict arose between what the cell members wanted and the views of management. In addition personal relationships between certain cell members and management interfered with relocation decisions. The same issues arose with the location of strip lighting above the

Cell as well as the location of the PreCom rig which was too near the cooling fan of the Lathe. thus tending to heat up the rig and distort measurements.

The cell members in Cell D shared the same views regarding the purpose and role of the continuous improvement meetings. Charting was also used for accumulating cell production and machine utilisation data. Final decisions were made in the absence of the cell members although they felt more confident in initially proposing improvements. This was because the supervisors and management tended to listen to them more than those in Cell C due to higher skill levels. These cell members were treated more like experts in their job. Although this level of trust and respect has taken a long time to cultivate, the cell members did not understand why they could not participate in making final improvement decisions. The view of management towards the cell members in both Cells tended to hinder the pace and content of Cell improvements in Cells C and D during the research period.

The independence of Cells C and D is constrained by the 'interactive' nature of the work, poor system and machine transparency, low skill levels, high cell loads and poor industrial relations. The latter issues reduce the involvement of the cell members in continuous improvement activities. As with Division C, the preventative maintenance activities help pre-empt machine failures in the Cells. The responsibility for implementing Cell improvements and solving Cell problems and difficulties are allocated to the setters, management and supervisors because the cell members are excluded from key Cell meetings and decision making forums.

The independence of the Cells rely largely on the efforts of the setters and supervisors. They do not work in the Cells and so are unable to predict machine failures. They are, however, central to sustaining cell performance in the long term by carrying out continuous improvement activities and rectifying disruptions when they occur. Rectification activities and cell production may consequently be delayed because disruptions elsewhere on the shopfloor can occupy the setters and technicians for anything up to a week. This situation is fostered by the low skill levels of the cell members. In addition, poor industrial relations and perceptions of inequity regarding the new payment structure do not encourage the cell members to improve their skills. Finally, the company training programme tends not to reflect the nature of the work in the Cells. The mismatch between the efforts of the company to promote human-centred concepts are constrained by this, management style and the inflexible and low skilled workforce.

D1.3.3.4 Interaction Requirements

Interaction and communication needs refers to the occasions when various parties are required to discuss production matters. These encompass maintenance, rectification, production planning and improvement issues. In Division C, disruptions are dealt with in varying degrees by effective communication between the cell members and supervisors. This is realised through cell meetings, informal face-to-face discussion on the shopfloor and the clear display of methods and techniques through Cell notice-boards and flip-charts. In Division V, Cell disruptions are dealt with by the supervisors, setters and in Cell D, the more highly skilled cell

members. Consequently, under disruptive conditions methods for dealing with cell problems and the way they are communicated vary from Cell to Cell and depend on the number of people in the Cell, the abilities of the cell members and industrial relations. In Cells A and B, under 'normal' operating conditions, tasks are co-ordinated between cell members through informal discussion on shopfloor. Communication between cell members is, however, affected by the proximity of each person, high technical coupling and high cell loads.

In all Cells, the propensity for various parties to communicate is influenced by the skill levels of the cell members, industrial relations and extant communication mechanisms. In Division C, for example, where the cell members are highly skilled and the communication mechanisms well established, the cell members and supervisors typically communicate overtly and effectively to deal with uncertainties, for production planning and in the case of Cell B, to co-ordinate material flows between cells. In Division V, however, the communication mechanisms are fewer and less effective. Cell members rarely discuss with the supervisors issues relating to rectifying breakdowns, implementing cell improvements and production planning. This reflects the low skill levels of the cell members, the relatively young age of the Cells, management style and the state of industrial relations. The more highly skilled cell members in Cell D are consulted on production planning issues when disruptions occur in the Cell and when the Cell is needed to manufacture overspill or late work from other cells.

Interaction and communication needs were studied by interviewing cell members and supervisors and by observing activities in the Cells. Interaction and communication needs varied throughout the research period and depended on the type and severity of Cell disruptions.

D1.3.3.4.1 Cells A and B

Cells A and B operate with either one or two people depending on levels of demand for these and for other cells on the shopfloor. High cell loads require two people to work in both Cells. In Cell A, one cell member concentrates on 'feeding' the Primary Machine with work, whilst the other performs the deburring and washing operations. The two cell members can communicate verbally because of the close proximity of the manufacturing operations. This, as well as the standardisation of all tasks (clearly displayed on the Cell notice-board) facilitates task co-ordination. The largely interactive nature of the allocated functions, short cycle times and high cell loads does, however, constrain their physical movement around the Cell and the shopfloor in general.

When two people work in Cell B, the Cell is divided into two sub-cells. There are few opportunities for interaction during 'normal' operation between sub-cells due to physical distance and the need to keep at least two machines running in parallel at all times. Task co-ordination is, however, determined verbally and facilitated through the standardisation and clear description of all manufacturing operations.

Under 'normal' conditions in Cell B, daily planning activities can last between five to twenty

minutes at the start of a shift or changeovers. In Cell A, this is carried out between the cell members and the supervisors. In Cell B, this is typically carried out between the cell members in Cell B, the cell members in the downstream assembly cell and the supervisors. A kanban system, however, maintained by both cells specifies production requirements and, under 'normal' conditions, requires little planning to be undertaken on a daily basis. Production planning is carried out often between a number of supervisors and the cell members when disruptions occur because of potential disturbances to the production levels of other cells as well as the need to find solutions elsewhere on the shopfloor. Rectification activities to solve Cell based problems are also planned between cell members and supervisors.

D1.3.3.4.2 Cells C and D

The lesser skilled cell members in Cells C and D do not play a significant role in cell improvements, planning cell loads and rectification activities when disruptions occur. In the case of the former, because of the relatively young age of the Cells, management feel the need to determine the content and timing of cell improvements with little input from the cell members themselves. Under 'normal' conditions, the cell members work on their own. Because of high cell loads and high technical coupling, the movement of the cell members around the Cells and the shopfloor in general is strongly determined by production requirements. Consequently, in manufacturing terms and as far as the company is concerned, the cell members need to interact with few other parties.

If machines breakdown in other cells, then Cell D is frequently utilised to maintain the output levels of a particular component. Planning cell loads in this Cell is, therefore, of great importance. If the Cell has been utilised to manufacture overspill work from other cells, then often two people need to work in the Cell to maintain high production levels. Under these conditions, the supervisors, who have a clear picture of the activities of the whole shopfloor, plan cell loads with the cell members.

APPENDIX E

QUESTIONNAIRE FINDINGS

During the complete research period, three self-completion questionnaires were submitted. The Job Diagnostic Survey (JDS) questionnaire was submitted twice for all cell members to identify key elements of the job characteristics theory (Hackman and Oldham, 1980) encompassing different job characteristics, psychological states and motivational outcomes.

The second questionnaire was submitted once. It was designed for collecting data on key issues identified during the pilot study encompassing cell management, training and cell layout issues. The third questionnaire was submitted twice. Its purpose was to collect data on identified features for analysis at the man-machine and job design levels of analysis. This questionnaire complements the JDS which collects data on the 'experienced responsibilities' and 'process feedback' features.

E1.1 Questionnaire Transcripts

E1.1.1 Questionnaire One

The CIM Institute / Bendix HVS
Cell Questionnaire #1

On the following pages you will find several different kinds of questions about your job. Specific instructions are given at the start of each section. Please read them carefully. It should take you no more than 25 minutes to complete the entire questionnaire. Please move through it quickly.

The questions are designed to obtain your perceptions of your job and your reactions to it.

There are no trick questions and no right or wrong answers. Your individual answers will be kept completely confidential. Please answer each item as honestly and as frankly as possible.

Thank you for your co-operation.

SECTION ONE

This part of the questionnaire asks you to describe your job, as *objectively* as you can. Please do *not* use this part of the questionnaire to show how much you like or dislike your job. Questions about that will come later. Instead, try to make your descriptions as accurate and as objective as you possibly can.

An *EXAMPLE* is given below:

Q. To what extent does your job require you to work with mechanical equipment?

1	2	3	4	5	(6)	7
Very Little; the job requires almost no contact with mechanical equipment of any kind			Moderately		Very much; the job requires almost constant work with mechanical equipment	

You are to circle the number which is the most accurate description of your job. If, for example, your job requires you to work with mechanical equipment a good deal of the time; but also requires some paperwork, you might circle number six.

If you do not understand these instructions, please ask for assistance. If you do understand then please begin:

1. To what extent does your job require you to work *closely with other people* (either "clients", or people in related jobs in your own organisation)?

1	2	3	4	5	6	7
Very little; dealing with other people is not at all necessary in doing the job.		Moderately; some dealing with others is necessary			Very much; dealing with other people is an absolutely essential part of doing the job.	

2. How much *autonomy* is there in you job? That is, to what extent does your job permit you to decide *on your own* how to go about doing the work?

1	2	3	4	5	6	7
Very little; the job gives me almost no personal "say" about how and when the work is done.		Moderate autonomy; many things are standardised and not under my control, but I can make some decisions about my work.			Very much; the job gives me almost complete responsibility for deciding when the work is done.	

3. To what extent does your job involve doing a "whole" and identifiable piece of work? That is, is the job a complete piece of work that has an obvious beginning and an end? Or is it only a small part of the overall piece of work, which is finished by other people or by automatic machines?

1	2	3	4	5	6	7

My job is only a tiny part of the overall piece of work; the results of my activities cannot be seen in the final product or service.	My job is a moderate-sized "chunk" of the overall piece of work; my own contribution can be seen in the final outcome.	My job involves doing the whole piece of work, from start to finish; the results are easily seen in the final product.

4. How much *variety* is there in your job? That is, to what extent does your job require you to do many different things at work, using a variety of your skill and talents?

1	2	3	4	5	6	7
Very little; the job requires me to do the same routine things over and over again.			Moderate variety.			Very much; the job requires me to do many different things using a number of different skills and talents.

5. In general, how *significant* or *important* is your job? That is, are the results of your work likely to significantly affect the lives or well-being of other people?

1	2	3	4	5	6	7
Not very significant; the outcomes of my work are not likely to have important effects on other people.			Moderately significant.			Highly significant; the outcomes of my work can affect other people in very important ways.

6. To what extent do *managers* or *co-workers* let you know how well you are doing on your job?

1	2	3	4	5	6	7
Very little; people almost never let me know how well I am doing.		Moderately; sometimes people may give me "feed back"; other times they may not.			Very much; managers or co-workers provide me with almost constant "feedback" about what I am doing.	

7. To what extent does *doing the job itself* provide you with information about your work performance? That is, does the actual *work itself* provide clues about how well you are doing - aside from any "feedback" co-workers or supervisors may provide?

1	2	3	4	5	6	7
Very little; the job itself is set up so I could work forever without finding out how well I am doing.		Moderately; sometimes doing the job provides "feedback" to me; sometimes it does not.			Very much; the job is set up so that I get almost constant "feedback" as I work about how well I am doing.	

SECTION TWO

Listed below are a number of statements which could be used to describe a job. You are to indicate whether each statement is an *accurate* or an *inaccurate* description of your job.

Once again, please try to be as objective as you can in deciding how accurately each statement describes you job - regardless of whether you like or dislike your job.

Write a number in the blank beside each statement, based on the following scale:

*How **accurate** is the statement in describing your job?*

1	2	3	4	5	6	7
Very Inaccurate	Mostly Inaccurate	Slightly Inaccurate	Uncertain	Slightly Accurate	Mostly Accurate	Very Accurate

1)_____ The job requires me to do use a number of complex high level skills.

2)_____ The job requires a lot of co-operative work with other people.

3)_____ The job is arranged so that I do *not* have the chance to do an entire piece of work from beginning to end.

4)_____ Just doing the work required by the job provides many chances for me to figure out how well I am doing.

5)_____ The job is quite simple and repetitive.

6)_____ The job can be done adequately by a person working alone - without talking or checking with other people.

7)_____ The supervisors and co-workers on this job almost never give me any "feedback" about how well I am doing in may work.

8)_____ This job is one where a lot of other people can be affected by how well the work gets done.

9)_____ The job denies me any chance to use my personal initiative or judgement in carrying out the work.

10)_____ Supervisors often let me know how well they think I am performing the job.

11)_____ The job provides me with the chance to completely finish the pieces of work I begin.

12)_____ The job itself provides very few clues about whether or not I am performing well.

13)_____ The job gives me considerable opportunity for independence and freedom in how I do the work.

14)_____ The job itself is *not* very significant or important in the broader scheme of things.

SECTION THREE

Now please indicate how *you personally feel about your job.* Each of the statement is something that a person might say about his or her job. You are to indicate your own personal *feelings* about your job by marking how much you agree with each of the statements.

Write a number in the blank beside each statement, based on the following scale:

*How much do you **agree** with the statements?*

1	2	3	4	5	6	7
Disagree Strongly	Disagree	Disagree Slightly	Uncertain	Agree Slightly	Agree	Agree Strongly

1)_____ It's hard, on the job, for me to care very much about whether or not the work gets done right.

2)_____ My opinion of myself goes up when I do this job well.

3)_____ Generally speaking, I am very satisfied with this job.

4)_____ Most of the things I have to do on this job seem useless or trivial.

5)_____ I usually know whether or not my work is satisfactory on this job.

6)_____ I get a great sense of personal satisfaction when I do this job well.

7)_____ The work I do on this job is very meaningful to me.

8)_____ I feel a very high degree of *personal* responsibility for the work I do on this job.

9)_____ I frequently think of quitting this job.

10)_____ I feel bad and unhappy when I discover that I have performed poorly on this job.

11)_____ I often have trouble figuring out whether I'm doing well or poorly on this job.

12)_____ I feel I should personally take the credit or blame for the results of my work on this job.

13)_____ I am generally satisfied with the kind of work I do in this job.

14)_____ My own feelings generally are *not* affected much one way or the other by how well I do on this job.

15)_____ Whether or not this job gets done right is clearly *my* responsibility.

SECTION FOUR

Now please indicate how *satisfied* you are with each aspect of your job listed below. Once again, write the appropriate number in the blank beside each statement.

Write a number in the blank beside each statement, based on the following scale:

*How **satisfied** are you with this aspect of your job?*

1	2	3	4	5	6	7
Extremely Dissatisfied	Dissatisfied	Slightly Dissatisfied	Uncertain	Slightly Satisfied	Satisfied	Extremely Satisfied

1)_____ The amount of job security I have.

2)_____ The amount of pay and fringe benefits I receive.

3)_____ The amount of personal growth and development I get in doing my job.

4)_____ The people I talk and work with on my job.

5)_____ The degree of respect and fair treatment I receive from my boss.

6)_____ The feeling of worthwhile accomplishment I get from doing the job.

7)_____ The chance to get to know other people while on the job.

8)_____ The amount of support and guidance I receive from my supervisor.

9)_____ The degree to which I am fairly paid for what I contribute to the organisation.

10)_____ The amount of independent thought and action I can exercise in my job.

11)_____ How secure things look for me in the future in this organisation.

12)_____ The chance to help other people while I work.

13)_____ The amount of challenge in my job.

14)_____ The overall quality of supervision I receive in my work.

SECTION FIVE

Now please think of the other people in your organisation who hold the same job as you do. If no one has exactly the same job as you, think of a job which is the most similar to yours. Please think about how accurately each of the statements describes the feelings of those people about the job.

It is quite all right if your answers here are different from when you described your *own* reactions to the job. Often different people feel quite differently about the same job.

Write a number in the blank beside each statement, based on the following scale:

*How much do you **agree** with the statements?*

1	2	3	4	5	6	7
Disagree Strongly	Disagree	Disagree Slightly	Uncertain	Agree Slightly	Agree	Agree Strongly

1)_____ Most people on this job feel a great sense of personal satisfaction when they do the job well.

2)_____ Most people on this job are very satisfied with the job.

3)_____ Most people on this job feel the work is useless or trivial.

4)_____ Most people on this job feel a great deal of personal responsibility for the work they do.

5)_____ Most people on this job have a pretty good idea of how well they are performing their work.

6)_____ Most people on this job find the work meaningful.

7)_____ Most people on this job feel that whether or not the job gets done right is clearly their own responsibility.

8)_____ Most people on this job often think of quitting.

9)_____ Most people on this job feel bad or unhappy when they find that they have performed the work poorly.

10)_____ Most people on this job have trouble figuring out whether they are doing a good or a bad job.

SECTION SIX

Listed below are a number of characteristics which could be present on any job. People differ about how much they would like to have each one present in their own jobs. We are interested in learning how much you personally would like to have each one present in your job.

Using the scale below, please indicate the *degree* to which you would *like* to have each characteristic present in your job.

NOTE: The numbers on this scale are different from those used in previous sections.

4	5	6	7	8	9	10
Would Moderately like to have			Would like to have this very much			Would extremely like to have

this this

1)_____ High respect and fair treatment from my supervisor.

2)_____ Stimulating and challenging work.

3)_____ Chances to exercise independent thought and action in my job.

4)_____ Great job security.

5)_____ Very friendly co-workers.

6)_____ Opportunities to learn new things from my work.

7)_____ High salary and good fringe benefits.

8)_____ Opportunities to be creative and imaginative in my work.

9)_____ Quick promotions.

10)_____ Opportunities for personal growth and development in my job.

11)_____ A sense of worthwhile accomplishment in my work.

SECTION SEVEN

People differ in the kinds of jobs they would most like to hold. The questions in this section give you a chance to say just what it is about a job that is most important to *you*.

For each question, two different kinds of jobs are briefly described. You are to indicate which of the jobs you personally would prefer - if you had to make the choice between them. In answering each question, assume that everything else about the jobs is the same. Pay attention only to the characteristics actually listed.

Two ***EXAMPLES*** are given below:

Example one.

JOB A A job requiring work with mechanical equipment most of the day.			JOB B A job requiring work with other people most of the day.	
1	2	(3)	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

If you like working with people and working with equipment equally well, you would circle number 3. Using the scale below, please indicate the *degree* to which you would *like* to have each

Example two.

JOB A A job requiring you to expose yourself to considerable physical danger.			JOB B A job located 200 miles from you home and family.	
1 Strongly Prefer A	(2) Slightly Prefer A	3 Neutral	4 Slightly Prefer B	5 Strongly Prefer B

If you like slightly prefer physical danger to working far from your home, you would circle number 2.

Please ask for assistance if you do not understand how to do these questions.

1)

JOB A A job where the pay is very good.			JOB B A job where there is considerable opportunity to be creative and innovative.	
1 Strongly Prefer A	2 Slightly Prefer A	3 Neutral	4 Slightly Prefer B	5 Strongly Prefer B

2)

JOB A A job where you are often required to make important decisions.			JOB B A job with many pleasant people to work with.	
1 Strongly Prefer A	2 Slightly Prefer A	3 Neutral	4 Slightly Prefer B	5 Strongly Prefer B

3)

JOB A A job which greater responsibility is given to those who do the best work.			JOB B A job in which greater responsibility is given to loyal employees who have the most seniority.	
1 Strongly Prefer A	2 Slightly Prefer A	3 Neutral	4 Slightly Prefer B	5 Strongly Prefer B

4)

JOB A A job in an organisation which is in financial trouble, and might have to close down within the year.			JOB B A job in which you are not allowed to have any say whatever in how your work is scheduled, or in the procedures to be used in carrying it out.	
1 Strongly Prefer A	2 Slightly Prefer A	3 Neutral	4 Slightly Prefer B	5 Strongly Prefer B

5)

JOB A A very tedious job.	JOB B A job where your co-workers are not very friendly.

1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

6)

JOB A A job with a supervisor who is often very critical of you and your work in front of other people.			JOB B A job which prevents you from using a number of skills that you worked hard to develop.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

7)

JOB A A job with a supervisor who respects you and treats you fairly.			JOB B A job which provides constant opportunities for you to learn new and interesting things.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

8)

JOB A A job where there is a real chance you could be laid off.			JOB B A job which provides lots of vacation time and excellent fringe benefit package.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

9)

JOB A A job in which there is a real chance for you to develop new skills and advance in the organisation.			JOB B A job which provides lots of vacation time and excellent fringe benefit package.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

10)

JOB A A job with little freedom and independence to do your work in the way you think best.			JOB B A job where the working conditions are poor.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

11)

JOB A A job with very satisfying teamwork.	JOB B A job which allows you to use your skills and

				abilities to the fullest extent.
1 Strongly Prefer A	2 Slightly Prefer A	3 Neutral	4 Slightly Prefer B	5 Strongly Prefer B

12)

JOB A A job which offers little or no challenge.			JOB B A job which requires you to be completely isolated from co-workers.	
1 Strongly Prefer A	2 Slightly Prefer A	3 Neutral	4 Slightly Prefer B	5 Strongly Prefer B

SECTION EIGHT

Biographical Background.

1. Sex: Male_____ Female_____

2. Age (tick one) _____under 20 _____40-49

_____20-29 _____50-59

_____30-39 _____60 or over

3. Education (tick which ones apply to you)

_____High school

_____Apprenticeship

_____Some Technical College experience

_____Other. Please specify:

4. What is you job title? (briefly)

END OF QUESTIONNAIRE

E1.2 Questionnaire Two

E1.2.1 Features Under Analysis

The features encompassed the following:

1) Cell Layout

a) *Component Awareness*. Knowledge of the function and design characteristics of the manufactured components.

b) *Visibility*. The level of awareness and understanding of factors in the Cells at different 'levels'. Firstly, from a 'low-level' perspective, with reference to the state of machine process at any moment and secondly, from a wider perspective, with reference to the overall manufacturing process encompassing people, machines and procedures.

c) *Routing*. Appreciation of where the components come from and where they go after machining.

d) *Role Identification*. Appreciation of function within the 'whole' organisation.

e) *'Assembly' Awareness*. Understanding and awareness of what goes on in the assembly shop. This encompasses procedures and problems encountered.

2) Training

a) *Relevance*. Appropriateness of training compared to the nature of work in the Cells.

b) *Style*. Adopted training methods as well as the demeanour of and delivery by trainer.

c) *Frequency*. Timing and number of courses.

d) *Policy*. Long term organisational training strategy.

e) *Follow-up*. Use of acquired skills and knowledge at work as well as support from management for skills and knowledge retention.

3) Cell management

a) *Teamworking*. Experience of working in a team environment.

b) *Communications*. Changes in and mechanisms for communication amongst cell members and management.

c) *Supervision*. Experienced styles of supervision.

d) *Responsibility*. Experienced responsibilities by cell members.

e) *Continuous Improvement*. Mechanisms for and content of the Continuous Improvement programme.

E1.2.2 Questionnaire Schedule

The CIM Institute / Bendix HVS Cell Questionnaire #2

On the following pages you will find several different kinds of questions about your job. Specific instructions are given at the start of each section. Please read them carefully. It should take you no more than 40 minutes to complete the entire questionnaire. Please move through it quickly.

The questions are designed to obtain *your* perceptions of your job and *your* reactions to it.

There are no trick questions. Your individual answers will be kept completely confidential. Please answer each item as honestly and as frankly as possible.

Thank you for your co-operation.

SECTION ONE

Each statement represents some aspect of your job. Please indicate how your **understanding** of each aspect is affected by working in a cellular environment.

Write a number in the blank beside each statement, based on the following scale:

*How has your level of **understanding** of the following aspects been influenced by working with manufacturing cells?*

1	2	3	4	5	6
Decreased	Decreased Slightly	**Unchanged**	Improved Slightly	Improved	Greatly Improved

1)_____ How the different components are fully manufactured.

2)_____ The advantages and disadvantages behind team-working.

3)_____ Where the components go when you have finished manufacturing them.

4)_____ What the components you manufacture are actually used for.

5)_____ Why the tolerances you work to are so important for the successful operation of the final product.

6)_____ The other parts that are assembled with your components to make a completed product.

7)_____ The difficulties with the assembly process.

8)_____ Daily *management* concerns and problems associated with the work you do.

9)_____ Who handles the raw castings before they arrive at the stores.

10)_____ The general problems supervisors encounter from day to day.

11)_____ What my role is within the company.

12)_____ What my responsibilities are in my job.

13)_____ The advantages and disadvantages of the continuous improvement programme.

14)_____ How my job relates to the jobs other people carry out in the company.

15)_____ What the company is trying to achieve through training.

16)_____ The purpose of training in my job.

17)_____ The idea behind the continuous improvement programme.

18)_____ The responsibilities of other people at all levels in the company.

19)_____ The sequence of operations needed to manufacture the different components.

20)_____ The role of the supervisors in the company.

21)_____ The route a component takes between operations throughout the manufacturing process.

22)_____ Where the raw castings that you work with come from.

SECTION TWO

Listed below are a number of statements which are related to your work with manufacturing cells. You are to indicate whether each statement is an ***accurate*** or an ***inaccurate*** description of your job.

Once again, please try to be as objective as you can in deciding how accurately each statement describes your job - regardless of whether you like or dislike your job.

Write a number in the blank beside each statement, based on the following scale:

*How **accurate** is the statement in describing your job?*

1	2	3	4	5
Inaccurate	Slightly Inaccurate	**Uncertain**	Slightly Accurate	Accurate

1)_____ The training I receive is relevant in my daily work.

2)_____ The supervisors don't bother me that often.

3)_____ The routing of the components from initial delivery to final assembly tends to be very complicated.

4)_____ Generally, at work, I feel like a member of a team.

5)_____ I don't really need to go on any of the training courses, they are a waste of time.

6)_____ Problems in the assembly department do not affect my work.

7)_____ Communication between management and the training department appears to be quite poor.

8)_____ There are just the right number of training courses.

9)_____ The cell meetings I go to are not very useful, and tend to just waste my time.

10)_____ I can carry out all the operations to completely manufacture all the components.

11)_____ The continuous improvement programme has stopped because I'm always very busy.

12)_____ Management try to generally reinforce and emphasise what I have learnt during the training courses.

13)_____ I am allowed a lot more responsibility since we started using cells.

14)_____ The training courses are a lot of effort.

15)_____ I cannot clearly identify my role within the company.

16)_____ The company's training courses have helped my understanding of (16 to 19):

17)_____ What is involved in sustaining the continuous improvement programme.

18)_____ The principles of Total Quality Management (TQM).

19)_____ The principles of cellular manufacturing.

20)_____ Why the company is adopting a Just In Time / Cellular Manufacturing approach.

21)_____ I know that the components I make are an important elements of the final product.

22)_____ The training courses come around far too often.

23)_____ The main force behind the continuous improvement programme comes from management.

24)_____ I am largely left alone to get on with my work.

25)_____ The cellular manufacturing approach has helped to clearly define my role in the company.

26)_____ The raw castings just arrive at my work area without me knowing where they come from.

27)_____ The standard of communication between the shop-floor and management is very good.

28)_____ I understand the problems encountered during the assembly process if the components I make are not within tolerance limits.

29)_____ Management are not really committed to a team-working environment.

30)_____ The skills I learn during the training courses don't seem to be useful to me in my daily work.

31)_____ I understand how the components work when they are fully assembled.

32)_____ The training courses are professionally carried out.

33)_____ Generally, all decisions relating to my work seem to be made for me by other people.

SECTION THREE

Now please indicate how *satisfied* you are with each aspect of your job listed below. Once again, write the appropriate number in the blank beside each statement.

Write a number in the blank beside each statement, based on the following scale:

*How **satisfied** are you with this aspect of your job?*

1	2	3	**4**	5	6	7
Extremely Dissatisfied	Dissatisfied	Slightly Dissatisfied	**Uncertain**	Slightly Satisfied	Satisfied	Extremely Satisfied

1)_____ The manner in which the training programmes are carried out by the company.

2)_____ The way the work flows between machines.

3)_____ The usefulness of the cell meetings.

4)_____ The visibility of the processes performed on the shop-floor.

5)_____ My understanding of the assembly processes involving my components.

6)_____ The importance management places on the continuous improvement programme.

7)_____ The frequency of the training programmes.

8)_____ My knowledge of how my components actually work when fully assembled.

9)_____ The amount of responsibility I have in my work.

10)_____ My knowledge about how the components I manufacture are used by the customer.

11)_____ The 'follow-up' from management regarding the content of the training courses.

12)_____ The way I am supervised in my work.

13)_____ The degree of openness, and communication about the state of the company, shown by management.

14)_____ The way management reinforces the issues raised during the training programmes.

15)_____ The amount of communication between me and the assembly shop.

16)_____ The content of the training courses.

17)_____ My understanding of how the company is trying to benefit, in the long term, from the training programme.

18)_____ The ability to make decisions and to use my own initiative.

19)_____ The amount of time spent on the continuous improvement programme.

20)_____ My understanding of the processes involved in fully manufacturing the components.

21)_____ The number of training courses I have been on.

22)_____ The overall relevance of what I learn during the training courses in your daily work.

23)_____ The way the machines are organised on the shop-floor.

24)_____ My knowledge, specifically, of the company's training policy.

25)_____ The relationship I have with the supervisors.

26)_____ The degree of team-working between the shopfloor and management.

27)_____ The way the training sessions are organised and presented.

28)_____ My own role within the company.

29)_____ The importance management places on team-working.

SECTION FOUR

Please think about how accurately each of the statements describes your feelings about your job, working with manufacturing cells.

Write a number in the blank beside each statement, based on the following scale:

*How much do you **agree** with the statements?*

1	2	**3**	4	5
Disagree	Slightly Disagree	**Uncertain**	Slightly Agree	Agree

1)_____ I am clearly aware of how valuable my work is to the company.

2)_____ I have found the training courses to be very relevant in my daily job.

3)_____ Teamworking is an integral part of my everyday working life.

4)_____ Cellular manufacturing has helped my understanding of all the processes involved with producing the various components.

5)_____ I often wonder why I bother to go to the training courses.

6)_____ On the whole, I only talk to the supervisors when I have a problem.

7)_____ Management seems to extend the things learnt during the training sessions into the work place.

8)_____ There just don't seem to be enough training courses.

9)_____ Manufacturing cells have helped me see what is going on in my work at all times.

10)_____ The reorganisation of the company has resulted in better communication between me and the assembly shop.

11)_____ It is not clear to me why the company is undertaking these training courses.

12)_____ The supervisors let me get on with my work.

13)_____ The continuous improvement programme is an integral part of the work that I do.

14)_____ I feel that management don't seem to be familiar with the contents of the training programme.

15)_____ The cellular manufacturing approach has improved the routing of the components between operations.

16)_____ The training I receive is vital for improving the competitiveness of the company.

17)_____ Management seem to value ideas from the shop-floor.

18)_____ Customer satisfaction is ultimately my responsibility.

19)_____ The training courses seem to be very unstructured.

20)_____ Management relations with the shopfloor are poor.

21)_____ The group technology approach has helped to integrate the assembly and machining shops.

22)_____ I have a great sense of responsibility over what I do.

23)_____ The way the training courses are organised puts me at ease.

24)_____ The continuous improvement programme is vital for the long term success of the company.

25)_____ I can identify a clear role for myself in the company.

26)_____ Teamworking is not really required in the work that I do.

27)_____ Manufacturing cells have simplified material handling.

28)_____ I have the chance to use my initiative and make more decisions.

29)_____ Cellular manufacturing and the continuous improvement programme have encouraged me to learn about what the components are actually used for.

SECTION FIVE

Indicate whether **you** need to know about, and how much you would **like** to know about the following in your job? Please complete *both* sides of all statements.

	Need to Know	Don't Need to Know	Unsure		Would Like to Know	Would not Like to Know	Already Know
1				The state of the market within which the company is competing			
2				Future company training plans			
3				The financial state of the company			
4				The state of arrears in the assembly shop			
5				Quality problems in the assembly shop			
6				Any problems with the suppliers			
7				Quality complaints from external customers			
8				What the components you make are used for			
9				The reasons behind the design of the components you make			
10				The purpose for the high tolerance specifications on the components			
11				The problems setters face from day to day			
12				Any problems with the assembly processes			
13				The formal roles of other people in the company			
14				The purpose of the training programme			
15				The role of management in carrying on the training programme in the workplace			
16				The methods the company will adopt to maintain the continuous improvement programme			
17				The responsibilities of other people on the shopfloor			

18 ☐☐☐ The decisions the supervisors need to make on a daily basis ☐☐☐

END OF QUESTIONNAIRE

E1.3 Questionnaire Three

The CIM Institute / Bendix HVS Cell Questionnaire #3

On the following pages you will find several different kinds of questions about your job. Specific instructions are given at the start of each section. Please read them carefully. It should take you no more than 15 minutes to complete the entire questionnaire. Please move through it quickly.

The questions are designed to obtain *your* perceptions of your job and *your* reactions to it.

There are no trick questions and no right or wrong answers. Your individual answers will be kept completely confidential. Please answer each item as honestly and as frankly as possible.

Thank you for your co-operation.

SECTION ONE

Listed below are a number of statements which are related to your work in a Cellular Manufacturing environment. Using the scale below, please indicate whether each statement is an **accurate** or an **inaccurate** description of your job.

Please try to be as objective as you can in deciding how accurately each statement describes your job - regardless of whether you like or dislike your job.

Please write the appropriate number in the blank beside each statement:

*How **accurate** is the statement in describing your job?*

1	2	**3**	4	5
Inaccurate	Slightly Inaccurate	**Uncertain**	Slightly Accurate	Accurate

1)_____ The type of work I do mostly involves manual work.

2)_____ I feel that I am aware of what is going on in the cell at all times.

3)_____ I know enough about the machinery and tools to intervene before a problem arises.

4)_____ I usually make most of the decisions about the work in the cell.

5)_____ I can vary the order of the tasks that I usually carry out if I want to.

6)_____ I am always aware of what is going on in the cell.

7)_____ I hardly ever need to use my hands much in my job.

8)_____ I can usually predict when there is going to be a mechanical breakdown.

9)_____ The tasks that I carry out do not vary from day to day.

10)_____ I usually make most of the decisions about the work in the cell.

11)_____ I have to keep track of more than one process at once.

12)_____ I understand the stages that the *equipment* goes through in order to manufacture a component.

13)_____ I need to think hard in my job.

14)_____ The machinery has no decision making capabilities - it's just the people that make the decisions.

15)_____ I usually find that cell decisions are difficult to fulfil.

16)_____ There's always a lot to think about when I'm working in the cells.

17)_____ I am competent to act upon any of the decisions made about the cell.

18)_____ I am able to override the automated tasks if I need to.

19)_____ I use a wide range of skills.

20)_____ I feel very isolated at work - I never get to talk to anybody.

21)_____ I typically use both my physical and mental skills.

22)_____ All the manual tasks that I carry out can't be automated.

23)_____ I work mostly in just one cell.

24)_____ I do many of the tasks now that colleagues from the shopfloor used to do.

25)_____ I find that I can maintain my skills whilst working in the cells.

26)_____ I've taken over some of the tasks that the supervisors used to carry out.

27)_____ I frequently work in other cells - not just the one I'm in at the moment.

28)_____ I typically get to discuss work with many people.

29)_____ I now do some tasks that management used to do.

SECTION TWO

Now please indicate how **satisfied** you are with each aspect of your job listed below. Please write the appropriate number in the blank beside each statement.

Please write the appropriate number in the blank beside each statement:

*How **satisfied** are you with this aspect of your job?*

1	2	3	**4**	5	6	7
Extremely Dissatisfied	Dissatisfied	Slightly Dissatisfied	**Uncertain**	Slightly Satisfied	Satisfied	Extremely Satisfied

1)_____ The amount of physical activity I do during work.

2)_____ My ability to predict errors in the system before they happen.

3)_____ My ability to move freely about the cell during work.

4)_____ The amount of mental activity I need to do during work.

5)_____ The amount of decision making I am expected to do.

6)_____ My ability to be able to intervene and put things right before a break down happens.

7)_____ The opportunity for me to change the order of tasks.

8)_____ The ability of the machines to provide assistance for making decisions.

9)_____ My ability to override the automated processes.

10)_____ My overall level of awareness of what is going on in my cell at any given time.

11)_____ My ability and skill to act upon decisions made about the cell.

12)_____ The way that machines can help me by taking over some of the more manual tasks.

13)_____ My level of understanding of *how* the machines carry out their machining operations.

14)_____ The way the machines seem to control my activities in the cell.

15)_____ The variety of different cells I'm asked to work in.

16)_____ The number of people I come into contact with during the working day.

17)_____ The ability at work to maintain my skill levels.

18)_____ The amount of work I do now that colleagues on the shopfloor used to do.

19)_____ The opportunity to use a wide range of skills.

20)_____ The level of interaction with other people.

21)_____ The amount of work I do now that management used to do.

SECTION THREE

Please indicate how you personally feel about your job.

Each statement is something that a person might say about his or her job. You are to indicate your own personal feelings about your job by marking how much you agree or disagree with each of the statements.

Please write the appropriate number in the blank beside each statement:

*How much do you **agree** with these statements?*

1	2	**3**	4	5
Disagree Strongly	Disagree Slightly	**Uncertain**	Agree Slightly	Agree Strongly

1)_____ The work in the cell is mostly physical and I don't need to think much.

2)_____ It is only ever clear whether a machine operation on a component has been successful or not when the operation is over.

3)_____ I know enough about the machinery and tools to intervene before one of them breaks down.

4)_____ The work I do requires me to use my brain a lot.

5)_____ The machines in the cell demand my undivided attention at all times.

6)_____ The order I carry out my tasks never varies.

7)_____ I can describe, in detail, what the machines are doing at any time.

8)_____ I act upon all the cell related decisions.

9)_____ The tasks I perform need to be carried out in a fixed order.

10)_____ At any time during my work, I could describe, in detail, what the machines are doing.

11)_____ In my cell, the supervisors are the main decision makers.

12)_____ The machines provide no help in the decisions that need to be made.

13)_____ Procedures have been defined for all tasks.

14)_____ When I work in the cells, I find that I'm losing my skills.

15)_____ The manual tasks that I perform can be automated if required.

16)_____ In the cell, the machines make many of the process decisions.

17)_____ In the cells, I can maintain the standard of my skills.

18)_____ The automated tasks cannot be carried out manually.

19)_____ Other people tend to make most of the decisions about the cell.

20)_____ All operations have been clearly defined by the company.

21)_____ Some of the automated tasks can be carried out manually.

22)_____ I work in different cells from time to time.

23)_____ I do a lot more different types of task than before, now I work in cells.

24)_____ In the cells, I find that I hardly use any of my skills.

25)_____ I don't carry out any of the tasks that management traditionally perform.

26)_____ Any manual task can be automated.

27)_____ I come into contact with many people during a working day.

28)_____ In the cells I need to do a lot more different things directly linked with production.

END OF QUESTIONNAIRE

E1.4 Scoring Mechanisms for Questionnaires

The numbers in the tables denote question numbers. Numbers in bold denote questions where the scores were reversed. For example when dealing with a five point scale, the score is subtracted from six.

E1.4.1 Questionnaire One

	S1	S2	S3	S4	S5	S6	S7
JOB CHARACTERISTICS							
Skill Variety	4	1,**5**					
Task Identity	3	11,**3**					
Task Significance	5	8,**14**					

	S1	S2	S3	S4	S5	S6	S7
Autonomy	2	13,**9**					
Feedback from the Job Itself	7	**4,12**					
Feedback from Agents	6	10,7					
Dealing with Others	1	2,**6**					
EXPERIENCED PSYCHOLOGICAL STATES							
Experienced Meaningfulness of Work			7,**4**		6,**3**		
Experienced Responsibility for Work			8,12,15, **1**		4,7		
Knowledge of Results			5,**11**		5,**10**		
AFFECTIVE OUTCOMES							
General Satisfaction			3,13,**9**		2,**8**		
Internal Work Motivation			2,6,10,**1**		1,9		
Growth Satisfaction				3,6,10,13			
CONTEXT SATISFACTIONS							
Satisfaction with Job Security				1,11			
Satisfaction with Pay				2,9			
Satisfaction with Co-Workers				4,7,12			
Satisfaction with Supervision				5,8,14			
INDIVIDUAL GROWTH NEED STRENGTH							
'Would Like' Format						2,3,6,8,10 ,11	
'Job Choice' Format							1,5,7,10,11,12,**2**,**3**,**4** **,6,8,9**

E1.4.2 Questionnaire Two

CELL LAYOUT	Section One	Section Two	Section Three	Section Four
Component Awareness	1,4,5	30,20	10,8	29
Visibility	3,9,22	10,**25**	20,4	4,9
Routing	19,21	**3**	23,2	27,15
Role Identification	11,14	24,**15**	28	1,25,22
Assembly Awareness	6,7	**6**,27	5,15	10,21

TRAINING	Section One	Section Two	Section Three	Section Four
Relevance	16	1,**29**	22,16	2,16
Style		**14**,31	1,27	23,**19**
Frequency		**21**,8	7,21	8
Policy	15	**5**,16,17,18,19	24,17	**11**,5

Follow-up		7,12	11.14	**14**.7

CELL MANAGEMENT	Section One	Section Two	Section Three	Section Four
Teamworking	2	4,**28**	26,29	3,**26**
Communication		26,29	3,13	**20**,17
Supervision	8,10,20	2,23	12,25	6,12
Responsibility	12,18	13,**32**	9,18	28,18
Continuous Improvement	13,17	**11**,22	6,19	24,13

E1.4.3 Questionnaire Three

E1.4.3.1 Man-Machine Level of Analysis

	Section One	Section Two	Section Three
NATURE OF OPERATOR LOADING			
Physical	1,7	1	1
Cognitive	13,16	4	4
TRANSPARENCY			
General Awareness	2,6	10	10
Transparency of Machine Processes	12	6,13	**2**,7
Failure Prevention	3,8	2	3
TECHNICAL COUPLING			
Constraint Upon Movement	4,11	3	5
Pre-Defined Task Methods	9	14	13,20
Workflow Rigidity	**5**	7	6,9
DECISION AUTHORITY AND COMPETENCE			
Decisions Made by Cell Members	10	5	**11,19**
Ability of Machines for Decision Making	**14**	8	**12**,16
Competence to Act Upon Decisions	**15**,17	11	8
ADAPTIVE ALLOCATION OF FUNCTIONS			
Opportunity for Manual Override	18	9	**18**,21
Opportunity for Automation of Manual Tasks	**22**	12	15,26

E1.4.3.2 Job Design Level of Analysis

	Section One	Section Two	Section Three
SKILLS USE AND RETENTION			
Skills Use	19,21	19	**24**
Skills Retention	25	17	**14**,17
INTERACTION REQUIREMENTS			
Level of Interaction	**20**,28	16,20	27
TASK FLEXIBILITY			
Job Enlargement	24	18	23,28
Job Enrichment	26,27	21	**25**
Job Rotation	**23**,27	15	22

E1.5 Questionnaire Results

E1.5.1 Questionnaire One

	Cell A								Cell B							Cell C								Cell D					
	CM1		CM2		CM3		AVG		CM1		CM2		AVG			CM1		CM2		CM3		CM4		AVG	CM1		CM2		AVG	
Job Characteristics																														
Skill Variety	2.0	2.0	4.7	4.7	3.0	5.0	3.6		5.3	5.0	4.7	5.0	5.0			1.7	2.0	2.3	3.0	4.3	4.3	2.7	3.0	2.9	6.3	6.0	4.0	4.5	5.2	
Task Identity	2.0	2.3	4.7	5.0	3.0	5.0	3.7		5.0	5.0	5.3	5.0	5.1			5.7	5.3	5.7	5.0	5.0	5.2	2.0	2.5	4.6	6.0	6.0	4.0	4.0	5.0	
Task Significance	4.3	4.0	6.3	6.0	5.3	4.5	5.1		6.7	5.7	5.7	5.3	5.9			4.7	5.0	6.3	5.7	6.3	6.0	4.7	4.0	5.3	6.7	5.5	6.3	6.0	6.1	
Autonomy	1.3	3.5	4.3	4.7	5.7	5.7	4.2		6.0	5.3	6.0	4.7	5.5			1.7	2.0	5.3	5.0	5.3	5.0	3.3	4.0	4.0	4.3	4.0	4.0	4.5	4.2	
Feedback from the Job Itself	2.7	3.0	4.7	4.7	2.3	3.0	3.4		4.3	4.7	4.7	4.3	4.5			2.0	2.0	6.0	6.0	5.7	5.7	3.7	4.5	4.5	4.7	4.3	4.7	4.7	4.6	
Feedback from Agents	1.0	1.5	4.3	3.5	4.0	4.5	3.1		2.0	2.3	4.0	4.3	3.2			2.3	2.7	6.0	5.7	6.3	6.0	4.7	3.0	4.6	4.3	5.0	2.7	3.0	3.8	
Dealing with Others	3.0	3.0	3.7	4.0	5.3	5.0	4.0		4.0	4.0	4.3	4.7	4.3			3.7	3.7	3.3	3.0	5.0	5.3	4.0	5.0	4.1	4.0	5.0	5.0	4.0	4.5	
Experienced Psychological States																														
Experienced Meaningfulness of Work	2.3	2.3	3.0	3.5	4.3	3.5	3.2		4.3	4.5	4.0	4.3	4.3			2.8	3.0	6.3	6.3	4.5	4.0	3.0	3.7	4.2	4.5	4.7	5.5	6.0	5.2	
Experienced Responsibility for Work	3.8	4.0	4.5	4.5	5.8	4.7	4.6		4.8	4.4	4.5	4.5	4.6			5.0	5.3	6.3	6.0	5.3	5.0	5.0	4.7	5.3	5.2	5.0	6.0	6.0	5.6	
Knowledge of Results	3.5	3.3	5.3	5.8	5.0	5.0	4.7		3.3	4.0	4.0	5.0	4.1			3.8	3.5	5.8	5.0	5.5	5.0	5.0	5.0	4.8	3.5	4.0	5.8	5.2	4.6	
Affective Outcomes																														
General Satisfaction	2.4	3.0	2.4	3.0	5.6	5.6	3.7		4.2	4.2	4.2	5.0	4.4			2.6	2.6	5.8	5.5	6.2	5.7	4.2	5.0	4.7	5.4	5.0	5.0	5.4	5.2	
Internal Work Motivation	2.8	2.4	3.7	3.7	5.3	5.0	3.8		4.8	5.7	5.0	5.0	5.1			3.3	3.7	6.0	6.0	5.7	6.0	2.7	4.0	4.7	6.2	5.7	4.3	5.7	5.5	
Growth Satisfaction	1.5	3.5	2.8	3.8	4.3	5.0	3.5		5.0	5.0	5.0	5.0	5.0			2.5	2.5	4.3	4.7	5.0	6.0	3.0	5.0	4.1	4.8	5.0	3.8	4.0	4.4	
Context Satisfactions																														
Satisfaction with Job Security	2.5	2.5	3.0	3.0	3.5	3.5	3.0		4.0	4.0	3.0	3.5	3.6			3.0	3.0	4.0	4.5	4.0	4.5	3.5	4.0	3.8	2.5	3.0	2.0	2.3	2.5	
Satisfaction with Pay	3.5	3.0	1.0	1.0	3.0	3.0	2.4		4.0	3.5	3.4	3.4	3.6			1.0	1.5	3.0	2.7	3.5	2.7	5.0	3.5	2.9	2.0	3.0	2.0	2.0	2.3	
Satisfaction with Co-Workers	4.3	5.0	4.0	4.5	5.3	6.0	4.9		3.0	3.0	6.0	5.7	4.4			1.7	1.5	5.0	6.0	5.7	5.5	3.7	4.0	4.1	4.3	5.0	7.0	7.0	5.8	
Satisfaction with Supervision	1.3	1.8	4.3	4.5	3.7	6.0	3.6		3.3	3.3	5.7	6.0	4.6			3.3	4.0	6.0	6.0	5.7	5.5	3.0	4.0	4.7	5.7	4.7	5.0	5.7	5.3	
Individual Growth Need Strength																														
Would Like' Format	7.0	7.0	4.0	4.0	5.5	7.0	5.8		5.3	6.0	5.7	7.0	6.0			2.2	2.7	7.0	7.0	5.0	5.0	4.2	5.0	4.8	3.3	4.0	7.0	7.0	5.3	
Job Choice' Format	4.6	4.6	3.3	3.3	4.4	5.0	4.2		2.3	3.0	3.0	5.1	3.4			4.0	4.0	5.1	5.7	4.4	6.0	3.5	3.5	4.5	4.6	5.0	4.6	4.3	4.6	
Combined Growth Need Strength	5.8	5.8	3.6	3.6	5.0	6.0	5.0		4.3	4.5	4.4	6.0	4.8			3.1	3.3	6.0	6.3	4.7	5.5	3.9	4.2	4.6	4.0	4.5	5.8	5.6	5.0	
Motivating Potential Score	10	29	106	116	49	83	65		146	130	148	103	132			14	16	152	137	157	147	38	57	90	128	100	90	102	105	
Motivating Potential Score (additive)	13	16	29	29	23	28	23		29	28	30	29	29			18	19	32	30	33	32	21	21	26	32	31	26	27	29	

E1.5.2 Questionnaire Two

	Cell A				Cell B			Cell C					Cell D		
	CM1	CM2	CM3	AVG	CM1	CM2	AVG	CM1	CM2	CM3	CM4	AVG	CM1	CM2	AVG
Cell Layout															
Component Awareness	4.3	5.0	4.7	4.7	4.7	5.0	4.9	4.3	4.0	4.5	4.5	4.3	4.5	4.5	4.5
Visibility	4.0	4.3	4.5	4.3	4.5	4.5	4.5	4.0	4.5	3.0	3.0	3.6	4.2	4.0	4.1
Routing	5.0	4.5	4.7	4.7	5.0	4.3	4.7	4.0	3.5	4.0	4.3	4.0	5.0	4.5	4.8
Role Identification	4.2	4.0	4.3	4.2	4.0	4.0	4.0	3.5	4.0	4.5	4.0	4.0	4.5	4.0	4.3
Assembly Awareness	0.0	0.0	0.0	0.0	4.7	4.5	4.6	2.5	3.0	3.0	2.0	2.6	4.0	3.0	3.5
Overall Understanding	4.8	4.5	4.5	4.6	4.7	4.5	4.6	3.5	3.0	3.3	3.8	3.4	4.5	4.2	4.4
Overall Satisfaction	4.4	4.7	4.4	4.5	4.0	4.0	4.0	4.0	4.5	4.0	3.8	4.1	4.0	4.3	4.2
Training															
Relevance	3.0	3.5	3.8	3.4	2.0	3.5	2.8	3.0	2.5	2.0	2.0	2.4	3.0	2.5	2.8
Style	4.0	4.5	4.5	4.3	4.0	4.0	4.0	4.0	4.2	2.5	4.0	3.7	4.0	4.5	4.3
Frequency	3.0	3.0	3.0	3.0	2.0	3.0	2.5	2.0	3.0	2.0	2.5	2.4	4.0	2.8	3.4
Policy	4.0	3.5	3.8	3.8	4.0	3.0	3.5	2.0	3.5	2.5	2.0	2.5	3.0	3.0	3.0
Follow-up	3.5	2.0	2.0	2.5	2.0	1.5	1.8	2.5	2.8	3.0	1.8	2.5	3.0	2.5	2.8
Overall Understanding	4.5	4.0	4.0	4.2	4.5	4.0	4.3	3.0	3.2	3.3	3.3	3.2	4.0	4.0	4.0
Overall Satisfaction	4.0	4.1	4.1	4.1	3.0	3.2	3.1	3.0	2.5	3.0	2.0	2.6	4.0	3.5	3.8
Cell Management															
Teamworking	4.0	3.0	3.5	3.5	3.0	3.2	3.1	3.5	3.0	3.0	3.0	3.1	2.5	3.0	2.8
Communication	4.5	4.8	4.2	4.5	4.0	4.2	4.1	3.0	3.5	4.5	3.0	3.5	3.0	3.5	3.3
Supervision	4.5	4.0	4.8	4.4	4.5	4.2	4.4	4.0	4.2	4.0	4.0	4.1	4.0	4.5	4.3
Responsibility	3.0	3.5	4.5	3.7	4.0	3.8	3.9	4.0	3.0	3.5	4.0	3.6	4.0	4.0	4.0
Continuous Improvement	3.0	3.2	4.0	3.4	3.2	3.0	3.1	3.0	3.0	2.5	2.8	2.8	2.5	4.2	3.4
Overall Understanding	4.1	4.0	3.9	4.0	4.5	4.0	4.3	2.5	3.0	3.8	3.0	3.1	3.8	4.0	3.9
Overall Satisfaction	4.0	4.1	4.5	4.2	3.8	4.0	3.9	3.0	3.0	4.2	3.0	3.3	3.0	3.5	3.3

E1.5.3 Questionnaire Three

	Cell A							Cell B					Cell C									Cell D				
	CM1		CM2		CM3		AVG	CM1		CM2		AVG	CM1		CM2		CM3		CM4		AVG	CM1		CM2		AVG
Man-Machine Level of Resolution																										
Nature of Operator Loading																										
Physical	4.0	4.0	4.3	4.7	4.0	4.0	**4.2**	4.0	4.3	4.0	4.0	**4.1**	5.3	5.3	5.7	5.3	5.7	5.3	4.7	5.0	**5.3**	5.0	5.0	4.7	5.0	**4.9**
Cognitive	3.7	4.0	3.0	3.7	3.3	3.0	**3.5**	4.0	4.0	4.3	4.0	**4.1**	3.0	2.7	1.3	2.0	2.0	2.0	1.3	2.0	**2.0**	3.0	2.3	3.3	3.0	**2.9**
Satisfaction	2.3	2.7	3.0	3.3	2.7	3.0	**2.8**	3.7	4.3	3.7	4.0	**3.9**	5.0	4.0	5.0	4.0	4.0	5.0	4.0	5.0	**4.5**	4.0	4.3	4.0	4.3	**4.2**
Transparency																										
General Awareness	4.0	4.0	4.0	4.3	4.0	4.7	**4.2**	5.3	5.0	5.7	5.3	**5.3**	3.0	2.0	2.0	2.0	3.0	3.0	4.0	4.0	**2.9**	5.0	5.3	4.0	5.0	**4.8**
Transparency of Machine Processes	3.0	2.7	4.3	4.3	3.3	3.0	**3.4**	4.3	5.0	5.0	5.0	**4.8**	3.0	2.0	2.0	2.0	3.0	3.3	3.0	3.0	**2.7**	3.0	2.7	3.0	3.0	**2.9**
Failure Prevention	4.0	3.3	4.3	4.0	3.3	3.0	**3.7**	4.7	5.3	4.0	4.7	**4.7**	2.0	2.0	2.0	2.3	3.7	3.0	3.0	2.0	**2.5**	3.0	2.7	3.0	3.0	**2.9**
Satisfaction	4.8	4.5	4.0	4.0	3.0	3.0	**3.9**	4.7	5.0	4.0	4.0	**4.4**	3.3	4.0	3.3	4.0	4.0	3.0	3.3	3.0	**3.5**	3.0	3.0	3.0	3.0	**3.0**
Technical Coupling																										
Constraint Upon Movement In Cell	4.3	4.3	4.0	3.0	4.0	3.0	**3.8**	5.0	5.0	5.0	5.0	**5.0**	3.0	4.0	4.0	5.0	4.0	5.0	4.0	5.0	**4.3**	4.7	5.3	4.0	5.0	**4.8**
Pre-Defined Task Methods	5.3	5.0	5.7	5.3	5.3	5.7	**5.4**	5.0	5.3	5.0	4.7	**5.0**	5.0	5.0	4.0	5.0	4.0	5.3	5.0	5.0	**4.8**	4.7	5.0	5.0	5.0	**4.9**
Workflow Rigidity	5.3	6.0	5.7	5.7	5.0	6.0	**5.6**	5.3	5.7	5.0	5.7	**5.4**	5.7	5.7	5.3	5.0	5.7	5.0	4.7	5.0	**5.3**	5.0	5.0	5.0	5.0	**5.0**
Satisfaction	4.0	4.0	4.0	4.0	3.3	4.0	**3.9**	4.0	4.0	4.0	4.3	**4.1**	3.3	3.0	2.3	4.0	4.0	5.0	4.0	4.3	**3.7**	4.0	4.3	4.3	4.0	**4.2**
Decision Authority and Competence																										
Decisions Made by Cell Members	4.3	5.0	4.3	5.0	4.7	4.3	**4.6**	5.0	5.0	5.0	4.3	**4.8**	2.0	2.0	2.0	2.0	2.0	3.0	3.0	3.0	**2.4**	4.3	3.7	4.3	4.0	**4.1**
Decision Making Ability of Machines	1.0	1.0	1.0	1.0	1.0	1.0	**1.0**	1.3	1.0	1.0	1.0	**1.1**	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	**1.0**	1.0	1.0	1.0	1.0	**1.0**
Competence to Act Upon Decisions	5.0	5.0	4.3	5.0	5.0	5.7	**5.0**	5.7	5.3	5.0	5.7	**5.4**	4.0	3.0	3.0	3.0	4.0	4.3	4.0	4.0	**3.7**	4.3	5.0	4.0	4.7	**4.5**
Satisfaction	4.0	5.0	5.0	4.3	3.7	4.0	**4.3**	5.0	5.0	5.0	5.0	**5.0**	5.0	4.3	4.3	4.0	4.7	4.0	4.0	4.3	**4.3**	4.0	4.3	4.7	5.0	**4.5**
Adaptive Allocation of Functions																										
Opportunity for Manual Override	1.3	1.3	1.0	1.0	1.0	1.0	**1.1**	1.0	1.0	1.0	1.0	**1.0**	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	**1.0**	1.0	1.0	1.0	1.0	**1.0**
Automation of Manual Tasks	1.0	1.0	1.0	1.0	1.0	1.0	**1.0**	1.0	1.0	1.0	1.0	**1.0**	1.0	1.0	1.3	1.0	1.0	1.0	1.0	1.0	**1.0**	1.0	1.0	1.0	1.0	**1.0**
Satisfaction	4.0	3.0	3.0	2.0	3.0	3.0	**3.0**	2.7	3.0	2.0	3.0	**2.7**	3.0	4.0	3.0	3.3	3.3	3.0	3.0	3.3	**3.2**	3.7	3.0	3.0	3.0	**3.2**
Job Design Level of Resolution																										
Skills Use and Retention																										
Skills Use	3.7	3.0	2.0	2.3	2.3	1.0	**2.4**	2.0	3.0	2.0	5.0	**3.0**	3.0	4.0	2.7	2.0	3.0	4.0	3.0	3.0	**3.1**	3.0	2.0	4.0	3.0	**3.0**
Skills Retention	1.3	1.0	2.0	2.3	2.0	1.0	**1.6**	2.0	2.3	2.3	3.0	**2.4**	2.7	3.0	2.7	2.0	3.0	3.0	3.0	3.0	**2.8**	3.3	2.0	3.0	3.0	**2.8**
Satisfaction	1.5	2.0	1.5	2.0	2.0	1.5	**1.8**	2.0	2.0	2.0	3.0	**2.3**	3.0	3.5	4.0	4.0	3.0	4.0	3.0	3.0	**3.4**	4.0	3.0	4.5	4.0	**3.9**
Interaction Requirements																										
Level of Interaction	5.0	5.3	5.0	5.3	4.3	5.0	**5.0**	4.7	5.0	4.0	5.0	**4.7**	4.0	4.7	4.7	5.0	5.0	5.0	4.7	5.3	**4.8**	5.0	5.3	4.3	5.0	**4.9**
Satisfaction	4.0	5.0	5.0	5.5	4.0	5.0	**4.8**	5.0	4.5	4.0	4.5	**4.5**	4.0	4.0	4.5	4.5	5.0	5.0	4.0	5.0	**4.5**	4.5	5.0	4.5	4.5	**4.6**
Task Flexibility																										
Job Enlargement	4.3	4.7	4.0	4.7	5.0	5.3	**4.7**	5.0	5.3	5.0	5.3	**5.2**	4.0	4.0	3.0	4.0	3.3	4.0	4.7	4.0	**3.9**	5.0	5.0	4.7	5.0	**4.9**
Job Enrichment	4.0	4.0	3.3	4.0	2.3	3.7	**3.6**	4.0	5.0	5.0	4.0	**4.5**	2.3	3.0	1.0	2.0	2.0	2.0	3.3	2.0	**2.2**	4.3	3.0	4.0	4.0	**3.8**
Job Rotation	5.3	5.0	5.7	5.3	5.3	5.0	**5.3**	5.0	6.0	4.7	5.3	**5.3**	4.0	4.0	3.3	4.0	4.3	5.0	4.7	5.0	**4.3**	4.3	4.0	4.7	4.7	**4.4**
Satisfaction	4.0	5.0	4.3	5.0	4.0	5.0	**4.6**	3.7	4.0	3.7	4.0	**3.9**	4.0	4.3	4.0	4.0	4.3	5.0	5.0	5.0	**4.5**	4.7	5.0	5.0	5.0	**4.9**

APPENDIX F

FUNCTION ALLOCATION LITERATURE REVIEW

This appendix summarises the literature on work in the field of allocation of functions.

F1.1 Allocation of Functions Literature Review

Table F-1 divides the work in the field of function allocations into human-robotic, process control, air traffic management, aerospace, inspection and surveillance, human-computer and man-machine application domains.

Figures F-1 to F-7 illustrate seven methods for allocating functions between people and machines. These methods are typical of the proposed allocation methods in the literature. The figures detail allocation decisions and criteria in the aerospace (Price, 1968, 1985), human-robotic (Ghosh and Helander, 1983), human-computer (Greenstein and Lam, 1985; Hou, Lin and Drury, 1993) and manufacturing (Clegg, 1994) systems. Chapanis (1965a) describes a general allocation method.

These function allocation criteria and processes are summarised by Table F-1.

	Allocation Criteria / Assessment									Allocation Process					
	Psychological Needs and Workload	Human Reliability and Capabilities	Machine Performance and Capabilities	Information and Knowledge Needs	Organisational and Cultural Issues	Economic and Market Factors	Health and Safety	Criticality and Importance	Responsibility	Comparative Frameworks	Job and Skills Analysis	Dynamic and Adaptive	Participatory Approach	Complementary Approach	Computer Methods
Human-Robot Systems															
Genaidy, A.M. et al., 1992		✣	✣			✣				✣	✣				
Ghosh, B.K. et aL, 1986		✣	✣			✣	✣	✣		✣	✣		✣		
Kamali, J. et al, 1982	✣	✣	✣				✣			✣	✣				
Nof, S.Y. et al, 1980		✣	✣				✣			✣	✣				
Singleton, W.T., 1979	✣	✣	✣								✣				
Process Control															
Pulliam, R. et al, 1983	✣	✣	✣							✣				✣	
Kisner, R.A. and Frey, P.R., 1982		✣	✣											✣	✣
Swain, A.D. et al, 1980		✣	✣				✣			✣				✣	✣
Pack, R.W., 1979		✣	✣	✣			✣	✣			✣				
Air Traffic Management															
Mertes, F. and Jenny, L., 1974	✣	✣	✣				✣	✣		✣		✣		✣	✣
Fitts, P.M., 1962	✣	✣		✣						✣					
Fitts, P.M. et al., 1951	✣	✣		✣				✣	✣	✣					
Aerospace General															
Mouloua, M. et al., 1993		✣					✣					✣			
Morrison, J., 1993	✣	✣	✣	✣			✣	✣		✣		✣		✣	
Norman, S.D. et al, 1989		✣	✣							✣					✣
Rouse, W.B. & Cody, W.J., 1986	✣	✣	✣					✣		✣		★			
Strieb, M.I. et al, 1979	✣	✣	✣												✣
Parks, D.D. et al., 1976	✣	✣	✣					✣		✣					✣
Price, H.E. et al, 1968	✣	✣		✣			✣			✣				✣	
Price, H.E. et al, 1964	✣	✣		✣			✣			✣					
Corkindale, K.G., 1967		✣				✣				✪				✣	
Connolly, M.N. et al., 1960		✣	✣							✣				✣	
Inspection and Surveillance															
Drury, C.G., 1994	✣	✣	✣	✣			✣	✣		✪		✣		★	
Bhatt, S.C. et al., 1991	✣	✣	✣	✣	✣	✣	✣	✣		✣				✣	
Drury, C.G. et al, 1983		✣	✣												
Wylie, C.D. et al, 1975	✣	✣	✣							✣		✣			

Table F-1 Summary Function Allocation Literature Review

	Allocation Criteria / Assessment									Allocation Process					
	Psychological Needs and Workload	Human Reliability and Capabilities	Machine Performance and Capabilities	Information and Knowledge Needs	Organisational and Cultural Issues	Economic and Market Factors	Health and Safety	Criticality and Importance	Responsibility	Comparative Frameworks	Job and Skills Analysis	Dynamic and Adaptive	Participatory Approach	Complementary Approach	Computer Methods
Human-Computer Systems															
Lee, J.D. et al, 1994		✢										✢			
Endsley, M.R., 1994	✢	✢		✢						✢		✢			
Rencken, W.D. et al, 1993		✢	✢									✢			✢
Morrison, J., 1993	✢	✢		✢								★			
Lee, J.D. et al, 1992		✢										✢			
Helander, M. (ed.), 1991		✢			✢										✢
Ip, K.W. et al., 1990		✢	✢	✢						✢			✢	✢	
Ip, W.K., 1990		✢	✢	✢									✢	✢	
Pawlowski, E., 1988	✢	✢		✢											
Millot, P. et al, 1988		✢	✢									✢		✢	
Greenstein, J.S. et al, 1986		✢	✢	✢					✢			★			
Greenstein, J.S. et al, 1985		✢	✢							✪		★	★		
Millot, P. et al, 1985		✢		✢								✢			✢
Barfield, W. et al, 1984	✢	✢	✢						✢	✢					
Rieger, C.A. et al, 1982		✢	✢						✢	✪		✢		✢	
Rouse, W. B., 1981		✢	✢					✢				✢			
Sheridan, T.B. et al, 1979	✢	✢	✢												
Chu, Y. et al, 1979		✢	✢						✢			✢			
Streeb, R. et al, 1979		✢	✢	✢								✢			
Sheridan, T.B., 1979		✢	✢	✢						✢					
Edwards, E., 1979		✢	✢	✢								✢			
Rouse, W.B., 1979		✢	✢	✢					✢			★			
Rouse, W.B., 1977		✢	✢						✢			✢			✢
Edwards, E. et al, 1974		✢	✢					✢		✢					
Licklider, J.C.R., 1960	✢	✢	✢							✢		✢		✢	

	Allocation Criteria / Assessment									Allocation Process					
	Psychological Needs and Workload	Human Reliability and Capabilities	Machine Performance and Capabilities	Information and Knowledge Needs	Organisational and Cultural Issues	Economic and Market Factors	Health and Safety	Criticality and Importance	Responsibility	Comparative Frameworks	Job and Skills Analysis	Dynamic and Adaptive	Participatory Approach	Complementary Approach	Computer Methods
Man-Machine Systems															
Grote, G. et al., in press	✣				✣							★	★	★	
Weik, S. et al., 1995	✣	✣	✣		✣					✪		★	★	★	
Grote, G., 1994	✣									✣		★	★	★	
Wei, Z.G. et al., 1994	✣	✣	✣	✣	✣	✣	✣	✣		✪		★	★	★	
Levis, A.H. etal., 1994	✣	✣	✣												✣
Weik, S., 1993	✣	✣	✣		✣							★	★	★	
Goom, D., 1993		✣					✣								
Shoval S. et al., 1993		✣	✣	✣								✣			✣
Levis, A.H. et al., 1992	✣	✣	✣												✣
Rouse, W.B. et al., 1991		✣	✣	✣						✪		★		★	✣
Helander, M., 1991		✣						✣							✣
Mital, A. et al, 1991		✣	✣							✣					
Denley, I., 1989			✣	✣								✣			✣
Clegg, C. & Symon, G., 1989		✣	✣		✣									★	
Clegg, C.W. et al, 1989	✣	✣		✣	✣	✣	✣	✣	✣	✪		★	★	★	
Sheridan, T.B., 1988	✣	✣	✣							✣		✣			✣
Madni, A.M., 1988		✣	✣			✣				✣					★
Brennan, L., 1988		✣			✣										
Corbett, J.M., 1985	✣	✣			✣					✣				★	
Shi-quan, S., 1985		✣							✣	✣		✣			✣
Rouse, W.B., 1985		✣	✣												
Hancock, P.A. et al, 1985	✣	✣								✣		✣			✣
Brennan, L., 1984		✣	✣							✣	✣			✣	
Price, H.E. et al, 1982															✣
Sheridan, T.B. et al (eds.), 1979	✣	✣	✣												
Wirstad, J., 1979	✣	✣		✣	✣	✣	✣			✣			★	✣	
Meister, D. et al, 1978		✣								✣	✣				✣
Crooks, W.H. et al, 1974															
Hormann, A.M., 1971		✣	✣									✣		✣	
Sheridan, T.B., 1970	✣	✣					✣			✣	✣				✣
Jordan, N., 1963	✣							✣	✣	✪				★	
Bamford, H.E. Jr., 1959		✣													
Whitfield, D., 1967		✣	✣			✣				✣				✣	

	Allocation Criteria / Assessment									Allocation Process					
	Psychological Needs and Workload	Human Reliability and Capabilities	Machine Performance and Capabilities	Information and Knowledge Needs	Organisational and Cultural Issues	Economic and Market Factors	Health and Safety	Criticality and Importance	Responsibility	Comparative Frameworks	Job and Skills Analysis	Dynamic and Adaptive	Participatory Approach	Complementary Approach	Computer Methods
General Discussion															
Older, M. et al., in press	✢	✢	✢	✢	✢	✢			✢	✪		★	★	★	
Mital, A. et al, 1994	✢	✢	✢	✢		✢	✢			✪		✢	✢	✢	✪
Papantonopoulos, S.A., 1992		✢	✢										✢	✢	
Beevis, D., 1990		✢	✢								✢				
Kantowitz, B.H. et al, 1987	✢		✢	✢						✪		★		✢	
Meister, D., 1982	✢	✢	✢												✢
Whitfield, D., 1967	✢	✢	✢							✢				✢	
Meister, D. et al., 1965		✢	✢							✢				✢	
Chapanis, A., 1965a	✢				✢	✢				✪					
Chapanis, A., 1965b		✢	✢												
Bamford, H.E., 1959		✢	✢												

Key	
Advocated	★
Discussed / Covered	✢
Criticised	✪

Chapanis 1965a

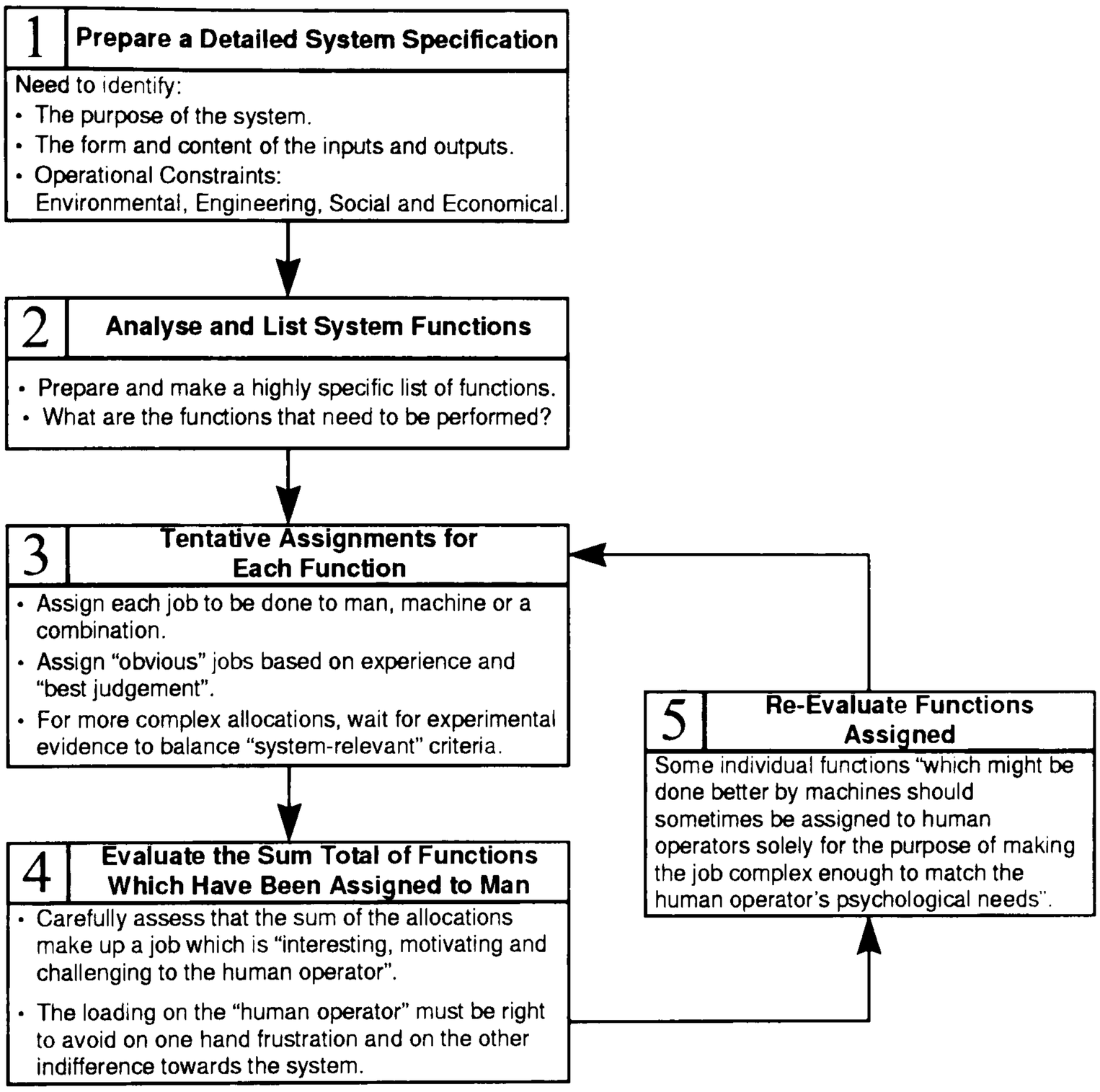


Figure F-1 General Function Allocation Method - Chapanis, 1965a

Price 1968 (NASA)

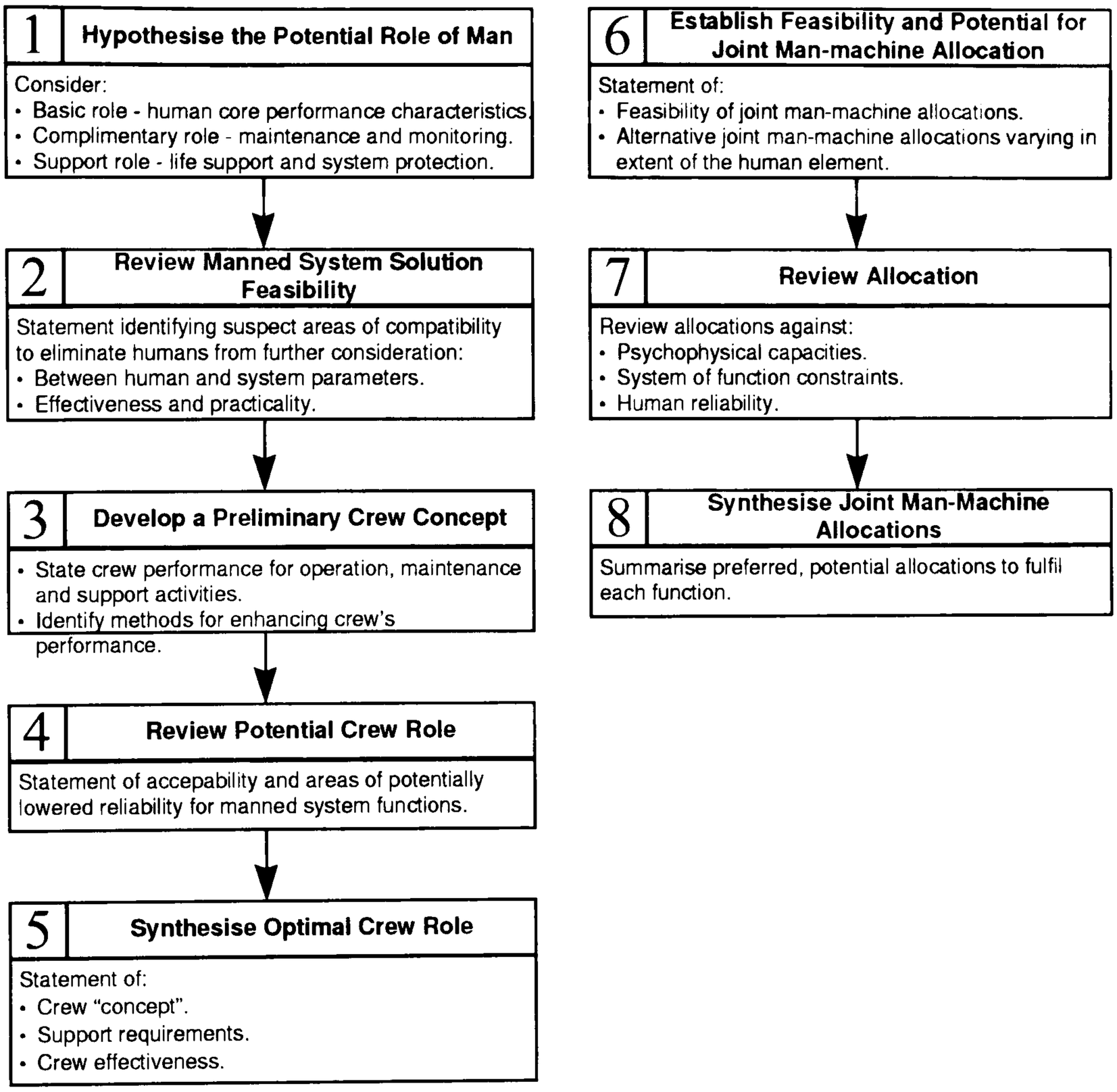


Figure F-2 Aerospace Function Allocation Method - Price, 1968

Ghosh and Helander 1983

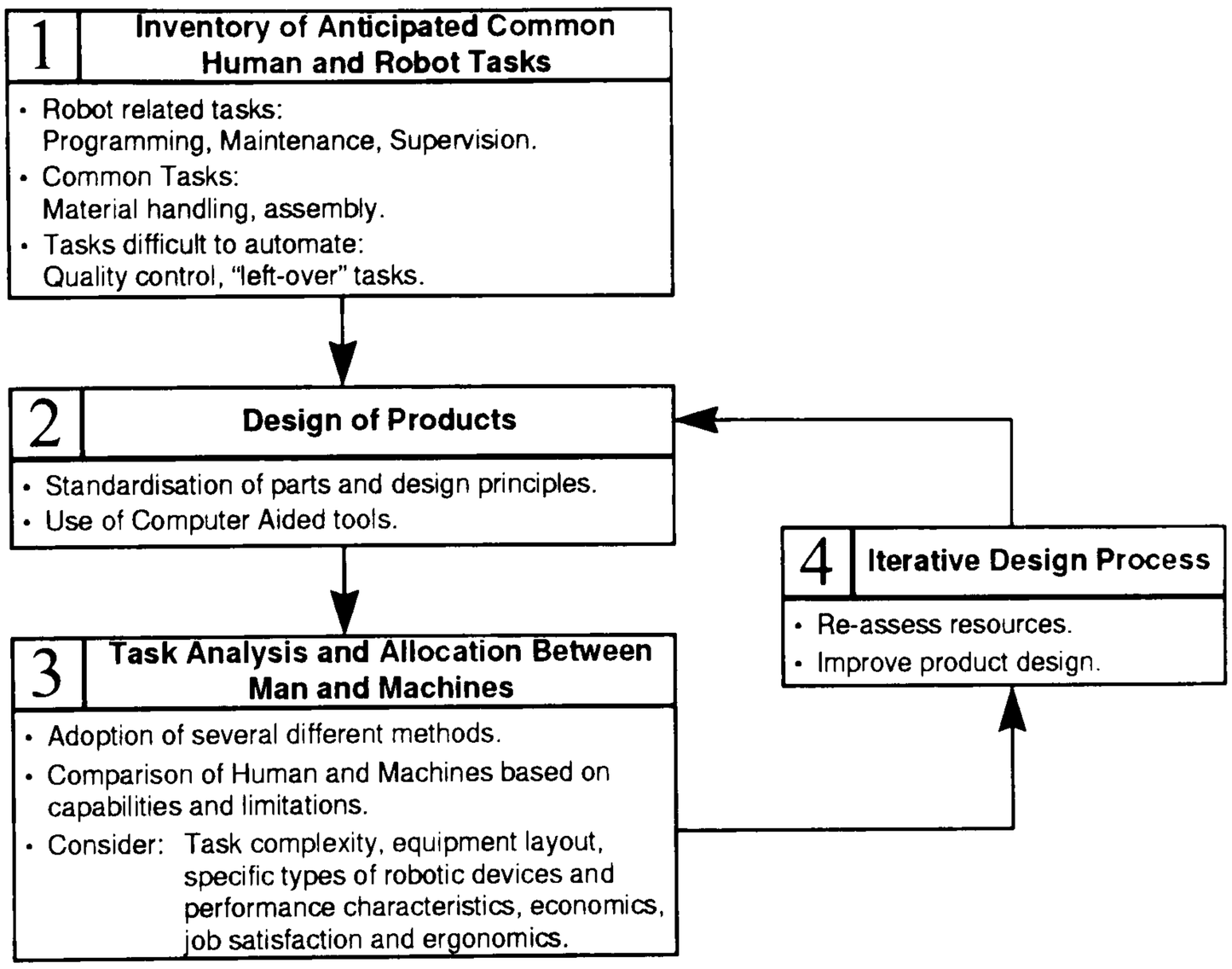


Figure F-3 Human-Robotic System Function Allocation Method - Ghosh and Helander, 1983

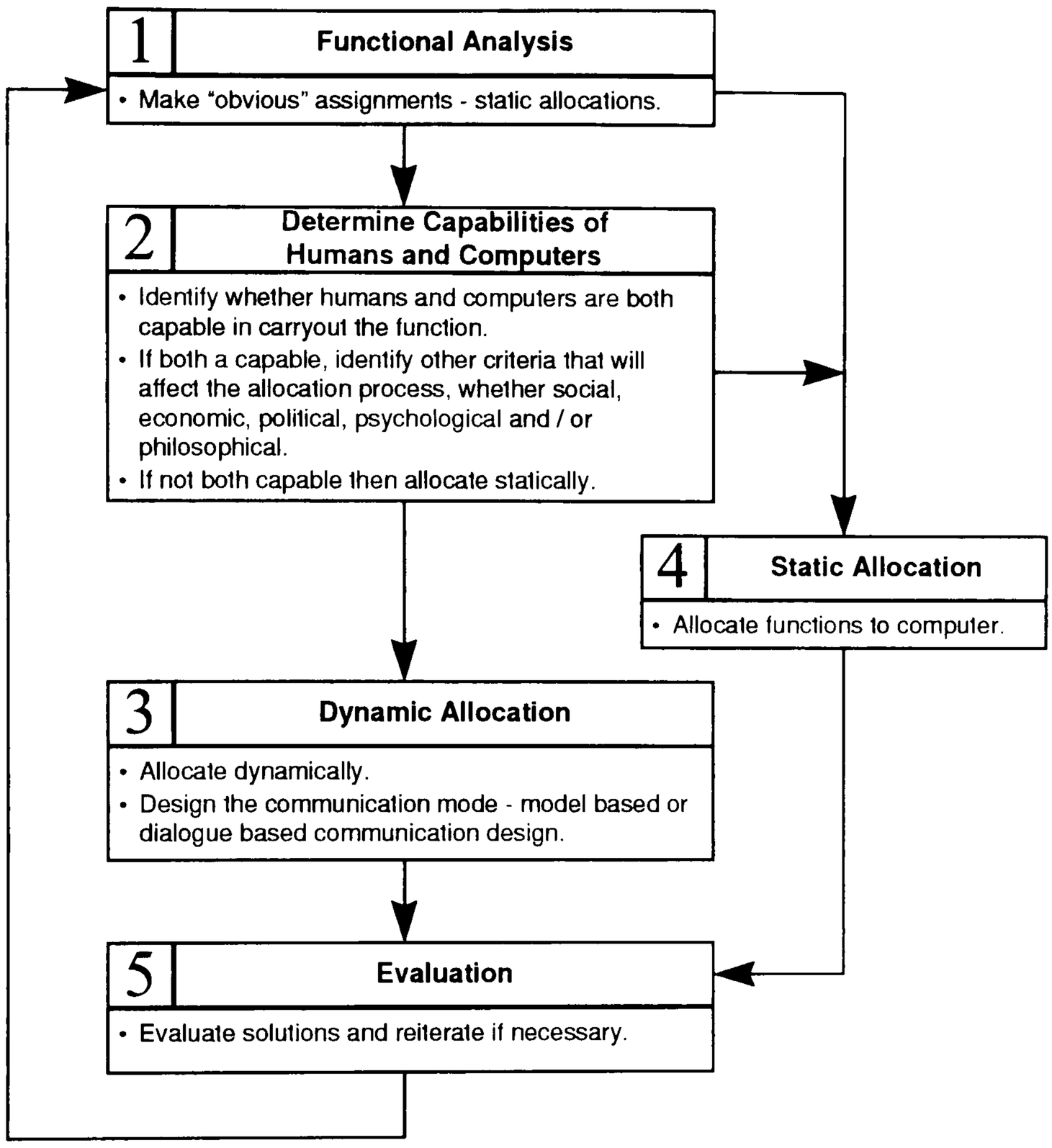


Figure F-4 Human-Computer System Function Allocation Method - Greenstein and Lam, 1985

Price 1985

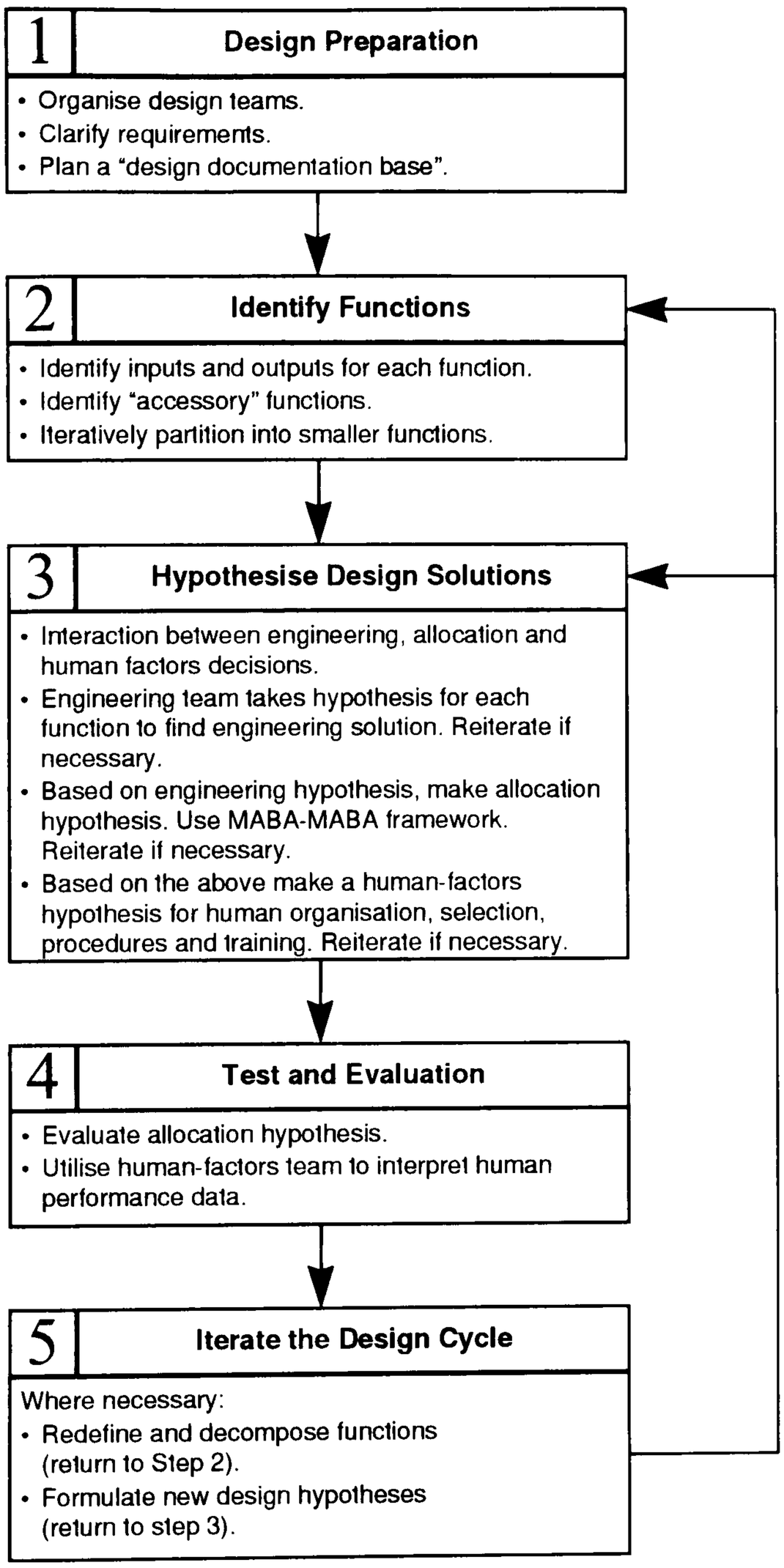


Figure F-5 Aerospace Function Allocation Method - Price. 1985

Hou, Lin and Drury 1993

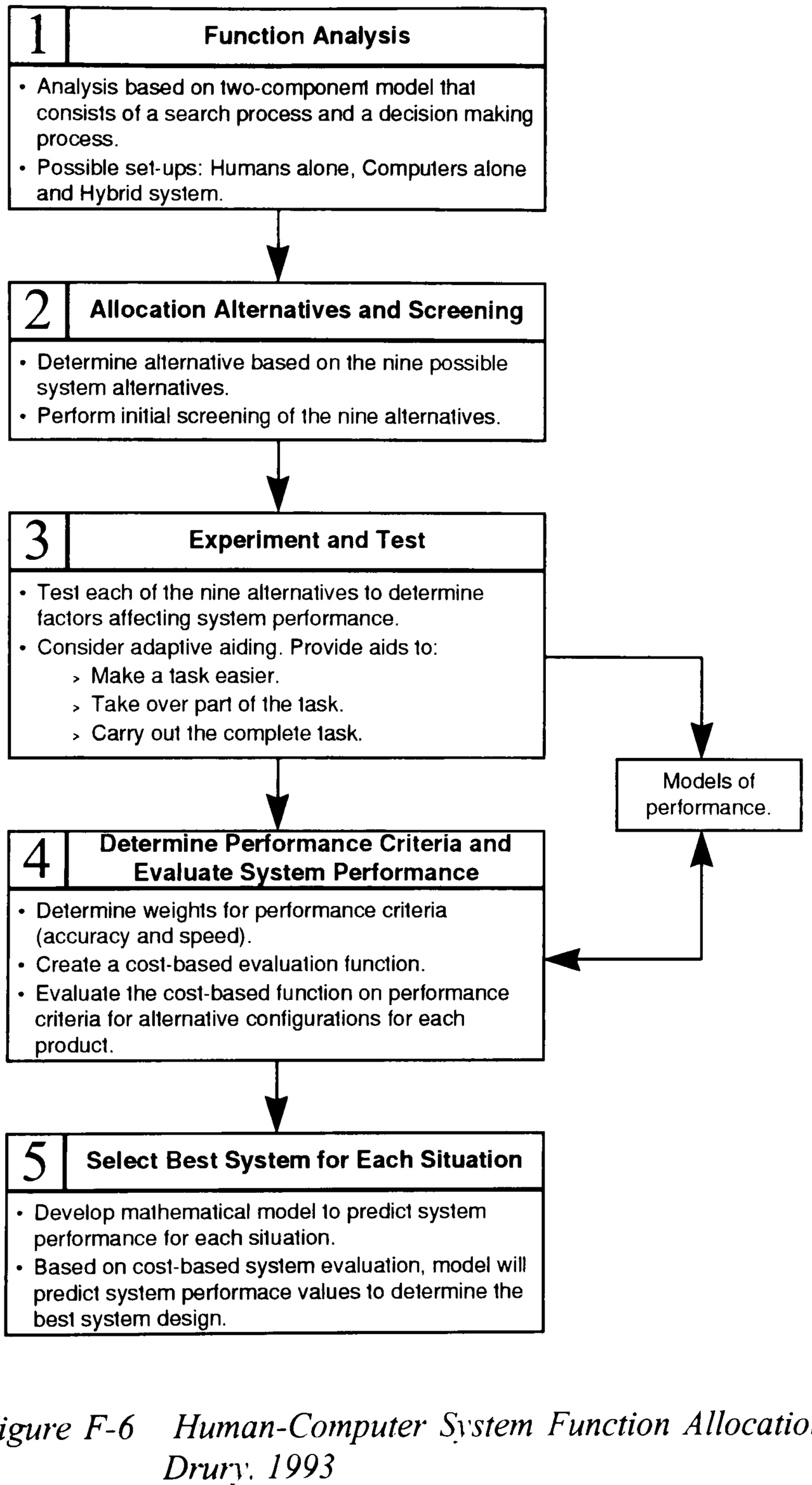


Figure F-6 Human-Computer System Function Allocation Method - Hou, Lin and Drury, 1993

Clegg 1994

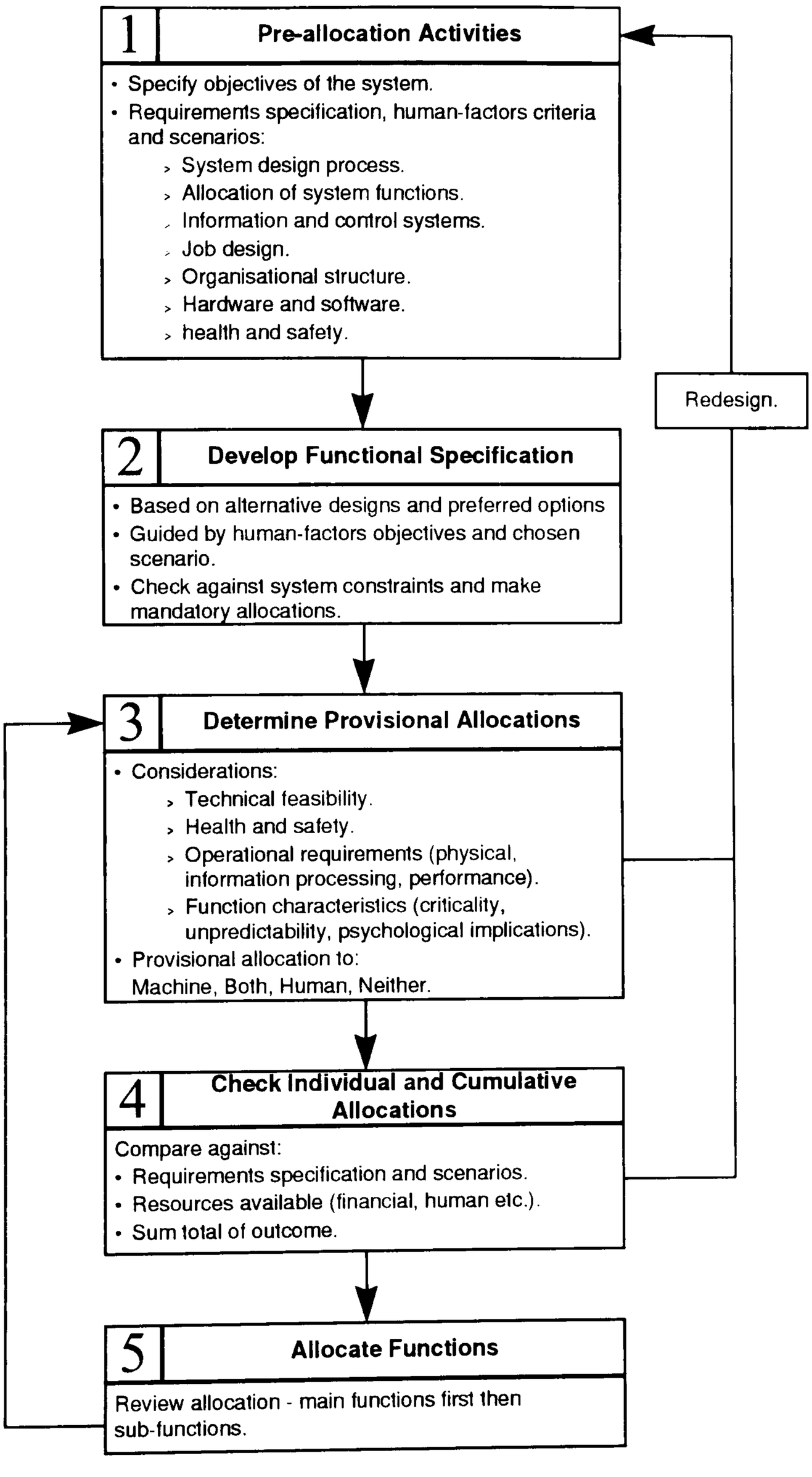


Figure F-7 Manufacturing Function Allocation Method - Clegg. 1994

APPENDIX G

FUNCTIONAL ANALYSES

This appendix contains the tabulated summaries of the high level functional analyses of the four Cells. The hierarchical task analysis (HTA) for Cell A is included.

G1.1 Tabulated Summaries

The following tables summarise the high level findings of the four Cells in terms of the features analysed at the man-machine and job design levels of analysis.

Table G1.1 Cell A, Man-Machine Level of Analysis

	Transparency	Nature of Operator Loading	Technical Coupling	Decision Authority and Competence	Adaptive Function Allocation	Summary
Operate Primary Machine	Transparency and the opportunity for controlling manufacturing operations is poor. Cell members are restricted to performing low-level interactive functions distancing cell members from and constraining their understanding of the manufacturing operations.	Cell members restricted to performing interactive, low-level functions. Few opportunities for planning and decision making functions. Majority are physical functions. Cell members visually inspect all work and fully maintain the equipment.	Technical coupling is high. The function of the cell members is to feed the machine work. The task methods performed by cell members are predetermined. The pace and timing of work is prescribed by the machine and when it fails, all cell activities stop (except work on buffer stock).	The machine assists cell members with identifying tool wear. The machine monitors tool wear and indicates when tools need replacing. Cell members decide whether to replace tooling before or when this occurs. Cell members replace all tools.	Functions are rigid and unalterable. Machine not designed for adaptive function allocation. Auto-mated functions cannot be overrided manually and visa versa.	All manufacturing cutting operations are automated and have no manual over-ride. Poor transparency due to interactive and rigid nature of function allocation. Minimal input intervention from the cell members. Pace of the work prescribed by machine and is critical.
Perform Deburring Operations	The processes are fully transparent for both drilling and wire brush operations. Both operations are manually controlled and are performed by cell members.	As above plus: Cell members ensure that all burrs are removed. Good manual dexterity is needed to orientate and handle the work for the wire brush operation.	The method for both deburring operations are predetermined. Automation is low. Pace of work is determined by part condition and the skill of cell members - not the machinery. Slack is not critical.	Process decisions made by cell members - preparation maintenance and inspection functions. Machines have no decision making abilities.	As above plus: The machines essentially act as tools for the cell members to manually deburr the components.	Deburring operations are manually carried out by cell members who visually inspect all work and deter-mine pace and timing of work. Both operation are fully transparent and are not critical.
Operate Washer	The washing process is fully transparent and controlled by cell members.	Machine operation involves mostly physical functions. In addition, cell members visually inspect all work and fully maintain the equipment.	Task methods are predetermined and is automated. Pace of work is not determined by loading, unloading and preparation functions and is not critical.	Process decisions made by cell members - preparation and maintenance functions. Machine has no decision making abilities.	Functions are rigid and unalterable. Machine not designed for adaptive function allocation. Work *could* be cleaned manually.	Cell members prepare the machine and parts for washing. Pace of work is not determined by the equipment and is not critical. Washing is easily understood, automated and transparent.
Pull Work From Stores	N/A	Cognitive functions involve planning daily requirements and liaising with downstream cell and supervisors. Physical functions involve pulling work from stores and material handling.	N/A	Planning and decision making not machine assisted. Performed manually by cell members and supervisors.	Functions are rigid and unalterable.	N/A
Perform Quality Operations	Cell members prepare and (re)calibrate equipment. Surfaces are measured automatically. Cell members do not have control over the measuring process.	Quality tasks involve a mix of physical and cognitive functions. Cell members gauge threads manually, visually inspect all work, maintain and prepare	The task method is strictly prescribed. The functions performed by cell members are mostly preparatory and are critical for ensuring a correct measurement. Pace of work is	Process decisions made by cell members. Machine has no decision making abilities. Cell members interpret measurement readouts and decide whether to reject work,	Functions are rigid and unalterable. Measurement devices not designed for adaptive function allocation. Surfaces cannot be measured manually.	Cell members perform cognitive and physical functions. Task methods are strictly prescribed. Surface measurements are automated. Process has low transparency

	Transparency	Nature of Operator Loading	Technical Coupling	Decision Authority and Competence	Adaptive Function Allocation	Summary
		equipment and interpret measurement readouts.	not determined by equipment and timing is not critical.	recalibrate device or repeat measurement process.		and cell members have little control except through preparatory functions.
Store Finished Work	N/A	Physical functions dealing with box assembly and filling.	N/A	N/A	Functions are rigid and unalterable.	N/A
Plan Activities	N/A	Planning functions.	N/A	Planning function not machine assisted. Performed manually by cell members and supervisors.	As above.	Function is not machine assisted.
Perform House-Keeping Activities	N/A	Physical functions dealing with cleaning cell area and machines as well as preparing machines for operation.	N/A	N/A	As above.	N/A
Improve processes	Transparency of machine processes limits and constrains the quality and range of improvement proposals.	Functions involve pro-posing, implementing and evaluating improvements.	N/A	Functions performed by cell members and supervisors.	As above.	Where transparency is poor quality and range of proposals are constrained. Function is not machine assisted.
Summary	Low transparency on fully automated processes Function allocation con-strains ability and opportunity for cell members to intervene and understand machine processes Cell members control the more simple processes and are fully transparent	Cell members constrained to performing interactive, low-level functions. Cog-nitive functions involve proposing improvements, interpreting readouts and planning. Few opportunities for carrying out cognitive functions.	Technical coupling high for main automated process. Function allocation con-strains ability and opportunity for cell members to structure the order, pace and timing of work. Task methods for all processes are predetermined.	Primary machine assists with predicting tool changes. All other process decisions are made by cell members. They have the skills and competence to make decisions and plan corresponding work steps.	For all processes, functions are rigid and unalterable. Automated functions cannot be overrided manually and visa versa.	

Table G1.2 Cell A, Job Design Level of Analysis

	Skills Use and Retention	Task Flexibility	Responsibility	Process Feedback	Interaction Requirements	Summary
Operate Primary Machine	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass physical, interactive functions and demand occa-sional planning and improvement functions.	Job rotation employed for this function. Job enlargement and enrichment constrained by rigid function allocation and prescribed task method.	Cell members responsible for quality of work and undertake inter-active functions to maintain throughput. Not fully autonomous. Difficult to predict machine failure and consequently to rectify errors.	Nature of functions distance cell members from manufacturing process. Part quality visually inspected after process is completed.	Interaction with other people and cells during normal operation is small. Required during disruptions to discuss corrective and maintenance activities. Functions do not promote information sharing and isolate cell members.	Functions constrain skills maintenance and use as well as autonomy of cell members. Job rotation but limited scope for enlargement and enrichment. Inter-action requirements and process feedback low.
Perform Deburring Operations	As above.	As above.	Cell members responsible for quality of work and undertake inter-active functions to maintain throughput. Very autonomous. Can predict, identify and rectify most disruptions to equipment.	Part quality visually inspected during deburring processes. Corrective feedback is constant and immediate.	As above.	Functions constrain skills maintenance and use. Autonomy good. Job rotation but limited scope for enlargement and enrichment. Inter-action requirements low. Process feedback good.
Operate Washer	As above.	As above.	As above.	Part quality visually inspected after washing process.	As above.	As above.
Pull Work From Stores	As above.	As above.	Cell members responsible for daily cell loading. Autonomous with assistance from supervisors.	N/A	Function requires manual, prospective communication between cell members, supervisors and other cells.	Autonomy good. Daily interaction with cell members and other cells. Job rotation.
Perform Quality Operations	As above plus: Required to interpret surface measurement readouts.	As above.	Cell members responsible for quality measurements and for quality of parts throughout 'whole' process. Can identify when equip-ment is faulty but cannot rectify all major failures.	Feedback from surface measurement process displayed digitally and from thread gauging in form of the stiffness of gauge in tapped hole.	Interaction with other people and cells is small. Functions do not promote information sharing and isolate cell members.	Autonomy good. Interaction requirements low. Feedback on part quality from equipment. Skills usage narrow.
Store Finished Work	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass physical, interactive functions.	Job rotation employed for this function. Job enlargement and enrichment constrained by rigid function allocation and prescribed task method.	Cell members responsible for quality of work and carry out inter-active functions. Very autonomous. Can predict, identify and rectify most disruptions to equipment.	No feedback from the function itself except through inspection.	As above.	Function constrains skills maintenance and use. Autonomy good. Job rotation but limited scope for enlargement and enrichment. Inter-action and process feedback low.

	Skills Use and Retention	Task Flexibility	Responsibility	Process Feedback	Interaction Requirements	Summary
Plan Activities	Daily planning functions with few variations.	As above plus: Planning functions performed daily but provide little opportunity for enrichment.	Cell members responsible for daily cell loading and part manufacture. Autonomous with assistance from supervisors.	No feedback from the function itself.	The function requires manual, prospective and regulatory communication between cell members, supervisors and other cells.	Planning functions vary little and provide little opportunity for enrichment. Interaction requirements and autonomy good.
Perform House-Keeping Operations	As above.	Job rotation employed for this function. Job enlargement and enrichment constrained by rigid function allocation.	Cell members responsible for cleanliness and maintenance of equipment. Fully autonomous.	No feedback from the function itself except through inspection.	Interaction with other people and cells is small. Functions do not promote information sharing and isolate cell members.	Autonomy good. Job rotation but limited scope for enlargement and enrichment. Inter-action requirements and process feedback low.
Improve Processes	As above.	All cell members per-form this function when the opportunity arises (on a monthly basis) but provides little opportunity for enrichment.	Cell members propose improvements to super-visors and others for evaluation. Supervisors assist with implementing improvements.	Improvements evaluated over time.	The function requires manual, prospective and improvement communication between cell members and supervisors.	Improvement functions infrequent and demand a lot of interaction between cell members and supervisors. Autonomy good.
Summary	Overall. Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass interactive functions and demand occasional planning and improvement functions	Job rotation on all functions. Job enlargement and enrichment constrained by rigid function allocation and prescribed task method.	Cell members responsible for quality of work and maintain through-put. Very autonomous except during disruptions to automated processes. Can predict, identify and rectify most disruptions.	Poor feedback from the functions. Feedback from inspection of work after operations - using the equipment and also visually.	Interaction with other people and cells during normal operation is small. Required during disruptions, and during improvement and planning functions. Function allocation does not promote information sharing.	

Table G1.3 Cell B, Man-Machine Level of Analysis

	Transparency	Nature of Operator Loading	Technical Coupling	Decision Authority and Competence	Adaptive Function Allocation	Summary
Operate 'Cincinnati' Machine	Transparency poor. Cell members perform low-level interactive functions. Control over the operations is small because of the 'distance' from the process and the design of the machine itself.	Cell members constrained to performing interactive low-level physical functions. Cell members inspect all work and maintain the equipment -remove swarf, clean jigs, replace tooling.	Technical coupling is high. Cell members 'feed' the machine with work. Task methods are predetermined. The pace and timing of work is prescribed by this and other machines running in parallel. This process is critical to the Cell.	The machine does not provide any process decision support. Cell members decide when to replace tooling.	Functions are rigid and unalterable. Machine not designed for adaptive function allocation. Not adaptable or adaptive.	All cutting operations are automated and have no manual override - rigid function allocation. Poor transparency and little control over operations. Pace of work and methods prescribed by machine and is critical to the Cell.
Operate 'Kingsbury' Machine	As above.	As above.	As above.	As above.	As above.	As above.
Operate 'Splitter' Machine	As above.	As above.	As above.	As above.	As above.	As above.
Operate Bolt Rig	Fully transparent. Parts manually manipulated and controlled.	As above plus: Parts loaded and bolts inserted by hand.	Methods are predetermined. Automation is low and pace of work determined by the cell members. The process is not critical.	As above.	Machines essentially act as tools. Final tightening by machine. This could be done manually. Functions therefore adaptable not adaptive.	Part and bolt handling and insertion performed manually. Process fully transparent. Pace of work determined by the cell members and is not critical.
Operator Washer	The washing process is fully transparent and controlled by the cell members.	Machine operation involves mostly physical functions. In addition, cell members visually inspect all work and fully maintain the equipment.	Task methods are predetermined and are automated. Pace of work is not determined by loading, unloading and preparation functions and is not critical.	Process decisions made by cell members - preparation and maintenance functions. Machine has no process decision making abilities.	Functions are rigid and unalterable. Machine not designed for adaptive function allocation. Work *could* be cleaned manually.	Cell members prepare the machine and parts for washing. Pace of work is not determined by the equipment and is not critical. Washing is easily understood, automated and transparent.
Operate 'Vibro'	The 'vibro' process is fully transparent and controlled by the cell members.	As above.	As above.	As above.	Functions are not adaptive and adaptable. Process could not be performed manually.	Process fully transparent. Pace of work determined by cell members and is not critical.
Operate Chamfer Machine	Process is transparent and cell members have good control over the process.	As above plus: Additional deburring performed by hand.	As above.	As above.	As above.	Process transparent. Pace of work determined by cell members and is not critical. Task methods are predetermined. Cell members perform interactive functions and

	Transparency	Nature of Operator Loading	Technical Coupling	Decision Authority and Competence	Adaptive Function Allocation	Summary
						inspect all work.
Operate VM40 NC Machine	Transparency good. Design of machine provides good information and corrective feedback. Cell members can intervene in process.	Low-level interactive functions plus the ability to interpret machine feed-back and intervene - programming offsets and program selection. Cell members inspect all work and maintain equipment.	Technical coupling is high. Task methods predetermined - programs preloaded and are selected by cell members. Programs can not be altered. The pace of work (and of the Cell) is pre-scribed by the machine. Slack is critical to the Cell.	Machine has no process decision making abilities. Decisions made by cell members with information and corrective feedback from machine.	Functions are not adaptive and adaptable.	Technical coupling is high but transparency and control of process if good. Functions are rigid and unalterable. Machine provides information feedback - cell members make process decisions. process in critical to Cell.
Perform Quality Operations	Low transparency of SPC dimensional measurement processes. Little control over automated process itself except through good preparation methods.	Quality tasks involve a mix of physical and cognitive functions. Cell members gauge threads manually, visually inspect all work, maintain and prepare equipment and interpret measurement readouts on the SPC equipment.	Task methods are strictly prescribed. Pace of work is not determined by equipment and timing is not critical.	Process decisions made by cell members who interpret measurement readouts and decide whether to reject work, recalibrate device or repeat measurement processes.	Functions are rigid and unalterable. Measurement devices not designed for adaptive function allocation.	Cell members perform cognitive and physical functions. Task methods are strictly prescribed. Dimensional measurements are automated. Process has low transparency and cell members have little control except through preparatory functions.
Pull Work from Stores	N/A	Cognitive functions involve planning daily requirements and liaising with downstream cell and supervisors. Physical functions involve pulling work from stores and material handling.	N/A	Planning and decision making not machine assisted. Performed manually by cell members and supervisors.	Functions are rigid and unalterable.	N/A
Perform House-Keeping Activities	N/A	Physical functions dealing with cleaning cell area and machines as well as preparing machines for operation.	N/A	N/A	As above.	N/A
Store Finished Work	N/A	Physical functions dealing with material transportation to downstream cell. Kanban system requires updated.	N/A	N/A	As above.	N/A
Improve Processes	Transparency of machine processes limits and constrains the quality and	Functions involve pro-posing, implementing and evaluating improvements.	N/A	Functions performed by cell members and supervisors.	As above.	Where transparency is poor quality and range of pro-posals are constrained. The

	Transparency	Nature of Operator Loading	Technical Coupling	Decision Authority and Competence	Adaptive Function Allocation	Summary
	range of improvement proposals.					function is not machine assisted.
Plan Activities	N/A	Planning functions on a daily basis.	N/A	Planning function not machine assisted.	As above.	Performed manually by cell members and supervisors.
Summary	Low transparency on fully automated processes. Function allocation constrains ability and opportunity for cell members to intervene and understand machine processes. Cell members control the more simple processes and are fully transparent.	Cell members constrained to performing interactive, low-level functions. Cognitive functions involve proposing improvements, interpreting readouts and planning. Few opportunities for performing high-level functions.	Technical coupling high for main automated process. Function allocation constrains ability and opportunity for cell members to structure the order of work. The pace and timing are sustained by the cell members. Task methods for all processes are prescribed.	All process decisions are made by cell members. The VM40 NC machine provides information feedback. They have the skills and competence to make decisions and plan corresponding work steps.	For all processes, functions are rigid and unalterable. Automated functions cannot be overrided manually and visa versa.	

Table G1.4 Cell B, Job Design Level of Analysis

	Skills Use and Retention	Task Flexibility	Responsibility	Process Feedback	Interaction Requirements	Summary
Operate 'Cincinatti' Machine	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass physical, interactive functions.	Job rotation between sub-cells if two people in Cell. Job enlargement and enrichment constrained by nature of cellular manufacturing, rigid function allocation and prescribed task method.	Cell members responsible for quality of work and undertake interactive functions to maintain throughput. Not fully autonomous. Difficult to predict machine failure and consequently to rectify errors.	Nature of functions distance cell members from manufacturing process. Part quality visually inspected after process is completed.	Interaction with other people and cells during normal operation is small. Required during disruptions to discuss corrective and maintenance activities. Functions do not promote information sharing and isolate cell members.	Functions constrain skills maintenance and use as well as autonomy of cell members. Job rotation but limited scope for enlargement and enrichment. Inter-action requirements and process feedback low.
Operate 'Kingsbury' Machine	As above.	As above.	As above.	As above.	As above.	As above.
Operate 'Splitter' Machine	As above.	As above.	As above.	As above.	As above.	As above.
Operate Bolt Rig	As above.	As above.	Cell members responsible for quality of work and undertake inter-active functions to maintain throughput. Very autonomous. Can predict, identify and rectify most disruptions to equipment.	Part quality visually inspected after process is completed.	As above.	Functions constrain skills maintenance and use. Autonomy good. Some job rotation but limited scope for enlargement and enrichment. Interaction requirements low. Process feedback is good.
Operate 'Turbex' Washer	As above.	As above.	As above.	As above.	As above.	As above.
Operate 'Vibro'	As above.	As above.	As above.	As above.	As above.	As above.
Operate Chamfer Machine	As above.	As above.	As above.	As above plus: Deburring is performed manually after process is completed. Corrective feedback is constant and immediate.	As above.	As above.
Operate VM40 NC Machine	Not all cell members have the skills to fully operate this machine. Skills acquired to deal with all system failures, setting offsets and	As above plus: Job rotation constrained by skill levels of cell members.	Cell members responsible for quality of work and undertake interactive functions to maintain throughput. Autonomy good.	Good informational and corrective feedback from machine.	As above.	High skill levels required. Function allocation and nature of work constrains inter-action and communication

	Skills Use and Retention	Task Flexibility	Responsibility	Process Feedback	Interaction Requirements	Summary
	interpreting program readouts.		Difficult to predict major machine failures and consequently rectify errors.			opportunities. Autonomy and process feedback is good.
Perform Quality Operations	Skills required encompass interactive functions and ability to interpret SPC data. Overall a narrow range of skills is required. Few opportunities to maintain and develop new ones.	Job rotation between sub-cells if two people in Cell. Job enlargement and enrichment constrained by nature of cellular manufact-uring, rigid function allocation and prescribed task method.	Cell members responsible for quality measurements and for quality of parts throughout 'whole' process. Can identify when equip-ment is faulty but cannot rectify all major failures.	Feedback from thread gauging in form of the stiffness of gauge in tapped hole. Feedback from dimensional measurement activities on computer screen.	Interaction with other people and cells is small. Functions do not promote information sharing and isolate cell members.	Autonomy good. Interaction requirements low. Feedback on part quality from equipment. Skills usage narrow.
Pull Work from Stores	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass physical, interactive functions and demand occa-sional planning and improvement functions.	Job rotation employed for this function. Job enlargement and enrichment constrained by rigid function allocation and prescribed task method.	Cell members responsible for daily cell loading. Autonomous with assistance from supervisors.	Informational feedback from operating kanban system.	Function requires manual, prospective communication between cell members, supervisors and other cells.	Autonomy good. Daily interaction with cell members and other cells. Job rotation. Feedback from kanban system.
Perform House-Keeping Activities	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass physical, interactive functions.	Job rotation employed for this function. Job enlargement and enrichment constrained by rigid function allocation.	Cell members responsible for cleanliness and maintenance of equipment. Fully autonomous.	No feedback from the function itself except through inspection.	Interaction with other people and cells is small. Functions do not promote information sharing and isolate cell members.	Autonomy good. Job rotation but limited scope for enlargement and enrichment. Inter-action requirements and process feedback low.
Store Finished Work	As above.	As above.	As above.	As above.	As above.	Function constrains skills maintenance and use. Autonomy good. Job rotation but limited scope for enlargement and enrichment. Inter-action low.
Improve Processes	As above.	All cell members per-form this function when the opportunity arises (on a monthly basis) but provides little opportunity for enrichment.	Cell members propose improvements to super-visors and others for evaluation. Supervisors assist with implementing improvements.	Improvements evaluated over time.	The function requires manual, prospective and improvement communication between cell members and supervisors.	Improvement functions infrequent and demand a lot of interaction between cell members and supervisors. Autonomy good.
Plan Activities	Daily planning functions with few variations.	As above plus: Planning functions	Cell members responsible for daily cell loading and part	No feedback from the function itself.	The function requires manual, prospective and	Planning functions vary little and provide little opportunity

	Skills Use and Retention	Task Flexibility	Responsibility	Process Feedback	Interaction Requirements	Summary
		performed daily but provide little opportunity for enrichment.	manufacture. Autonomous with assistance from supervisors.		regulatory communication between cell members, supervisors and other cells.	for enrichment. Interaction requirements and autonomy good.
Summary	Few opportunities to maintain and develop new skills. High levels skills required for VM40 machine. Skills required encompass physical, interactive functions as well as communication and planning functions.	Job rotation on all functions (VM40 - dependant on skill levels). Job enlargement and enrichment constrained by rigid function allocation and prescribed task method.	Cell members responsible for quality of work and maintain through-put. Very autonomous except during major disruptions to auto-mated processes. Can predict, identify and rectify most disruptions.	Poor feedback from functions. Feedback from inspection of work after operations - using the equipment and also visually. Informational and corrective feed-back from the VM40 machine	Interaction with other people and cells during normal operation is small. Required during disruptions, and during improvement and planning functions. Function allocation does not promote information sharing.	

Table G1.5 Cell C, Man-Machine Level of Analysis

	Transparency	Nature of Operator Loading	Technical Coupling	Decision Authority and Competence	Adaptive Function Allocation	Summary
Operate Fanuc NC Machines	Transparency and the opportunity for controlling manufacturing operations is poor. Cell members perform low-level interactive functions.	Cell members constrained to performing interactive low-level physical functions. Cell members inspect all work and maintain the equipment -remove swarf, clean jigs, replace tooling.	Technical coupling is high. Cell members 'feed' the machine with work. Task methods are predetermined. The pace and timing of work is prescribed by this and other machines running in parallel. This process is critical to the Cell.	The machine does not provide any process decision support. Cell members decide when to replace tooling and coolant.	Functions are rigid and unalterable. Machine not designed for adaptive function allocation. Not adaptable or adaptive.	All manufacturing cutting operations are automated with no manual override. Poor transparency due to interactive and rigid nature of function allocation. Minimal input intervention from the cell members. Pace of the work prescribed by machines and are critical.
Operate CNC Lathe	As above.	As above.	As above except: Process most critical to Cell.	As above.	As above.	As above.
Remove Swarf	The process is fully transparent. The operation is manually undertaken by cell members.	As above plus: Cell members ensure that all swarf is removed. Some manual dexterity is needed to orientate and handle the work.	The method for the operation is predetermined. Automation is low. Pace of work is determined by part condition and the skill of cell members. Operation is not critical.	Process decisions made by cell members - preparation maintenance and inspection functions. Equipment has no decision making abilities.	As above plus: The machines essentially act as a tool for the cell members to manually remove swarf from the work.	Swarf removal performed manually carried by cell members who visually inspect all work and deter-mine pace and timing of work. Operation is fully transparent and is not critical.
Perform Quality Operations	Cell members prepare and (re)calibrate PreCom equipment. Surfaces are measured automatically. Cell members do not have control over the measuring process.	Quality tasks involve a mix of physical and cognitive functions. Cell members gauge threads manually, visually inspect all work, maintain and prepare equipment and interpret measurement readouts.	The task method is strictly prescribed. The functions performed by cell members are mostly preparatory and are critical for ensuring a correct measurement. Pace of work is not determined by equipment and timing is not critical.	Process decisions made by cell members. Machine has no decision making abilities. Cell members interpret measurement readouts and decide whether to reject work, recalibrate device or repeat measurement process.	Functions are rigid and unalterable. Measurement devices not designed for adaptive function allocation. Surfaces cannot be measured manually.	Cell members perform cognitive and physical functions. Task methods are strictly prescribed. Surface measurements are automated. Process has low transparency and cell members have little control except through preparatory functions.
Pull Work from Stores	N/A	Physical functions involve pulling work from stores and material handling.	N/A	Planning and decision making not machine assisted. Performed manually by cell members and supervisors.	Functions are rigid and unalterable	N/A
Perform House-Keeping Activities	N/A	Physical functions dealing with cleaning cell area and machines as well as preparing machines for operation.	N/A	N/A	As above	N/A
Store Finished	N/A	Physical functions involves storage of work in pallets	N/A	N/A	As above	N/A

	Transparency	Nature of Operator Loading	Technical Coupling	Decision Authority and Competence	Adaptive Function Allocation	Summary
Work		for transportation to assembly cell.				
Improve Processes	Transparency of machine processes limits and constrains the quality and range of improvement proposals.	Functions involve proposing and implementing improvements.	N/A	Functions are not machine assisted and are performed by cell members and supervisors.	As above.	Where transparency is poor quality and range of proposals are constrained. Function is not machine assisted.
Plan Activities	N/A	Planning functions performed by supervisors on a daily basis.	N/A	Planning function not machine assisted and are performed by cell members and supervisors.	As above.	Function is not machine assisted.
Summary	Low transparency on fully automated processes. Function allocation constrains ability and opportunity for cell members to intervene and trace machine processes. Cell members control the more simple processes and are fully transparent.	Cell members constrained to performing interactive, low-level functions. Cognitive functions involve proposing improvements and interpreting readouts. Few opportunities for cell members for cognitive functions and planning.	Technical coupling high for main automated processes. Function allocation constrains ability and opportunity for cell members to structure the order, pace and timing of work. Task methods for all processes are predetermined.	Process decisions (planning and process improvements) are not machine assisted and are performed by cell members and supervisors.	For all processes, functions are rigid and unalterable. Automated functions cannot be overrided manually and visa versa.	

Table G1.6 Cell C, Job Design Level of Analysis

	Skills Use and Retention	Task Flexibility	Responsibility	Process Feedback	Interaction Requirements	Summary
Operate Fanuc NC Machines	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass physical, interactive functions.	No job rotation employed for this function (only for the Cell as a whole). Job enlargement and enrichment constrained by rigid function allocation, prescribed task method and low skill levels.	Cell members responsible for quality of work and undertake inter-active functions to maintain throughput. Not fully autonomous. Difficult to predict machine failure and consequently to rectify errors.	Nature of functions distance cell members from manufacturing process. Part quality visually inspected after process is completed.	Interaction with other people and cells during normal operation is small. Required during disruptions to discuss corrective and maintenance activities. Functions do not promote information sharing and isolate cell members.	Functions constrain skills maintenance and use as well as autonomy of cell members. No job rotation and limited job enlargement and enrichment. Interaction requirements and process feedback low.
Operate CNC Lathe	As above.	As above.	As above.	As above.	As above.	As above.
Remove Swarf	As above.	As above.	Cell members responsible for quality of work and undertake inter-active functions to maintain throughput. Very autonomous. Can predict, identify and rectify most disruptions to equipment.	Part quality visually inspected during deswarfing process. Corrective feedback is constant and immediate.	As above.	Functions constrain skills maintenance and use. Autonomy good. No job rotation and limited job enlargement and enrichment. Interaction requirements low. Process feedback good.
Store Finished Work	As above.	As above.	As above.	As above.	As above.	Function constrains skills maintenance and use. Autonomy good. Interaction low. No job rotation and limited scope for enlargement and enrichment.
Pull Work from Stores	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass physical, interactive functions and demand occa-sional planning and improvement functions.	As above.	Supervisors responsible for daily cell loading. Autonomous with assistance from supervisors.	N/A	Some interaction with supervisors when necessary.	Autonomy good. No job rotation and limited scope for enlargement and enrichment.
Perform House-Keeping Activities	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass	As above.	Cell members responsible for cleanliness and maintenance of equipment. Fully autonomous.	No feedback from the function itself except through inspection.	Interaction with other people and cells is small. Functions do not promote information sharing and isolate cell members.	Autonomy good. No job rotation and limited scope for enlargement and enrichment. Inter-action requirements and process feedback low.

	Skills Use and Retention	Task Flexibility	Responsibility	Process Feedback	Interaction Requirements	Summary
	physical, interactive functions.					
Improve Processes	As above.	All cell members per-form this function when the opportunity arises (on a monthly basis) but provides little opportunity for enrichment.	Cell members propose improvements to super-visors and others for evaluation. Supervisors assist with implementing improvements.	Improvements evaluated over time.	The function requires manual, prospective and improvement communication between cell members and supervisors.	Improvement functions infrequent and demand a lot of interaction between cell members and supervisors. Autonomy good.
Plan Activities	Occasional planning with supervisors and with few variations.	As above plus: Occasional planning with supervisors but provide little opportunity for enrichment.	Supervisors responsible for Cell loading.	No feedback from the function itself.	The function requires occasional regulatory communication between cell members, supervisors.	Planning functions vary little and provide little opportunity for enrichment. Interaction requirements and autonomy low.
Summary	Few opportunities to maintain and develop new skills Skills required encompass physical, interactive functions as well as communication and some planning functions.	Job rotation in Cell as a whole. Job enlargement and enrichment constrained by rigid function allocation and prescribed task method.	Cell members responsible for quality of work and maintain through-put. Very autonomous except during disruptions to automated processes.	Poor feedback from functions themselves. Feedback from inspection of work after operations - using the equipment and also visually.	Interaction with other people and cells during normal operation is small Required during disruptions, and during improvement and planning functions. Function allocation does not promote information sharing.	

Table G1.7 Cell D, Man-Machine Level of Analysis

	Transparency	Nature of Operator Loading	Technical Coupling	Decision Authority and Competence	Adaptive Function Allocation	Summary
Operate Lathes	Transparency and the opportunity for controlling manufacturing operations is poor. Cell members perform low-level interactive functions.	Cell members constrained to performing interactive low-level physical functions. Cell members inspect all work and maintain the equipment -remove swarf, clean jigs, replace tooling.	Technical coupling is high. Cell members 'feed' the machine with work. Task methods are predetermined. The pace and timing of work is prescribed by this and other machines running in parallel. This process is critical to the Cell.	The machine does not provide any process decision support. Cell members decide when to replace tooling and coolant.	Functions are rigid and unalterable. Machine not designed for adaptive function allocation. Not adaptable or adaptive.	All manufacturing cutting operations are automated with no manual override. Poor transparency due to interactive and rigid nature of function allocation. Minimal input intervention from the cell members. Pace of the work prescribed by machines and are critical.
Operater Washer	The washing process is fully transparent and controlled by the cell members.	Machine operation involves mostly physical functions. In addition, cell members visually inspect all work and fully maintain the equipment.	Task methods are predeter-mined and are automated. Pace of work is not deter-mined by loading, unloading and preparation functions and is not critical.	Process decisions made by cell members - preparation and maintenance functions. Machine has no process decision making abilities.	Functions are rigid and unalterable. Machine not designed for adaptive function allocation. Work *could* be cleaned manually.	Cell members prepare the machine and parts for washing. Pace of work is not determined by the equipment and is not critical. Washing is easily understood, automated and transparent.
Perform Quality Operations	Cell members prepare and (re)calibrate PreCom equipment. Surfaces are measured automatically. Cell members do not have control over the measuring process.	Quality tasks involve a mix of physical and cognitive functions. Cell members gauge threads manually, visually inspect all work, maintain and prepare equipment and interpret measurement readouts.	The task method is strictly prescribed. The functions performed by cell members are mostly preparatory and are critical for ensuring a correct measurement. Pace of work is not determined by equipment and timing is not critical.	Process decisions made by cell members. Machine has no decision making abilities. Cell members interpret measurement readouts and decide whether to reject work, recalibrate device or repeat measurement process.	Functions are rigid and unalterable. Measurement devices not designed for adaptive function allocation. Surfaces cannot be measured manually.	Cell members perform cognitive and physical functions. Task methods are strictly prescribed. Surface measurements are automated. Process has low transparency and cell members have little control except through preparatory functions.
Pull Work from Stores	N/A	Cognitive functions involve planning daily requirements and liaising with supervisors. Physical functions involve pulling work from stores and material handling.	N/A	Planning and decision making not machine assisted. Performed manually by cell members and supervisors.	Functions are rigid and unalterable.	N/A
Perform House-Keeping Activities	N/A	Physical functions dealing with cleaning cell area and machines as well as preparing machines for operation.	N/A	N/A	As above.	N/A

	Transparency	Nature of Operator Loading	Technical Coupling	Decision Authority and Competence	Adaptive Function Allocation	Summary
Store Finished Work	N/A	Physical functions involves storage of work in pallets for transportation to assembly cell.	N/A	N/A	As above.	N/A
Improve Processes	Transparency of machine processes limits and constrains the quality and range of improvement proposals.	Functions involve proposing, implementing and evaluating improvements.	N/A	Functions are not machine assisted and are performed by cell members and supervisors.	As above.	Where transparency is poor quality and range of proposals are constrained. The function is not machine assisted.
Plan Activities	N/A	Planning functions on a daily basis.	N/A	Planning function not machine assisted and are performed by cell members and supervisors.	As above.	Performed manually by cell members and supervisors.
Summary	Low transparency on fully automated processes. Function allocation constrains ability and opportunity for cell members to intervene and understand machine processes. Cell members control the more simple processes and are fully transparent	Cell members constrained to performing interactive, low-level functions. Cognitive functions involve proposing improvements, interpreting readouts and planning. Few opportunities for performing high-level functions.	Technical coupling high for main automated processes. Function allocation constrains ability and opportunity for cell members to structure the order of work. The pace and timing are sustained by the cell members. Task methods for all processes are prescribed	Process decisions (planning and process improvements) are not machine assisted and are performed by cell members and supervisors.	For all processes, functions are rigid and unalterable. Automated functions cannot be overrided manually and visa versa.	

Table G1.8 Cell D, Job Design Level of Analysis

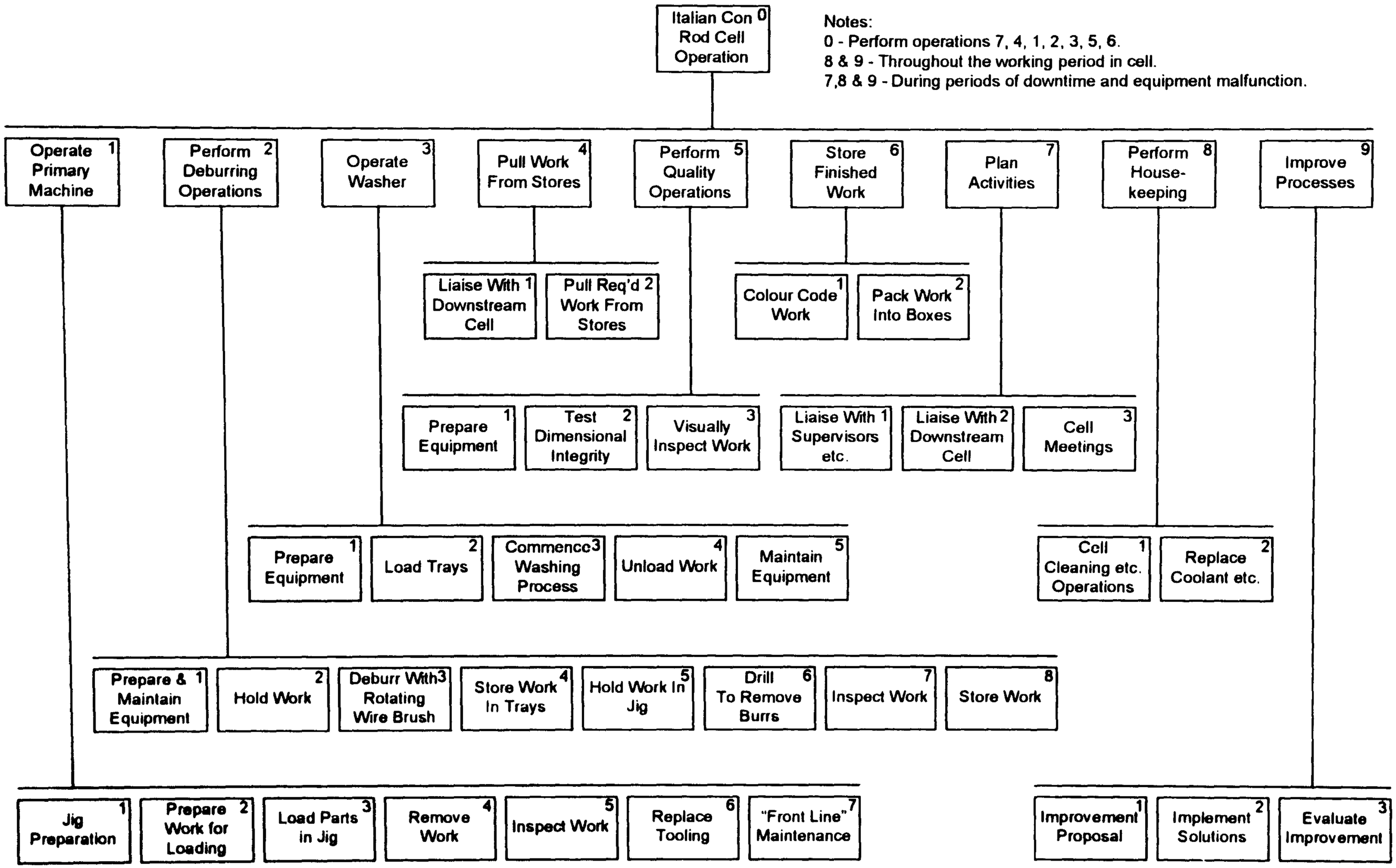
	Skills Use and Retention	Task Flexibility	Responsibility	Process Feedback	Interaction Requirements	Summary
Operate Lathes	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass physical, interactive functions.	No job rotation employed for this function (only for the Cell as a whole). Job enlargement and enrichment constrained by rigid function allocation and prescribed task method.	Cell members responsible for quality of work and undertake interactive functions to maintain throughput. Not fully autonomous. Difficult to predict machine failure and consequently to rectify errors.	Nature of functions distance cell members from manufacturing process. Part quality visually inspected after process is completed.	Interaction with other people and cells during normal operation is small. Required during disruptions to discuss corrective and maintenance activities. Functions do not promote information sharing and isolate cell members.	Functions constrain skills maintenance and use as well as autonomy of cell members. No job rotation and limited job enlargement and enrichment. Interaction requirements and process feedback low.
Operate Washer	As above.	As above.	Cell members responsible for quality of work and undertake inter-active functions to maintain throughput. Very autonomous. Can predict, identify and rectify most disruptions to equipment.	Part quality visually inspected after process is completed.	As above.	As above.
Perform Quality Operations	Skills required encompass interactive functions and ability to interpret PreCom computer readouts. Overall a narrow range of skills is required. Few opportunities to maintain and develop new ones.	As above.	Cell members responsible for quality measurements and for quality of parts throughout 'whole' process. Can identify when equipment is faulty but cannot rectify all major failures.	Feedback from thread gauging in form of the stiffness of gauge in tapped hole. Feedback from dimensional measurement activities on computer screen.	Interaction with other people and cells is small. Functions do not promote information sharing and isolate cell members.	Autonomy good. Interaction requirements low. Feedback on part quality from equipment. Skills usage narrow.
Pull Work from Stores	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass physical, interactive functions and demand occasional planning and improvement functions.	As above.	Supervisors responsible for daily cell loading. Autonomous with assistance from supervisors.	N/A	Some interaction with supervisors when necessary.	Autonomy good. No job rotation and limited scope for enlargement and enrichment.
Perform House-Keeping Activities	Narrow range of skills required and few opportunities to maintain and develop new ones. Skills required encompass physical, interactive	As above.	Cell members responsible for cleanliness and maintenance of equipment. Fully autonomous.	No feedback from the function itself except through inspection.	Interaction with other people and cells is small. Functions do not promote information sharing and isolate cell members.	Autonomy good. No job rotation and limited scope for enlargement and enrichment. Inter-action requirements and process feedback low.

	Skills Use and Retention	Task Flexibility	Responsibility	Process Feedback	Interaction Requirements	Summary
	functions.					
Store Finished Work	As above.	As above.	As above.	As above.	As above.	Function constrains skills maintenance and use. Autonomy good. Interaction low. No job rotation and limited scope for enlargement and enrichment
Improve Processes	As above.	All cell members per-form this function when the opportunity arises (on a monthly basis) but provides little opportunity for enrichment.	Cell members propose improvements to super-visors and others for evaluation. Supervisors assist with implementing improvements.	Improvements evaluated over time.	The function requires manual, prospective and improvement communication between cell members and supervisors.	Improvement functions infrequent and demand a lot of interaction between cell members and supervisors. Autonomy good.
Plan Activities	Occasional planning with supervisors and with few variations.	As above plus: Occasional planning with supervisors but provide little opportunity for enrichment.	Supervisors responsible for Cell loading.	No feedback from the function itself.	The function requires occasional regulatory communication between cell members, supervisors.	Planning functions vary little and provide little opportunity for enrichment. Interaction requirements and autonomy low.
Summary	Few opportunities to maintain and develop new skills. Skills required encompass physical, interactive functions as well as communication and some planning functions.	Job rotation in Cell as a whole. Job enlargement and enrichment constrained by rigid function allocation and prescribed task method.	Cell members responsible for quality of work and maintain through-put. Very autonomous except during disruptions to automated processes. Can predict and rectify most sources of disruption.	Poor feedback from functions themselves. Feedback from inspection of work after operations - using the equipment and also visually.	Interaction with other people and cells during normal operation is small. Required during disruptions, and during improvement and planning functions. Function allocation does not promote information sharing.	

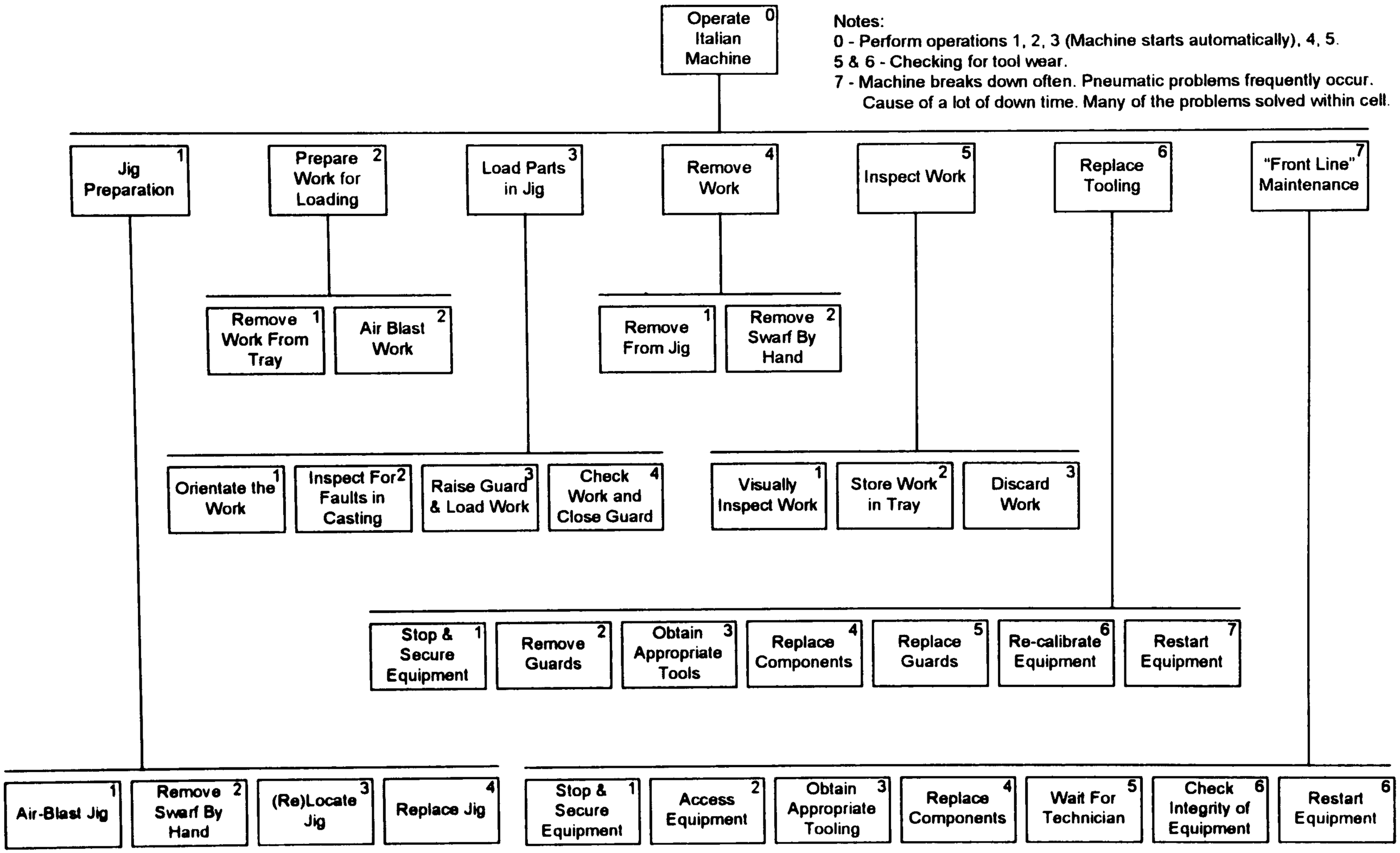
G1.2 Functional Diagrams for Cell A

The following figures describe the first two levels of the hierarchical analysis for Cell A.

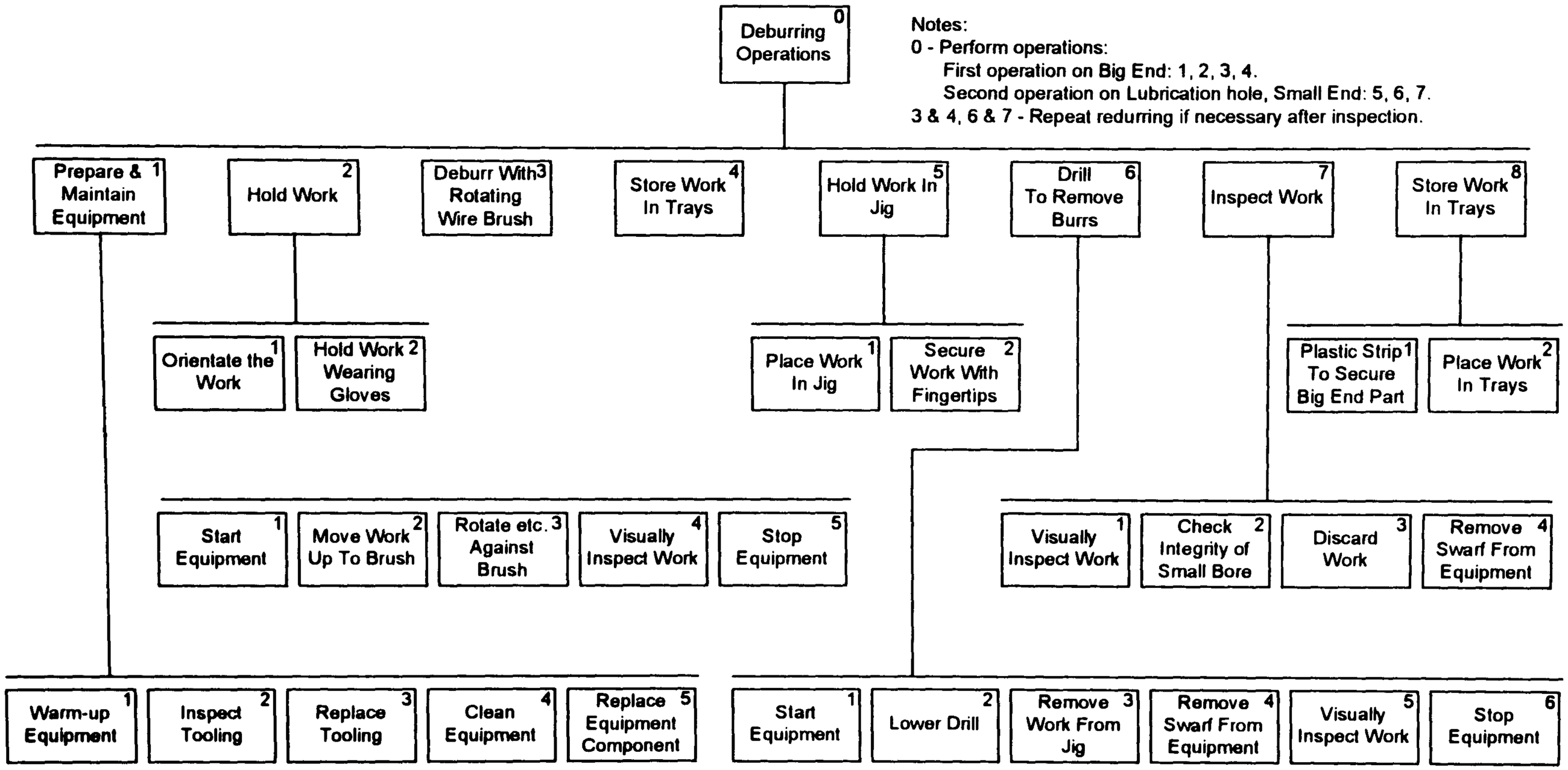
Functional Analysis - Cell A



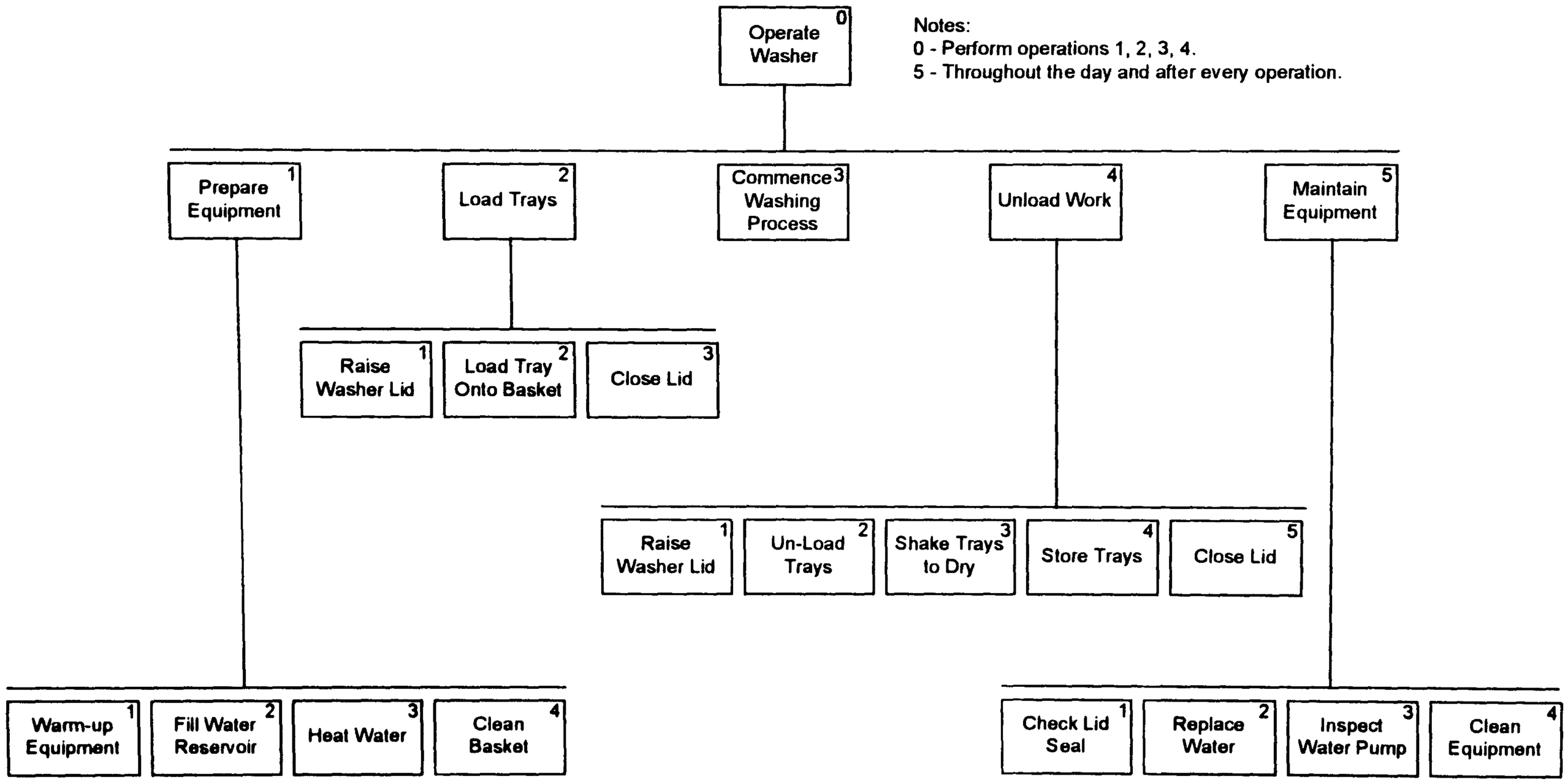
Operate Primary Machine (01)



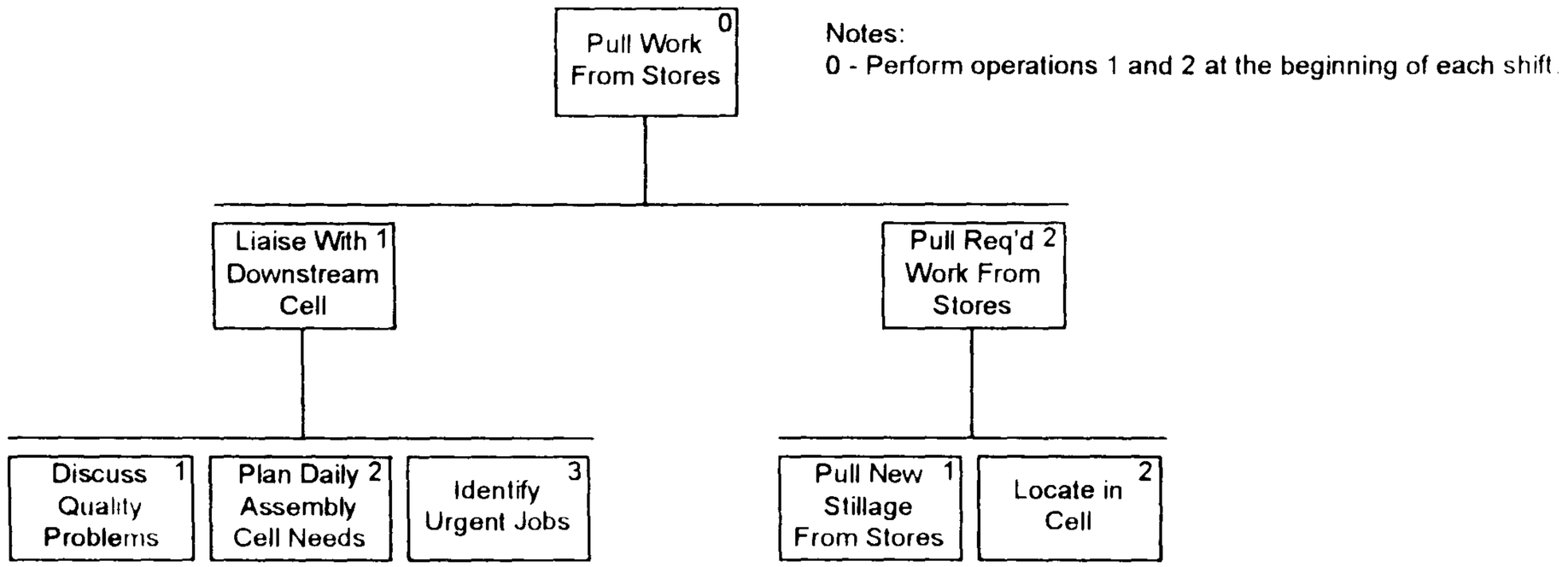
Deburring Operations (02)



Operate Washer (03)

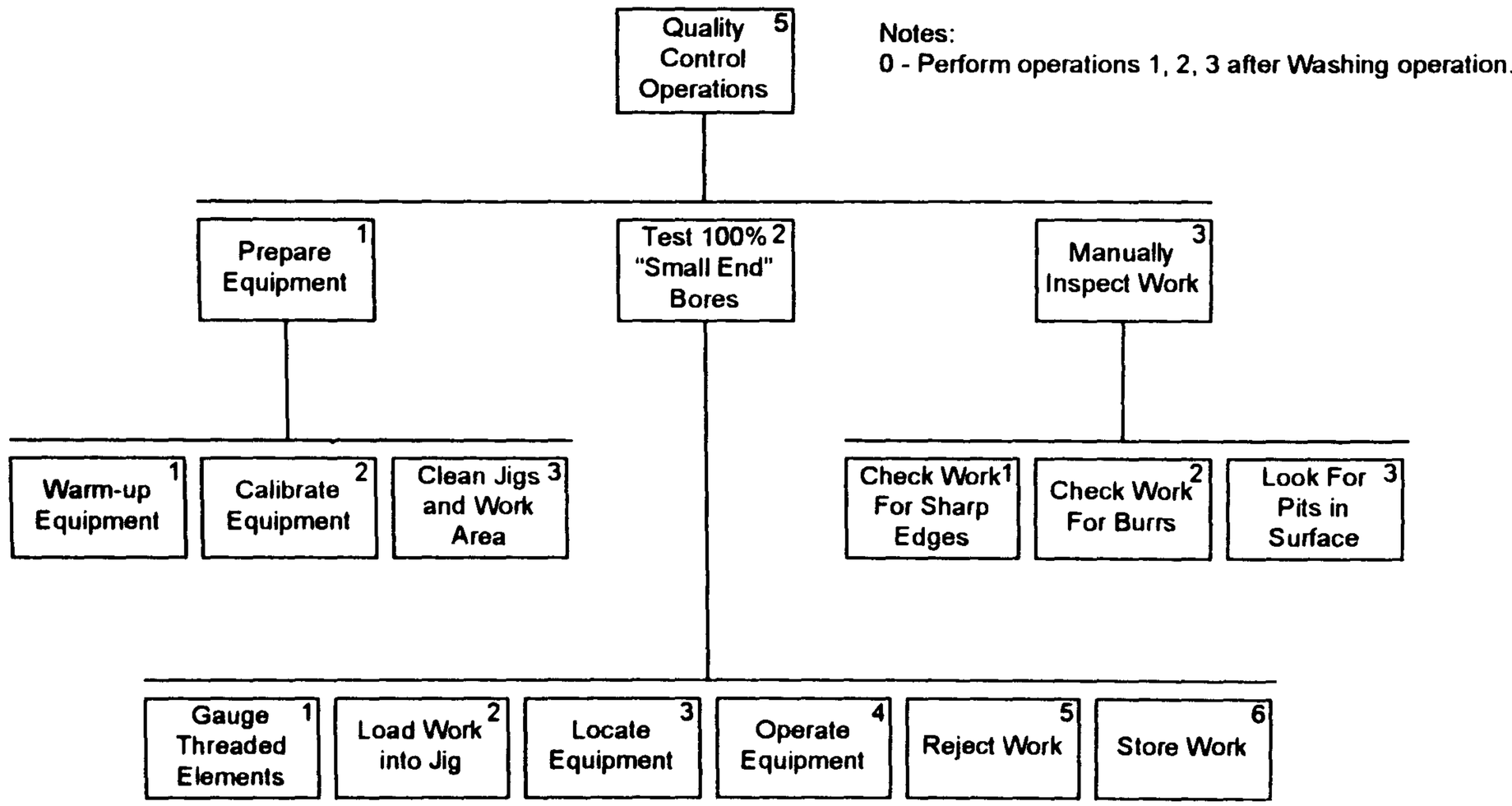


Pull Work From Stores (04)

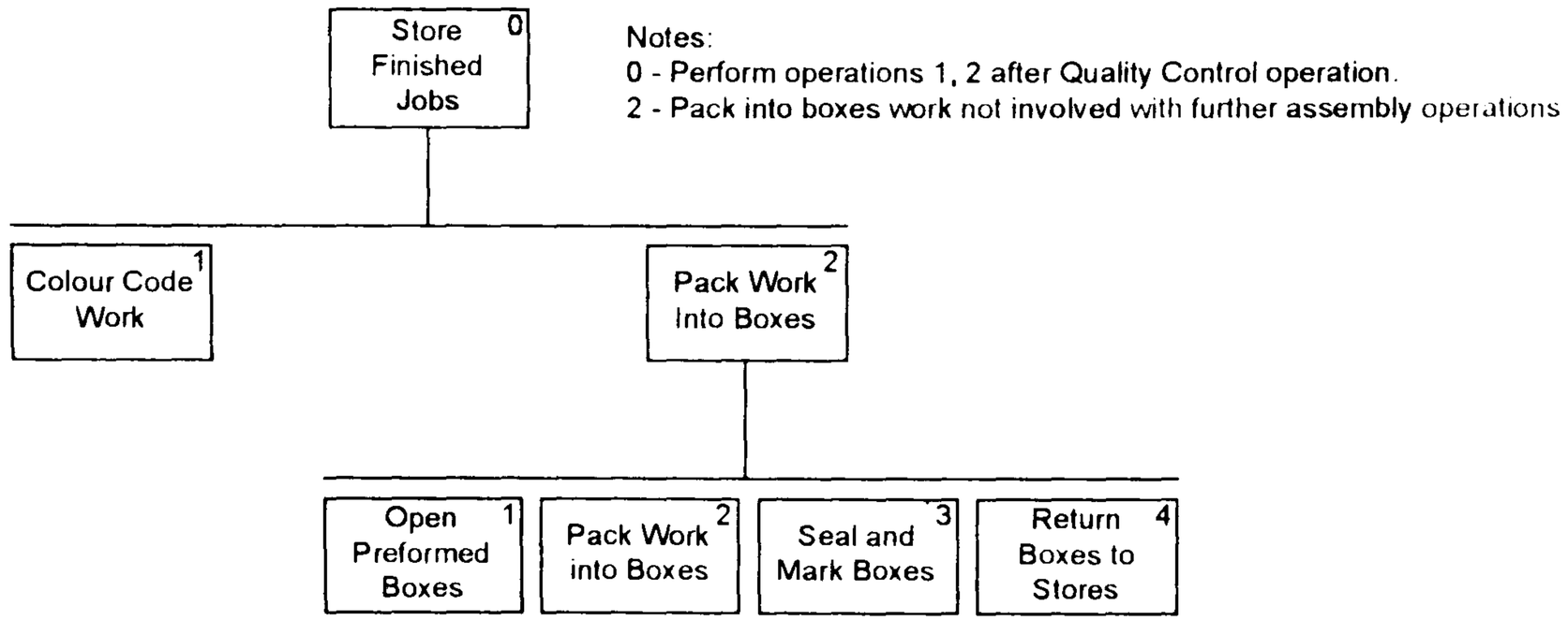


Notes:
0 - Perform operations 1 and 2 at the beginning of each shift.

Quality Control Operations (05)

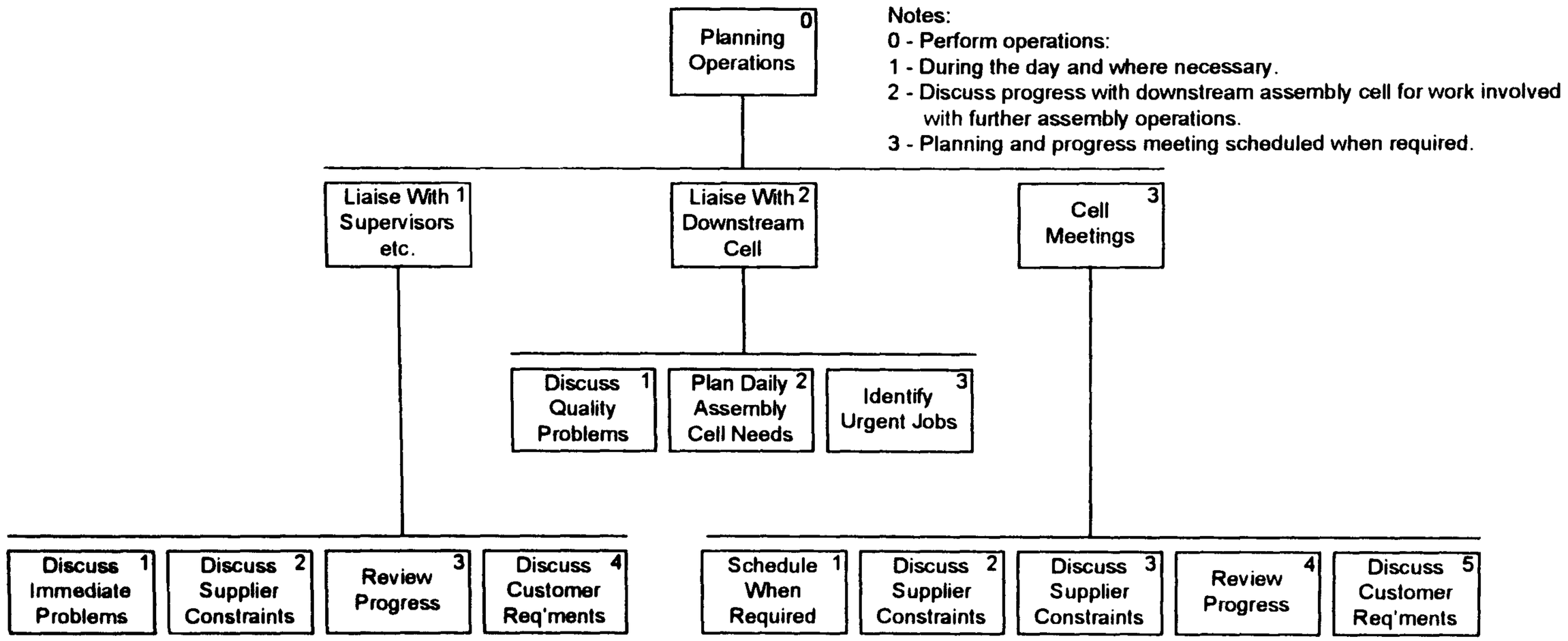


Store Finished Jobs (06)

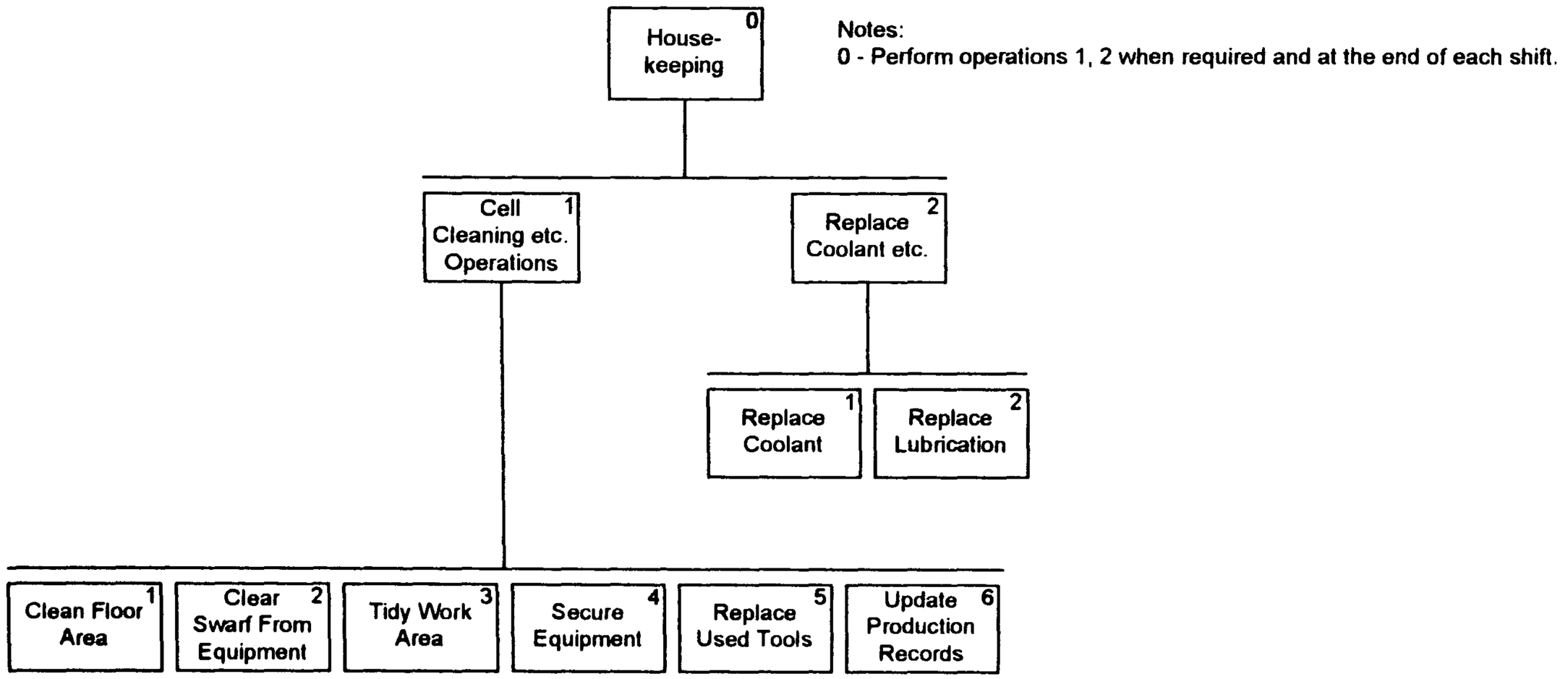


Notes:
0 - Perform operations 1, 2 after Quality Control operation.
2 - Pack into boxes work not involved with further assembly operations

Planning Operations (07)

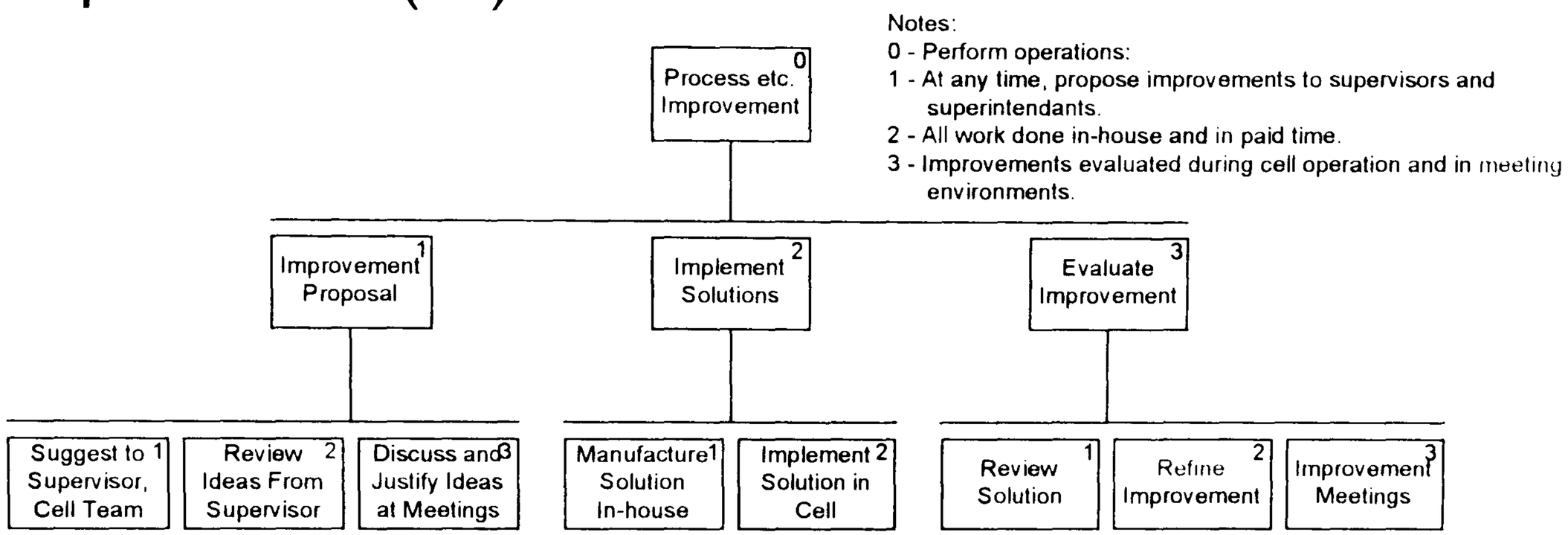


Housekeeping (08)



Notes:
0 - Perform operations 1, 2 when required and at the end of each shift.

Process Improvement (09)



Notes:
0 - Perform operations:
1 - At any time, propose improvements to supervisors and superintendants.
2 - All work done in-house and in paid time.
3 - Improvements evaluated during cell operation and in meeting environments.