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Design Techniques for Factory Management Information System Using Human Factors Applications

by

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ABSTRACT

As an application of the Industrial Engineering field of Human Factors which aims at a higher work efficiency and effectiveness, improved productivity, safety, and user's convenience, this research illustrates the techniques used in the design of a management information system for use of effective reporting at factory management level in a manufacturing environment applying the Total System Design approach. The components of the system include the human-beings who are constituted of the primary users namely the factory and departments managers, and the secondary users, namely the operating clerks. The components include also the computer.

A strong background has been established through reference to the relevant literature, essentially in Human Factors. The literature review proceeds through applicable first principles related to human performance and design considerations, towards recent papers describing experiments empirical results and guidelines that covered the visual displays of information and human computer interface.

In the first stage of the system design process, having defined the objective and identified the users, data related to the users' needs have been collected, and design alternatives are detailed.

It is found that the design alternative that satisfies the system objectives requiring communication of the daily and monthly production quantities effectively and in a presentable format, is a production summary report including actual and planned values in the form of tables, plots and remarks to be circulated and communicated in the factory daily management meeting. Major production results are to be plotted and presented monthly using overhead projector transparencies. The outputs are aggregated in a manner that the audience, made of experienced, field-independent engineers, readily perceive and interpret.

The operators are found to be knowledgeable intermittent users who are experienced in the domain of production calculations, and occasionally use computer.

Applying functional analysis, the tasks are allocated to the humans or computer relying on strategical approaches and rules defined in the Human Factors literature, such as the mandatory, balance of value, affective and cognitive support, and economic rules.

In the interface design stage, the daily report is designed as well as monthly graphical representations. The former is automatically prepared by the computer using the developed program. The monthly graphs are plotted in an interactive manner using QPRO 4 spreadsheet package graphical capabilities.

The daily report processing involves output and input screens design including arrangement and colors. The interface includes also user guidance, and computer messages that provide feedback and tools for effective human performance and motivation.

The menu style is applied as the predominant dialogue design to match the users category. Questions and answers, and data entry are used to a lesser degree.

The hardware to which the system is fitted including PC standard keyboard, mouse, super VGA display, and printer are described from the ergonomic point of view. They are satisfactory.

To support the human performance, a balance of materials is identified in the facilitator design stage for both designed work modules of the analyzed human tasks.

The defined human performance requirements for the operators including speed, satisfaction and motivation, and skill acquisition, are evaluated. Similarly, the managers' fast and correct interpretation of outputs is justified.

Finally, the system designed in an iterative manner and the developed application program satisfy the objectives of the thesis within the defined scope. Thus, it is recommended that the design be implemented in practice. It should later be tested and re-evaluated. The developed program is not only reliable but also can be maintained to match the users' changing needs.

CHAPTER ONE

INTRODUCTION

Although computers, especially Personal Computers (PC), have become widespread and reach many users, but, in Jordan, computer-based Management Information Systems (MIS) have not in the industrial companies. According to a recent report, only 5% of major business functions are computerized (1). The report claims that there is a clear dissatisfaction with software houses because they are hardware driven, apply inadequate customization, and implement piecemeal solutions. The main problem with information is timeliness and completeness. On the other hand, operational and clerical functions are the main beneficiaries of existing information systems, while tactical and strategic functions are incidental beneficiaries. Thus, true MIS and Decision Support Systems (DSS) are a rarity at the present time (1).

As a result, the industry is losing an opportunity for improving competitiveness through higher productivity and timely delivery. This is, in addition, to the considerable costs incurred in the initial investment, rehabilitation, and operation of such information systems. For example, in the Jordan Cement Factories Co. (JCF), an operational level maintenance MIS, commissioned in mid 1980's, is still not totally functional.

The above mentioned report highlighted several issues including: staff reluctance to accept automation, inadequate attention to training, and improper reporting (1). Such issues may be related to the lack of considerations to Human Factors (HF). On the other hand, complaining about difficulty of computer systems and of not using them is not only specific to Jordan. This is shown later in the chapter. Some reasons for not using HF in such applications may be enumerated as follows:

- HF is a new field that started after World War 2.
- Literature in HF applications to computer systems and information displays has recently emerged and flourished.
- HF is a field of Industrial Engineering (IE) that has just recently been realized in Jordan.

1.1. DEFINITION OF THE PROBLEM

The purpose of this research is to demonstrate the application of design procedures for effective information systems for use in the Jordanian industry. Such a system is based on the latest HF principles applied in proper design of computer hardware, software and information displays according to human-system interface analysis. This research aims at demonstrating how HF can be applied for the design of part of an effective MIS, for use in the Production Department of JCF Co.; chosen as an example, with the following objectives and constraints.

1.1.1. Objectives

The objectives are:

1. To provide 'good' information for the use of factory management.
2. To apply HF principles in the design.
3. To use current technology with cost consideration.
4. To allow maintenance and updating.
5. To ease training, and induce user friendliness.
6. To consider health aspects.

1.1.2. Scope

The scope of the sample MIS will include all stages of Total System Design (TSD), as explained later in the chapter, with the following constraints:

The focus is not on developing a completely functional integrated MIS or database management system, nor to develop a complex program to do reporting in a real company. Therefore, with the above mentioned scope in mind, no elaborated data or otherwise security measures, nor networks are in the prospect. The focus is also hardly aiming at answering 'what-if' questions or developing a DSS. However, the methods developed to design the information system for demonstration can be applied to develop fully operational MIS/DSS in the industry to increase productivity.

The potential users of outputs are, hereby, defined as Works Manager and Department Managers. Therefore, the relevant time frame of the information system will range from daily to one year, and all inputs, processing and outputs will be in English.

The application is adapted to a PC environment. The computer will be IBM compatible with sufficient RAM (about 1 Mb) and hard disk storage capacity (20-40 Mb). Its microprocessor will be Intel's 80286 or above. The accompanying hardware will include a standard keyboard, a VGA monitor or above, and a near letter quality (NLQ) printer or better. The hardware in mind will be evaluated from the HF point of view wherever applicable. The evaluation is not aiming at confirming the selection of the equipment to be used for the sample application program, or otherwise.

The HF design techniques are applied wherever possible within the framework of the packages and the proposed system. Thus, the design follows the principles in as much technical application as possible within the software and hardware limitations.

No effort is made to perform actual measuring of system performance, task performance or human performance such as measuring of accuracy, speed, skill development time and user satisfaction. Also, there is no measuring of observable human behavior nor non-observable intellectual process as when hoping to have some clues about causes of human performance improvement. The last stage of TSD, namely testing and evaluation, will not be done. Such experimental testing would include a factorial design of many levels. It is not because such an evaluation is not necessary but because of the long time it will take. However, real functional design will use such experimental testing. Thus, the evaluation of the design in this research is limited to analysis mainly based on my personal experiences during the research.

For the purpose of the thesis, it is assumed there is virtually no control of the designer over the users' selection, training or motivation, and thus, focus is rather on the general user with management perspective. However, the actual human component (the specific prospective user) of the proposed system, characterized by his sensory receptors, processing (cognitive) brain and responders, or by his abilities, deficiencies, health, skills or motivation, are not to be discussed nor described. In addition to that, no 'formal' Human Computer Interaction (HCI) methods are to be applied aiming at analyzing the users.

The context may include the room where the computer is located and the environmental conditions such as: illumination, noise and temperature. It may also include the workstation itself including the computer and its peripheries, and the workbenches and chairs. Although, all of the above-mentioned is very important from the HF point of view, nevertheless this is excluded from the focus of the thesis.

1.2. HUMAN FACTORS AND ITS APPLICATIONS

HF, which is also sometimes called, depending on what is to be emphasized, Ergonomics, Human Performance Engineering, Human Engineering, and Engineering Psychology, is concerned with the human beings and their interaction with all that constitute their everyday living (2).

HF is gaining much acceptance as a major source of principles and data pertinent to the design of systems, product liability litigation and the use of warnings to enhance the safety of products, our life space including cities and buildings, and highway and related facilities (2).

1.3. CRITERION MEASURES IN HUMAN FACTORS

Three types of criteria can be applied to HF related research, namely the system-descriptive criteria which reflect the engineering aspects such as reliability and maintainability, the task performance criteria which reflect the outcome of a task such as number of errors of the system, and human criteria such as performance measures, physiological indices and subjective responses (2).

Human Performance may be defined as "the result of a pattern of actions carried out to satisfy an objective according to some standard. The actions may include observable behavior or non-observable intellectual processing". Accuracy, user speed, skill development time, and user satisfaction are the major standards of human performance for designers (3). Effectiveness includes measures such as increased convenience of use, reduced errors, and reduced latency (increased speed) (2).

1.4. SYSTEM DESIGN APPROACH

1.4.1. Conventional Approach

The following line of reasoning is used in the conventional approach: (1) Gather information and fact. (2) Formulate the problem. (3) Explore alternatives. (4) Select the solution. (5) Detail the solution. (6) Finally, implement the solution (4).

In the conventional approach, the designers widen the area of search for a solution of a design problem, thus, generating a universe of alternatives that are quite innovative but may not be suitable for the selected project. As a result, much effort is put to produce limited solutions because "the designer often gets involved in doing well what may not need doing at all, instead of focusing on the guidelines of purposes" (4).

1.4.2. System Approach in Human Factors

A comprehensive systematic approach to the design process, devised in the first place for the major military and space systems, has been developed. Such an approach is called *Total System Design* (TSD) which is a developmental approach of clearly defined stages that gives ample attention to human performance. Thus, the major system components (the people, hardware, and software) are given equal considerations in the developmental process. Using this approach the design stages can be simplified as follows (2,3):

Stage 1: Determining objectives and performance specifications.

Stage 2: Definition of the system.

Stage 3: Basic design (Function Allocation).

Stage 4: Interface design.

Stage 5: Facilitator design.

Stage 6: Testing and evaluation.

In the development of some systems, some aspects related to the above stages may be irrelevant, especially, if the system that is under consideration is simple. Consequently, the particular aspects of the design process that are relevant should be the ones that should be given attention. In practice, the stages often overlap and are performed iteratively.

1.4.3. Users

The users that are supposed to be involved should be identified. The primary users, who are supposed to be the employees to be using the output, are normally the potential participants. The secondary users, i.e. the ones who operate the system are also involved (5).

On the other hand, systems should be designed such that they incorporate the perspective of change:

-Since people, at time of design, may be unknown, or depart after implementation of the system if have been known, the system must be directed to a general audience.

-The system must be designed in an adaptive manner to be able to modify later on to the users' changing needs (6).

1.5. MANAGEMENT INFORMATION SYSTEMS

MIS has been given many definitions. For clarifying the concept, the simple definition given by Kroenke is used: MIS is the "development and use of effective information systems in organizations". On the other hand, DSS is a collection of models and data which support managers in making decisions on unstructured problems (7).

1.5.1. Management

MIS is supposed to help the management with its mission and attaining its goals, which the management usually does through planning, controlling and so forth. Planning is the process of setting objectives, taking account of available resources and constraints, and determining a course of action and the required means. Controlling involves the process of comparing the actual results with the proposed objectives and correcting them where necessary.

1.5.2. Information

There is a clear distinction between data and information. Data refers to raw facts concerning people, objects, events, or other entities. On the other hand, information is acquired as a result of processing data with the purpose of describing the characteristics of the entity. 'Good' information has to be pertinent, timely and accurate. It reduces uncertainty about the entity (7).

1.5.3. Information Systems

A system is an entity that exists to carry out some purpose (2). An information system is a group of components that interact to produce information (7).

1.6. MANAGEMENT INFORMATION SYSTEMS IN MANUFACTURING ORGANIZATIONS

In addition to the internal support of the information system to the organization, it does support the organization externally through improved product quality, and meeting delivery schedules. Thus, it results in a competitive advantage (7).

Reporting systems are vital in companies success. Information systems help motivate managers to implement the companies strategies.

1.6.1. Management Levels in the Organization

Organizing in the first place serves accomplishing jobs and tasks, reduces duplication, clarifies responsibilities, creates stability, makes authority formal, and provides framework for resolutions of conflicts. Formal organizations are "documented, their functions and authorities are formally defined, they are organized by company organization charts" (7).

The higher the level in the hierarchical vertical organization, the broader the vision required and the longer the time frame to be considered. Information is communicated up and down the line of the organization. To survive and avoid conflicts with organizations being characterized as intended". Such goals go in parallel with good IE practices. Thus, there exists an intersection among IE, Information Management, and Software Engineering (10).

HF is a field of IE that is considered in the design problem. Designing of software product should have consideration for the user. "Rather than strive towards the much-overworked term user-friendly, the whole system requirements should be integrated including user-centered requirements analysis, etc." However, there is not a great degree of freedom in design; HF needs also to compromise between power, usability and economy, and balance with hardware and software limitations. This may reduce the available alternatives (10).

1.8. COMPUTERS

A computer is a system that consists of input, output and a processor. Depending on the size of the memory, the processor speed and number of users that can be simultaneously served, the computers can be classified into the following types with overlapping in most cases: supercomputers (transputers), mainframes, minicomputers and microcomputers, known also as PC. In addition to the central processing unit (CPU), in which the computer performs the arithmetic and logic operations, the computer system configurations typically include: a keyboard for data input, disk drives that read and store data on floppy or hard disks (as secondary storage), a monitor that displays data and that is used for editing, and a printer to produce the output in the form of printed material (hard copy).

Main memory, including the random access memory (RAM) and secondary storage capacities have become quite large, that they can accommodate relatively large business information systems. For complicated communications among computers and users, interconnection of micro-computers and various kinds of terminals is quite possible.

Several kinds of computer output devices are possible. The most important are the monitors and printers. Monitors have also become very much flexible, using colors (thousands of color shades), and high resolution video graphics (super VGA with 1024*768 pixels). Hard copies are also quickly produced with wide range of letter qualities.

A variety of input devices are available in the market. Other than the keyboard, mouse, digitizers, light-pen etc. have become popular.

1.9. HUMAN COMPUTER INTERACTION

People have realized and complained for a long time about difficulty of computer systems, especially when it became widespread as a result of microcomputers reaching many users (11).

Design is not an intuitive process. "True, some designers have a flair for finding innovative and good designs, but most people do not" (11).

Although computers have been for such a long time without considerations to HF, this does not mean such resources

CHAPTER TWO

LITERATURE REVIEW

The aim of this chapter, relying heavily on literature review, is to give some background and insight of certain concepts of the thesis through appealing to some selected references essentially in Human Factors.

2.1. OBJECTIVES AND APPROACH OF HUMAN FACTORS

HF aims at a higher work efficiency and effectiveness through less errors, improved productivity, and user's convenience. Another objective of HF is the enhancement of some desirable human working conditions such as safety, less fatigue and stress, comfort, job satisfaction and quality of life (2). Defining the approach, Sanders & McCormick state that "HF discovers and applies information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable, and effective human use" (2).

2.2. THE HUMAN PERFORMANCE PROCESSES

In designing systems for optimal human performance, the senses and the physical capabilities of the body need to be understood. The brain processes are important as well in the study of HF. *Cognitive processes* or *cognition* are those brain processes that are situated between the sensing and movement. Three stages of cognitive processing can be assumed, namely *perception*, *intellection* and *movement control*, in addition to the brain processes of *memory* and *motivation*. The model shown in figure (2-1) illustrates the major human performance processes (3).

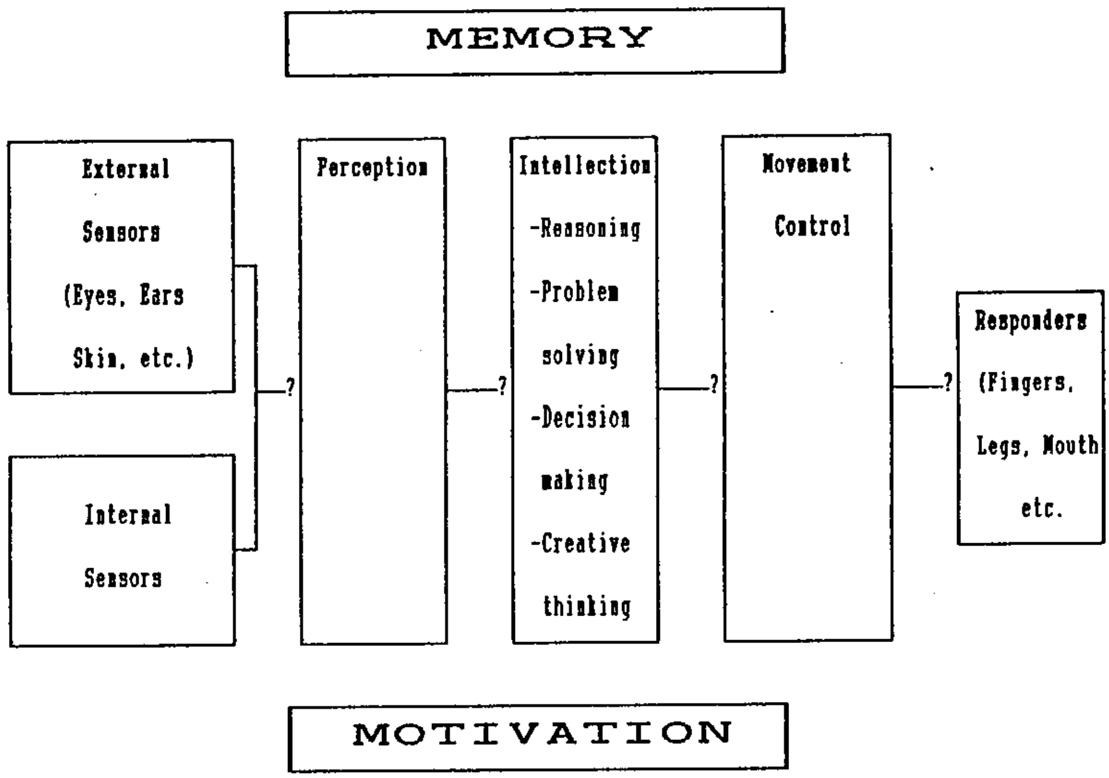


Figure (2-1): Stage Model of Major Human Performance Processes. (Source: Bailey, 1989, pp. 93).

2.2.1. Sensing and Systems Design

In systems design, the most important senses are: *vision, auditory*, and *kinesthetic* (related to the position of the body), in order (3). Although touch is not a great deal consciously used in human-computer interaction, tactile feedback conveys important subconscious information (15).

2.2.1.1. Visual Processing

The human visual system is designed to produce organized perception in terms of motion, size, shape, distance, relative position, and texture (15).

In this context, it is worthwhile defining certain key terms. *The visual angle* is defined as the angle subtended by an object at the eye. *Visual acuity* defines the minimum visual angle which can be resolved (2,15).

2.2.1.2. Kinesthetic Sense

It is used when people are positioning, making movements, controlling forces, judging weights, and so on. Although audition is the second most important sense related to human performance in many systems, in the human-computer interface the kinesthetic is probably more important (3).

2.2.2. Movement and Human Performance

In human output and control, movement becomes an important issue. Movement is directly related to human performance.

Movement of the body members, and, thus, the physical activities are controlled by the skeletal muscles. The control may be conscious, or innately automatic or through learning by experience or training (2).

2.2.2.1. Work Space Envelopes

Relevant to the design criteria is anthropometry which deals with the measurements of the dimensions and certain other physical characteristics of the body. *Anthropometry* is used in defining, for example, the functional arm reach. Limits of work space envelopes are determined by the functional arm reach and nature of the manual activity. Thus, they provide data relevant for the design of the activity.

2.2.2.2. Speed of Movement

Total response time consists of reaction time and movement time. Movement time depends on the nature and direction of the movement.

2.2.2.3. Distance of Movement

The speed of movement is not proportional to the distance traveled. Movement time first increases more sharply due to acceleration until maximum speed is reached. At the end of the movement span, secondary or corrective movement is required to bring the body member to the precise position.

2.2.2.4. Accuracy of Movement

Accuracy of movements in blind positioning, such as of the hands or fingers, depend on the kinesthetic sense for feedback.

2.2.2.5. Compatibility

Compatibility refers to the degree of consistency with human expectations. Compatibility of relationships between controls and displays can be *spatial* and *movement* compatible. Compatible relationships result in faster learning, faster reaction time, fewer errors and higher user satisfaction.

2.2.3. Memory Considerations in Systems Design

There are three kinds of memory: sensory, short-term (STM) and long-term (LTM). A new theory of memory postulates a single store with two different states: *active*, and *inac-*

tive. The active state of memory corresponds to the old concept of STM, but functions as a *working memory*. The inactive state of memory corresponds to the old concept of LTM. Consequently, STM is not thought as a separate store (13).

2.2.3.1. Sensory Memory

Each sensory channel has a temporary storage where the stimulus is maintained for a short period. The *iconic* storage is associated with the visual channel and the stimulus lasts there for about 1 second. The auditory channel has the *echoic* storage. The auditory stimulus is maintained in the sensory memory for a few seconds (2).

2.2.3.2. Working Memory

Information in working memory is coded with three types of codes: *visual*, *phonetic*, and *semantic*. Visual and phonetic codes are visual or auditory representations of stimuli. Semantic codes are abstract representations of the meaning of a stimulus rather than the sight or sound generated by the stimulus (2).

The capacity of the working memory is very small and correct recalling is possible only within a few seconds.

2.2.3.3. Long Term Memory

Long-term memory depends on encoding, storage and retrieval in the process of remembering and forgetting.

Knowledge Representation in Memory: It is thought that the knowledge people acquire and use is represented in some form of knowledge structure in LTM. Three main families of knowledge representation can be identified: propositional, analogical and procedural. *Propositional representation* refers to knowledge *about* something (ie factual or declarative knowledge) and assumes that knowledge of concepts is represented by a collection of *semantic features or attributes* (symbols). *Procedural representation* refers to knowledge about *how to do something*. *Analogical representations* are assumed to be responsible for the representation of *mental images* (13).

Information Storage: Facts having relationships, and which are thus linked together, form *associative knowledge*. Also, information in memory is not isolated. Knowledge is stored alongside other items of knowledge. Propositions and facts are stored within and alongside other facts to form *elaborated structures* of knowledge in memory. Through the processes of elaboration and inferencing, facts become contextualized in an interpretive knowledge structure. The effect of this elaboration and interpretation is that facts become stored as units of personalized knowledge that represent the individual's interpretation or understanding of the world (13).

Retrieval and Recall: Elaborated knowledge structures provide *redundant* retrieval cues and alternative retrieval routes. These routes make it possible for people to recall information by *inference* rather than directly (13).

Recall and Recognition: People are better at recognition than at recall. " With recognition the amount of forgetting is less" (3).

Learning and Memorizing Techniques: For long term memory to be usable for learning and recalling more information, it must be analyzed, and compared to past knowledge. The more organized the information is, the easier it is transferred to the long term memory, and the easier it is to retrieve (2).

2.2.4. Motivation Impact on System Design

The impact of system design have just recently been discovered to effect motivational levels of users.

Types of Motivational Influences: Two types of motivational influences can be distinguished namely internal and external. Both types affect the user. Money is a clear example of external influences. However, as can be concluded such influences are not normally under the system designers direct control. In contrast, the designer can affect the user's internal motivation through understanding the concept of such influences and applying them. As can be understood, internal motivation brings no obvious external rewards; but rather it is a "positive need for competence and self-determination, or as a search of optimal amount of psychological incongruity" (3).

Motivational Needs: People do have the drives of physical needs, and motives. But, also, people frequently do things because they feel good doing them, and because these activities represent a positive value for them, or because they simply have learned to enjoy performing the tasks. User achievement can be better felt when the system provides him with greater *responsibility, autonomy, and variety.* Figure (2-2) illustrates motivational needs (3).

Feedback is also an important aspect of system design, that keeps the user motivated.

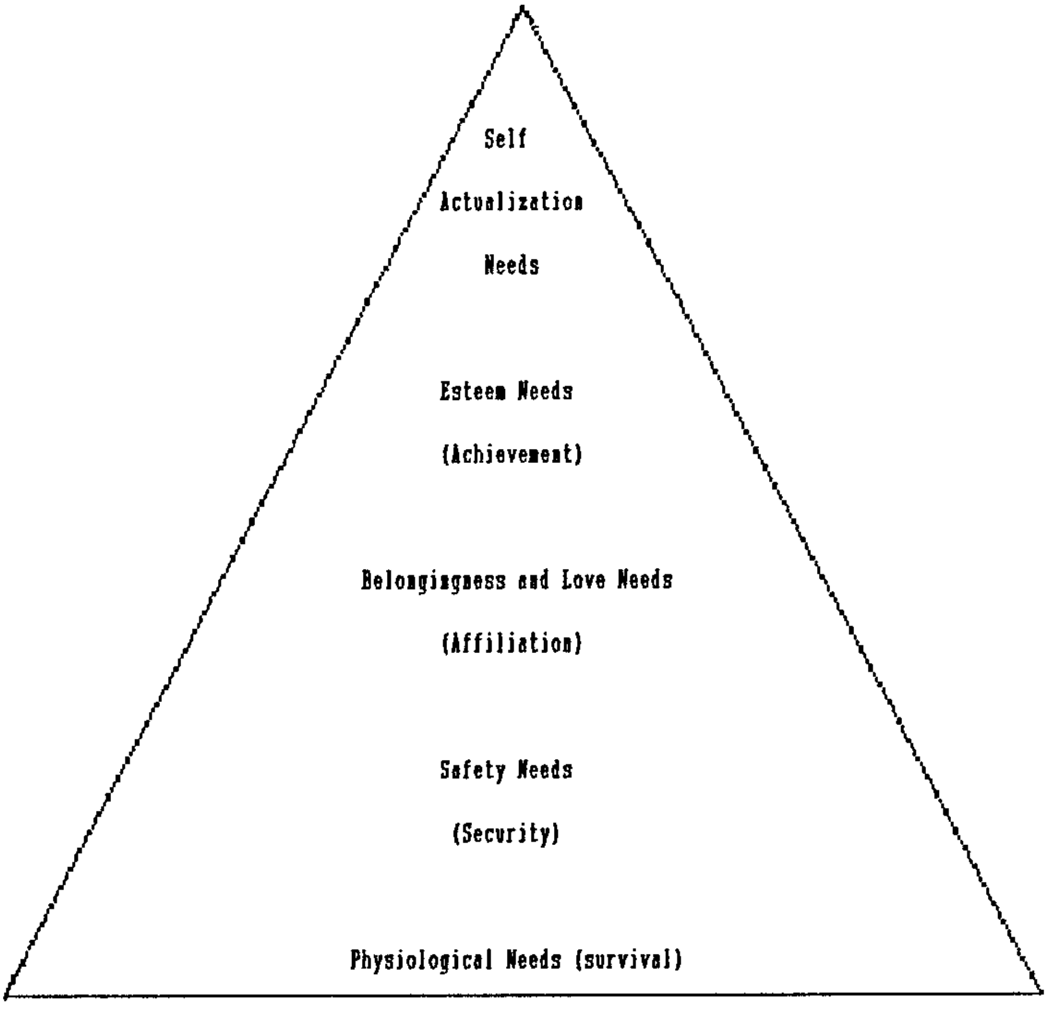


Figure (2-2): Maslow's Hierarchy of Motivational Needs. (Source: Bailey, 1989, pp. 159).

2.2.5. Cognitive Processing and Skills

Skill refers to a level of proficiency obtained in a specific activity. Skill is concerned with performance and the quality of performance, whether that is intellectual, perceptual or motor action (movement) (3,13).

2.2.5.1. Perceptual Skills in the Design

Perception is the process of receiving information from the outside. People interpret the physical world and develop some semantic representations of colors, sounds, objects, spaces, actions and events that are perceived (3,11,13).

2.2.5.2. Intellectual Skills

Intellection (sometimes referred to as cognition), is the mental activity described by reasoning, problem solving, thinking and learning. Intellectual Skills links perception with appropriate action through the mental activity described above (11).

2.2.5.3. Processing Levels

The skill acquisition theory, postulates three levels of skill acquisition: The *cognitive Level* during which the person learns the *facts* that are associated with the *domain* of the skill, the *associative level* during which the outcome is a successful procedure for performing the skill and performance improves in terms of speed and errors, and the *automatic level* (13).

2.2.5.4. Reaction Time

Relevant to the concept of cognitive processing is speed of performance and accuracy. Response time, discussed earlier is related to speed, and is constituted of reaction time and movement time. Reaction time refers to the time required to recognize a signal. Reaction time is affected by the stimulus modality (3).

2.2.5.5. Accuracy

Unlike reaction time, accuracy seems to be more under the person's control. Certain critical activities can be performed with near perfect accuracy (3).

2.2.6. Fatigue and Stress

Design features are evaluated, not only from the human performance point of view, but also, with respect to safety, physical effects and comfort, which in turn also affect performance (2).

2.2.6.1. Fatigue

Sensory factors can cause fatigue. Strong stimuli, such as bright colors, intense light and loud noise all cause sensory overload as they bombard the perceptual system and demand attention (11).

2.2.6.2. Stress

Stress refers to some undesirable condition, circumstances, task, or other factor that impinges upon the individual. *Strain* refers to the effect of stress.

"*Occupational stress* is suspected to be a major cause for cardiac and stomach disorders". The stress level is frequently associated with attention, information processing, decision making and uncertainty. The human-computer interaction may result in high stresses because it is high attention demanding and people may have to perform more than one task at once (16).

Too much or too little arousal for task performance results in low productivity, job satisfaction and worker's health. There is an optimal region of arousal needed for maximizing productivity, job satisfaction and worker's health. This optimal region may vary depending on the criterion to be optimized. See figure (2-3).

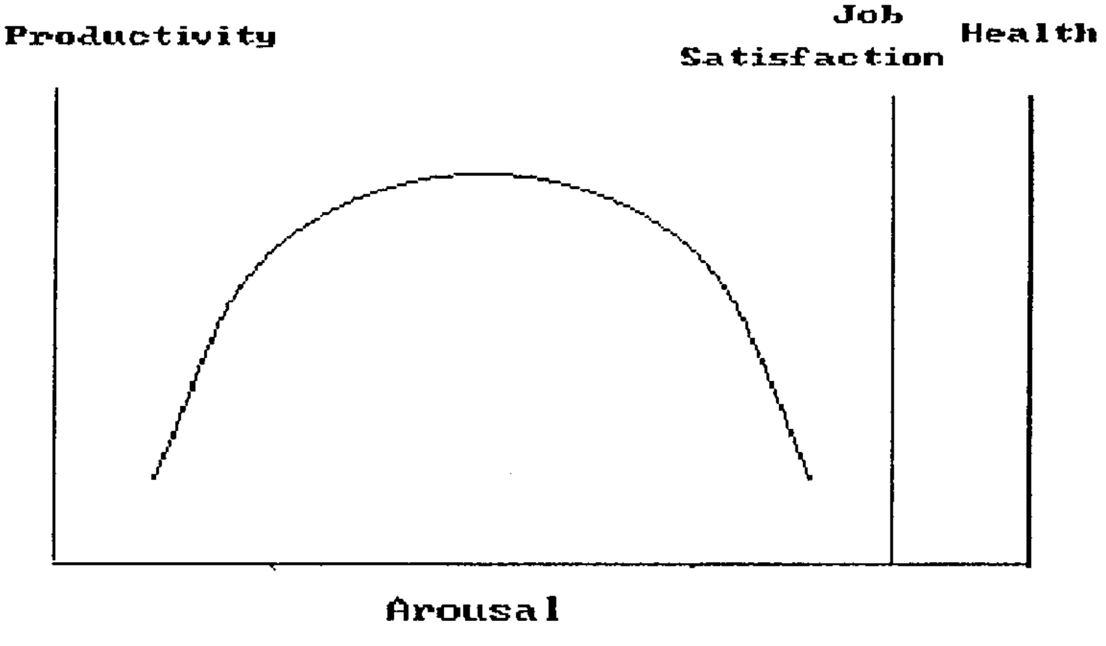


Figure (2-3): Tasks Arousal Effects. (Source: Salvendy, G., Ergonomics, 1982).

2.3. VISUAL DISPLAYS OF INFORMATION

"Display is a term that applies to virtually any indirect method of presenting information". Visual displays are probably the most commonly used displays. Static visual displays are those that display visual stimuli that are unchangeable or remain in place for a reasonable time. Such displays include alphanumeric, symbolic, identification, representational, status, and warning information (2).

2.3.1. Visual Coding

Good coding systems are characterized by their detectability, discriminatibility, meaningfulness, standardization, compatibility, and using of multidimensional coding (2).

Some of the visual coding dimensions are color, geometric and other shapes, letters, numerals, flash rate, visual angle, and size (2).

Sanders and McCormick (1987) reported a study of correct responses in which five different tasks were used in scanning the display (identification, location, counting, comparison, and verification), on single coding dimension showed that the numeric code was best. Then, color code followed. The third was letter. Shape and configuration codes were the worst (2).

2.3.2. Alphanumeric Displays

The following are HF criteria distinguished in written materials and visual display terminal (VDT): *Visibility* refers to the quality of a character or symbol that makes it separately detectable from its surroundings. *Legibility* refers to identifying and discriminating one alphanumeric character from another, by virtue of their features such as stroke width, and form of characters, in addition to contrast, and illumination. *Readability* refers to the recognition of the information content of the material when presented by alphanumeric characters in meaningful grouping such as words, sentences, or continuous text, through spacing, margin combinations, etc. (2).

2.3.3. Symbolic Displays

Symbolic signs are more preferable to verbal signs if the symbol properly describes the referent. On the other hand, symbolic coding may require more learning and recoding. The symbolic code should best represent its referent. This depends on the strength of association of a code symbol with the referent. One important aspect of symbols is simplicity. Such geometric codes are the icons which are used in VDTs designs (2).

2.3.4. Content in Information Representation

Representing the complex features of a problem is one aid in reducing informational demand. However, it is important not to omit any of the essential elements of the problem. Also, one strategy to use in order to make correspondence between information load and processing capacity is to reduce the problem into subproblems (17).

Another approach is to partition information into an optimal level of aggregation prior to its presentation to a decision-maker; such as exception reports, or summarizations (17).

2.3.5. Format in Information Representation

Remus (1984), in his attempt to find out *whether graphical or tabular displays are better*, designed an experiment using a production scheduling model (18).

Subjects were first given a presentation on production scheduling including several examples of how to use the graphical and tabular aids to make better decisions. Then, they were asked to *judge intuitively* on what to assign as production quantity, and workforce for 24 periods by considering the cost of overtime, workforce change, and inventory, which were presented to one group in tabular form, and to the other in graphical form. The performance was then measured in terms of the resulting cost while using either method.

The main finding of the experiment was that there is no significant advantage of either type of display.

Powers et al. (1984) conducted an experiment to find out *the form of data presentation* that is easiest to comprehend and is most accurately recalled. They presented data to subjects grouped in such a way that one group had to recall the presented data when attempting to answer multiple choice questions in three categories: A, B and C that increased in difficulty. The other group was allowed to refer to the distributed material while attempting to answer the questions. In either group, certain subjects were presented with data in tabular form, others in graphical form namely bar charts and pie charts, and the remaining in a combined form including tables and graphs (19).

As a result, the non-recall graphic/tabular combination achieved the highest percentage correct. However, the experiment showed also that when speed of performance is important, the above combination should be avoided due to overwhelmingly increased volume of information. Thus, when performance speed is important, it is better to represent the data in the most familiar form.

Benbasat, Dexter and Todd (1986) conducted three laboratory experiments to investigate the *effects of graphical and color-enhanced information presentation formats* on decision maker's behavior and performance in a decision making task and integrated the results with current literature aiming at giving insights and guidance for designers of information systems, using high resolution color graphics visual displays and employing a widely used graphics software package. The comparisons involved tabular versus line charts presentations, color versus monochrome displays, and users' cognitive styles namely field dependent versus field independent subjects (20).

The task setting in all the experiments involved the allocation of scarce monetary resources to various alternatives. The objective was to maximize the total income derived from these alternative resources. The main difference in the experiments was related to the length of the time namely ten decision periods, up to 30 simulated trials, and fixed time limit (5 or 15 minutes), respectively. Colors in the experiments were used as redundant attributes.

The researchers found as a <u>result</u> that the only benefit of graphical representations is to enhance decision making speed but solely if the report is designed to directly assist the applicable problem solving heuristic. However, a combination of tabular and graphical formats is found superior to either tabular or graphical formats if sufficient time is given to solve the problem.

Color was found to have a positive influence on decision making effectiveness; however, the benefits of color are more evident for graphical reports, under time constraints, during learning period, and strongly for field dependent individuals. Multicolor tabular presentations give no advantage over monocolor tabular presentations.

Boehm-Davis et al (1989), while pointing out to the conflicts on *the best form of representation*, studied the hypothesis that a match between the format of the information being sought and the format in which the information is stored facilitate performance. Two databases were used.

An 'airline' database was designed as a spatial correlate, given the natural spatial arrangements of cities and flights among them, including departure time etc.. A 'thesaurus' database was designed as a verbal correlate, given the semantic meaning relationships among words, including relational information of words in broad and narrow sense (21).

The results of the experiment supported the hypothesis. Performance as measured by both response time and percentage correct was best when the format of the database presentation matched the type of information to be retrieved. Also, performance of participants was improved when using the format of which (spatial, tabular, or verbal) matches the format they preferred. However, only preexisting preferences for information format played a role in performance although preferences may change with experience with an alternative form of representation. An important result also is that the format of a database that facilitate quick response are not necessarily the same forms as those producing accurate responses.

2.3.6. Graphical Principles and Design Techniques

In the early stages of developing graphics design guidelines, there were hardly any empirical data relevant to HF principles. One of the early studies was on labeling by *Milroy and Poulton (1978)*. One of the guidelines sources that rather depended on experience was by *Tuft (1983)* for whom "it comes out of experience and little research work has been conducted on the subject matter".

2.3.6.1. Labeling Graphs

In order to find a labeling method of line graphs that enables the reader to extrapolate data more quickly, *Milroy and Poulton (1978)* conducted an experiment comparing three different methods. In the first method, the individual functions are directly and separately labeled. In the second, the label is inserted in a convenient space in the graph field. In the third, legend is used as an explanatory key outside the graph field (22).

Subjects were asked certain specific questions that needed numerical answers. The time taken to read the graph was then noted.

As a result, the errors of the different methods of labeling were not significantly different. However, direct labeling proved to be significantly quickest. It is explained that subjects readily read the appropriate label and extracted the required value. In the other two methods, the subjects had to refer to the explanatory key first, retain in short memory until matching relevant function code and then extracting the value.

2.3.6.2. General Design Guidelines

High Information Graphics: The following principle is suggested. "Maximize data density and the size of the data matrix, within reason." The target is high-information graphics. Typical high information graphics are geographical maps. On the other hand, figure (2-4) shows an example of low data density graphical display (23).

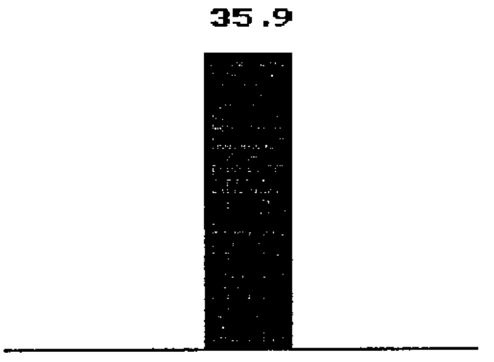


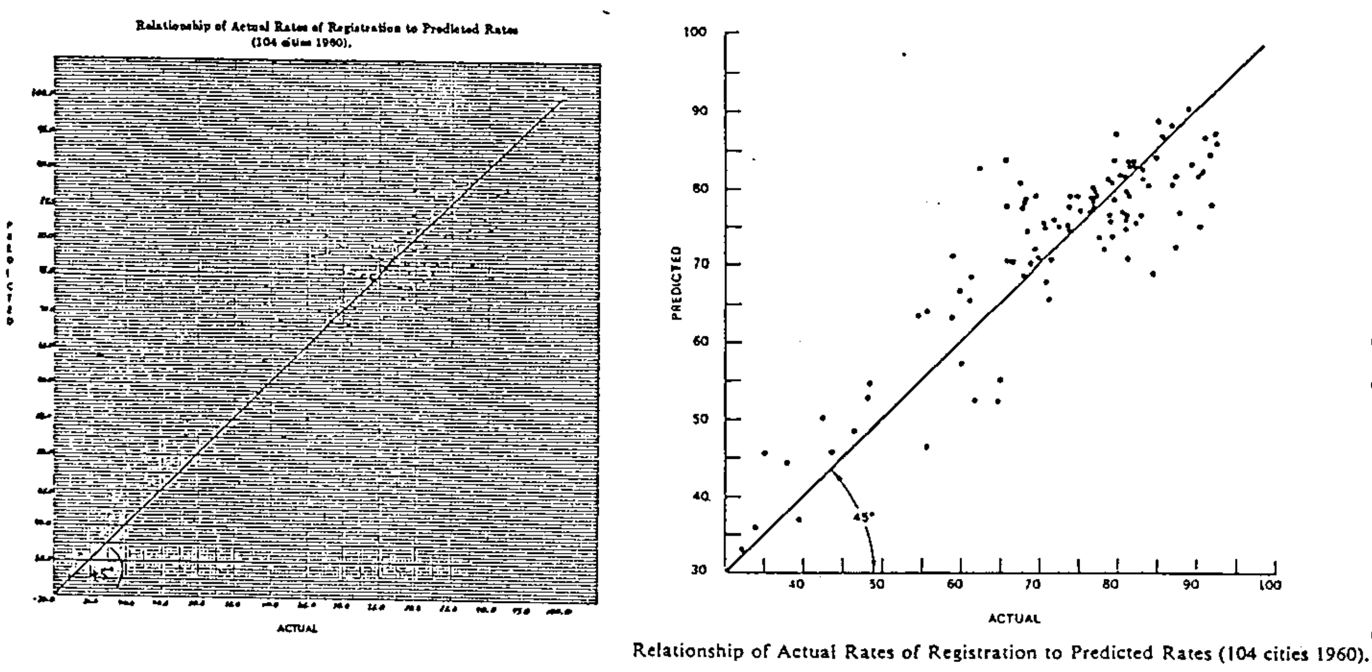
Figure (2-4): Low Density Information Bar Chart Display (Source: Tufte, 1983).

In addition to that, the shaded bar chart, in the above figure, locates the altitude in six separate ways: (1) height of the left line, (2) height of shading, (3) height of right line, (4) position of top horizontal line, (5) position of number at top of bar, and (6) the number itself. Thus, any five of the six can be erased and still convey the information (23).

On the other hand, in certain cases, redundancy can be used to give a context and order to complexity, facilitate comparisons over various parts of the data, or add an aesthetic dimension (23).

Focus of Graphics on Data Avoiding Clutter & Embellishment

The data graphical form should reflect the quantitative content of the data rather than data containers as a design strategy. Too many ornaments seem to distract and divert attention from the information to be communicated by the data (24).



Part 1 Part 2

Figure (2-5): Clutter and Data Focus. Part 1 shows overwhelming grid effect causing clutter while part 2 focuses on data. (Source: Tufte, 1983, pp. 94-95).

Two much 'non-data-ink' results in a clutter and fails to depict statistical information. Consequently, such a graphic is not interesting to the viewer (23).

For example, figure (2-5) presents the same graphic in two different manners. In the first display, part 1, with all its 'ink' devoted to matters other than data, the grid has an overwhelming effect. Another published better version of the same data is shown in part 2.

Uniformity of Graphics and Correct Perception: This principle requires that the representation of numbers, as physically measured on the surface of the graph itself, should be directly proportional to the numerical quantities. Parts 1,2, and 3 in figure (2-6) show examples of good perception and graphical distortion.

Visual representation is effected by the physically measured surface of the graphic, and by the perception of the visual effect. The misrepresentation of numbers on the physical surface can be measured by the *lie factor* (23):

$$\text{Lie Factor} = \frac{\text{size of effect shown in graph}}{\text{size of effect in data.}}$$

The Lie Factor should not be out of the range .95-1.05 so that the graphic is classified as reasonable.

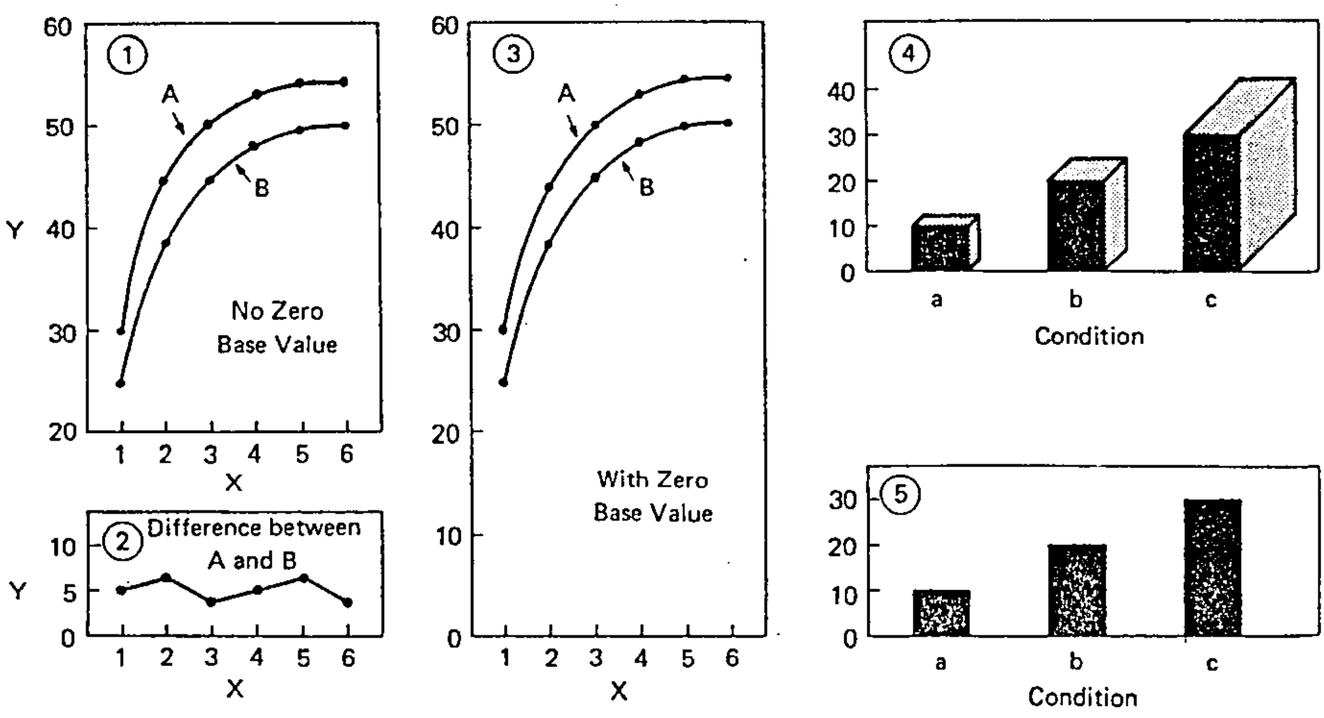


Figure (2-6): Examples of Possible Distortions in Perception of Data Presented in Graphics: Part 1 can suggest that the difference between A and B increases; however, part 2 shows that this is not the case. Part 1 also can imply that both A and B are lower than they really are; part3 (with a 0 base) corrects this impression. Part 4 can suggest disproportionate increases from condition a to b to c; part 5 corrects for such an impression. (Source: Sanders and McCormick, 1987, pp. 112).

Table (2-1): Basic Judgments of Graphical Perception

(1) Position along a common scale.
(2) Position along identical but non-aligned scales.
(3) Length.
(4) Angle.
(5) Slope.
(6) Area.

For example, a histogram requires judgment of positions. A divided bar chart requires position and length judgments. A line chart having a local rate of change requires a slope judgment.

In the experiment, subjects judged the seven types of stimuli. Then, the average of subjects absolute errors were analyzed.

The results showed that the two position judgments were the most accurate. Length was next. Angle and slope were comparable and appeared less accurate than the length and position judgments. The area judgments were found to be the least accurate. The researchers reported that previous studies showed also that length judgments were higher in accuracy than area judgments, and area judgments when compared to volume judgments were more accurate.

2.3.6.4. The Effect of Graphical Formats

Jarvenpaa (1989) studied the effect of different graphical formats on decision making and how they should be adapted to changing task environments. The scope included information acquisition, information evaluation, decision time, and quality of the decision (26).

When multicue information (i.e. coming from a number of sources, or having two or more attributes) must be combined (i.e. integrated) in some fashion by the human, displays with close proximity or proximate (i.e. physically integrated) will enhance system performance. For example, the vertical and horizontal positions of a point in a two dimensional space are integral dimensions that are processed together. Similarly, the line connecting two points in space does not only lead to the perception of the two points but also all points on the line between them.

When the task requires the information to be selectively attended or acted on, with attention focused on one variable (i.e. independent processing of each source of information or isolated attributes), displays with low proximity (i.e. separable or non-integrated displays) will improve performance. For example, the bar graph display is considered as a convenient format of a separable representation because it uses the same dimension (height) to display multivariate information. The digital displays (separate digits) are certainly separable representations that maximize the separation of variables.

Goettle and Wickens (1986) conducted an experiment in which subjects had to extrapolate data (a mentally integral task) from integral displays (coordinates (line) graphs) and separable displays (bar graphs), using different slopes. The coordinate graphs resulted in better performance than the bar graphs (27).

2.3.6.6. Object Displays

However, most of the work of Wickens and his collaborates with respect to the proximity compatibility principle was on dynamic displays. This gave rise to experiments of object displays. The object display typically represents several variables as attributes of a single geometric object such as triangles, rectangles and other multidimensional shapes which were mainly tested to represent multivariate data using detection and diagnosis tasks. In other words, two or more pieces of quantitative information are integrated in one configural unit.

For example, two variables may be represented by the height and width of a rectangle. The change in the variables can be perceived collectively by watching the change in the rectangle. Assume the height (h) of the rectangle represents fuel feed rate to a cement kiln and the breadth (b) represents the material feed rate. If (rectangle 1) at time 0 in figure (2-7) represents a balanced stable operation, then (rectangle 2) at time x might be perceived as representing improperly sintered output while (rectangle 3) at time y might imply overheating.

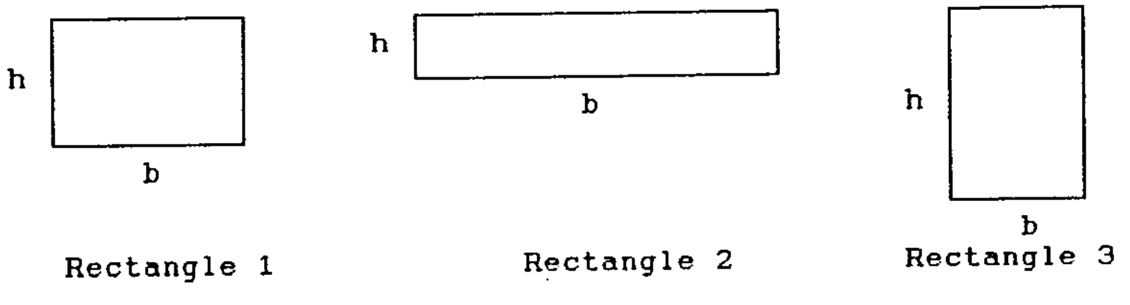


Figure (2-7): Rectangles as Object Display.

Carswell and Wickens (1987), for example, used a triangle for object display in a failure detection task where integration of information from multiple sources was required. The object display resulted in better performance than when a traditional bar graph was used. The bar graph was a better design for the multi-cue detection task that did not require integration of the information sources (28).

2.3.6.7. Emergent Features

In parallel, work on dynamic visual displays and comparisons between object displays and separable displays matured efforts in understanding emergent features. Emergent features are perceptual cues which could be physical or imaginary that tie graphs together and result in information integration. Examples of emergent features are ascending or descending linearity of tops of adjacent bars, as shown in figure (2-8).

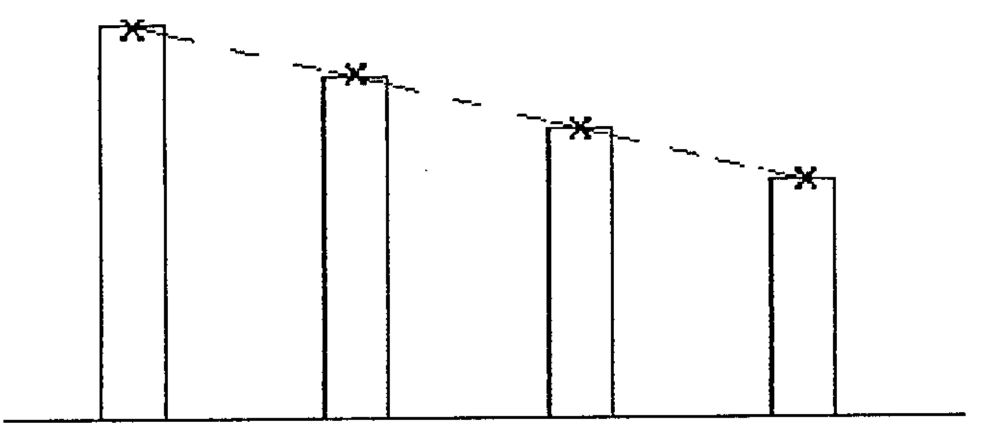


Figure (2-8): Imaginary Dotted Line on Top of Bars as Emergent Feature.

Using the same concepts of the experiments conducted by Carswell and Wickens mentioned above, *Buttigieg and Sanderson (1991)* applied the concepts of the emergent features and came with the conclusion that emergent features can be used to support tasks that require integration of information or separated focal information (29).

2.3.6.8. Graphical Taxonomy

Hollands and Spence (1992) capitalized on the different findings of research into experiments that investigated the hypothesis that performance with a particular type of graph depends on the judgment task (30).

Thus, subjects would judge change most efficiently with graphs allowing direct perception of change. This is consistent with the proximity compatibility principle which predicts that subjects will perform better with integral graphs in an integration task such as judging change. In this manner they predicted that line graph should produce better performance than the pie chart or the bar graph. A subject can directly perceive a change, i.e. whether a variable is increasing or decreasing, from the slope of the line.

The subjects would also judge proportion most efficiently with graphs that allow direct perception of proportion. This is also consistent with the proximity compatibility principle which predicts that subjects will perform better with separated graphs in a focused attention task, such as judging proportion. Therefore, they predicted that estimation of proportion should be better performed by a pie chart and a bar graph. With the pie chart, the subject perceives proportion directly. The part and the whole are represented by two physical objects- the slice and the pie- and are, therefore, immediately available to the perceptual system for discrimination.

In the first experiment, subjects fulfilled tasks of finding whether each variable is decreasing, increasing or no change, or of determining the proportion of the whole as percentage to the nearest integer. The tasks were performed on either line graph, bar graph or pie chart.

Assessing each judgment of change as correct or incorrect for the change task, more errors were made with pie charts than with line and bar graphs. Errors were more with smaller rates of change. Pie charts also required longer completion times than bar graphs. The latter required longer time than the line graph. Assessing judgment of proportion was done by finding the absolute difference between judged and true proportion. There were more errors with pie charts than either bar or line graphs. Again pie charts required longer completion time than bar graphs which needed longer time than line graph.

As predicted, the line graph as an integrated display, offered better information integration and, thus, judgment of change was better performed. On the other hand, the group of pies was worse. With the proportion judgment task, it was concluded that the line graph was also superior because of the scales on the axis; opposite to the pie charts which had no scales as is the convention. The bars also resulted in a better performance on judgment of change. The reason was attributed to the emergent features of the display. Subjects were connecting imaginary lines between bars tops. Thus, bar graphs can be considered as an integral graph in addition to its property as a separated display.

The second experiment was similar to the first but with the addition of divided and tiered bar graphs. Tiered bar graphs are formed of groups of bars presented on different levels (i.e. not aligned). Scales were used in half of the graphs only. It was proposed that scales would facilitate judgments in discriminating proportions. Tiered graphs were used to test the emergent features effect with groups of bars on different panels. In this manner, tiered graphs resembled pies. It was speculated also that perception of proportion should be direct with the divided bar graphs as with pie charts, and so would be performance when no scale is used. On the other hand, it was reasoned that with divided bars and pies reading a scale is a three-stage operation, compared to a one-stage operation of line and bar graphs. This would result in a better performance for the latter.

As expected the tiered bar and pie charts resulted in more errors in the judgment of change tasks. Errors were larger with smaller rates of change. The largest errors were when there was no scale. Completion time was best with line and followed by bar graphs. Divided bars required longer time. Tiered bar and pie charts required the longest time. With respect to judgment of proportion, there was no difference among graph types with a scale. Without a scale, divided bars and pies produced less errors. Completion time results were similar to absolute errors results. The results satisfied the hypothesis.

2.3.7. Visual Aids

One of the important factors that affect a manager's decision is the way in which the data are presented to him (18).

2.3.7.1. Overhead Transparencies

Awad (1988) cited a major study justifying the use of business graphics in the University of Pennsylvania (1981). The study assessed the use of overhead transparencies in business meetings. The main results were (8):

-Recommendations were more acted on when presented using transparencies.

-Presenting using graphics were perceived to be better prepared, more persuasive, and more interesting.

-Length of meetings were shorter. Decisions were made earlier using overhead transparencies.

2.3.7.2. Visual Display Terminal

In order to justify the use of VDT for presentation, different experiments related to the comparison of cathode ray tube (CRT) are studied as follows.

Swanston (1984) conducted *a study on speed of acquisition* *of tabulated information from VDT*. The study was considering reading task of an item in a tabulated set. This was done on a monochrome VDT in which the letter height was 5 mm. The reading distance was varied at about 56, 89, and 114 cm to study the viewing angle effect. The task was to read the number that was at the same horizontal line as a pointer located on the other side of the screen (31).

The results showed that the reaction time did not vary significantly with distance when the pointer changed position randomly.

Swanston (1984) conducted another experiment to check on the *effect of physical separation between pointer and target*. This was done on viewing distances as in the first experiment but the pointer was changing horizontally at five different locations.

The results showed that reaction time did not change significantly with distance. However, there was a significant effect of pointer target separation. This was ascribed to the effect of the increase of the size of displacement in eye fixation.

Gould et al (1984), in their attempt to study the *effect of working on CRT compared to hardcopy* applied a task of proofreading by using misspelled words in four different ways: letter omissions, letter substitutions, letter transpositions, and letter additions. Monochromatic displays, with green characters on a dark background, were used. Subjects could sit at any distance from the CRT or white hardcopy paper. Three classes of measurements were made: performance, feelings, and vision (32).

The key finding was that changes in participants performance, feelings, and vision were the same throughout the six hour periods for CRT and hardcopy. That is, there was no interaction between work period or display type. Taken separately, vision was not affected by type of display. Feelings ratings toward type of display were also similar. However, it was found that reading from hardcopy was faster 20 to 30% than CRT and, thus, significantly different. It was found also that the errors of proofreading were only slightly more with CRT than hardcopy.

Gould et al (1987), as a result of the previous study, did more research in order to find out the *reason behind slower reading from CRT compared to hardcopy, by isolating single variables* in a series of experiments. The isolated factors in the experiments were: good paper versus poor paper, paper orientation (horizontal and vertical), proofreading versus comprehension reading, reading distance, visual angle (changing character size), eye movement (a natural phenomenon during reading), photograph of CRT (as hardcopy compared to paper), different CRT, polarity (reversing of text with background color), and font type (33).

The results of the ten experiments showed that reading from CRT was slower than reading from hardcopy paper. The conclusion was that no single variable seemed to account for most of the reading speed difference. The difference was tentatively attributed to the combination of the different factors.

Harpster et al (1989) , in an experiment to explore the *visual performance on CRT screens and hardcopy displays,* asked subjects to find four prespecified numbers in a table. The researchers recorded the time required to accomplish the search task. The presentation was as follows: (1) low resolution screen (320 x 200 pixels), wide letter display, (2) high resolution screen (640 x 200 pixels), narrow letter display, (3) high resolution, wide letter display, and (4) hardcopy print (using 9 pin dot matrix characters) (34).

<u>The results</u> showed that search time was faster for hard copy displays followed by high resolution CRT displays, and then low resolution CRT displays. However, the response time of hardcopy and high resolution displays were not significantly different. This was explained by the poor quality printer used.

Jorna et al (1991) , suspecting that, in previous studies, the display types may have confounded with the *image quality when comparing performance on CRT and hardcopy,* conducted an experiment in which subjects performed reading as quickly as possible on a high resolution monochrome CRT display (1024 x 1024 pixels), and on a hardcopy (photograph) display with the same image quality. Both displays were presented in the same orientation (vertical) and at the same distance (51 cm). The text passages were presented in both displays with the same font, spacing, character size, polarity, and filter condition. Four filter conditions were used to give four different image qualities (35).

The results showed that subjects reading times were significantly different for various filter conditions. The fastest reading was from the highest quality image and so on, for both hard-copy displays and soft-copy displays. Subjects reading was also as fast in the hard-copy display condition as in the soft-copy display condition with reading times in favor of hard-copy display condition when the image quality decreased. The subjective ratings gave similar results.

2.4. HUMAN COMPUTER INTERFACE

2.4.1. Users

2.4.1.1. Capabilities

People's capabilities are not the same, and differences may need to be detected for their effect on performance. But one should be careful when studying individual capabilities since people can be, in certain cases, under the effect of fatigue, stress, illness. Other factors such as tolerance and mood may also effect human performance (36).

2.4.1.2. Individual Differences

Certain capabilities of people may change with age. For example, brightness requirements of displays increases with age, up to 250% after the age of 60s compared to the young (2). Also not all people have perfect vision. Some correct visual acuity by using lenses or glasses. About 8% of men and 1% of women have color blindness such as inability to discriminate between reds and greens. 10% of the population have hearing impairment (3,11,15).

Psychological Scales: Shneiderman (1987) claimed there are hundreds of psychological scales that have been developed to measure individual personality types, such as field dependence/independence, high/low motivation, etc. (37).

Differences among Information Systems Users: Relevant to the above mentioned psychological scales and, thus, psychological types, *Benbasat (1982)* suggests that the designers of information systems should give each psychological type the kind of information to which he is psychologically attuned and will use most effectively. "Cognitive styles are characteristic self-consistent modes of functioning which individuals show in their perceptual and intellectual activities" (17).

For example, decision makers can be divided into field dependent and field independent. The former are unable to perceive discrete parts of a field. They also have preferences to decreasing level of report complexity; in one experiment, the decision makers preferences ratings decreased when presented with tabular raw data, percentage data, and histograms respectively. Thus, they perform better with untransformed reports (17).

Some people are attracted or are eager to use computers. Others dislike computers or are anxious about them. *Bailey (1989)* argues that managers tend to have little interest in directly using many computer systems. On the other hand, clerical workers tend to be regular users. Thus, the clerical workers need more done in shorter times. They also need protection from repetitive, boring, and routine tasks (3). *Sutcliffe (1989)* states that computer usage may be discretionary or non-discretionary. For example, clerks usage may be non-discretionary, that is, they may be using systems in a compulsory manner because it is a part of their job. In this case, the interface design should be more attractive than if it were for discretionary usage (11).

2.4.1.3. Users' Categories

According to *Lingaard and Perry (1988)*, one way of categorizing users is as shown in figure (2-9) and below (38):

-*Novice*: A user who knows little of the general applications area (e.g., finance) and has had infrequent (including no) usage of the specific model in question.

-*Intermediate*: One who still knows only a moderate amount about the general application area, but now frequently uses the computer model.

-*Experienced*: A user who frequently uses the model and has learned a considerable amount about the general applications area.

-*Casual*: A former experienced user whose model usage has decreased to the point where that user's model abilities have become rusty.

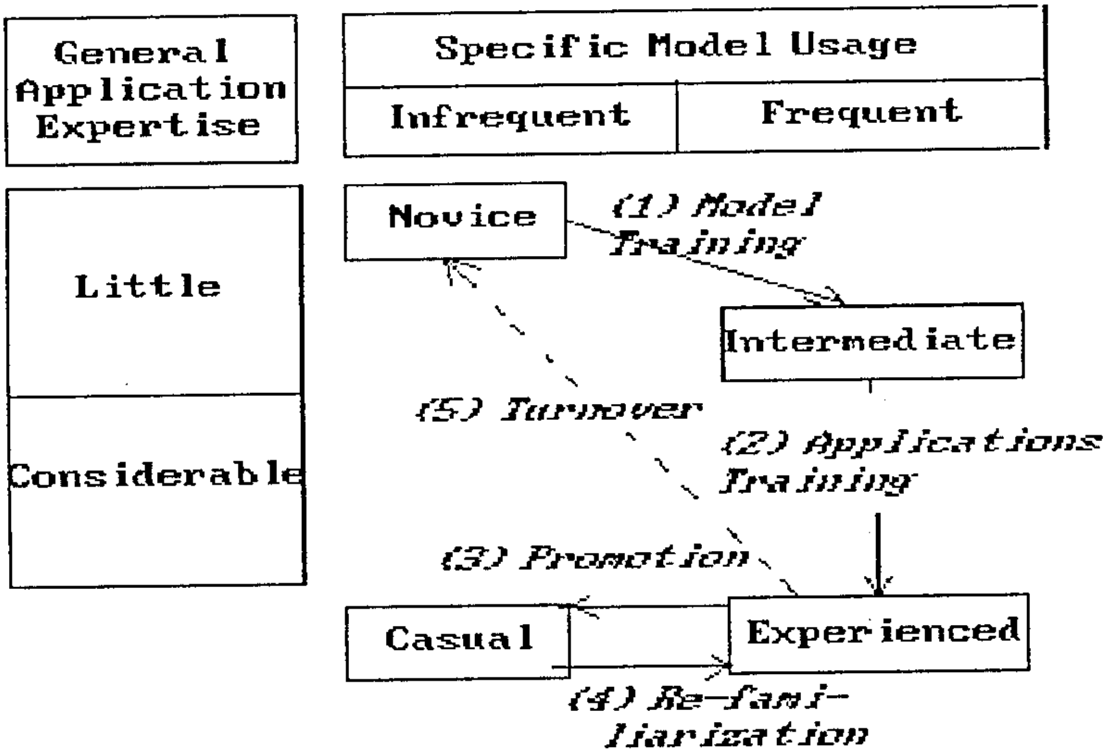


Figure (2-9): Users Categories Development. (Source: Lingaard and Perry, Ergonomics, 1988, pp. 803-806).

In addition to the above mentioned categories, *Downton (1991)*, suggest the following categories (36):

-*Knowledgeable Intermittent Users*: Typically, these are professional staff who use a wide range of different types of computer support equipment. They generally have a clear idea of the task they wish to accomplish, and a good general understanding of the capabilities of computer technology. They have limited familiarity with specific systems.

-*Experts*: Compared to experience which "relates to the general understanding which the user has of the problem, and of computer technology in general", expertise "implies the more specific detailed knowledge which the designer may expect the user to have in carrying out the task using the system".

2.4.1.4. Relative Capabilities of Humans and Computers

Table (2-2) provides a simplified statement of the respective merits of human and computer (39).

Table (2-2). Allocation of Functions between Man and Computer. (Source K.D. Eason, Ergonomics, 1980, pp. 882).

COMPUTER IS GOOD AT:	MAN IS GOOD AT:
Mass storage of information Fast and accurate retrieval Fast and accurate information processing Following predefined instructions (Program following;) Non-adaptive	Pattern recognition Goal formation Identifying new issues Resolving ambiguity and uncertainty (Self-programming;) Adaptive

2.4.1.5. Limitations of Human Computers Interaction

Although certain functions will probably be better allocated to computers, if, for example, only the relative capabilities are considered, but also other factors related to the human cognitive processes and the limits of the human beings due to fatigue and stress should be considered. The following will illustrate.

As mentioned earlier, *Gould et al (1984)*, studied the effect of working on CRT compared to hardcopy. The main finding was that changes in participants performance, feelings, and vision were the same throughout the six hour periods for CRT and hardcopy. Feelings ratings and vision were significantly affected for each display type when considered separately (32).

On the other hand, work with VDT continues to be a cause of a high rate of visual complaints among operators; when working for long time periods. VDTs are characterized by an unusual contrast pattern (bright characters on a dark background) and annoying reflections. Visual complaints may be accompanied or even caused by transitory variation of ocular functions (40).

Gratton et al (1990) conducted an experiment using seven female subjects who have been working on VDTs for 5 to 14 years. Their daily exposure during the last year ranged between 4 to 6 hours. All subjects were tested before the trials for different kinds of eyes accommodations. The ocular tests were repeated after exposure to VDT work for 6 hours with an interruption of 30-45 minutes interval half-way.

Six out of seven subjects reported some kind of ocular complaints, mainly 'tired eyes' and 'gritty feelings'. This is in addition to general tiredness and 'heavy' work-load. The tests, at far distance, showed that an increased use of accommodation (myopization), with a mean change of .19 diopters. At near distance, the tests showed a decrease of used accommodation with a mean of .18 diopt-ers. These results were statistically significant. They are a sign of visual fatigue.

On the other hand, *Turner et al (1984)* argue that the psychosomatic stress in jobs using CRT, may be due to operating characteristics of the overall system, such as systems. However, money saved, for example, by giving functions to people in order to shorten the design process, may be lost many times during the life of the system.

The Humanized Task Approach: Opposite to the leftovers approach, functions that justify the use a person from the job design point of view are allocated to people. The justification process refers to human skills, abilities, limitations and motivational aspects. The leftovers are allocated to computers.

The Flexible Allocation Approach: The functions are allocate by users according to their values, needs, and interests. This approach requires the design of a computer-based system that allows the reallocation by users manipulation of software.

Price's Four Rules: *Sanders and McCormick (1987)* cited Price for developing a functions allocation strategy. With this method, the rules are taken in turn until one applies to the function under consideration. The process is repeated for the next function and so on (2):

-*Mandatory Allocation*: This refers to the compulsory allocation due to systems requirements.

-*Balance of Value Allocation*: The function is allocated according to the relative goodness at which either human or computer can perform it. This is not much different from the comparison allocation approach. However, the former requires the exclusion of functions which both human and computer are good at or are not good at. The excluded functions are allocated according to other rules.

-*Utilitarian and Cost-Based Allocation*: Tasks are allocated to humans simply because they are there, and there is no compelling reason why not to. Cost is also taken into consideration. This allocation rule may be facing the same problems as the leftovers and economic approaches mentioned above.

-*Affective and Cognitive Support Allocation*: It refers respectively to emotional requirements such as value of work and motivation, and human need for information such as to make decisions.

Adaptable Systems Allocation Strategy: Another important possibility is suggested by *Turner et al (1984)*, which requires that systems be designed such that they are dynamically adaptable to individual operators by adjusting the allocation of functions between system and operator; for instance, to skill level or state of arousal. The result is improved user performance and lower stress levels. This approach may be done through operator's monitoring, deducing his state from his task performance, and adapting to changing operator's capabilities, for example, 'eager' or 'fatigue', and variability of human information processing, by the computer (41).

2.4.2. Input Devices

Devices used in human control should be designed to be suitable for the desired control action in terms of sensory, psychomotor, and anthropometrics of the users (2,3).

2.4.2.1. Coding of Controls

The primary coding dimensions that are used for the identification of controls include shape, texture, size, location, operational method, color, and labels. The choice of coding depends on the detectability, discriminatibility, compatibility, meaningfulness and standardization of selected codes.

Coding of controls can be used in multiples *orthogonally*, when unique combinations of two or more codes are used to identify separate devices, or *redundantly* for especially critically accurate identification.

Shape Coding of Controls: Shape coding controls involve tactual sensitivity and should not be confused with one another by blindfolded subjects. For example, some keyboards make the F and J keys more concave than others to help users to properly locate their fingers in the home row when typing. *Sanders (1987)* presented a study which concluded that up to 15 different shapes could be discriminated.

Texture Coding of Controls: Although control devices can vary widely with respect to surface texture, reasonably accurate discrimination does not span more than three codes; such as smooth, fluted and knurled.

Size Coding of Controls: Size coding of controls is not as useful as shape.

Location Coding of Controls: Location coding involves the kinesthetic sense. Controls should be far enough not to be erroneously activated by adjacent ones, especially if vision is not involved. Accuracy is also effected by arrangement of adjacent switches such as vertically rather than horizontally.

Operational Methods of Coding Controls: Operational method coding includes push-pull button and rotation. Each control can be activated only by the movement that is unique to it.

Color Coding of Controls: Colors can be useful for identifying controls when they are meaningful, for example, red for an emergency. The problem with color coding is that one must look at the control to identify it.

Label Coding of Controls: Label coding is probably the most common for identification labels because they do not require much learning and can be used when dealing with a large number of controls. However, one should be careful because labels take time to read, and, thus, effect the speed of performance. Another problem with labels is when they become not visible when the hand or finger covers the control.

2.4.2.2. Control-Response Ratio

A specified movement of a control device will result in a system response. The system response may be represented on the display or it may be not. The ratio of the movement of the control device to the movement of the system response is referred to by the control-response ratio (C/R ratio). Depending on the device, the movement of the control, display, or system depending on it may be measured in linear distance or in angles or number of revolutions.

Controls Sensitivity: Sensitivity, referred to as *gain* also, of a control is contingent on its C/R ratio. A highly sensitive control when slightly moved results in a marked change in the controlled element (display).

2.4.2.3. Keyboards

Keyboard Feel: An important factor which has an impact on human performance is feedback. The feedback or 'feel' of a control is a function of resistance and displacement. Force and movement are sensed through the proprioceptive and kinesthetic senses. In addition to pressure and displacement, the keyboard feel is a function of auditory activation feedback and hysteresis which refers to the tendency of a key switch to remain in the closed position even after a partial release of downward pressure.

2.4.2.4. Cursor Positioning

The primary function of a control is to transmit control information to some device, mechanism, or system. The information that is transmitted may be discrete such as alphanumerics, or continuous such as the movement of a cursor positioning on a VDT.

Mouse: It is a device that rolls on a desktop and controls the movement of the cursor on the screen.

A mouse is easy and fast to use. Since it is not controlled by the fingers but rather with the whole hand it is not as accurate as a pencil-shaped stylus and is not as natural to use. Also, a mouse needs allocated space near the screen.

Comparison of performance using a mouse, keyboard cursor positioning step keys and text alphanumeric keys in a text editing task resulted in the mouse being the fastest and with least errors.

2.4.3. Input Styles

This is normally done through direct use of keyboards to type in the required input data. Data entry may involve questions and answers, form filling, or selection based methods.

2.4.3.1. Inputting Data

Green et al (1992) investigated the merits of entry and selection-based methods to find which method is preferable for data entry. They also examined the effect of the number of selection items in menus, the effects of users familiarity with the data base, the difficulty in items spelling, and the total size of the data base. Computer-experienced and computer inexperienced subjects were given tasks of specifying flights including three variable fields, on a PC display. Three entry methods were used.

Two were unaided, namely delayed entry and immediate entry with respect to feedback and correction. The third entry method, auto-completion, was aided by the computer which would complete the entry string as soon as the first few characters have been entered. With the latter, auto-tabbing was also in effect. However, a 'sponge' was devised, whereby if more characters were entered, matching the rest of the string, these characters would be ignored. Two selection-based methods were used, namely one-item selection menu, and a multiple-item selection menu (42).

The results showed a high accuracy for all entry and selection-based methods. Inexperienced users' ratings and speed were best for auto-completion. For experienced users, the ratings and speed were best for multiple-item selection and auto-completion. For them, the other interaction methods did not differ significantly in total time. They were also faster than the inexperienced, especially when it came to the unaided entry methods. Hard to spell words took more time than easy to spell words with the unaided entry methods. Spelling difficulty had no effect on entry speed when it was aided by auto-completion (42).

2.4.3.2. Inputting Dates

Entering dates can be considered as a special case of the general task of data entry discussed above. *Gould et al (1989)*: conducted an experiment that was similar, in general, with the above mentioned experiment but with some techniques that were suitable to dates entry and selection. However, for auto-completion no sponge was used. The other entry methods were: the requested completion method (in which the subject ordered the computer to complete the month after having input part of its string), and the modification entry method (in which the subject presented with a date modified it as instructed) (43).

Both experienced and inexperienced subjects preferred the entry methods. Computer-experienced subjects were faster than the inexperienced. For both groups entry methods were faster than selection methods with the following order: requested completion being best, auto-completion, and then modification. It is inferred that lack of sponging in auto-completion resulted in the superiority of the requested completion method (43).

2.4.4. Dialogue Styles

Some of the most common interactive styles are detailed below. *Questions and answers* style is one type of dialogue, which involve computer-initiated detailed questions and lengthy messages. *Form Filling* is another type which is used for data entry.

2.4.4.1. Command Languages

In this type of dialogue, instructions to the computer are passed through words (abbreviated in many cases) or sentences consisting of such words and governed by a special grammar frequently referred to by syntax. Command driven dialogues are user-initiated and generally consist of syntactically correct commands typed by the user without help from the system. Command languages are mainly useful for expert users, being fast, efficient, precise and flexible. However, they need lengthy training, regular use, and high memory load and they are poor for error handling (36).

2.4.4.2. Direct Manipulation

In this type of dialogue, functions are represented metaphorically by *icons* (graphical symbols). Such icons are presented to the users for direct manipulation. Direct manipulation is usually visually appealing to both novice and expert. It reduces learning, and is readily retained. However, they need complex and large software, high performance graphics displays, auxiliary input devices such as mice, and skilled designers (36).

2.4.4.3. Menus

Menu selection dialogues imply minimal training of users, but are generally considered as being too slow and contain too much explanation for the skilled user.

Structuring Menus: Menus are characterized by being structured in hierarchies that are easier to recognize by the novice and intermittent users as compared to command language dialogues. Such hierarchies are characterized by their *breadth* and *depth*. Menus can be arranged with many options on a menu panel (broad), or with few items on each menu and several levels in the hierarchical tree (deep). Figure (2-10) illustrates the concept of breadth and depth of menu hierarchy.

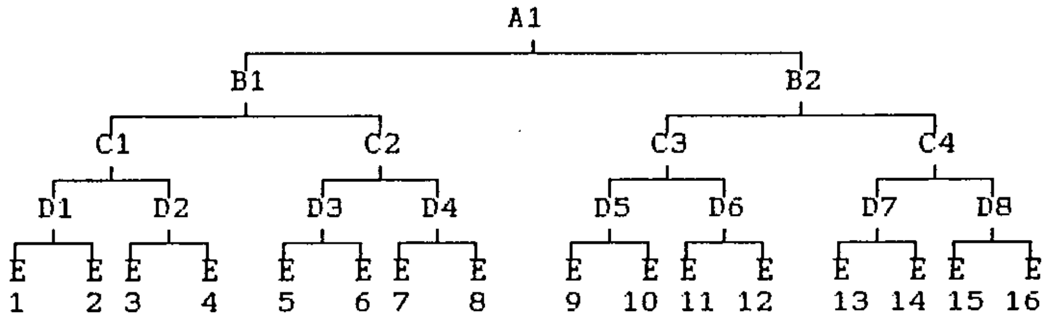


Figure (2-10): Menu Hierarchy: Complete, Homogeneous; and Two Items Broad, and Four Levels Deep (2^4).

Paap and Roske-Hofstrand (1986) argued that although there might be a menu depth disadvantage of having to recall the navigation path of how to get to each option and thus a cost of increasing error rates, there might be reasons behind using more depth such as *crowding*, the straightforward constraint imposed by the amount of available space on a panel, *insulation*, referring to hiding unlikely or illegal options for easier learning through better discriminating the target option from the alternatives, and *funneling*, reducing the number of options to be processed (44).

Snowberry and Parkinson (1983) evaluated the possibility of a breadth-depth tradeoff in hierarchical menu structures by comparing performances (search speed and accuracy) on both a randomized and a categorized 64 item display. Response time was kept constant (by typing consistently 2 digits to make a choice). Categorical grouping was also preserved. Common English words served as search targets (45).

As a result intermediate levels with the following breadth to depth: 4^3 and also 8^2, showed faster search times. Extreme levels (2^6 & 64^1) showed slower search times. When categorized presentation was used, there was an advantage for broad structures. Accuracy was highest in the broadest menus for either presentations.

On the footsteps of previous analytical work of menus of 64 items, which favored optimal menu breadth of less than 8 items per panel, *Paap and Roske-Hofstrand (1986)* analyzed the effect of *self-terminating search* and *restricted search*. The former defining the search that ends after having examined half of the options before deciding upon a selection (equal probability), was found to require broader menus (4-13). The latter, implying earlier decision, as a result of experience and practice, was found to require larger values; in such a case, ideally the user directly fixates the option (44).

For a general hierarchy, a mathematical model was proposed to calculate the optimal menu breadth.

Similarly, they analyzed the effect of *grouping* on search. Such an act of categorizing would result in broader menus.

Fisher et al (1990) criticized previous studies which have simplified the problem by focusing on hierarchies which are *complete*, ie having the same number of menus along each branch, and *homogeneous*, ie having the same number of options in each menu. Figure (2-10) shows a complete and homogeneous menu. They discussed the need for other *syntax* (structure) that is neither complete nor homogeneous because a homogeneous solution does not, in many real life cases, relate to the *semantics* of a hierarchy. Another problem is that proposed mathematical models do not always lead to integer solutions. In such a case, the closest integer does not have to be the optimal.

The following technique is derived. First a *seed hierarchy* is designed. Such a hierarchy is supposed to be semantically well-formed, ie all lower level (terminal and index (non-terminal)) options which are reached from a non-terminal option are members of the categories represented by the option and are not members of other categories. A terminal option in a seed hierarchy cannot be expanded efficiently any further. Then, all possible *nested hierarchies* are generated from the seed hierarchy ending with the terminal hierarchy which is the simplest nested hierarchy, formed only from terminal options. Nested hierarchies are thus semantically well-formed. Thereafter, the expected access time (average time the users take to access an option at lowest level) is calculated for all the set of semantic hierarchies (seed and nested). The computations are done recursively starting at the terminal options knowing their probabilities. The optimal hierarchy is then identified (46).

Menus Selection Techniques: Shinar et al (1985) studied the relative effectiveness of a pointer (using arrow keys) and two alphanumeric codes (options initial letter and options number) for selecting items from a menu by novice subjects in answer to computer generated questions.

Opposite to intuition , the fastest was the response to arrow sign and the slowest was with the letter key. The error rates were not significantly different. After some training, using fixed order menus, and using semantics for the initials, the letters were best, followed by numbers, and then arrow keys. On the other hand, menu length (referred to as breadth also above) affected performance when using arrow keys. The selection time was increasing in proportion to the number of options. Otherwise, there was no effect of menu length for the experiment range of (2-9) options (47).

Placement of Menus Options: Alan et al (1991) conducted three experiments to study the effects of placement with respect to menu options of alphanumeric codes to be used for menu option selection. In the first two, subjects presented with airlines reservations exercises were instructed to select the correct options (being destinations and originations of flights) by typing the abbreviations placed either to the right or right of the options. In the third experiment, subjects were required to select numeric codes placed either to the right or left of the menu options, being a set of different computer software commands. In this experiment, menu lengths were also changed.

The <u>results</u> showed that, contrary to intuition, the selections were more accurate when the alphanumeric codes were placed to the right. Also, it was concluded that, opposite to conventions, the placement to the right might be faster than to the left depending on users' mental model of the system. The third experiment showed that a correlation could be built to predict response time from menu length when right placements were in effect (48).

Menus Orientation: For comparing the effects of horizontal and vertical menus, *Backs et al (1987)* instructed subjects to search menus which were 4,8, or 12 items long for a target item and state the number code next to it.

It was found that search time was significantly shorter when vertical menus were used. Also, search time was shorter for shorter menus. These findings are particularly valid when full screen menu pages are used (49).

Case and Spacing of Menu Options: In order to study the effects of case and spacing on menu options search time, *Williams (1988)* asked subjects to select the correct option by calling its code number on different experimental treatments namely, capitals and double spacing, caps and single spacing, lowercase and double spacing, and lowercase and single spacing.

As a <u>result</u>, it was found that double spacing in combination with caps or lowercase required shorter search time due to better visual discrimination between options (words). However, the results were not always consistent. The same experiment showed that double-words (longer options lengths) required more search time (50).

2.4.5. Output Devices

2.4.5.1. Displays

There is a variety of electronic displays in the market. The most common for use with computers are the cathode ray tubes and liquid crystal displays.

Cathode Ray Tube: The operating principle of a *CRT* is as follows. A stream of electrons is emitted from an electron gun and focused and deflected by an electric field onto a phosphorus-coated screen which glows at the point of contact with the electrons (51). The result is a screen formed of rasters (horizontal scan lines) each of which is made of many separate elements called *pixels* (2).

Such a design is having the following drawbacks: CRT are bulky due to circuitry behind the screen. In case of lower resolution CRT's the diagonal lines appear jagged. They cause eye strain and fatigue caused by flicker and relatively low contrast (3,51).

On the other hand, CRT's are inexpensive. In addition to that they have very high capabilities of colors, high writing speed, high resolution (3,51).

2.4.6. Screen Design

Visual displays have been discussed earlier in general. Screen design should reflect the HF principles associated with VDTs including perception, coding, and alphanumeric type and features.

Similar to discussions on graphical displays, designing the screens should result in clutter free, clear, meaningful and easy to use displays. The screen is defined by its information content and format. Format can be approached by structural grouping. Non-information noise effects the detection of the required stimuli. If properly coded, the screen information is legible and easy to perceive.

2.4.6.1. Screen Format

In order to improve the screen format design, *Galitz (1989)* described some guidelines (52).

Screen Complexity: In order to reduce complexity, for the same number of fields the screen should be redesigned until the same number of fields result in less or minimal horizontal and vertical alignment points (52).

Screen Density: The overall screen density should be kept below 25%. The overall density is "a measure of the percentage of character positions on the entire screen containing data" (52).

2.4.6.2. Screen Color

Color makes pleasant screens and can improve the design of the screen by better recognition and identification of objects. It enhances perception and cognition, and helps in decision making if appropriately used. It can be used for integration of similarities or separations. If used incorrectly in number or harmony, color may be of a negative effect. Bright colors may result in fatigue. Eye fatigue might result also when color refocusing is needed for the perception of pure colors on the extreme ends of the spectrum.

Effects of Color on CRT Character Legibility: Mctyre and Frommer (1985) studied the recognition time and error rate in an experiment in which the following foreground/background color combinations were used: high intensity white/cyan, high intensity white/blue, white/brown, and magenta/brown. A character was situated in the middle of a matrix of other characters. The task was to identify the character.

The results showed that the first two color combinations had a significant effect on recognition time and error rate. They were best to worst as listed above (53).

In order not to confound the effect of luminance with chromatic difference, bearing in mind that colored stimuli of equal luminance do not appear equally bright, *Matthews and Mertins (1987)* designed an experiment in which colors were set at similar subjective brightness, using a search-ing task namely scanning a CRT for a target symbol in a context of non target symbols. All target and background colors were matched to a blue color brightness of 17 cd/m^2. There were three monochromatic conditions: green, red and blue on a black background, one achromatic condition: white on black, and three heterochromatic conditions: red on blue, red on green, and blue on green. The subjects had to determine in which of the four quadrants of the CRT the target appeared if any, then enter the perceived number after clearing the screen.

The target search accuracy was significantly lower for the red/green and red/blue. Performance with green/black was slower than all other conditions. However, differences were less than 10%. Fatigue ratings showed no significant effects of the different background combinations. It should be noted that this experiment does not reflect real applications on CRT where brightness differs with different screen colors (54).

Lalomia and Happ (1987), devised an experiment in which subjects identified characters presented in one of 16 colors: (low and high intensity) on random combinations with 8 low intensity background colors.

They plotted response time, as a measure of legibility, and rating, as a measure of preference, to show the best color combinations. The most flexible combinations were found to be black and blue as background. Brown and green background colors were poorest (55).

Wilson and his collaborates conducted a series of experiments applying the signal detection theory (SDT). The excellence of the theory lies in the fact that many parameters can be determined systematically specially perceptual sensitivity (d') which is defined as the difference between the means of signal + noise (SN) and noise (N), probability of a hit p(Hit), probability of a false alarm p(FA), receiver operating characteristic (ROC) curves which are a plot of p(FA) versus p(Hit).

The appropriateness of the theory was tested by *Wilson and Kupeman (1988)*. Subjects were asked to detect the CRT primaries: red, green, or blue symbols on a color background that differed randomly by .01 through .05 units in either one of the other two primaries direction or white in CIE/UCS-1976 (Commission International D'eclairage uniform color space). See figure (2-11):

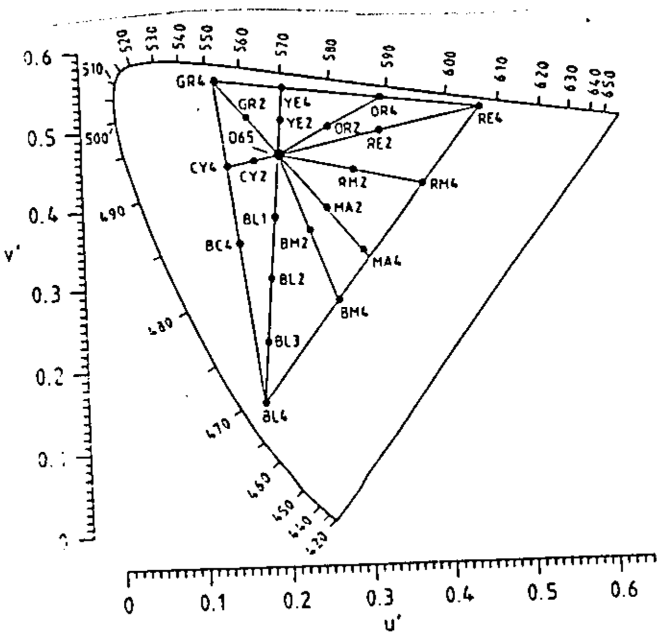


Fig. (2-11): The Chromaticity Coordinates of the 1976 CIE UCS: The horseshoe-curve represents the locus of spectrally pure colors. (D65)= achromatic reference. BC=bluish-cyan; BL=blue; BM=bluish-magenta; CY=cyan; GR=green; MA=magenta; OR=orange; RE=red; RM=reddish-magenta; YE= yellow. (Source: Pastoor, S. Human Factors, 1990, pp. 160).

extended from green to red. The other represent a constant which is the sum of the medium (m), and long (L) wave-length retinal cones classes extended from yellow to blue. The achromatic axis extends from black to white. The two chromatic axes form an equiluminent chromatic stimuli plane. The three axes intersect at a notional white point. The theory is that chromatic neurons in the visual system are tuned to one of the two chromatic 'cardinal' axes.

To come to some general principles concerning the use of colors and luminance on display monitors, they designed an experiment in which subjects were supposed to detect colored stimuli which were uppercase alphabetic strings of six letters that varied along the three axes on a white background of a CRT having a luminance of 98 cd/m^2. They were also supposed to discriminate the stimuli by saying whether the string was a real word or a nonsense anagram (non-word string).

It was found that both detection and discrimination improve with changes in chromaticity along the cardinal axes and the changes in luminance along the achromatic axis. The conclusion was that any combination of text and background colors is suitable on condition that the combination maintains adequate luminance or chromatic contrast. Given that luminance contrast is easier than chromatic contrast to realize with CRT displays, they suggest that color pairs be used, which maintain a luminance contrast of 50% (59).

Pastoor (1990) conducted an experiment to explore the role of chromaticity (defined by hue and saturation) at constant levels of luminance. Subjects were required to specify their ratings of 22 color combinations presented on CRT displays in either one of two polarities with specified luminance contrasts namely 4 cd/m^2 text versus 26 cd/m^2 background for light-on-dark polarity and 40 cd/m^2 text on 4 cd/m^2 for dark-on-light polarity. Selected color saturation levels were based on CIE/UCS-1976 color space such that they were uniformly spread among the three primaries of CRT colors gamut. See figure (2-11).

The <u>results</u> of light-on-dark polarity showed that the highest mean rating was for achromatic text (white) on desaturated blue background. The worse was for saturated magenta text on saturated red background. In general, ratings of desaturated text on desaturated background were higher than desaturated/saturated. The lowest was saturated/saturated. On the other hand, dark-on-light polarity results concluded a highest mean rating for bluish cyan text on an achromatic background. The worst was saturated red text on a saturated red background. In general, there were no significant effects for dark text color saturation on ratings either in combination with saturated or desaturated background. Ratings of desaturated background colors combinations were significantly higher than combinations with saturated background (60).

Pastoor (1990) conducted another experiment to test a reduced number of color combinations by referring to the previous experiment results. Nine color combinations of both luminance polarities were selected. Three levels of color combinations were used: (1) no colors (black and white), (2) color exclusively for text or background, and (3) full color. Because humans cannot simultaneously perceive opponent colors such as red and green, or blue and yellow, opponent and also similar colors were used. Also, best and worst rated color were used. Subjects were given three tasks: reading, search and rating. For the first task, three pages reading time was measured. For the second, the time to find a word in a column of 10 is measured. In the third, 18 rating scales were used categorized to aesthetics, power, legibility and strain.

There were no significant effects of either polarity or color combinations on reading or search times. On the other hand, there were significant effects of ratings, namely color combinations, and scales. Investigating color combinations as rated in the second experiment one may come to the following conclusion. For light-on-dark polarity and for dark-on-light polarities, similar colors and opponent colors, which were rated highest in the first experiment are optimal. Achromatic/chromatic combinations are similarly optimal for dark-on-light polarity (60).

2.5. CONCLUDING REMARKS

As can be seen from the literature review, many studies involving HF have been recently published, which give practical guidelines for analyzing.

CHAPTER THREE

SYSTEM DESIGN PROCESS

3.1. DETERMINING OBJECTIVES AND PERFORMANCE SPECIFICATIONS

Having declared the objectives of the thesis, the objectives of the system and performance specifications will be derived so that they are clearly identified as follows:

3.1.1. System Objectives

The purposes of the system are stated in general terms giving sufficient coverage in case the performance requirements are altered in response to realizing inadequate resources, insufficient availability of expected technologies, or other constraints.

Examples of constraints related to the thesis are available software packages, and consequent hardware limitations, or organizational constraints.

For the purpose of the thesis, the identified system objective can be stated as follows:

The objective of the system is to provide an effective medium for reporting to the management.

3.1.2. Human Factors Activities

At this stage, certain HF activities have been exercised:

3.1.2.1. Intended Users of the System

For the purpose of the thesis, the users of outputs are identified as being the middle management namely:

Works Manager and Department Managers at Factory level.

The users that will do the work are identified as being:

Clerks of the Production Department.

3.1.2.2. Existing System and Users' Needs

Identification of users' needs is normally done through observation, interviews, and questionnaires. The researcher, having served as assistant works manager and manager of the Production Department and having daily contacts with the existing system, collected information of operations needs, and the Factory Management outputs needs, through actual job performance, contacts and observation. The results are reflected in the systems requirements and constraints.

A major Human Factors issue is that the company does not seem to want to make any basic changes in the available staff or radical organizational changes.

Jordan Cement Factories: The Jordan Cement Factories Co. (JCF) was established in 1951 as a public share-holding company. A concession agreement has been concluded between the government and JCF, under which the latter is authorized, as the only enterprise, to establish and operate cement factories in Jordan for a period of fifty years.

When first established, the capital was 1 million JD's. In 1985, the South Cement Co. was merged in JCF. The capital of JCF has become 50 million JD's since the merger.

In 1954, the first line was commissioned and the production started with a capacity of 200 tons per day. The total nominal production capacity at the time being is 4 million tons per year. The organization chart of the company is shown in figure (3-1).

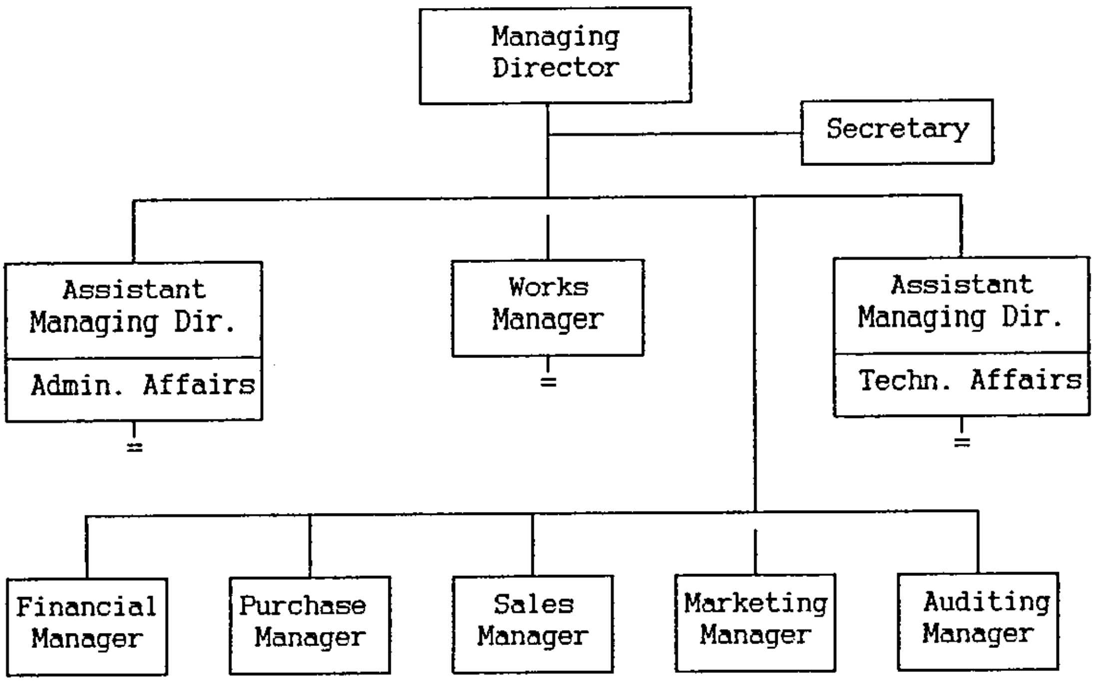


Figure (3-1): Organization Structure of the Company.

The Factory at Fuhais: The works at Fuhais is located at about 20 kms away from the center of Amman to the North West. The concession area is about 180 hectars.

Manufacturing Site: It is constituted of three operating plants namely lines 4,5 and 6. The production capacity of the lines is 700, 2000 and 3000 tons of clinker per day respectively. Lines 1,2 and 3 were decommissioned in 1983 because of their obsolete facilities which made them ineffective from energy conservation point of view, operating cost and also a nuisance on the environment due to air pollution. Each line incorporates a raw-mill plant for raw-materials grinding, a kiln plant for clinker burning, which is an intermediate product in cement production and a cement mill plant. In 1986, the supplemental installation was operated as a solution to bottlenecks in the system. Thus, cement mill number 7 and crusher 7 were commissioned then.

Organizational Structure: The factory management is organized into ten departments namely Production, Quality Control, Mining, Mechanical Maintenance, Electrical Maintenance, Parts Manufacturing, Vehicles Maintenance, Inventory, Training and Administrative. Figure (3-2) shows an organizational chart of the departments in the factory. The total number of employees in the factory is about one thousand.

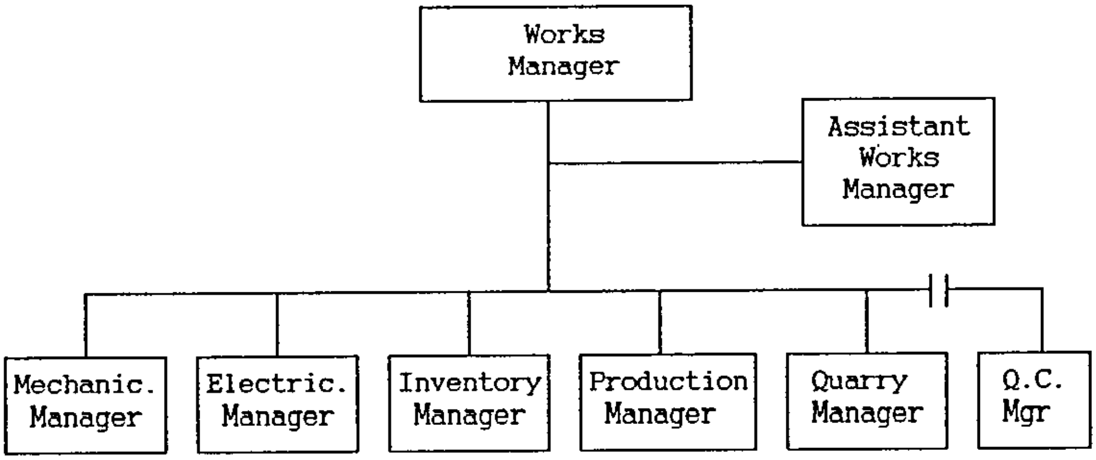


Figure (3-2): Organizational Structure of the Factory.

The Production Department in the Factory: One of the most important departments in cement manufacturing is the production department whose major functions are to plan, control production, operate the plants, including the packing plants, and control the process. Operation takes place throughout the 24 hours of the day in shifts. The principle sections of the department are shown in figure (3-3).

Information Status: A typical example of flow of information may be traced by following the line of command between the department management and the operating shifts that manage the production lines in the production section, in figure (3-3). The main reports are initiated by the shifts operators and foremen. They issue all kinds of data logging about the operation including operating conditions and trouble-shooting.

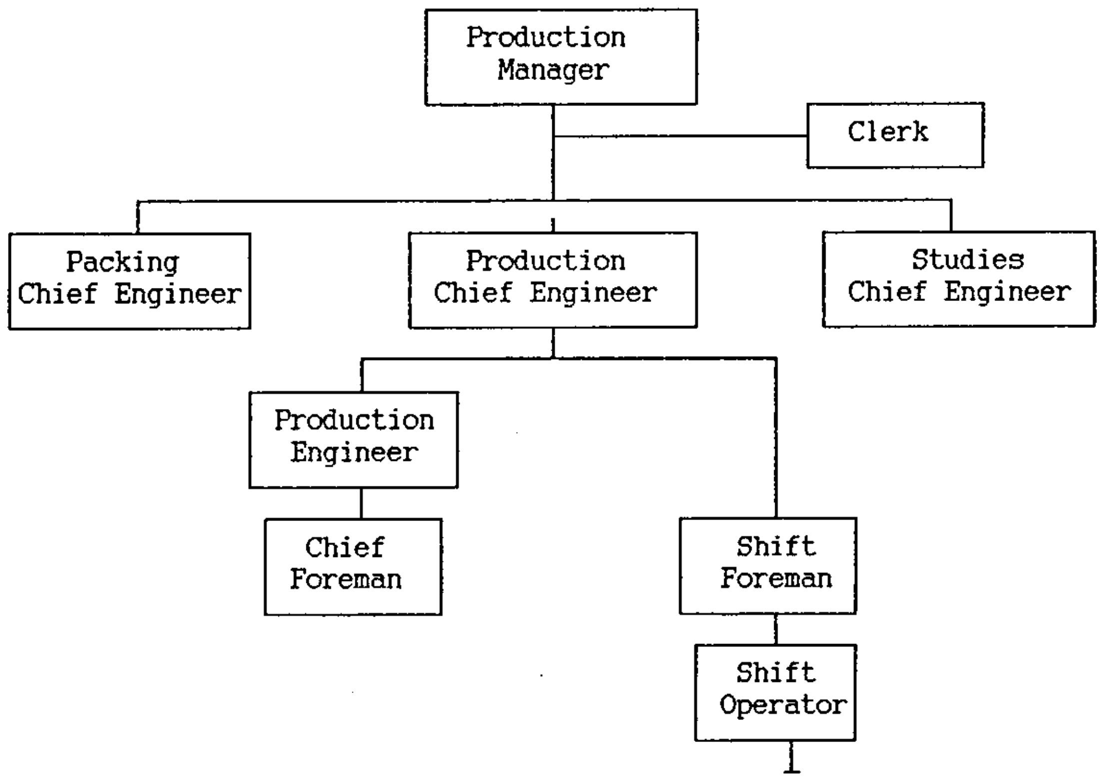


Figure (3-3): Organizational Structure of the Production Department.

Production Reports: The shift foremen also initiate reports of production quantities, operating hours, and energy consumption. A sample *Daily Operation Report* is shown in appendix (I). The data, received by the production department clerk, is manually processed and produced in the manner shown in the sample *Daily Production Report* shown in appendix (II). The information in the report also includes specific and percentage figures. A cumulative *Monthly Production Report* is issued as shown in the sample form in appendix (III).

Production Planning and Control: Using forecast figures supplied by top management of monthly sales, the production department does some detailed aggregate planning of cement, and clinker which is the key material in cement

-The system should help the factory management from the point of view of planning and controlling.

3.1.3.2. Constraints

-All inputs, processing and outputs should be in English.

-The sample application should be adapted to IBM compatible PC environment. Ram capacity is one megabyte (Mb), hard disk capacity 40 Mb and speed 20 megahertz (MHz).

-The hardware includes: super VGA monitor, mouse, and near letter quality (NLQ) printer.

3.1.4. Design Alternatives

There may often be more than one alternative for the design. It is best to set alternatives after objectives and performance specifications are identified. The alternatives are divided into main and complementary issues that can be combined in a variety of ways.

Output Medium: The following major alternatives are proposed as effective media for daily presentation of results in the meeting room. The production manager would still read the figures to the audience of middle managers and comment through:

-Communicating through words only.

-Rotating one copy of outputs to the audience while holding the original.

-Exhibiting the outputs on the walls of the meeting room.

-Using an overhead projector and transparencies.

-Using a visual display terminal (VDT) and computer.

-Using an overhead projector linked to the computer.

Output Details: Relevant to the above major alternatives, the following are concerned with report contents:

-Similar to present content.

-Aggregate results through summaries.

-Including planned figures and target values for comparison for production control purposes.

-Including other specific results related to production and comparing them to targets.

Format: Applied wherever logical the format alternatives are:

-Keeping present output form.

-Using table(s) but revising layout.

-Using graphical plots.

-Combining table(s) and plots redundantly or uniquely (orthogonally).

3.1.5. Survey of Design Alternatives

In order to justify the choice of one alternative over another, it is found convenient to give some literature support for the different ideas by reference to the previous chapter.

Although one alternative will be preferred for the design, however, as implied earlier, the system must be adaptive to the users' changing needs.

3.1.5.1. Communicating through Words

It has been shown that words are not always sufficient to transfer information. Graphic aids should be used to supplement words, present minor details not covered in words, and improve the report's appearance.

Taking the word of *Remus (1984)*, for a better manager's decision, large volumes of data can be dealt with by summarizing them in a form of data presentations such as statistics, tables and graphs.

In general, visual aids are needed for a better efficiency in describing objects and concepts.

3.1.5.2. Overhead Transparencies

As understood by the study cited by *Awad (1988)*, use of transparencies, being a special case of using visual aids, converges with the idea that visual aids shorten the length of meetings.

On the other hand, since a long time overhead transparencies have been used in training, seminars, conferences and education. Using them in regular meetings at production sites may not have been reported as being used.

3.1.5.3. Visual Display Terminal

In order to justify the use of VDT for presentation, different experiments related to cathode ray tube (CRT) have been presented.

Although the different distances, as reported by the different studies did not affect the speed of acquisition of (tabulated) information, the normal viewing distances of VDT's, governed by the viewing angle, are found to be about 50 to 110 cms.

With the problem of changing of speed of acquisition of (tabulated) information with changing distance between related targets on a display, being affected by eye fixation, there is a need to use a close pointer to show the item under discussion. Such a scheme may present a difficulty when a VDT is used for a relatively large audience.

Attributed to some collective factors, studies on CRT's showed that reading from a hardcopy is faster than CRT, although accuracy is not significantly different. Also, although when the hardcopy is an exact image of the CRT display, still reading from a hardcopy paper is faster than either of them.

3.1.5.4. Aggregation

Information should be optimally aggregated prior to presenting them to a decision-maker. It was emphasized that designers of information systems should not overburden managers with information with which they cannot cope.

One way of aggregation may be effected by converting tabular data into graphs, exception reports, or summarizations.

3.1.5.5. Graphic Representation

The results and conclusions of some of the papers brought about have been found contradictory, especially from the point of view of choice among tables versus graphics. However, the type of representation is contingent on objectives, context, tasks, individual cognitive styles, and preexisting preferences.

Comparing the results with the Human Factors principles described earlier, certain guidelines can be accepted. Tables are found in most cases indispensable for when the human performance objective is accuracy. This may be explained by the fact that numeric coding results in more correct responses due to its meaningfulness, which is a requirement that may be considered important in a computing process.

3.1.6. Conclusion

Complying with the scope of the thesis, whereby the focus is defined as being rather on the general user with management perspective, the alternatives are set such that they fulfill the users' changing needs. For example, during the design of the system, the works manager has been changed. The previous works manager was in favor of presenting outputs as graphics exhibited on the walls of the meeting room. The contemporary works manager favors holding a very quick meeting. At the same time, some other department managers have been interchanged including the production manager.

With the above mentioned ideas in mind, almost all the alternatives suggest the use of visual aids in one way or another.

Another example is related to the technology. During the design period the production department PC was changed from 1 Mb RAM, 16 MHz processor speed, and VGA monitor, to 2 Mb RAM, 25 MHz, and super VGA.

The discussion on using VDT's implies dropping the alternative due to the following reasons:

-The problem of viewing distance.

-The difficulty of using a hard pointer on VDT to guide the audience. A soft pointer or highlighting is thought to cause some delay in performance.

-Performance with output on VDT is relatively inferior.

The same discussion leads to the drop of the alternative of using an overhead projector linked to a computer. It was shown that the image of a CRT gives similar performance results. Moreover, such a state-of-the-art overhead projector gives images that are of lower quality than the CRT itself. Also, such projectors are still expensive.

Talking of using a transparencies overhead, the argument is as follows: Use of an overhead projector requires the redesign of the meeting room for all people to see. Presently, the meeting table is just a normal and elliptically shaped one and everybody just sits around. A good alternative design is the meeting room of the Industrial Engineering department in the University of Jordan which takes a U-shape, and is furnished with a blackboard, overhead projector, and screen. Since there is no great literature support, the alternative is dropped to save the costs of redesign of the meeting room in addition to the cost of equipment.

Moreover, using daily numerous transparencies causes another problem to cost in addition to the problem of time of preparation with respect to the system constraints. A solution would be to add daily the new point manually on the same transparency until the end of the period. Another advantage of daily manual adding to a transparency over a transparency copy of computer printout, for example, would be the chance to add colors.

The major problem with CRT, exhibits, and overhead projector is that the manager will move to the presentation ground, which may be a drawback for so much short a meeting.

Furthermore, with respect to exhibits, with too many of them, the walls on all sides will have to be used. Thus, people will have to turn to the side where the output under discussion is exhibited. One can imagine how difficult the situation is when turning the other way around behind some audience. To solve the problem of wall exhibits, again the meeting room should be redesigned, probably in U-shape, and all exhibits should be in the front facing the audience. Again, new points would be better added manually to save on time and money. However, the effort with so many exhibits of the different departments would be large.

Discussion with some users about the effectiveness of using graphs and tables on the walls in the meeting room after certain trials were done, showed that it was hard to grasp the outputs information with normal hardcopy size because of the distance. The alternative would be to use larger hardcopy displays. The wall would, then, be extremely overcrowded with all those exhibits from all departments reminding of the control room of Three-Mile Island nuclear power plant (2).

Thus, it is important to reduce the total number of exhibits from all departments, use large size displays, and follow a proper arrangement complying with HF principles. However, with all the above mentioned constraints, the alternative of using wall exhibits is dropped.

Since a circular output, ie a copy of the output passed to each one of the audience in turn, may be prepared using a computer program, no disadvantage is foreseen using this

3.2. DEFINITION OF THE SYSTEM

At this stage, the functions, which the system has to perform to meet its objectives and performance specifications, are identified. These functions are supposed to meet the users needs. Information regarding the users' characteristics are also collected.

At the definition stage, description of what is to be done takes place only. Assigning functions to people, hardware or software is done at a later stage.

Defining the alternative: The alternative that is thought to satisfy the system objectives and performance specifications has been basically defined as follows:

Use a summary report of for the daily factory management meeting including actual and planned in the form of tables, plots and remarks. Using probably overhead transparencies, present plots of the major manufacturing results on a monthly basis.

Beyond the scope of the thesis and, thus, the objectives and specifications of the system, the definition might have been extended to include the following:
Keep but improve, wherever relevant, on the present daily and monthly reports for the reference of the Production Department, and Financial Department and so on in the head offices.

There are possibly parallel efforts at present at the production department to automate the present daily and monthly production reports. Nevertheless, this is assumed.

3.2.1. Definition of Inputs, Outputs and Functions

After having established the basic layout, as a result of selecting the best among the different alternatives, the system level outputs and inputs, and work activities (functions) are defined. A system-level functional flow-chart may be created such that it shows roughly the defined functions in the order they will be performed. Detailed narrative descriptions can otherwise be prepared for each function.

3.2.1.1. Outputs

Having identified the proper alternative, the system outputs are then specified.

The outputs of the system:

-Production daily summary including:

- -Clinker production of kilns 4, 5, and 6, total production and, total inventory in common stores.
- -Cement production, dispatch and inventory, and their total.
- -Deviations of cumulative clinker production and dispatch cement from plans.
- -Daily plots of actual compared to planned production of clinker and actual dispatch of cement compared to forecasted demand.
- -Textual remarks of plant major stoppages, and operational deviations.

-Monthly plots of manufacturing results (restricted for the developed example to clinker production).

3.2.1.2. Functions

The functional analysis is concerned with *what* function need to fulfill the objectives and not with *how* these functions are to be performed.

The major daily activities:

-Enter periodically planned values for daily report.

-Calculate totals and deviations of the attributes of the daily report and check deviations from plans.

-Enter remarks on causes of stoppages, alarms of below-minimum stock levels of raw-materials, semi-finished, finished, and utilities, and messages of beyond-control-limits specific operational information.

-Display the daily report.

The major monthly activities:

-Plot daily report graphs.

-Display monthly graphical representation of data of clinker.

3.2.1.3. Inputs Reports and Data

Daily Input:

-Intermediate computer data base files.

-Daily stoppages and faults reports issued by shifts foremen.

-Display of attribute and value of daily exceptional inventory and operational results, including warnings, and messages.

Monthly Input:

-Intermediate computer data base files.

3.2.2. Collecting People-Related Information

More detailed information regarding the basic characteristics, capabilities, and limitations of intended users population are collected. Collected information is also intended at matching identified functions to the needs of the intended users.

3.2.2.1. Users

The designer, being the production manager, is very well acquainted with the users and is informed of their curriculum vitae (CV).

Output Users: The Works Manager and technical departments managers are all engineers, either chemical, mechanical, or electrical. They all have fairly good command of English. Their ages range between 35 and 50. They all have at least 10 years of experience, mainly in the same company.

The users form a homogeneous group of managers. None of them have got any physical or other limitations that might render their performance in getting, perceiving, processing or, judging the information from the proposed output medium inferior. They all may be considered as field independent and are thus supposed to be able to understand the aggregated results as summaries and plots without any difficulties.

System Operating Users: There are two clerks in the Production Department, who are supposed to be the main ones that will run the system. Their ages now are about 30 and 32. Both worked for the company for about eight years now. They joined the company as fresh graduates from community colleges majoring in accounting and computer operating respectively. They have joined the department almost from the very beginning of their appointment in the company. They have been doing the production reports since then, in addition to other clerical or secretarial work.
Although in his majoring, one of the clerks has studied some computer programming, he did not have the chance of keeping the skill. Both have interest in computers and may be considered eager to use them.

During the last year or so, certain departments were supplied with a PC, including the Production Department. Related people, including the department clerks, were given introductory courses on use of some computer application packages such as word processing etc. None of the departments have put any real efforts and, thus, none have obtained any significant results from using computers. Among these people the clerks were trying to do some work using the computers. They seem to gain some preliminary to intermediate knowledge in spreadsheets through inputting, equation utilization and plotting graphs. However, what they do is mostly manual, and by and large trial and error.

In addition to their normal general capabilities and skills, both clerks may be considered as being quite knowledgeable in their field of work, namely production calculations. In other words, they do have a clear specific idea of the task domain, and a good general understanding of the capabilities of computer technology. At the beginning, they are expected to be having limited familiarity with the specific new system under design. Thus, they can be described as being knowledgeable intermittent users. It is expected that their motivation to use the system will be high. On the other hand, given so many activities to do and the time limitations they will probably be exercising limited tolerance.

3.2.2.2. Matching Users' Needs

The kind of outputs described in the previous section, are expected to be satisfying these users' needs. As a matter of fact, when asked about their opinion about the present reports, one clerk was eager to test some new ideas. The other thinks that the present form is best because they can easily make comparisons among lines and among the different units of production, such as kilns. The present form is also helpful in manual calculations and in performing material balances.

3.3. BASIC DESIGN

At this stage, the system starts to take shape. Unforeseen changes and modifications may become necessary while adequate attention is given to the human, hardware and software. The Human Factors activities are identified in the following sections.

Users: The system operators have already been discussed from the point of view of their abilities, skills, knowledge, and motivation in the system definition stage.

3.3.1. Allocation of Functions

The functional responsibilities will be divided among the people and computer. The allocation of some functions will be straight forward. Others may require analysis according to Human Factors guidelines of relative capabilities and limitations of the human-beings and machines and according to the available resources.

Since "it is a serious responsibility to create the work that others will do, allocating functions is one of the most important activities designers ever perform" (3).

3.3.1.1. System Requirements

The designers do not always have the chance to the way of allocating the functions themselves. In certain cases, the functions will have already been allocated by the management. In others, the allocation is superimposed by stringent systems requirements.

Thus, some functions are readily and even easily allocated. However, it is important to make sure if the functions can be successfully handled by the expected personnel and whether they can be motivated to do so over a long period of time.

3.3.1.2. Function Analysis

Functions can be allocated at system (macro) or (micro) level as long as can be readily assigned to computers or people. In other words, functions that cannot be allocated at the system levels are subdivided into lower levels subfunctions. Thus, analysis of each function or subfunction is continued to the point that is sufficient for the allocation.

1-The daily functions are analyzed as follows:

1.1-Enter periodically planned values for daily report.

1.1.1-Check if there are new data.

1.1.2-Enter the new data.

1.2-Calculate totals and deviations of the attributes of the daily report and check deviations from plans.

1.2.1-Extract data from data base files.

1.2.2-Perform additions and subtractions.

1.2.3-Notify of negative deviations from plans.

1.2.3.1-Capture exceptional attributes & values.

1.2.3.2-Act on or communicate the results.

1.3-Enter remarks on causes of stoppages.

1.3.1-Extract relevant stoppages causes from reports.

1.3.2-Register causes of stoppages.

1.4-Notify of invalid results, warnings, and messages.

1.4.1-Capture exceptional attributes and values.

1.4.2-Act on or communicate the results.

1.5-Generate daily summary output report tables.

1.5.1-Convey information.

1.5.2-Fill in report.

1.6-Generate graphs of cumulative results.

1.6.1-Extract required data.

1.6.2-Convey the graphical information.

1.6.3-Plot the graphs.

2-The monthly functions are analyzed as follows:

2.1-Generate graphs of monthly results.

2.1.1-Extract required data.

2.1.2-Convey the graphical information.

2.1.3-Plot graphical charts.

3.3.1.3. Relative Capabilities of Humans and Computers

Certain elementary guidelines that show the relative capabilities of the human beings and computers have already been identified.

3.3.1.4. Limitations of Human Computers Interaction

Although certain functions will probably be better allocated to computers, if, for example, only the relative capabilities are considered, but also other factors related to the human cognitive processes and the limits of the human beings due to fatigue and stress should be considered.

3.3.1.5. Functions Allocation Strategies

Several strategies to allocate functions have been suggested.

It seems that the adaptive (dynamic) strategy of functions allocation is the most fulfilling of all requirements. The problem is that it is hard to have the computer decide when to shift allocation of functions. This approach is probably still beyond the capabilities of the present widespread computers software packages technology.

For the purpose of the thesis, it is decided to use the Price's four rule approach since it involves all the different acceptable possibilities of allocation. However, the rules will be used in an iterative manner, ie even if a function is found to fit into one prior rule, the alternative rules will also still be tested. It should be noted here that the humanized approach is considered as complementary to the fourth rule. The limitations of lengthy use of CRTs and computer systems tasks will be considered within this rule. Also, the economic approach is considered as complementary to the third rule. The flexibility of later reallocation of certain functions by users will be given if it is doubted that a given compromise is not satisfactory, under the condition that this can be achieved within the capacity of the software, hardware, and designer.

3.3.1.6. Allocation of Functions Activity

The functions defined in the previous stage will now be allocated according to the above mentioned strategical approach. The activity will proceed through system requirements and analysis of functions in an iterative manner. Each allocation is justified according to one or more rules. For the purpose of simplicity, any rule that is not discussed implies trivial exception of the rule. The results are also documented to help in the future during evaluation. Each function is first stated. Going back to the functional analysis, typical subfunctions are allocated. The other functions are allocated by virtue of the typical subfunction as follows.

1-The daily functions are allocated as follows:

1.1-Enter periodically planned values for daily report.

1.1.1-Check if there are new data.

Allocation is to the clerk because 'checking' requires human judging of written data. Thus, it is a balance-of-value allocation. Also, this is supported by the cognitive support rule since the activity is required for deciding whether to enter the data or not.

1.1.2-Enter the new data.

Allocation is to the clerk whether enter refers to write, or key into a computer. This is an allocation that is dictated by system requirement because, in the first place, the data are brought to the clerk manually. Thus, this allocation might be considered as following the mandatory rule.

1.2-Calculate totals and deviations of the attributes of the daily report and check deviations from plans.

1.2.1-Extract data from data base files.

The relevant saved data from prior system can be displayed on the screen so that the clerk writes down the needed data to be used for calculations. Otherwise, the data is selected and imported by the new system for further processing. The latter is chosen and, thus, allocation to the computer, because it is clear that the computer will do it faster and thus, is better at it. The allocation, thus, follows the balance-of-value. Also, the decision to allocate this subfunction to the computer is backed up by the next.

1.2.2-Perform additions and subtractions.

These are simple mathematical operations that can be performed by the clerk either manually or using a calculator, or by the computer. This may be just allocated to the clerk by the utilitarian and cost-based rule with the argument that the clerks are there. It is very important to notice that the system requirement of timeliness will be frequently violated. As a matter of fact, with the present manual system, the clerks are hardly able to finish before the daily morning meeting. They even get frustrated when they do not make it in time. This is, in addition, to the continuous management pressures rushing them. On the other hand, mental overload is frequently detected. Thus, it is decided to allocate such functions to the computer urged by the affective support rule. It should be noted that not a very large or sophisticated hardware is required. It is thought that software should not be a big economical problem.

1.2.3-Notify of invalid results, warnings, & messages

1.2.3.1-Capture exceptional attributes & values

Following the previous subfunctions this is allocated to the computer.

1.2.3.2-Act on or communicate the results.

As above.

1.3-Enter remarks on causes of stoppages.

1.3.1-Extract relevant stoppages causes from reports. Allocation is to the clerk by the balance-of-value rule since this is an act of judgment at which the computer within scope is incapable. The clerk may even need the support of engineers for decisions.

1.3.2-Register causes of stoppages.
Following the allocation of the previous subfunction, this is done by clerk whether that is input to the computer or written to the form.

1.4-Notify of invalid results, warnings, and messages.

1.4.1-Capture exceptional attributes and values.
The clerk records the information given by the computer from previous system operations, to act upon. This is a system requirement allocation.

1.4.2-Act on or communicate the results.
The clerk either acts on the information that he recorded or transfers it to the responsible as appropriate. This subfunction is allocated to the clerk by the utilitarian rule. Cognitive support rule is also applicable since the data will be needed for him to decide on further action.

1.5-Generate daily summary output report.

1.5.1-Convey information.

The extracted or calculated results from prior system can be displayed on the screen so that the clerk write them down into the appropriate form. Otherwise, this is transferred automatically by the system to the printer. The latter is chosen and, thus, allocation to the computer, because it is not envisaged that the clerk will be better motivated doing the activity. In addition, it is clear that the computer will do it faster and thus, is better at it. The allocation, thus, follows the balance-of-value and affective support rules. This decision is also following the previous decisions of not manually performing the calculations.

1.5.2-Fill in report.

The output is printed. The allocation to the computer is straight forward following the previous subfunction decision.

1.6-Generate graphs of cumulative results.

1.6.1-Extract required data.

*Similar to above subfunction

1.6.2-Convey the graphical information.

The selected plotting data points can be listed to use for manual plotting or also transfer them to another graphical charting software. Otherwise, this is transferred automat-

As human performance requirements, the volume of interaction with the computer, including other previous computer activities, and, thus, exposure time to the CRT should not be as large as to cause fatigue that may interfere with the performance of the clerk for the rest of the day with other tasks. Operating the system is hoped to trigger optimal human arousal for effective work. The clerks should be able to manipulate the system, and reach the minimum skill and performance satisfaction in a short time. They should perform fast enough such that the daily report is prepared in time, and the monthly graphs as early as possible. With the above allocation of functions, the data entry is very limited that accuracy is not a big issue. However, errors of interaction might result in system delay. Thus, this is considered under time of preparation above.

On the other hand, with respect to the users of the output, it is required that the daily presentation does not exceed about 5 minutes, and that monthly presentation does not exceed about 10 minutes. At the same time, the information to be communicated should be easily and correctly grasped by the managers (audience).

3.4. INTERFACE DESIGN

At this stage, the focus is turned towards the characteristics of the human-machine and human-software interfaces. These include workspaces, computer hardware, displays, computer dialogue, screen design etc. Areas where system performance are most improved by well-designed interfaces are identified.

Categories: The user-computer interface can be divided into the following nine categories: Users, input devices, input languages, dialogue design, user guidance, output devices, computer messages, screen design, and computer response time.

3.4.1. Output Design

3.4.1.1. Daily Report

The output medium design of the daily report is to be in the format of a hardcopy as justified by the system definition. See fig (3-4-a) for exhibit of the daily report.

The report is divided into groupings arranged according to their relative importance. One table showing the summary of the most important items that are of quick interest with factory management level. The summary includes the total inventory of cement and clinker. Also, it shows deviations of clinker from projected plan, and cement from forecasted demand.

Production Daily Summary

Date: 31-Aug-92

Table 1: Factory Summary (tons)

	Clinker Produced	Cement Dispatch
Deviation from Plan	(35, 875)	(16, 109)
Stocks	137, 842	35, 702

Table 2: Lines Summary (tons)

	Clinker	Cement		
L	Produced	Produced	Dispatch	Stocks
4	335	1, 005	697	6, 992
5	1, 100	450	2, 557	9, 832
6	0	1, 895	142	12, 038
7		2, 380	2, 982	6, 840
T	1, 435	5, 730	6, 378	35, 702

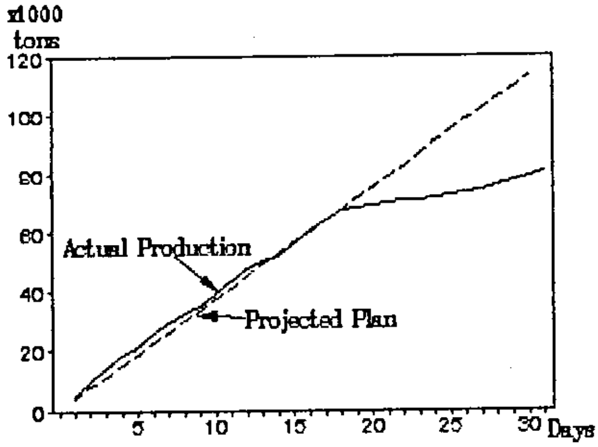


Fig 1: Cumulative Clinker Production for the Month: Aug-92

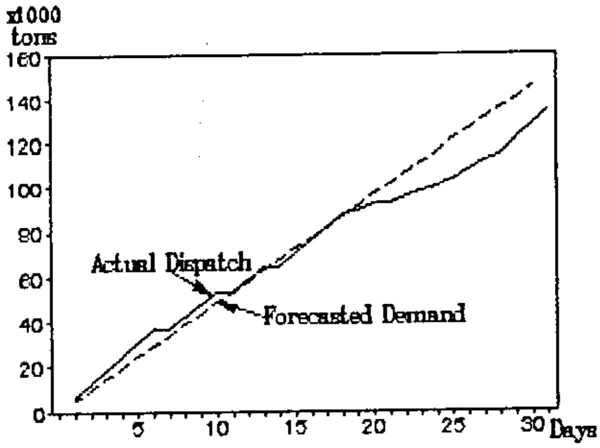


Fig 2: Cumulative Dispatched Cement for the Month: Aug-92

Remarks:

-Deviation of clinker production and cement dispatch from the plan.

-Line 6 is stopped due to electrical problem.

Figure (3-4-a): Proposed Production Daily Report

Next to the right of the factory summary table, the summary of all production lines is located. This table includes clinker production, and cement production, dispatch and inventory of all lines individually and in total. Since clinker inventory is physically pooled in factory common storages, such information is not found in the table.

Two graphs are added below the summary tables in the middle of the report. In contrast to the summary tables, the graphs provide a quick impression of a large set of data (daily results for about one month) about production and dispatch conditions compared to the plans.

Space is allocated at the bottom of the daily report for remarks relevant to logged information. The remarks may include faults, accidents, and causes of stoppages of the production lines. Any messages or alarming information concerning out-of-limit results, such as below-minimum inventory levels, are also reported therein.

Alternative Designs: Applying the same arguments, the output medium design of the daily report may be alternatively designed in different formats such as the ones shown in figure (3-4-b) and figure (3-4-c): parts 1, 2, and 3.

Production Daily Summary

Date: 31-Aug-92

Table 1: Factory Summary (tons)

	Clinker Produced	Cement Dispatch
Deviation from Plan	(35, 875)	(16, 109)
Stocks	137, 842	35, 702

Table 2: Lines Summary (tons)

Line	Clinker Produced	Produced	Cement Dispatch	Stocks
4	335	1, 005	697	6, 992
5	1, 100	450	2, 557	9, 832
6	0	1, 895	142	12, 038
7		2, 380	2, 982	6, 840
Total	1, 435	5, 730	6, 378	35, 702

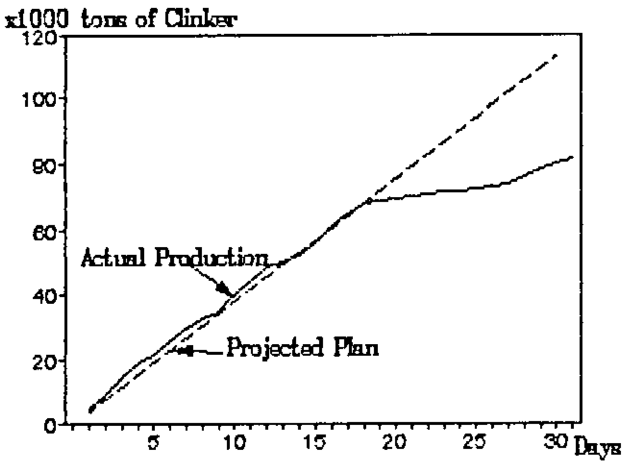


Fig 1: Cumulative Clinker Production for the Month: Aug–92

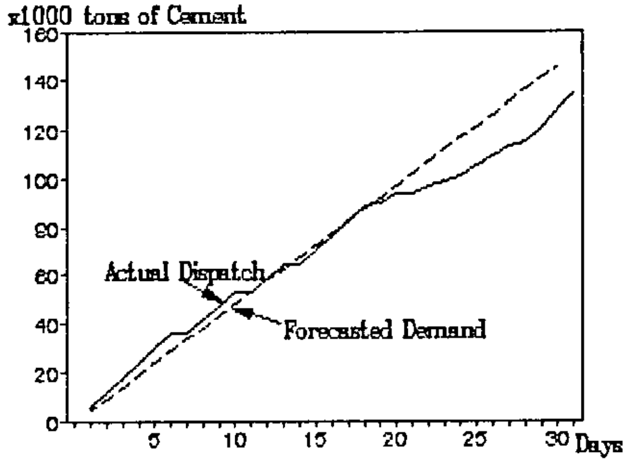


Fig 2: Cumulative Dispatched Cement for the Month: Aug–92

Remarks:

To whom it may concern

Figure (3-4-b): Proposed Production Daily Report (First Alternative)

Production Daily Summary

Date: 31-Aug-92

Table 1: Factory Summary (tons)

	Clinker Produced	Cement Dispatch
Deviation from Plan	(35, 875)	(16, 109)
Stocks	137, 842	35, 702

Table 2: Lines Summary (tons)

	Clinker		Cement	
Line	Produced	Produced	Dispatch	Stocks
4	335	1, 005	697	6, 992
5	1, 100	450	2, 557	9, 832
6	0	1, 895	142	12, 038
7		2, 380	2, 982	6, 840
Total	1, 435	5, 730	6, 378	35, 702

Remarks:

Figure (3-4-c): Proposed Production Daily Report (Second Alternative). Part 1: Summary Tables.

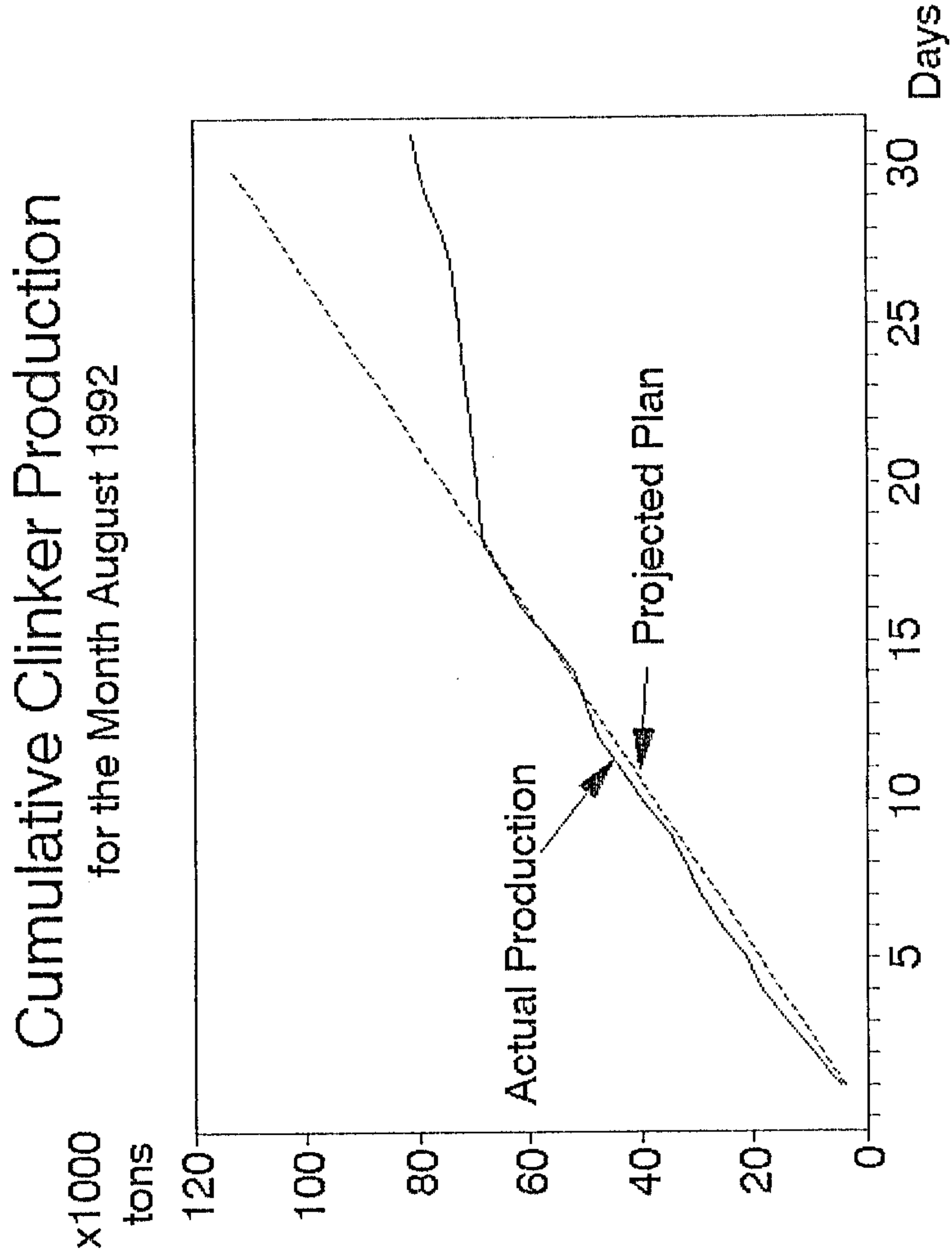


Figure (3-4-c): Proposed Production Daily Report (Second Alternative). Part 2: Plot of Clinker Production.

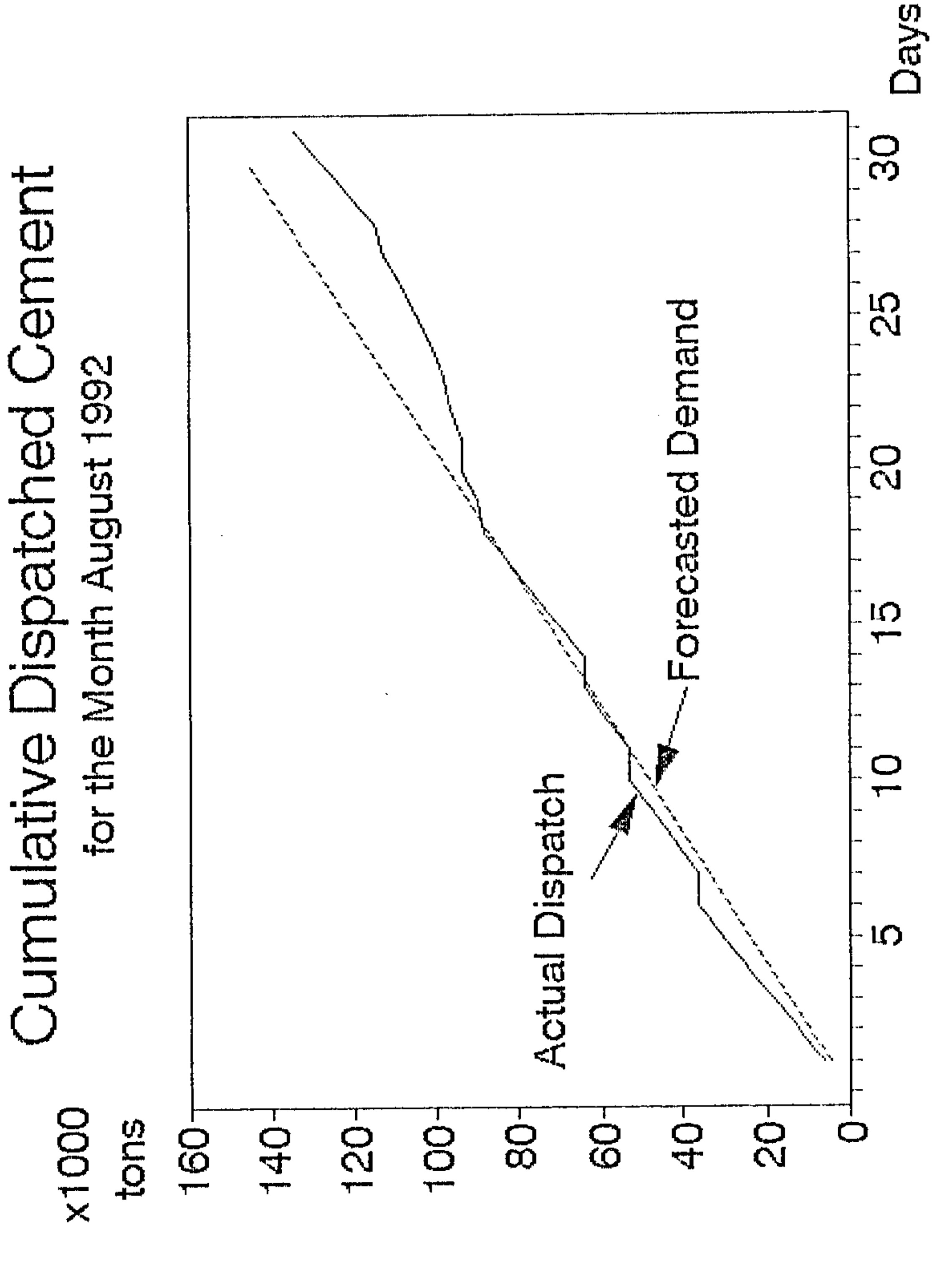


Figure (3-4-c): Proposed Production Daily Report (Second Alternative). Part 3: Plot of Cement Dispatch.

General Layout: Not to distract or divert attention from the information to be communicated, no cluttering ornaments are used. The only aspect that might be interpreted as non-data ink is the thin shading at the top of the report. As a matter of fact, this shading is used to separate the main heading. The main heading is highlighted also in larger font size. As for the rest of the report, the type is made clear, precise with upper-and-lower case and serifs (Roman) to maximize legibility. The date is announced openly in a long semantic format.

Since the daily report is considered as a communication tool for the daily meeting, the included information has been optimized and white space has been generously left over. The idea is to reduce mental load and lead the reader to directly perceive the most important information for the day.

Daily Report Tables: Since exact information is required in the summary, in addition to the fact that only small data sets are displayed, the factory summary and the lines summary are presented in table formats. The numbers are rounded to the first digit.

The factory summary table aims at a quick decision making based on accurate information of the most important attributes, namely aggregate inventory and plan deviations.

The lines summary contains more detailed information of each line. The results are laid side by side for easy comparison. If enough time is allocated during the daily meeting, such information may be intelligently processed by the field independent users.

Factory Summary Table: The factory summary table is designed such that it shows exactly the deviations in cumulative clinker production and cement dispatch aggregated at a factory level. To highlight negative deviations from the projected plan and forecasted demand, such results are displayed in brackets.

Although clinker inventory is shown in the table uniquely, cement inventory is redundantly shown for quick reference, being displayed under total in the lines summary.

Lines Summary Table: Designing the table, no horizontal or vertical rules are used except under the columns captions and as separation of individual lines information from their totals. Instead, white space is used between columns. Wider space is left between clinker information and cement information columns group. Also, a wider space is used to separate lines numbers column. Although vertical rules could have been used between the unrelated columns, such non-information surplus might result in clutter and noise. Moreover, it should be noticed that captions repetition is avoided.

Production Planning and Control Graphs: In the production planning and control domain, it is conventional to plot the cumulative production plan and cumulative forecasted demand in a line graphical representation. It is conventional in plotting trend logs to draw line graphs with the date as the abscissa and the variable of interest as the ordinate.

From the Human Factors principles point of view, the data of either the actual production and dispatch, or the projected plan and forecasted demand are mentally integral; noting that the daily values are literally integrated to get the cumulative values. Thus, the line graphs are very convenient representations since they are considered as integral displays and comply with the principle of the compatibility of proximity. The line graphs are best for detecting change.

On the other hand, comparison between actual and planned implies using a separable representation by the same principle, such as bar graphs which are better for diagnostic tasks.

However, as a tradeoff, it is decided to go for the line graph since it has not been foreseen to use the graphs for accurately comparing the values. In contrast, the deviations (comparisons) of the reported day are presented redundantly in the factory summary table. Thus, it is thought that the benefit of using the integral representation outweighs the cost of not using a separable display. Nevertheless, using the common x-axis as a common baseline, improves comparison. For better discrimination of the contrasting lines, solid texture lines versus dotted texture lines cues are used. Geometric shape (symbols) cues could have redundantly been used, had not the great number of points certainly resulted in clutter. Color could be added redundantly as another contrasting cue. Such an application would dictate the use of a color printer. Such an additional cost is not justified for the reasons mentioned above.

Since the idea is to give a good grasp of the actual production and dispatch versus planned, rather than to use the graphs to calculate the exact production lag or lead, grids are omitted. Otherwise, grids might have been used to improve the accuracy of the readings. On the other hand, the grids in the proposed format impose a cost on latency. Apart from that, grids, as embellishments, result in clutter. For the same reasons, the scales of the ordinates are in 10's of thousands and the days of the month in 5's, noting that tens and fives are more conceptually compatible than threes or fours for example.

The graphs are labeled in the manner recommended in the Human Factors literature. Labeling includes the detailed title and description of information provided by each axis. The ordinate labeling is horizontal for quicker perception, conceptually compatible with reading from left to right. No legends are used outside or inside the graph panel in a separate manner. The curve itself is rather labeled.

3.4.1.2. Monthly Presentation

As discussed in the system definition, the monthly results will be communicated through graphical displays in the form of overhead projector transparencies. Examples of the main slides for the production presentations include the information of productivity of each line. The results should compare the results of the month with previous data. One way is to consider such data on a weekly basis. Another is on a monthly basis. Weekly aggregations are more convenient when presentations are at the first few months of the year. Anyway the set of data collected for the thesis cover two months and are, thus, reproduced as weekly. Such periodical aggregations are possible by some computer packages such as Quattro Pro 4.

Graphical Representations for Trends in Productivity: One purpose of presenting the daily averages of clinker production of each line is to show the trend in the productivity of each line. Applying the proximity compatibility principle, the weekly trend is thought to imply the need for mental integration. Such a mental proximity requires physical proximity represented by the line graph. The line slope is considered as an emergent feature that is a directly perceived indicator of change in magnitude. In addition to that, displaying the three lines on the same slide helps in comparing their slopes, and thus their trends.

In order to comply with the principles of perceptual discriminatibility, the line graphs redundant coding is used. To reduce on the focal attentive processing the geometric shapes are made large. It should be noted that such large size symbols are not possible by almost all computer packages. That is why they are manually made. Limitations of computer-based graphics should not allow any violation of Human Factors principles. In many cases, one can simply change default settings. In other cases, manual corrections may be of help. Moreover, as redundant coding, lines are discriminated using texture such as solid and dotted etc.

Since printing on transparencies with the system printer will result in erasable slides, the graphs are rather first printed on paper then copied to the transparencies. See figure (3-5) for an exhibit of line graphs.

It should be noted that the exhibit has been produced in color to simulate slides while in practice the print does not have to. Color coding can be added manually to the transparencies for increased redundancy. Photocopying color transparencies has not yet become common.

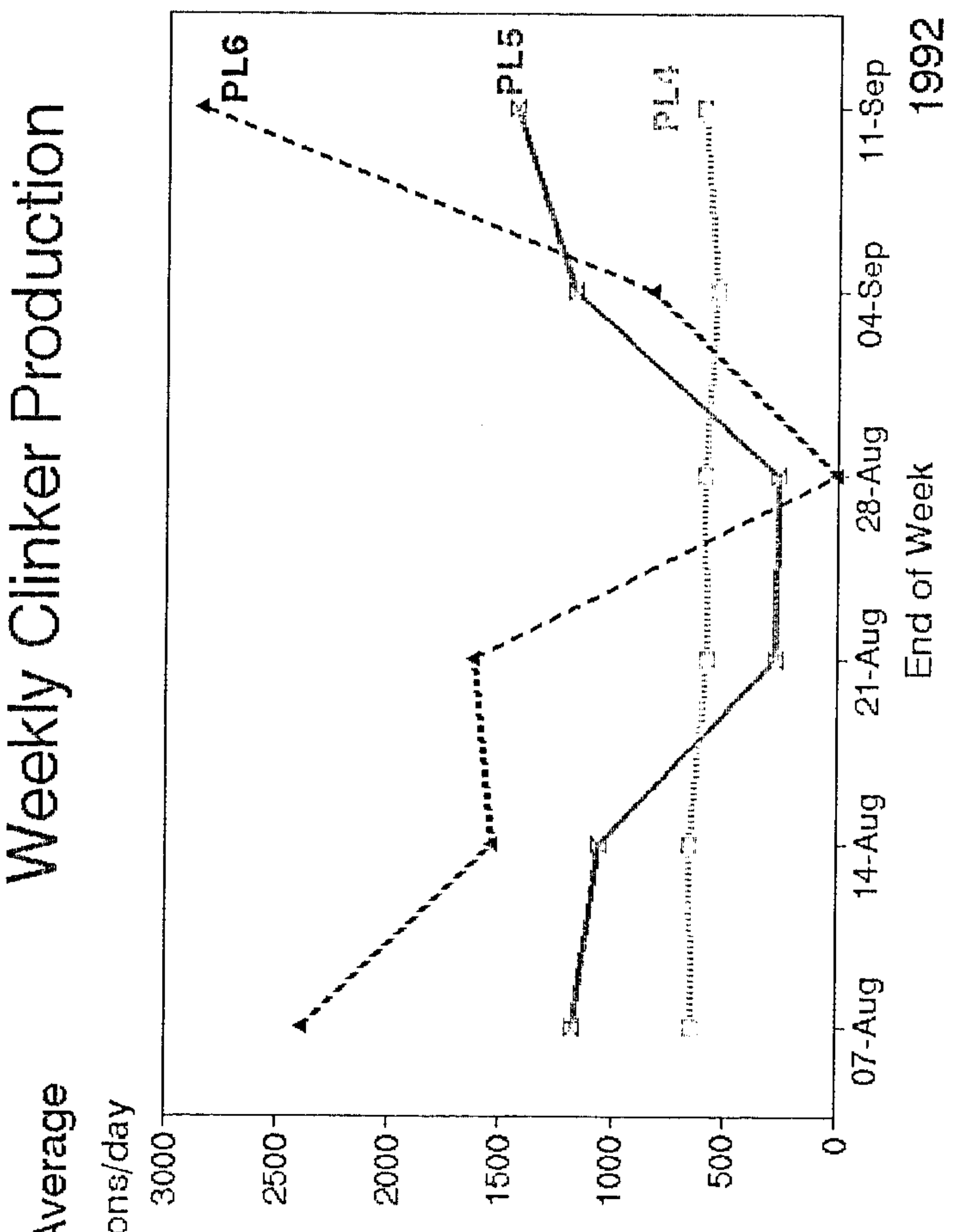


Figure (3-5): Display of Line Graphical Representation for Comparing Trends

Graphical Representation for comparing production: As discussed earlier, judgment of change is, also, best with bar graphs. Bar graphs are even better than line graphs when a comparison task is involved. The imaginary line connecting the tops of the bars of each line are the emergent features that help the direct perception of change.

The bar of each production line is represented with a discriminate specific coding to help in focusing while comparing the three production lines with bars as separable displays.

For proper perception and visibility, solid saturated colors fill the bars since bright screens will be conjugated with the overhead projectors. Varying shades of gray could alternatively be used. Red and brown colors are avoided because they are not normally preferred. Red is also avoided because it is rather compatible with alarming status.

As discussed earlier also, the range of wavelengths of colors used should not be wide because long exposures may cause eye fatigue. It is always assumed that not only production is presented but also, beyond the scope of this system design, other activities and results, such as energy management.

Thus, examples of close but easily discriminated colors which are also aesthetic and appealing are cyan, blue and green. However, blue should be avoided if very small bars are expected since it is not very detectable in small displays. Mixing of light colors with saturated colors is also avoided because bars with saturated colors may be perceived as smaller than their actual size compared with bars colored lightly.

The design reflects the understanding of the perceptual-cognitive interface. The audience should rapidly comprehend the main point of a briefly presented slide with minimal unnecessary demand on perceptual and cognitive resources.

As mentioned under the daily report design topic, labeling is used effectively. The size of representations is proportional with the quantitative information. The lie factors are one. Space between groups of bars is sufficiently wider than the bars to avoid any negative activation of such a white space which might be perceived as other bars.

To enhance comparisons the lines are represented on the same base line. So are the bars; bars are not tiered bars.

See figure (3-6) for a bars graphical representation. See also figure (3-7) which is similar to the above figure except for the added grid lines. In the former, the concentration is more on information ink.

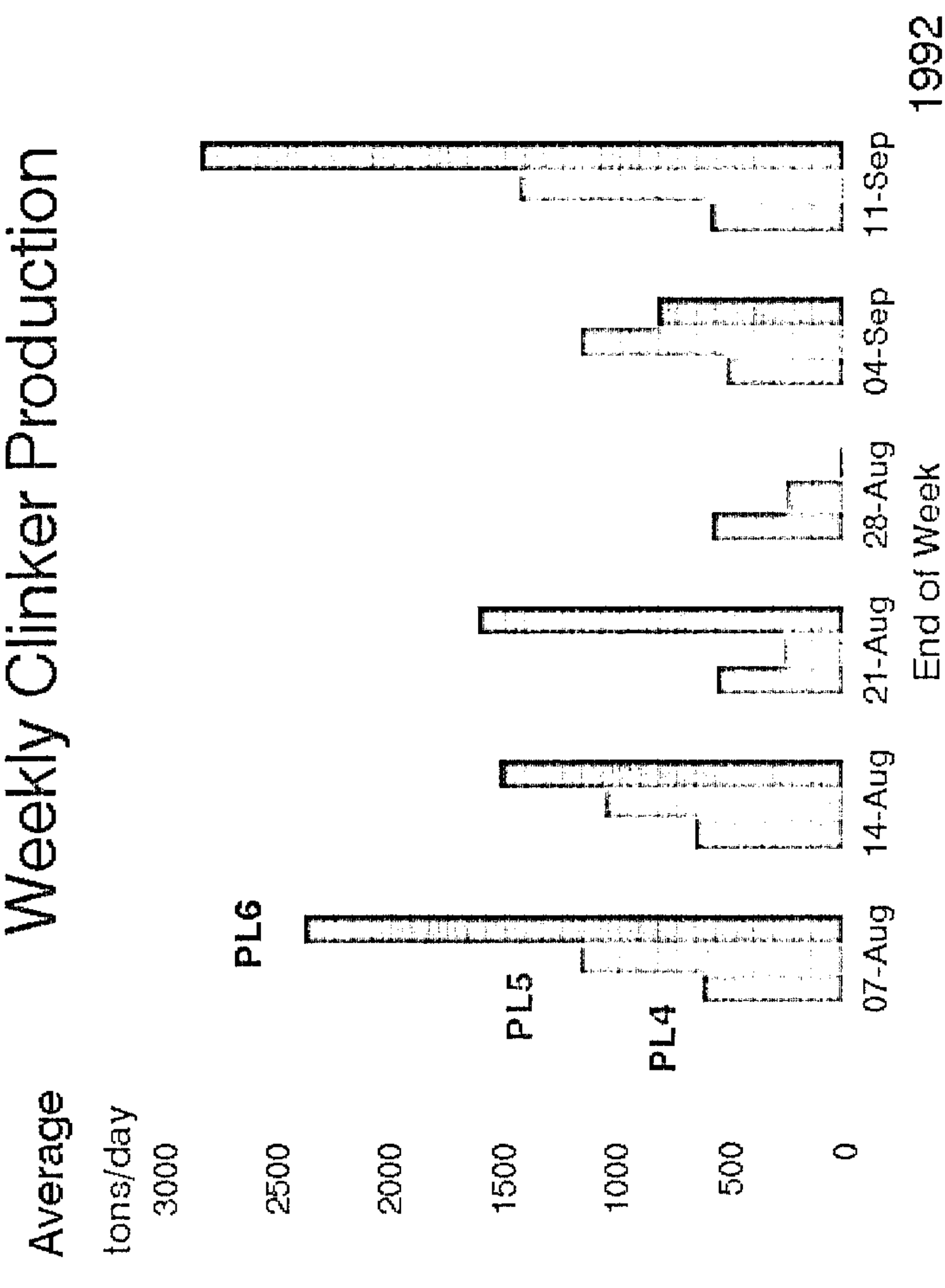


Figure (3-6): Bars Graphical Representation for Comparison Task.

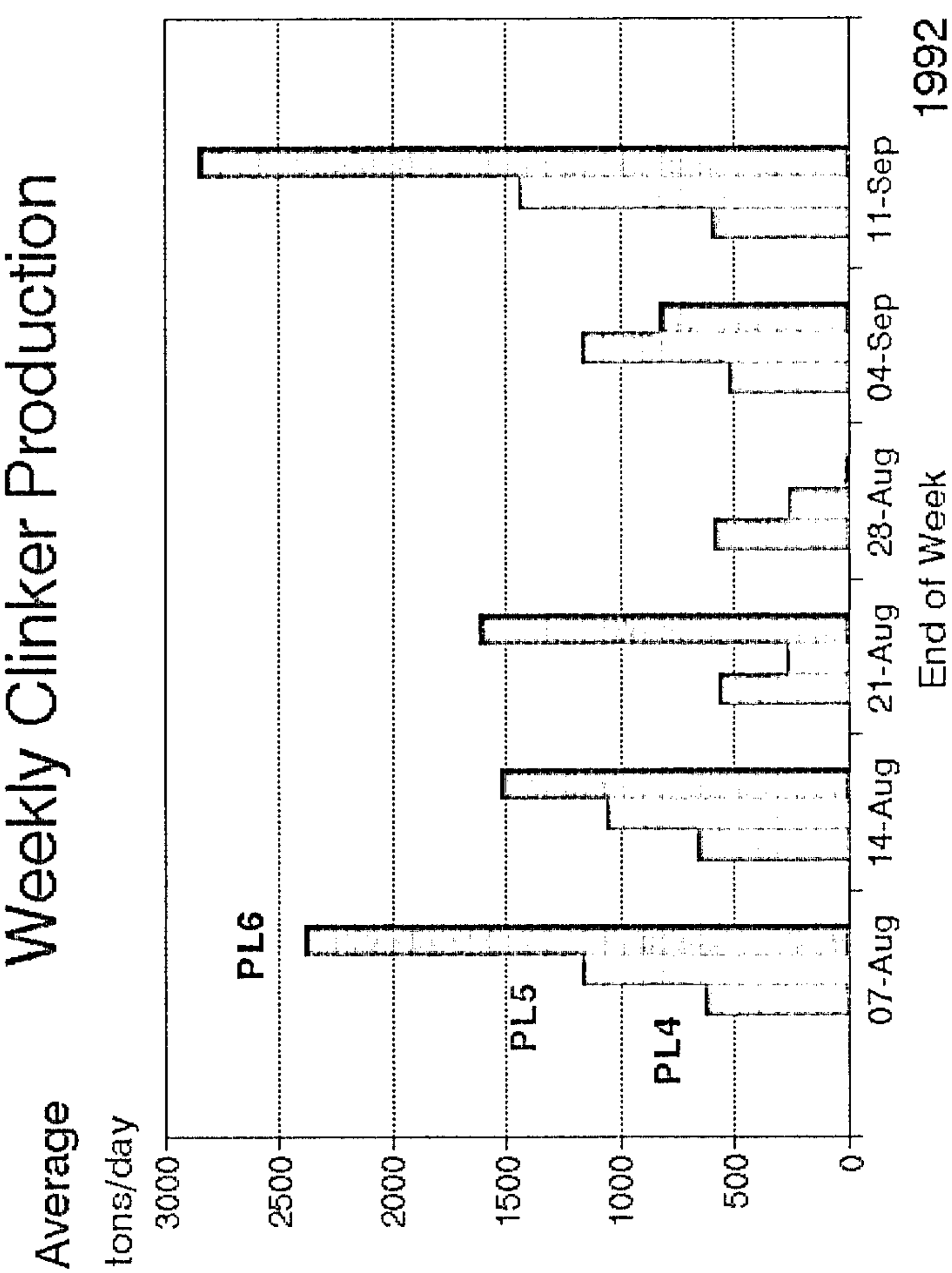


Figure (3-7): Bars Graphical Representation with Grids for Judgment of Proportion.

When it comes to showing the proportions of each line for only one week, for example or one whole long period, a pie is very useful specially if redundantly labeled with the correct percentage.

A column (one divided bar) is as effective.

The design of the pies and columns follow also the same guidelines mentioned above.

If the proportion of production of one line is to be emphasized, its respective slice can be exploded for more conceptually compatible perception of the represented objects.

Thinking in this manner, a three dimensional pie would seem superior. However, the actual quantitative information would be distorted due to introduction of a lie factor different than one since solid proportions are not any more proportional on the layout.

Figure (3-9) shows a pie graphical representation demonstrating its use in perceiving proportion for one whole period.

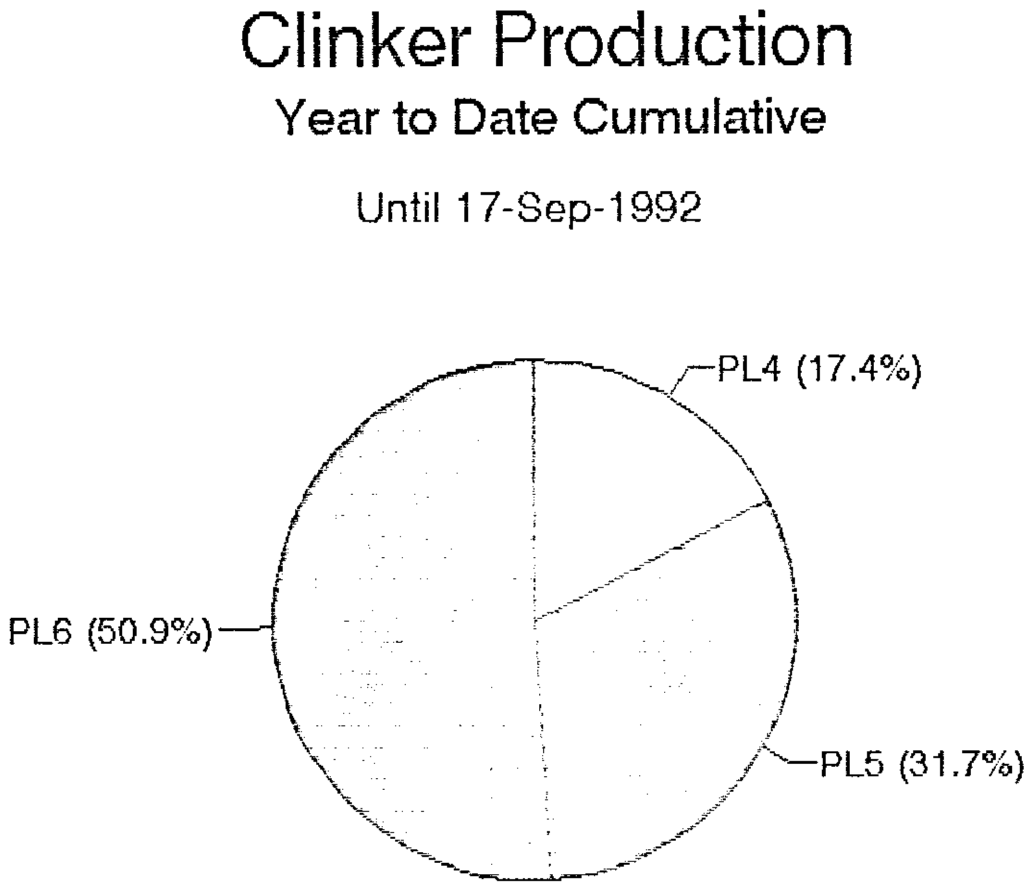


Figure (3-9): Display of a Pie Chart to Show Proportion.

3.4.2. Screen Design

3.4.2.1. Monthly Output Screens

The monthly graphical representations can be very similarly produced on the CRT as well as on hardcopies and transparencies. So all previous design remarks on monthly report graphical representation hold. Therefore, they will be discussed no further.

3.4.2.2. Daily Output Screens

New versions of major spreadsheets packages include a screen design capability whereby the screen can be made to look very much similar to a hardcopy output. Used in this system design, Quattro Pro 4 has such a feature which is called WYSIWYG (what you see is what you get). As contrasted to character mapping, WYSIWYG uses the bit mapping technique. This feature of Quattro Pro 4 is made use of.

Daily Output Screen Format: Since the daily report is produced in an automatic manner, other information than hardcopy is implied for feedback; such as status messages, errors messages, and menus, which will be discussed later on. Otherwise, the output screen format and information content look similar to the hardcopy. See Figure (3-4-a). However, the simulated font size is larger keeping a consistent visual angle for visibility at a farther distance. It should be noted that similar general layout of screen and hardcopy makes learning and recognizing the required information at their specific positions quicker. Early discussion of the daily report design holds for the screen design also. See figure (3-10) for output screen.

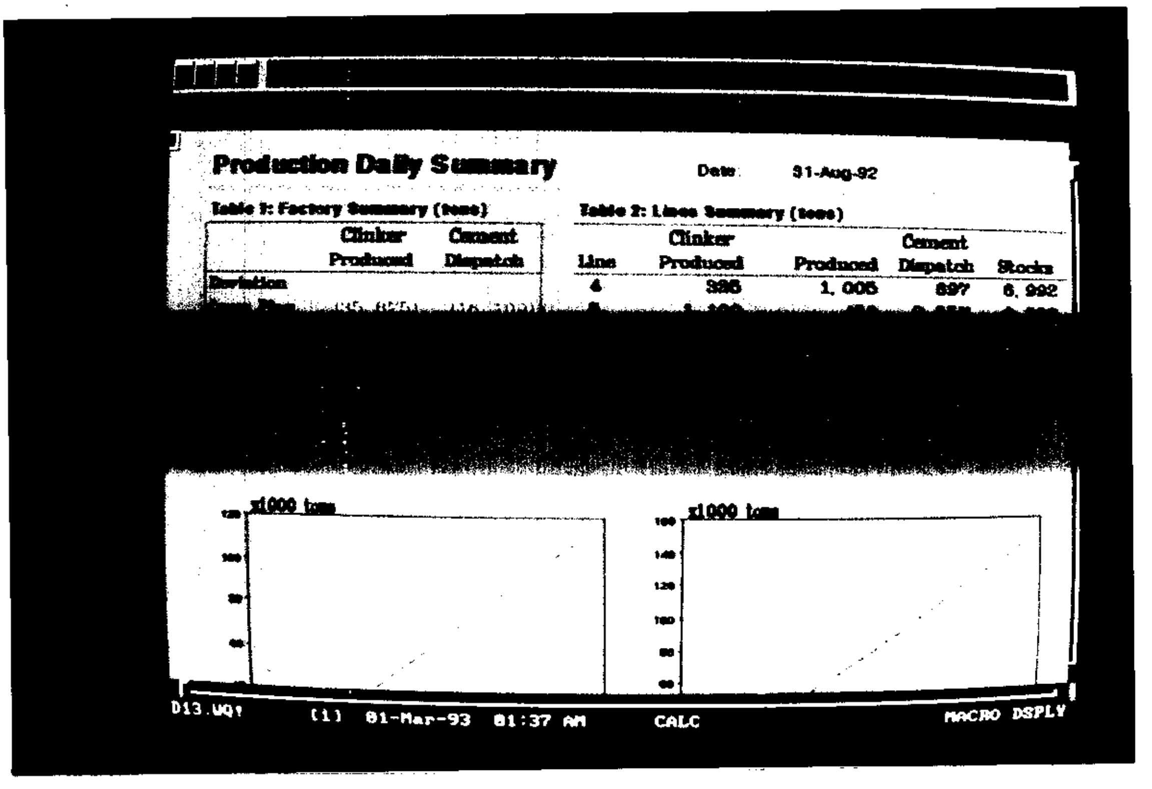


Figure (3-10): Photograph of Output Screen (First Page).

To give unity to the display, the space between the different groups is made not more than the margins as is the case with the hardcopy report. To reduce complexity of the display, the tables and graphs have been structured such that horizontal and vertical alignment points are minimized. The screen design has resulted in an overall density of about 10%. This is when both tables and graphs are seen together. Most of this density is strictly informational. Such a low screen density does not have any cost of illegibility or poor readability since the fact was not a result of extensive abbreviations, for example. As a matter of fact, longer familiar descriptions are used rather than short but unfamiliar or incomprehensible wording.

A system consequential benefit of the above design and of smaller number of screens is reduction in storage capacity requirements.

Screen Pages and Scrolling: The most important different aspect is that only about half the hardcopy page length can be seen at a time. In order to be able to see either part of the hardcopy page simulation, the output has been designed into four overlapping screen pages defined by the functional groupings. The operator scrolling task is facilitated by allowing him to change positions to pre-specified points through menu commands. The first screen page mainly presents the summary tables. See figure (3-10). The second page shown in figure (3-11) presents the graphical representations.

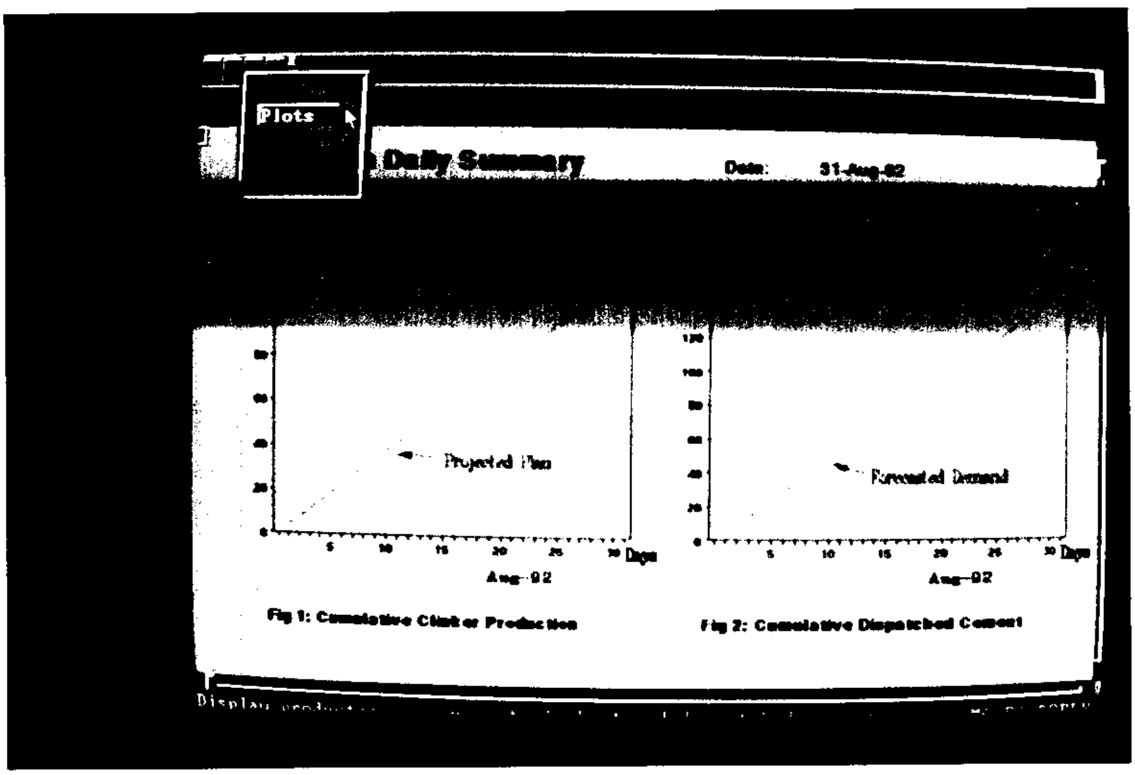


Figure (3-11): Photograph of Output Screen (Second Page)

In another position, both graphs can be seen simultaneously with the tables, on a third screen page. Such a possibility has the cost of not fully showing the descriptive information of the graphs. However, this tradeoff does not jeopardize clarity since one can always refer back to page two. The last is to concentrate on the remarks. This is page four.

Running from one screen page to another is, thus, realized through paging rather than scrolling. Paging is thought to result in better performance, especially for the novice since scrolling may result in loss in orientation.

Output Screen Colors: The output screen is designed in a dark-on-light polarity since such a polarity is more flexible with respect to the number of colors that can be optimally combined. This design strategy is also implied by the restriction in the software with black is the only allowed text color in WYSIWYG mode. With dark-on-light any text color saturation can be used.

On such a polarity , desaturated background colors are, however, preferred as per Human Factors guidelines. Quattro Pro 4 offers eight dark colors for background and eight light colors. Among these colors is bright white. Although generally preferred to other colors, bright white has been rated as eye straining. Desaturated cyan is one of the highest rated colors. Thus, light cyan is used for the background. Note that photographs colors in figures (3-10) and (3-11), are not exact replica of CRT display.

Such a choice of achromatic/chromatic for combination of text/background is found among the highest rated colors. Obviously such a choice avoids simultaneous display of highly saturated, spectrally extreme colors. On the other hand, the spatial distance of black (white) from cyan is measured to be about .03-.06 on the CIE/UCS-1976 diagram. Unfortunately, no data are available for such a combination. However, discrimination and legibility can be subjectively easily proved satisfactory. Cyan is frequently recommended for background being a cold color.

Not to use a large number of colors or endanger unity of the screen layout, separating lines and shades as well as text are colored black, especially since other colors are simultaneously used for other purposes, thus, avoiding a 'Christmas tree' effect.

For redundant separation and contrasting of line graphical representations of actual versus planned curves, desaturated magenta and desaturated blue colors have been used respectively.

3.4.2.3. Daily Input Screens

Figure (3-12) shows a typical Daily Input Screen.

Daily Input Screen Format: The input screen shows explicitly the screen title at the left top corner of the screen. It is written in standard character-screen alphabet. The date attribute and value are also shown at the top middle right side of the screen. The date format is made conceptually compatible with the conventional format used in the country, namely day, month and year respectively. Similarly the delimiter of the date components are also hyphens (or slashes during data entry). Nevertheless, not to confuse the user, the month name is alphabetically explicitly expressed, thus, preventing any mixing up with for example US conventions if numerals were used instead.

An editing line is located at upper position of the screen above the title line. A similar line is designed at the bottom of the screen to show when editing is activated the current date and time, and status. When the menus are active, the content of this line turns into an explanation of the highlighted menu choice, and status only.

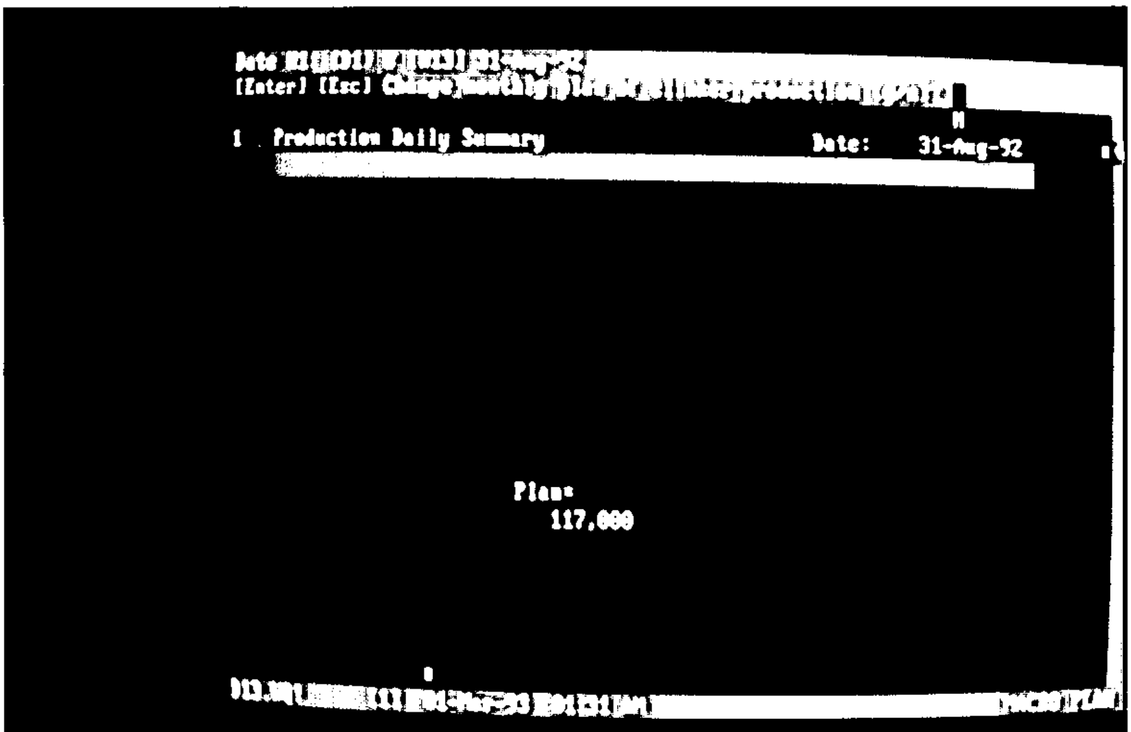


Figure (3-12): Input Screen

The middle area of the screen is blank being allocated for instructions for entry guidance, showing previous values, feedback, and other messages. Such generous blank areas result in a lower screen density and should help in a quick detection and identification of a message.

A second page of the input screen is reserved for entry of information constituting the remarks.

To a great extent, the input screens displays are mapped in a consistent manner with the output screens. This should help in automatic cognitive processing which represents a learned process associated with skilled performance. Thus, for consistency, the replicated input screen titles, date caption and field, status line, and paging are affected in a similar format and spatial compatibility as with the output screens. Moreover, as mentioned above, a character display rather than bit mapping is used as a tradeoff for quicker data entry and processing. Thus, the former screen characteristic condition results in a shorter system latency. With this tradeoff, the major difference is in type font and type size. Furthermore, it should be noted that the characters in the input screens subtend a larger visual angle in contrast with output screens where there is a cost of having to display a complete width of the report.

Screen Pages and Scrolling: It should be noted, however, that there are only two pages of the input screens since tables contents and graphical representations are displayed only in the output screens. As with the output screens, paging is used to go from one page to other rather than scrolling.

Input Screen Colors: Also, colors are purposefully different to recognize automatically the input screen mode for quicker human reaction time and minimal memory loading. As a matter of fact, polarity is also reversed with input screens designed as light-on-dark for the same purpose redundantly. Nevertheless, and maybe considered as another cost of the character display is the fact that Quattro Pro 4 permits only 8 dark colors for background.

As mentioned earlier, desaturated stimuli on desaturated backgrounds are preferred for light-on-dark polarity. In fact, bright white on blue background combinations resulted in the best rating. However, light yellow/blue is rather more optimal when strain ratings are considered, The latter colors combination has been shown not to differ significantly in overall preference ratings. Light cyan/blue being also not significantly different, light cyan is used for frame which is compatible with the output screens. Similarly, light cyan and yellow text are used for the status line being also compatible with the output screens. Editing line is also yellow on light cyan. Also, a separation shadow of title from the rest of the input screen is in cyan color. Such a color utilization minimizes also the total number of colors.

3.4.3. Input Design

In the system definition stage, it was decided to input the main data to the system through automatic extraction from the relevant Database files. Thus, only the report date, projected plan, and forecasted demand are left open to change and updating. In addition to that, the remarks about stoppages, accidents, alarms, and other operational and production abnormal status are filled in. Thus, there is no strictly dedicated input form design. As explained earlier, in addition to the title, a date field, a blank center of the screen, and a remarks field constitute the data entry form.

Date Entry: The date field value, depending on the stage of the input operation, may be representing either the default date, the most recent entry date, or the currently processed report date. When the program is first run for a new session, the default date appears on the screen representing the day before the current date. This implies that the default operation would result in a daily report of the previous day.

After entering the date, the tables are calculated, and the graphs are plotted. The plots of actual production and dispatch represent the period from the first day of the specified month until the entered date.

When the default or previously entered date is valid, only confirmation by pressing the Enter key is required. Otherwise, date entry is affected through entry method rather than selection-based. As discussed earlier, the entry method is preferable and faster especially if requested completion or sponged auto-completion is used. Thus, the date entry is designed such that when the required day is keyed in, entering the first three or more letters of the month result, after pressing the Enter key, in automatic completion of the month and current year. More than two letters are of course required because the same first letter(s) are common among two or several months names such as June and July. The objective is to make a faster human performance. The date entry is done in the separate input line at the top of the screen.

It is maybe clear now that the requested completion rather than sponged or auto skip completion is the affected design technique. Although the date is always presented in its own field at all times, the date entry is not also affected through modification.

Accuracy is made sure of through editing which is immediately allowable as far as the Enter key is pressed only once. A second press of the Enter key is required for confirmation before processing is started.

Projected Plan and Forecasted Demand: Changing the values of either the projected plan of clinker production or the forecasted demand for cement dispatched is done in response to an instruction for entering at the input line. Prior to the instruction, the previous value is shown in the middle of the screen. Pressing the Enter key would keep the value unchanged. Otherwise, the new value is entered. Since almost an infinite number of values are possible for entry, selection-based entry is simply not feasible. Immediate editing is possible while keying in the value before pressing the Enter key. Any further delayed editing is also possible through the menu command. See figure (3-12).

Adding Remarks to the Report: The remarks are first entered at the consistently preserved input line. Any changes to the remarks can be done as far as the Enter key is not pressed yet. Otherwise, another paragraph, items, or group of remarks may follow. The remarks span the width of the screen. Excessively long entries are automatically wrapped to the next line. See figure (3-13).

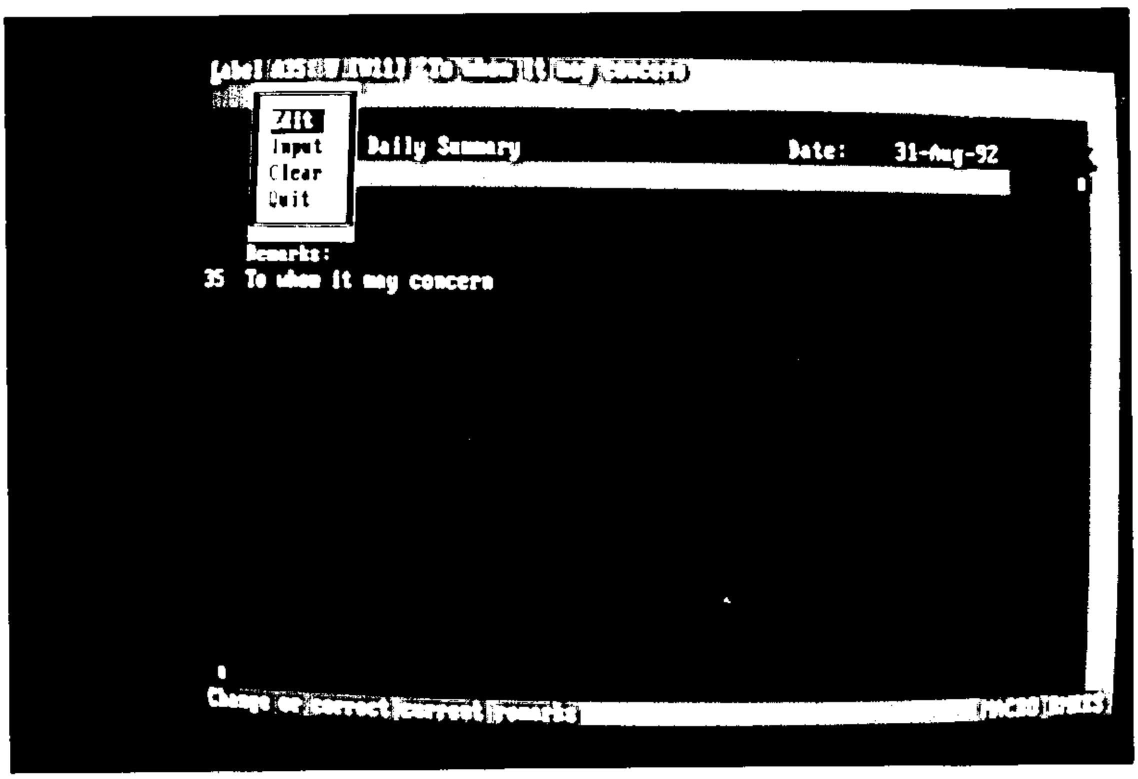


Figure (3-13): Remarks Input Screen

Input or editing is affected within the input line. Thus, any correction can be done at once. Pressing the Enter key transfers the information to the field. More information can still be entered. Editing is also still possible. Quitting the field can be done only after a second confirming press of Enter key, as discussed under date entry. The remarks field can be entered again for editing through menu command.

3.4.4. Dialogue Design

At the beginning of a new session of system run, the question-and-answer style is used as follows.

3.4.4.1. Questions and Answers

The questions are made simple. For this same reason, semantic binary answers are only permissible namely (Y,N). See figure (3-12). These questions are:

-Change date (y,n)?

-Change monthly plan of clinker production (y,n)?

-Change monthly forecast of cement dispatch (y,n)?

Other questions-and-answers dialogue is held between the computer and the user. For example, when the latter instructs for exit, the computer initiates through a message, then, prompts for an answer of confirmation with explanation as shown in figure (3-14):

-Are you sure?

-Press: N to return, Y if sure to exit; (y,n)?

Please note that the answer can be in lower or upper case.

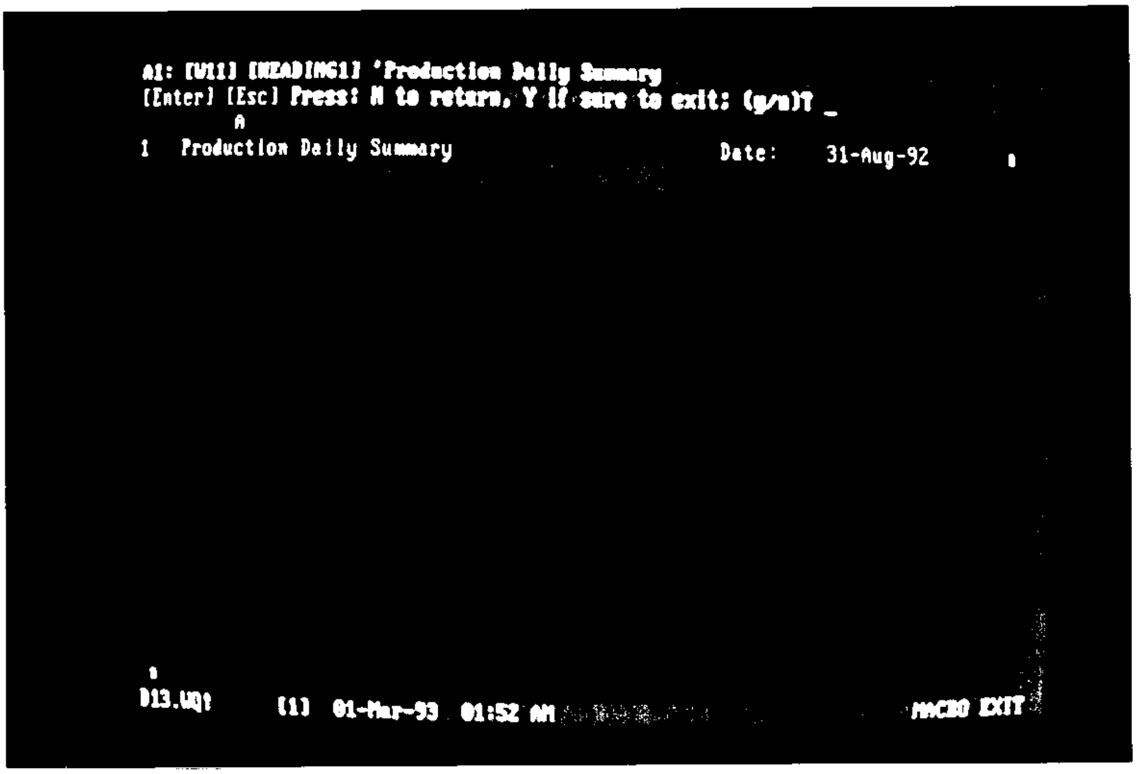


Figure (3-14): Questions and Answers Dialogue Style

3.4.4.2. Command Language

Command language is not chosen as a dialogue style for this system being addressing intermittent operators. As expressed in the system definition, if the general user is also considered, again this style is not suitable for the novice who will need sufficient familiarity with the language semantics and syntax. Nevertheless, some of this system menus selection techniques are, hereby, claimed to have equivalent powers and to be user-initiative as the command language.

3.4.4.3. Direct Manipulation

Although direct manipulation is becoming very popular and is claimed to be appealing for the novice and the expert users, this style is not chosen for the system design for the reasons to come. There is no satisfactory literature guidelines or principles for use of direct manipulation available yet.

Referring to first principles of Human Factors, one can claim that cognitive interpretation of symbolic coded signals termed icons might be different from one user to another. Icons need to be associated with a concept and the persons image of that concept. Abstract concepts are difficult to mnemonically imagine. In many cases, icons are only effective with accompanying labels. Labels alone may be better than icons alone. So may be menu options.

As a software constraint QPRO 4 hardly support any direct manipulation techniques, as most of the available software packages. As pointed out earlier, such applications require complex and large software that rapidly eat up all hardware capabilities defined for this system.

3.4.4.4. Menu Style

The great advantage of menus is that they minimize the user's memory load, especially for novice and intermittent users. They need minimal typing. They constitute semantically well defined structures.

Quattro Pro 4 supports mainly vertical pop-up menus to be built for programming applications. In the meantime, pull-down menus, with permanent (on display) first-level index options panel that may be positioned horizontally at the top of the screen, and vertical subsequent pull-down panels that appear in response to options selection, may be custom-made for application programs. Similarly, QPRO innovation of the termed speedbars may also be custom-made. Speedbars are permanent single-level menus whose options (words) are abbreviated. They are vertically positioned at the right side of the screen when using character displays or horizontally at the top of the screen when using WYSIWYG displays.

Pull-down menus are not applied for the following reasons: The permanent menu panel may add to screen cluttering. Literature review studies have favored vertical menus. Also, QPRO 4 menus when custom-made may require liquidation of other spreadsheet functions; making it harder for iterative design and maintenance.

Speedbars are not chosen because of the following reasons: Menu positioning for either screens displays are not consistent. Abbreviations of all menu commands will increase the users' memory load. The menus may need to be extended to more than one screen. The total number of options that can be designed are limited. The options cannot be categorized with the purpose of reducing search time. Also, the broad design is imposed though may not be the optimal. In such a case, the insulation and funneling possibilities are ignored, and the selection technique is restricted only to pointing. Mouse is the pointing device accompanying QPRO 4.

Menu Characteristics: Thus, pop-up menus are used for the system design. The following are the advantages of such a design, noting that some of these may still apply to the other menus. The pop-up menus do not have to be present at the screen all the time. The menu panels are vertical. The panel can be designed to appear at any specific position on the screen. Also, the options wording may be full-words containing as many words as required, capitals or lower-case, and single- or multi-spacing.

It is decided to fix the current menu panel always in position at the top left corner of the screen. Although urged by the need, for security and error handling purposes, to protect the spreadsheet from accidental consequences caused by a free moving cursor, the proposed consistent design of positioning is thought to affect positively acquisition time for locating a particular target option. This condition is only valid when the system awaits the operators initiation. When computer is processing a certain command, menu is no longer visible.

The options number of words are kept as short as possible to limit option locating time. More than single words options are only used whenever it was found essential to make explicit the command functional significance. For the novice, the command is explained at the bottom of the screen whenever highlighted if details are required. Such a facilitator helps in choice accuracy because forgetting of specific associations results in lower performance accuracy at lower levels.

alphanumeric codes. With the initial letters used as semantic alphanumeric codes for choices, having the letter placed to the left of the option is quite conceptually compatible as it is assumed to reflect the users' mental model of system options. The menu commands are chosen in such a manner that the initials are unique not to cause any confusion.

Menu Hierarchical Structure: Although various studies claimed higher accuracy using broad menus, selection time was found to increase as a function of menu length (breadth). On the other hand, very narrow menus (<4) are claimed to slow down navigation when too many levels are involved. Grouping was found to facilitate acquisition. Semantically categorized menus were found superior to alphabetized listings.

In order to find the optimal hierarchical structure, it was shown that it is important to discover the natural categories. The best set of categories will minimize the psychological distances within groups and maximize the distance between groups.

Menu Options: For identifying the menu options, the various possible functions that the computer will be required to perform upon the request of the operators are first narrated as follows:

1-Specifying the daily report date for data extraction and calculations.

As a matter of fact, the proper categorization may be open to discussion. The best is to reflect the users' mental model. Thus, the functions are categorized under the following index options (headings): updating, and displaying, in addition to the following terminal options: printing, saving, and exiting. Under each index option the following functions are grouped:

1-Updating: specifying date, revising plan, revising forecast, and updating remarks.

2-Displaying: tables, plots, both tables and plots, and remarks.

The above functions constitute terminal options except for updating remarks which is an index option constituted of: clearing, editing, and inputting.

Seed and Nested Hierarchies:

The seed hierarchies can, thus, be formed as shown in figure (3-15):

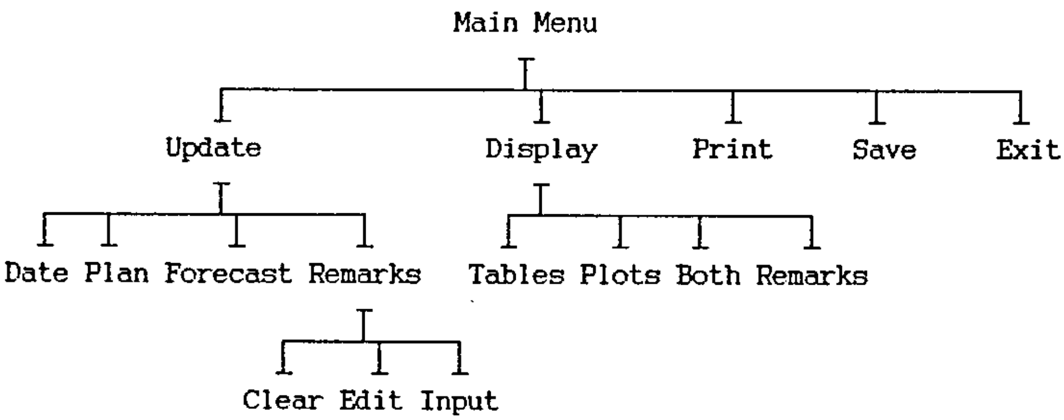


Figure (3-15): Seed Hierarchy

As can be seen, the seed hierarchy is formed of three levels. The first level includes five options. The second includes four for each of the two index menus. The third includes three for the single index menu.

In addition to the above mentioned, broad and deep designed menus, one more nested hierarchy could be formed as shown in figure (3-16):

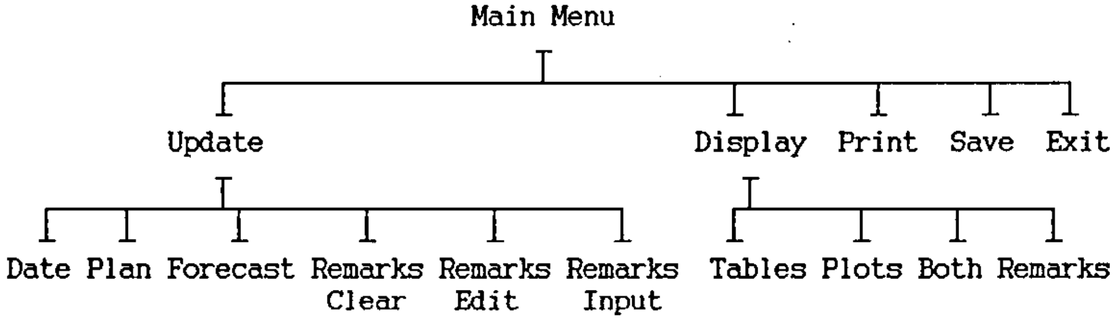


Figure (3-16): Nested Hierarchy.

The Optimal Menu Hierarchy: The first level of the nested hierarchy includes five options. The second level includes six terminal options for the first index menu, and four for the second.

Looking at above mentioned semantic hierarchies, it is obvious that they are not homogeneous nor complete. Therefore, the previously mentioned Fishers' recursive computations of the expected access time, E(T), need to be applied for each of the three above derived hierarchies.

Since the intermittent users are thought to prefer the pointing selection techniques, therefore, priority in arrangement of menu panels is given to frequency-of-use criterion; the more likely navigated menu is also placed at the top. Then, the options with equal probabilities are arranged according to their sequence of use.

Main Menu Panel Arrangement: All the main menu functions are probably navigated equally. Therefore, the following arrangement is used from top to bottom judged by sequence of use: 1-Update (remarks), 2-Display, 3-Print, 4-Save, and 5-Exit. See figure (3-17).

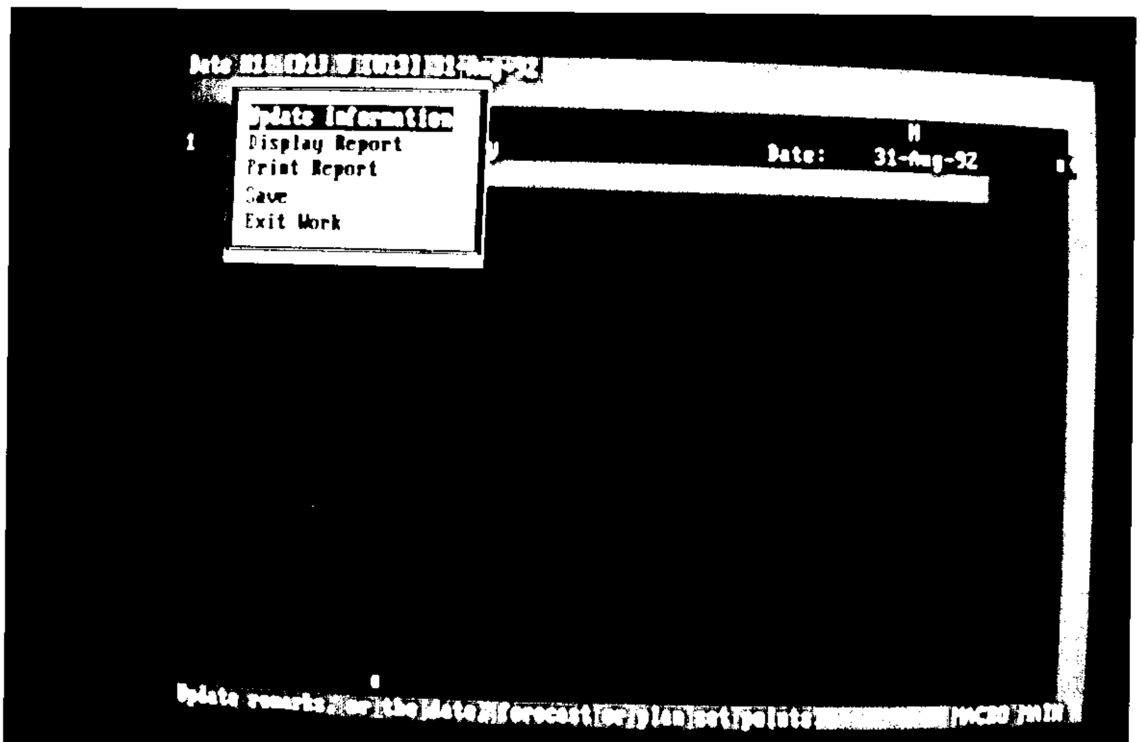


Figure (3-17): Main Menu Panel

'Update' Index Menu Panel: The following arrangement is used from top to bottom as shown in figure (3-18):

1-Remarks: This terminal menu is probably navigated once every day.

2-Date:

Once every while, a daily report different from the default of the previous day may be required. Moreover, the chance for the first changing is possible through the question and answer dialogue at the beginning of the run.

3-Plan:

Normally only once every month. Also may be used to answer 'what if' the projected plan has changed.

4-Forecast:

This is assumed to be used as frequently as the previous one. However, this is placed later following the users mental model of the manufacturing sequence.

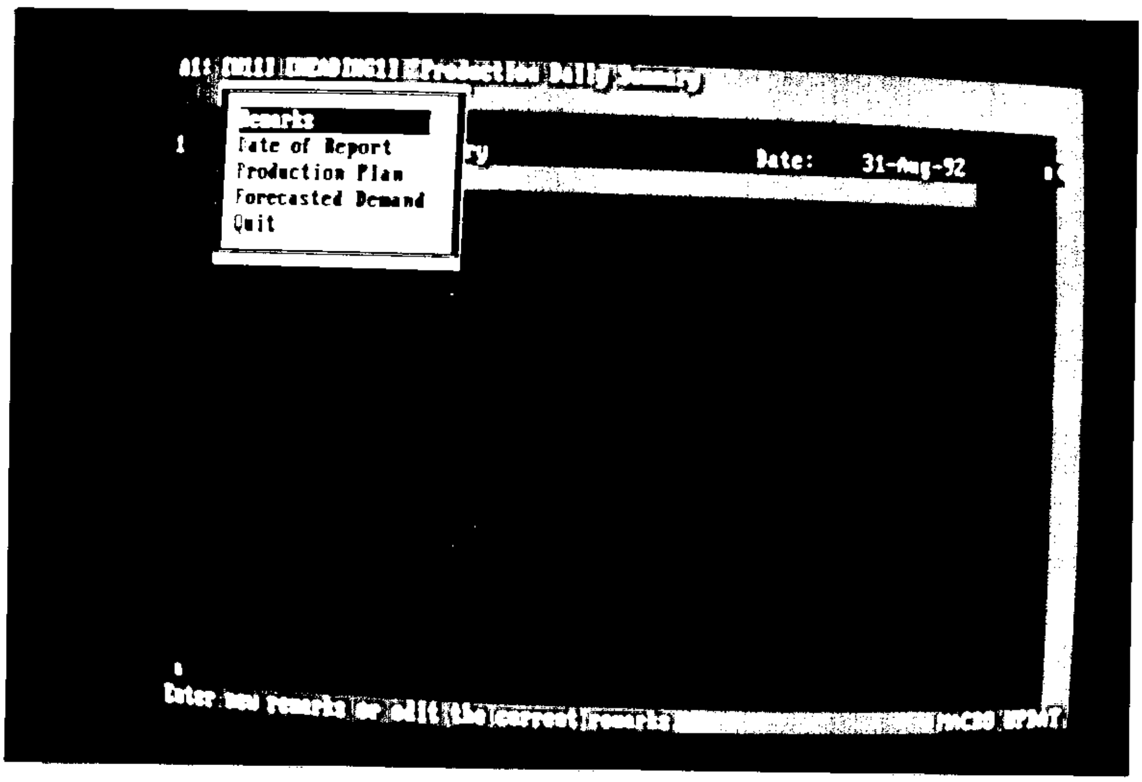


Figure (3-18): Update Menu Panel

'Remarks' Terminal Menu Panel: The following sequence is used from top to bottom as shown in figure (3-13):

1-Edit:

This option is put on top although less frequently used, for security reasons; if one of the other two is readily highlighted and selected, either one will result in clearing the remarks screen.

2-Input:

This command clears the screen and activates it for new remarks input.

3-Clear:

This command is required when there are no remarks for the current report.

'Display' Terminal Menu Panel: The following sequence is used from top to bottom as shown in figure (3-11):

1-Both (tables and plots):

Both displays are assumed to be required to be seen simultaneously more frequently.

2-Plots:

Plots are assumed to be next in frequency.

3-Tables:

Although tables are assumed to be displayed as frequently as Plots, the Plots are placed first as per alphabetical sequence.

4-Remarks:

They are assumed to be least displayed since they are presented during updating.

In addition to the above options, each terminal and index menu ends with a 'Quit' option to return to the main menu.

3.4.5. Output Devices

3.4.5.1. Display

The display used with the system computer is a high resolution CRT. It utilizes a super VGA (video graph adapter) which describes a resolution of 1026*768 pixels, ie 1026 dots horizontal and 768 lines. It has a (unlimited) full range of colors capability. Such characteristics are very much suitable to the screen design, with respect to flexibility with using colors and graphics, and bit mapping capability of the application software. The picture tube is 14 visual diagonal inches, with an active display area of 244 mm horizontally and 183 vertically.

CRT Controls and displays: With respect to the system design the most important are:

-Luminance control adapts luminance up to the operator's convenience. As discussed earlier, luminance is an important factor for visual detection and discrimination, and effects colors preference ratings. In addition to that, the luminance should be adapted with varying ambient luminance and glare to reduce eye strain.

-Luminance contrasts control is similarly important. For example, high luminance contrasts may increase frequency of eye complaints and cause temporary changes in accommodations.

It is worth pointing out that these control knobs are coded as follows: knurled textured, multiple rotational, and effecting increase in variable when turned clockwise.

In order to discriminate among the controls being located at the bottom of the VDU, symbols have been aligned with each of them and located at the front panel for visual identification and recognition. Otherwise, their relative arrangement does not seem to have any semantic cue, and would rather rely on long-term memory recall.

The power-on red status light is conceptually compatible.

Orientation: The VDU is tiltable and thus can be adjusted in alignment with line of sight. It can also be swung to either direction, which makes it useful in case the workplace does not allow direct positioning in front of the operator. Adjustability of VDT screen is proposed to be between 0-7 deg.

Other Characteristics: No flickering is sensed, which may appear if a CRT is not regenerating fast enough. The display has an automatic horizontal raster synchronization of 35.5 KHz, while above 30 KHz is recommended.

The picture tube conical glass is treated non-glare etching. The conical shape is a disadvantage of all CRT's from the point of view of glare. Evaluating the screen, it is still recommended to apply a mesh-filter specially if there are 'hot' sources of glare, ie luminance of adjacent surfaces clearly exceeds the luminance of the CRT.

Health Hazards: CRT's health hazards are not a major risk. Although not declared it is hoped that the CRT is complying with international stringent restrictions, especially with respect x-ray radiations whose low levels are supposed to be absorbed by the screen glass.

The above recommended filter may also be equipped with a thin cable that is supposed to discharged generated electrostatic fields that result from the tube high voltage. Such a precaution is useful if the user is possibly apt to suffer from minor rashes.

3.4.5.2. Printer

The system design conformed well with the constraint of using an NLQ printer as a print device. Confining discussion to the system design, the printer has the capability of printing Roman and Sanserif type style, a variety of type sizes, italics and bold prints.

The quality of the print, including graphic printing, is satisfactory. The speed for NLQ printing is 45 cps (characters per second). Above all its cost has been quite competitive.

3.4.6. Input Devices

3.4.6.1. Keyboard

The keyboard becomes important, not only when the operators gain more experience and start to use the menu words initials, but also, it is speculated their will be some effort entering all those remarks at the bottom of the daily report.

Keys Coding: In a keyboard discrimination , meaningfulness and standardization of the different keys are important. The keyboard accompanying the system computer is a standard IBM compatible with 101 keys. It uses the following for coding: location, size, shape, color, and label, which are used either orthogonally or redundantly.

-Alphanumeric Keys: Letters, numbers and the standard typing symbols are grouped together and arranged according to the conventional QWERTY standard like almost all keyboards in the market. In this manner they are conceptually compatible for English typing skills of professional typists and the sort. Location is the most important code for speed typing; typists rely totally on their movement skills of all fingers of the two hands which automatically locate the target keys. The labels are clearly printed on the keys in black on mat white. A small protruding texture is detected on G and J keys. The tactual coding helps in homing the fingers after manipulating other keyboard keys. The spacebar is located below the letters key and is identified by the length of the bar.

-Editing Keys: They include Enter, Tab, Shift, Alt, Ctrl, Esc, Backspace and Capslock. They are discriminated from the alphanumeric keys by their light gray color. They are labeled to identify them. They are also discriminated from each other by size which is not an effective coding for blindfolded discrimination. Enter key is different in shape from others which range from square to elongated rectangle. Insert, Delete, Home, End, PageUp, and PageDown keys are grouped together to the right of QWERTY.

-Function Keys: They are located at the top. They are arranged in groups of four with more spacing between one group and another and different color. The keys sequence is as numbers.

-Cursor Positioning keys: They are light gray in color and grouped together to the right of QWERTY. The arrows arrangement is conceptually compatible with UP to the top etc.

Keyboard Feel: The keyboard can be classified as an *elastomer* keyboard. Such keyboard have been highly rated. The system keyboard resistance builds up with further displacement until it reaches the closure point at 2 mm resulting in switching on the key with a click. Further increase of pressure finishes the downstroke at 4 mm. Thus, it has a hysteresis of 2mm.

Keyboard Other Features:

-The keys are concave to kind of help fingers settling.

-The mat color of the keys helps to minimize reflections and thus improves legibility.

-The keys required force of 40 cN is hoped to be within health standards to prevent fingers symptoms.

-The keyboard slope is adjustable.

-It is also detachable. The operator can place it at his convenience.

-It would be helpful to add a stand for the hand which is either held in the air, or dorsi-flexed. Such a device would relax the hand and help partially 'maintain a straight wrist' to prevent long-term symptoms in the carpal ligament tunnel.

3.4.6.2. Mouse

Both QPRO 4 and the daily report application system permit using a mouse as a menu selection device in addition to the keyboard arrow step keys.

Control: The mouse supplementing the system computer, has two press buttons. With QPRO 4 and the application, and most of the software packages, the left hand side is the one allocated for selections. The cursor is moved as a result of dragging the mouse on the table or pad.

As a matter of fact, the control-response ratio of this mouse is fixed. It would be beneficial to be able to adjust the sensitivity of the device according to the operators skill. Such a device is available in the market.

Feedback: The system response is displayed on the screen in the shape of an arrow. This represents the feedback of a reached target.

Selection, being affected by pressing the button, is felt when the end of the displacement is reached. Also, there is an auditory click for feedback.

Other Features of Mouse: The system mouse is called 'Beatles' due to its shape. Its size and smooth curvilinear top fit well in the palm of the hand. It is 30 deg in the back assuming the profile of a hand at rest. The angle where the buttons are located is smaller at the front to fit the index finger.

3.4.7. User Guidance

In order to guide the user for better accuracy and faster response time and decrease long term memory requirements, several techniques have been used.

3.4.7.1. Guidance in Data Entry

Date Entry: After the first dialogue, at the date field, the report date (the entered date) is now presented. If more report updating is requested, the most recent date entry is still on the screen. The date entry can be any date that is within the time span of the data base.

When the user is prompted for date input, a message is displayed at the center of the screen explaining the procedure. In the meantime, the date cell is highlighted with a different color. The screen text is in bright yellow. The date cell is in bright white. At any time now, at the user's own pace, date can be entered.

Correct date entry syntax is validated by the computer. Otherwise, the user is prompted for re-entry.

3.4.8.1. Introductory Information

The system is introduced at this instance. Information about author, date, and purpose are provided. The message is presented during loading of the program. In this manner the operator is not bored, especially, after having become familiar with the system. In the meantime, loading time is filled up. This message is full screen in input screen colors namely bright yellow on blue. See figure (3-21).

3.4.8.2. Status

These are simply single words abbreviated information in five letters consistently shown in the bottom right corner of the screen in yellow text over cyan. They are present all the time showing the last menu command that has been activated.

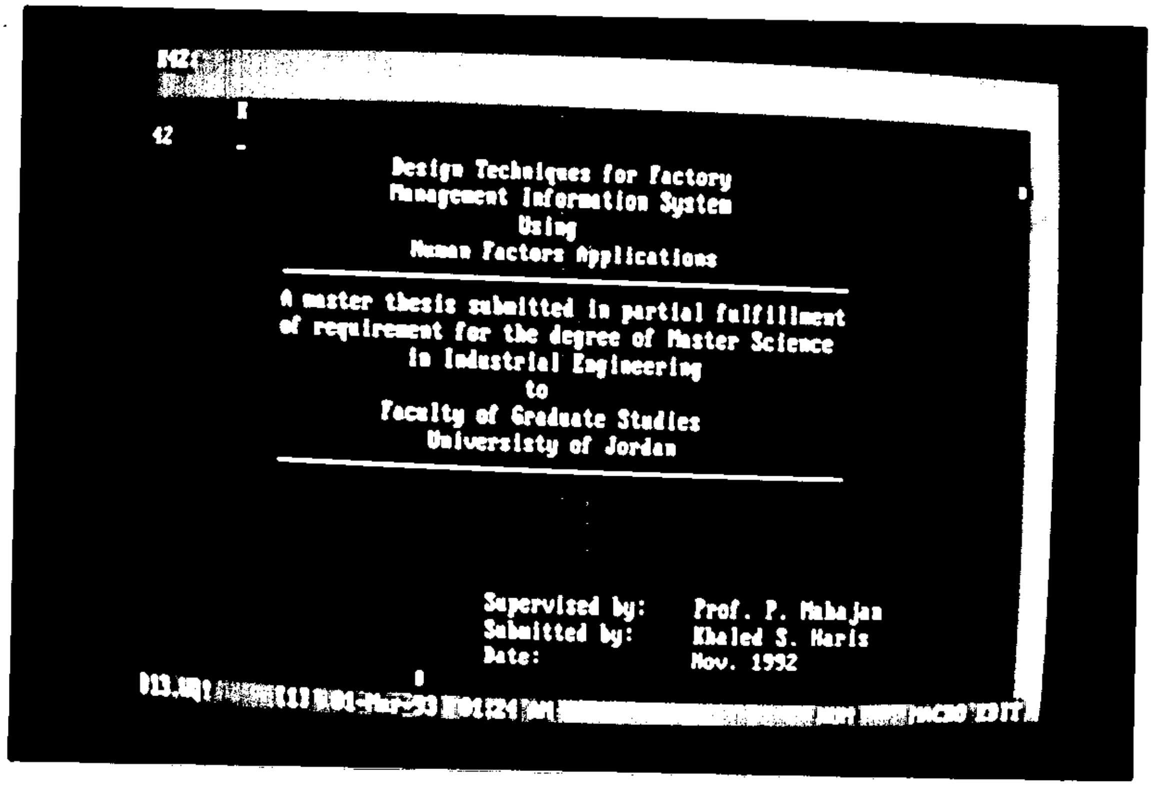


Figure (3-21): Introductory Information Message.

3.4.8.3. Processing Stage Messages

These are messages presented at the middle of the screen for attracting attention showing the routine that has either been processed or is still under processing such as:

-Please wait! Updating the report.

-Loading...

-Now printing CTRL Break to stop.

-There are no previous remarks for this report.

These messages are either shown in the middle of the screen in bright yellow on blue, or in a box for highlight in black text and black frame on white background. Some guiding messages include a 'beep' acoustic prompt.

3.4.8.4. Error Messages

The message describes apologetically the type of error and that operation will resume. The message is in a box as above. Another type in the middle of the screen, as mentioned above, upon a wrong entry, is shown below:

-Please enter a correct value of clinker plan.

-Please enter a correct value of cement forecast.

Error messages have also been accompanied by specific 'beep' as acoustic alarm.

3.4.8.5. Time

At the bottom of the screen, in addition to date time is shown for reference of the operator. In addition, he can always spend some time checking progress, especially, during long processing periods.

3.4.8.6. Instructive Messages

They have been included. The simplest are to prompt him for entering data such as:

-Enter the new monthly plan of clinker.

-Enter the new monthly forecast of cement.

The expected answer to some questions is also given:

-(y,n)

Others are:

-Type the date as: 15-sep-92, or 15/9/92, and press ENTER TWICE.

-Please make sure you have prepared the printer and put the paper in position. Make sure the printer is on.

3.4.9. Computer Response Time

3.4.9.1. Input Design

When the program is run it automatically calls the Database files containing the data to be extracted. These are files that are supposed to have been prepared by previous processing of Database 4. A file is supposed to contain all the pertinent data of a production line. Thus, QPRO 4 calls from Database 4 the following files: kiln 4, kiln 5, kiln 6, and cement mills. Attributes and sample data files are shown in appendix IV.

3.4.9.2. Initiating the Dialogue

It is conceived to first let the computer initiate the dialogue at the beginning of a new session of system run. The purpose is to allow quick issuing of a default daily report (of the previous day). Thus, the question-and-date is assigned for a report, the program looks automatically for an existing file of the remarks to be used as default. The benefit is in saving reentry time. The operator is thus relieved of any retyping of the remarks even if the report is recalculated. Such an act is also aiming at reducing any fatigue or boredom; the operator is motivated.

Quitting the field can be done only after a second confirming press of Enter key, as discussed under date entry.

3.4.9.4. Menu Style

They assume straightforward software. Within this system hardware capabilities, it is found that menus are not critically slow as would be claimed by early literature.

3.4.9.5. Daily Input Screens

Daily Input Screen Format: As mentioned earlier, a character display rather than bit mapping is used as a tradeoff for quicker data entry and processing. Thus, the former screen characteristic condition result in a shorter system latency.

There is a cost of using bit mapping for output screen. Computer response time increases significantly when such a screen is used instead of character screens. Moreover, there is processing latency when the screen is changed from one screen mapping to another. Similarly, there is processing latency when changing colors in between screens.

3.5. FACILITATOR DESIGN

At this stage, the interest is in planning for materials that will result in acceptable human performance. Some activities, such as identifying the needs for instruction manuals, performance aids, or training devices and programs, or defining the best mix of facilitator materials take place. Decisions are also made with respect to the extent of using either software, hardcopy, or a mix of them for the purpose.

3.5.1. Human Performance Requirements

AS a result of function allocations it was stated that the clerks should be able to manipulate the system, and reach the minimum skill and job satisfaction in a short time.

3.5.2. Operators Selection

During the previous stages, the users that will operate the system have been identified. Their qualifications have been described. Moreover, it was shown that their are no intentions to any changes with respect to the people doing the job.

3.5.3. Task Analysis

It is, thus, imperative to analyze the tasks to be performed by them by virtue of the functions allocated to them, design the new work modules, and compare the required skill levels with the existent. Consequently, the facilitators required to support human performance can be determined.

Tasks are broken down during task analysis in order to determine the number and skill level of people. In task analysis, the activities should be mutually exclusive and exhaustive. The activity complexities are then matched with previously determined skill levels. If the users have the necessary skills, the designer may not need to go much down to elementary level tasks analysis.

The following tasks do not have to be broken down further since they correspond to the skill levels of the clerks. The tasks involve the following skills: simple judgment, writing or keying through the keyboard, or memorizing:

-Check if there are new data.

-Enter the new data.

-Capture exceptional attributes & values.

-Extract relevant stoppages causes from reports.

-Register causes of stoppages.

The other tasks are analyzed to illustrate how the analysis proceeds:

-Act on or communicate the results.

a-Understand the signal.

b-Correct the errors.

c-Otherwise refer to the responsible (eg the production manager).

d-Enter specified (by manager) to the remarks.

-Interact with the computer through the designed system application software to perform the tasks allocated to the computer.

a-Run the application software.

b-Move through (or recall) command options.

c-Locate the appropriate command.

d-Make (or enter) the correct selection.

e-Enter (or select) the relevant data.

-Plot graphical charts.

Discussing the possibility of plotting the data using the graphing facilities of the software, such an activity requires the clerk to hold an interactive dialogue with the computer spreadsheet or graphical package.

The tasks required are as mentioned above in addition to the similar tasks relevant to destination spreadsheet.

3.5.4. Work Modules Design

A work module is a set of tasks that a user does as a part or all of his job. When designing work modules tasks are grouped according to data relationships, skill level for a task, task relationships and sequence, time dependencies, and human-computer interface considerations.

The tasks that are performed by human beings are grouped into two main work modules. These modules may be distributed alternately between the two clerks. See table (3-1).

Table (3-1): Operators Work Modules.

Module 1:

Functions:	Tasks:
-Interact with the computer through the designed system application software to perform the tasks allocated to the computer.	-Run the application software. -Move through (or recall) command options. -Locate the appropriate command. -Make (or enter) the correct selection.
-Enter periodically planned values for daily report.	-Check if there are new data. -Enter the new data.
-Enter remarks on causes of stoppages.	-Extract relevant stoppages causes from reports. -Enter causes of stoppages.
-Notify of invalid results, warnings, and messages.	-Capture exceptional attributes & values (from the prior system). -Read the messages (from the prior system). -Enter specified (by manager) to the remarks. -Understand the signals and messages (from the application system). -Correct the errors. -Otherwise refer to the responsible (eg the production manager).

Module 2:

Functions:	Tasks:
-Generate graphs of monthly results.	-Run the spreadsheet package (QPRO 4). -Move through command options. -Locate the appropriate command. -Make the correct selection. -Select the relevant data.
-Notify of errors.	-Understand the error signals from the spreadsheet package (QPRO 4). -Correct the errors. -Otherwise refer to the responsible (eg the production manager).

3.5.5. Balancing Facilitators

Evaluating the kind of tasks to be performed by the operators, the following can be argued with respect to each work module.

3.5.5.1. Work Module 1 Facilitators

The atomic tasks of the first module which are related to operating the designed application system in order to generate a daily report for the managers at their daily meeting are compared with the existent skills of either operator with the actual interface design in mind.

It is a straightforward conclusion that the modules tasks are within the operators current knowledge. The way the system is designed has already taken care of the fact that they are at the time being intermittent users. Menus dialogue styles for example will do them well. Since the system will be run daily they will soon become experts using it. With time, they may change the techniques they use such as the menu selection by commands initials.

On the other hand, it will be a first time for them when the system is completely developed. Thus, it is decided that training is conducted to orient them. Such a training is not imagined to span more than a few lectures with on the job application.

No written instructions or performance aids are to be designed additionally apart from the users guidance elaborated in the interface design. It is speculated that, with daily application of such a simple system, there will be no demand on longterm memory.

3.5.5.2. Work Module 2 Facilitators

Similarly, the tasks of the second module are within the operators existent skills. Moreover, they have positively used spreadsheets packages including QPRO. They should have no great difficulty in plotting graphs using QPRO 4 in the manner discussed earlier.

Therefore, no particular training will be conducted. However, it will be beneficial if they are allowed to attend a refreshing course in spreadsheets, preferably on QPRO 4. Such courses are certainly held in abundance in the market including the Jordan University.

It should be noted that applications on such a system will continue to be intermittent. Thus, instructions become necessary. A manual of the package will do well. With a sophisticated user guidance of QPRO 4, there will be no need for any additional performance aids.

However, the techniques of graphical representation design should be made available to them. Such techniques can be trained by the system designer referring to the output design and screen design in this research materials.

3.6. EVALUATION

Every decision and designing step, throughout the system development cycle, went through continuous evaluation in an iterative manner. The aim is to fit to the performance of the hardware, shape the performance of software, and support the performance of people to ensure the adequacy of attributes that have implications for human performance.

3.6.1. Data collection

Early and timely data collection, as implied by the system development, at all stages of design took place whether in the form of literature search or from the environment. Data collection ensued in information pertinent to the decisions required by the system design and development effort.

Data collection was done through observations. Face-to face interviews, being the best chance of collecting the most complete and usable information were used wherever appropriate. However, normally, such interviews result in highest costs and are much time consuming.

Thus, the technique was used according to the need except for sampling and testing which would require preparations that are rather more appropriate for larger systems, and were beyond the scope of the thesis.

3.6.2. Human Performance Requirements

Having designed the system and developed the sample program as described in the previous stages, the objectives have been realized as assumed in the system definition.

Consequently, the users are required to do their part and carry out the allocated functions within the prescribed human performance requirements which have been considered throughout the design activity. This is discussed next.

Exposure Time to CRT Physical Effects and Fatigue: Preparing the daily summary, the exposure of the clerks to the CRT is a matter of minutes. That is why this whole issue is negligible. However, all other activities related to computer use should be summed up for this concern. Nevertheless, as mentioned earlier, such other activities are only intermittent. Adding to that, in the design, the demand put on the human was minimal, with respect to intensity of stimuli. Strong stimuli can induce fatigue in receptors; high luminance can cause eye- and head-aches.

For example, in the interface screen design, the optimal text to background color was not the one with the highest preference but rather the one integrating fatigue effects. Strong stimuli are, thus, avoided. Highlighting is only used where necessary. Physical discomfort can also be caused by overloading as a result of too many attention seeking stimuli.

As for the monthly graphical preparations, the volume of work will depend on the changing needs of the responsible manager. Therefore, complying with the results of the different studies, it will be imperative that the clerks work alternately on the monthly job. Otherwise, the one doing the job should not work more than three to four hours daily in computer interaction, and should take ten to fifteen minutes of rest every one hour.

Avoiding extreme colors in the graphical design not only relieve the operator. Also, during the presentation, if there are too many displays the audience is also not confronted with fatigue causing stimuli.

Motivation and Optimal Arousal of the Human for Effective Performance, Performance Satisfaction, and Minimal Stress: This very aspect was first taken care of during the basic design while allocating the functions. Functions that impose some mental or sensory load were assigned to the computer system rather than to the user. This is in addition to the designer's awareness of users' need for motivation. Although it is difficult to identify the work that the designer can improve on to motivate the users, it helps towards a better design of work, interfaces, and aids. The better the work design, the higher the motivation level of many users.

Similarly the system is build such that the work modules are aiming at best ensuring motivating the users. For example, apart from the repetitive data points entry, which are allocated to the computer, plotting the monthly graph is allocated as an interactive task to the operator. As a result, there is high autonomy, whereby the users feel responsible for their work. The user is more motivated if he feels that a 'product', which is a module or an identifiable part, is his responsibility, or is associated with him. The part the user is assigned is 'worthwhile work', with some variety.

The manual processing, including data entry and menu selection, is not left for coping with the system. It is rather designed at the operator's pace. Had they not been realistic they might affect the user's motivation.

Feedback is applied generously; again for user's motivation and performance satisfaction, such as audible beeps and messages from the computer informing the user of the status of processing or to wait. Such messages are purely informational, for example showing the location in the program. They are also used for notification of generated errors. Messages present the desired information accurately, concisely, and in a complete manner.

Feedback is supposed also to reduce stress level significantly. The system design ignored human abilities such as divided attention, and performing multiple tasks. This should reduce cognitive demand and high stress level cost. For the same purpose, there are no uncertainties. Much is capitalized on compatibility, flexibility, consistency and similarity between the components of tasks.

In addition to the above, the dialogue is designed such that it tolerates errors through *input data validation*, *user protection* from the consequences of his own errors, providing *error recovery* capabilities, and meaningful *error messages*.

Relevant to users' motivation is the system response time. In fact, users seem to be willing to wait varying amount of times for different types of requests, as a function of perceived complexity. Thus, they may find it natural to wait for longer times at closure points at the end of a transaction. Quick response times may be at the cost of other system design requirements. Tradeoffs are usually important with respect to optimizing costs and benefits. Efforts have been exerted towards reducing the computers response time as explained under the subject matter in interface design.

Attaining Minimum Skill and Performance Satisfaction in a Short Time: The system is designed with minimal complexities. Nevertheless, user guidance is affiliated to the design. Most important is that a whole section is dedicated for supporting the human performance.

Speed of Performance: The total time required for the report to be prepared depends on the human response time and the computer response time which is discussed above. Response time is important in terms of the amount of work the users can do. The human response time is affected by the operator's movement time and reaction time.

As intermittent computer users, and novice with respect to the designed system, the operators are expected to start their interaction with the system using either the mouse or the keyboard step arrow keys. The movement time is very much contingent to the specific input devices of the system. From the previous discussions it could be inferred that they can be classified as satisfactory from the ergonomic and feedback point of view. For example, when using the keyboard or the mouse, it would have been very disconcerting if there was no obvious tactile or audible sensation that the switch has been operated. Their effect on movement time should be within the normal choices.

To improve on the situation, they should be properly situated in the workspace within anthropometric arm reach. In addition to that accuracy of continuous control movements, such as in cursor positioning devices depend on the freehand control during the movement. Such movements are most accurate (with minimum tremor) when the movement is on the horizontal plane, and in lateral (left-right) directions with the forearm pivoted at the elbow.

After some time, the operators may even develop some better utilization of their kinesthetic sensing. One main function of the kinesthetic sense is to enable people to control their voluntary muscular activities without the aid of vision, for example, keying on the computer keyboard. The input devices design are hopefully helpful in shifting dependence from visual cues to kinesthetic cues as quickly as possible when skills are being learnt. Such a shift coordinates blind positioning movements, and results in faster response time. It can be added that mouse control movements are compatible with the cursor movements on the display.

As mentioned above, reaction time is the other component of response time. To reduce the reaction time, for the intermittent operators, it was decided to rely mainly on recognition, such as menu options, rather than recall. Guiding messages have been added for the same purpose. If a set of instructions is given to a user, relevant to what he has been learning with respect to the system application, he is not likely to remember all set of responses pertinent to the activity. On the other hand, if instructions are presented to him in a kind of a menu with different choices, he will be in a better position. This situation is comparable with answering questions while presented with multiple answers to choose from.

After some practice with the system, the operators may become ready for more powerful dialogue using the menu commands through the semantic initial letters of the choices. To aid the users the menus have been carefully structured as mentioned earlier. People find things easier to remember if they are structured into meaningful categories that a person can easily identify and learn. To understand and memorize complex information, the complexity is broken down into simpler components using hierarchical approach.

Using auditory feedback in addition to seeing, as is the case with messages, supports faster reaction. Practice in the activity stimuli reduces the reaction time limits. Practice also helps in shifting performance from conscious cognitive levels to automatic, resulting in faster performance.

Fast and Correct Interpretation of Output: The daily and monthly output design has been justified all over. In order to show the opposite effect, examples of conversely bad designs are presented as follows.

As mentioned earlier, the current production daily report may prove satisfactory, from the contents point of view for the financial department. Although this output is not within the system definition, for the sake of comparison, referring to its current format, it can be noticed that too many data are displayed. The current format may be criticized for the following distorting features: Captions are not clearly stated, too many vertical and horizontal rules cluttering the medium and resulting in much noise, too small fill-in areas which result in overlapping figures and poor legibility, and a very large area for remarks.

Designing the graphs, no filling patterns are recommended for coding because elaborate schemes or patterns can be eye straining. Unnecessary embellishments such as vibration or 'Moiré effect' producing pattern cause tremors.

It is best to use varying densities or shades of gray or varying colors, and labeling with words. Heavy grids are also avoided because they produce noise, and non-informative ornamentation, which adds no benefit and may add cost. Using extensive colors, multi-dimensional graphics, when single dimensional will do, or decoration, result in distraction and less comprehension. Clutter confuses and increases visual search. Such graphs are shown in figures (3-22,3-23).

Designing to show trend and compare productivity, pies, divided (stacked) bars and tiered bars are avoided, being more demanding in such tasks. Horizontal representation of bars is also avoided whether they are used for judgment of change or comparison. The emergent features are not conceptually compatible going from top to bottom. The longer bars are also deceiving because they are perceived longer than what they really represent. Such a graph is shown in figure (3-24).

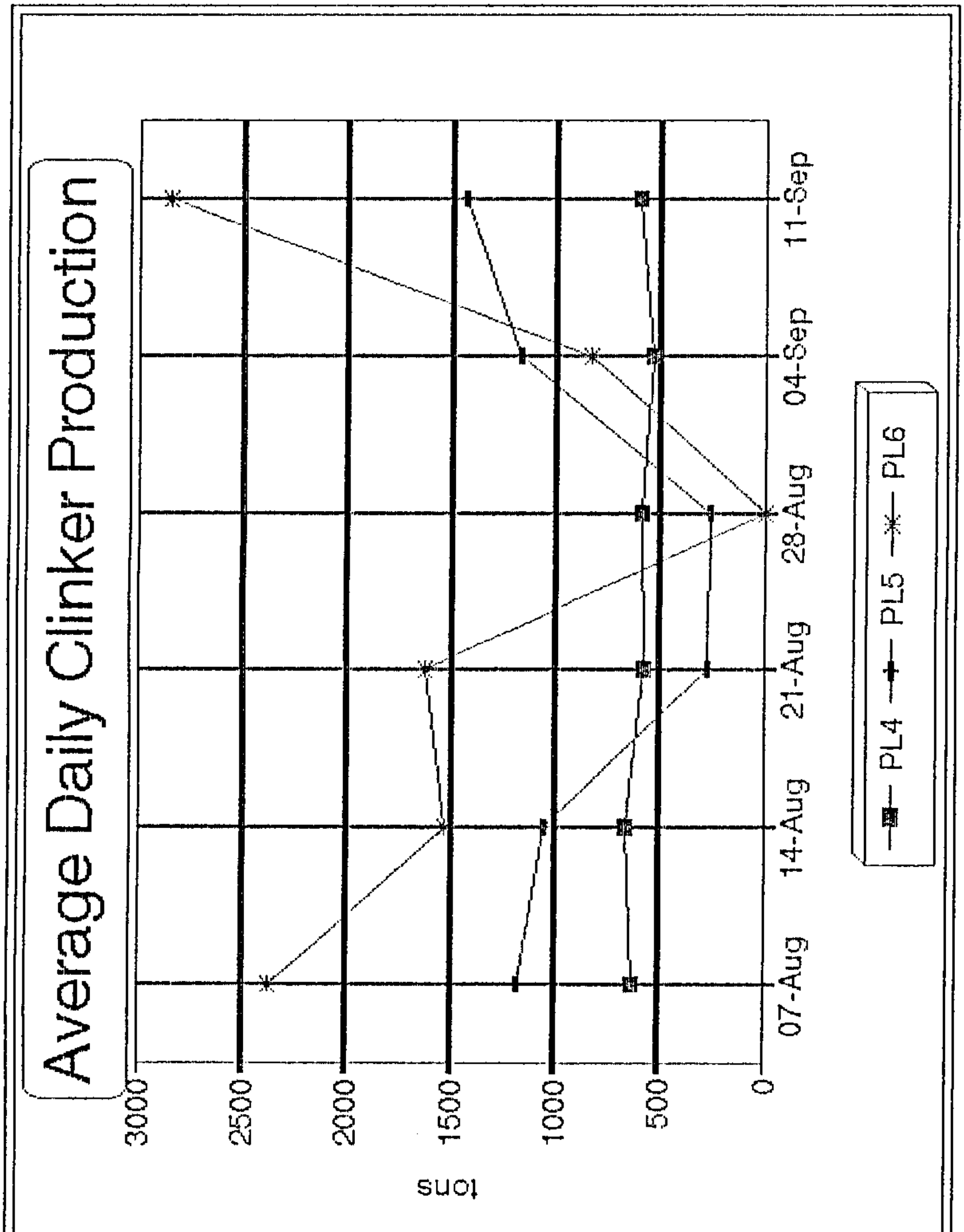


Figure (3-22): Incorrect Line Graph.

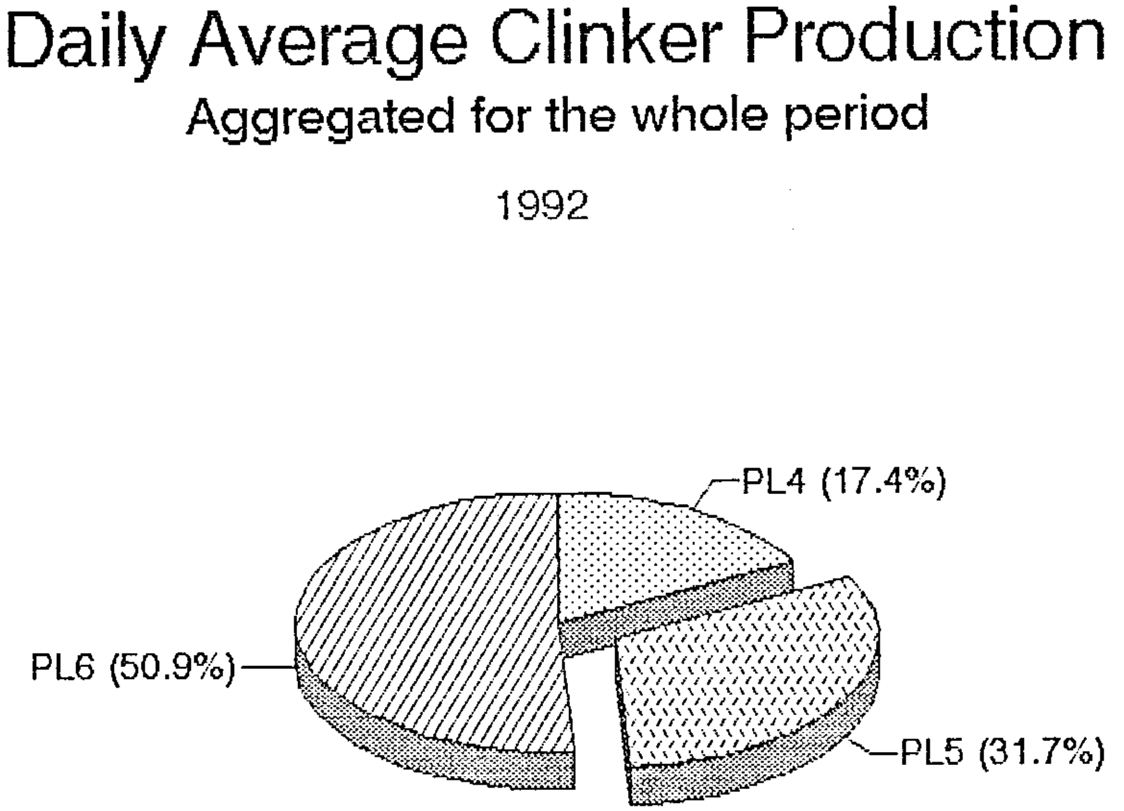


Figure (3-23): Incorrect Perception with Pie Chart.

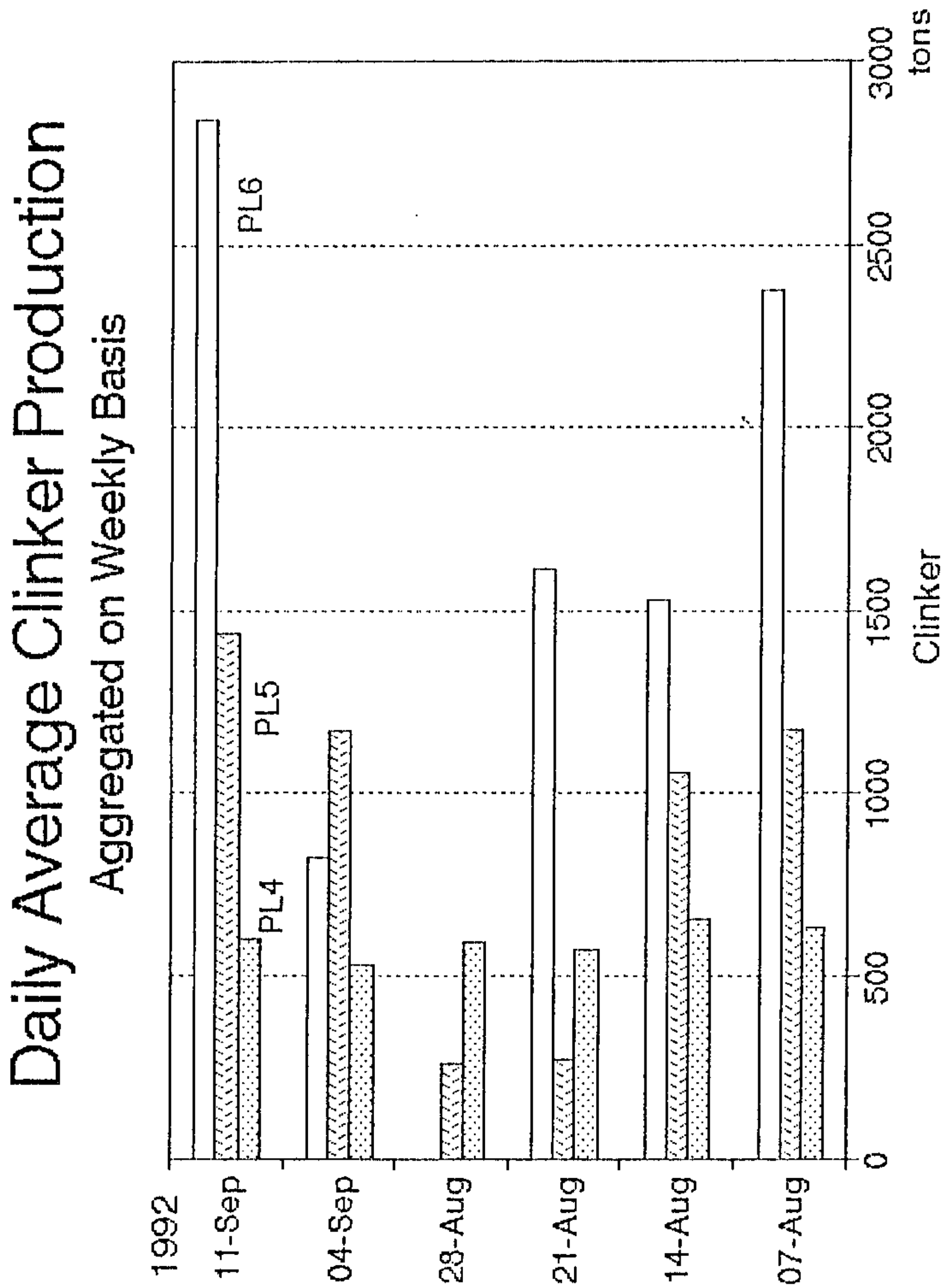


Figure (3-24): Incorrect Perception with Horizontal Bar Graph.

CHAPTER FOUR

DISCUSSION

In order to accomplish the research and satisfactorily realize the objectives defined in the first chapter, the TSD approach has been applied. Refinement and modification of decisions of earlier stages became necessary as more information has been gathered, in an iterative manner. All work was done within the scope of the thesis.

4.1. SYSTEM DESIGN PROCESS

The design stages have been followed systematically. In the final stage, design work has been evaluated against the human performance requirements developed in the basic design stage, which are principal human performance measures in HF. The major work has been done in the interface design stage. Facilitator design has been also given ample attention.

All points are supported by the literature review in HF. However, in many cases a trade-off has been made in a process of weighing costs and benefits of applicable criteria. When the guidelines have not been very clear or rather contradictory, HF first principles have been consulted and applied.

Care has been taken when considering the ideas of the emerging field which has been called HCI. Thus, analysis down to its atomic rules has been avoided.

Unfortunately, systems and people are complex; so to issue a simple set of guidelines for all situations may be appealing but in reality would only be misleading (11).

Nickerson suggests that only general principles are issued such that they are independent of the system since computer technology is moving so fast that specific guidelines may soon become out-of-date and research results become obsolete (12).

Similarly, Johnson, referring to the core discipline of cognitive psychology, argues "rather than provide guidelines or so-called principles, it is better that the HCI scholar has a good understanding of the core and contributing disciplines." Psychological theories and data provide the basis from which applicable guidelines and principles can be developed (13).

Moreover, Johnson thinks it is much too soon in the history of HCI to have much confidence in the contemporary principles and guidelines.

4.2. DEVELOPMENT OF APPLICATION PROGRAM

The MIS is capable of producing the reporting media as anticipated. The reports development is computer-based.

The macros command language program is shown in appendix V.

4.3. HUMAN PERFORMANCE

The monthly report (graphical representations) is devised interactively by the clerk himself. The key word is autonomy. This would lead to the clerks motivation. In addition to that, the plots generation capitalizes on the clerks' previous experience mainly by applying Quattro Pro. The user, in this case, interacts with two types of information namely what he senses, for example sees on the screen and what his past knowledge as preserved in his memory. Thus, while designing the system the users perceptual skills have been taken into consideration. The users old experiences and previous knowledge effect their abilities to manipulate data and messages accurately.

Issuing the daily report (middle management summary) is automatic under the clerks' control. With the support of the facilitator and as a result of experience, the clerk will enjoy an automatic level of processing, as opposed to the above described conscious levels, which proceeds without the need of feedback. Automatic level processing helps in faster performance. However, it is worth mentioning that as people gain experience on an activity, opposite to certain misconceptions, they mainly improve on their speed of performing the activity. If the performance is mainly automatic, there will be hardly any improvement in the proportion of errors.

As claimed earlier, the designed system should result in a performance satisfaction of the users. But, one should be careful not to jump to unrealistic conclusions. One cannot dare to claim job satisfaction as a result. There is a difference between job satisfaction and performance satisfaction. A persons job includes much more than a person performing an activity in a particular context. The designer cannot do much about the user's job satisfaction, which may be constituting a lot of one's life.

Luminance and contrast of the CRT screens are important from the human performance and health point of view. Controlling them, not only improve acceptance of screen colors, but also, helps to reduce unnecessary high intensity of the CRT display that may cause fatigue to the sensory system. In addition to that, insufficient contrast and bad legibility require more eye accommodation or even imposes cost with respect to cognitive processing.

The exposure time to CRT has been given ample attention in order to reduce fatigue and eye accommodation problems, and, also, to result in better human performance.

The operator doing the job should be allowed to focus his attention on the task. No need for imposing divided attention activities which although can be handled by the human, they may degrade his performance in addition to rapidly stressing him.

As for the factory management, who have been described during the design as middle managers and decision makers, the primary users of the system, care was taken not to overburden them by overabundance of information with which they cannot cope. Thus, information has been aggregated for them. The information covered mainly production and delivery attributes. Planning and controlling are emphasized through the daily summary tables and plots. Textual, tabular, and graphical formats have been used as appropriate. HF guidelines have been applied. In addition to the proposed production daily summary report, two more alternatives have been proposed. Although all of them conform from the HF point of view, still some may prove better preferred by certain users.

It should be noted that the representations and dialogues have been designed in English as mentioned in the scope of the thesis. This statement does not necessarily imply better human performance in Arabic. The users have been continuously presented with English tables and graphical representations as a normal daily routine. The computer applications are also consistently in English. Computer system performance is better in most packages if English is used.

4.4. SYSTEM PERFORMANCE

4.4.1. Hardware

As described in the scope, the system is adapted to a PC. The input and output devices have been described in details. Some changes during the design have been mentioned.

Several advantages are attached to microcomputers namely: Portability, low marginal cost of computing, availability of color and graphics display, low hardware maintenance, computer power available at the convenience of the user, full control of applications by user, and software needs less support because of limited complexity.

With Intel's latest microprocessor chips, including 80286, 80386 and 80486, IBM (and Compatibles) PC's, for instance, can relatively operate with very high speeds.

Talking of computers speed, it has been mentioned that the system response time affects users' motivation. In general, literature shows that response times of more than 15 seconds might require that other activities are made available to the user whose attention will be diverted and will not be expected to return to the task at hand but upon completion. On the other hand, less than 5 seconds do not result in any performance decrements. Therefore as mentioned earlier, it has been the designer's concern to make response time as short as optimal.

On the other hand, for example, the bit mapped screen design, and changing colors cost some longer time delay. Not only that, but also more important tasks such as updating and printing take long time. Nevertheless, when tested on Intel 80386 and speed of 25 MHz instead of 20 some improvement should be expected. If after some time, the system requires continuous processing of lengthy commands, and such a short session proves requiring a shorter computer response time, it will become probably of benefit to replace the system with an Intel 80486 that has a higher speed. Although processed time may be relatively long at certain tasks processed by the computer, it would be unfair to compare the processing time with the existing manual system. Nevertheless, as discussed earlier, motivating the operators implies search for some improvement. The speed of the new versions of Intel's 80486 processors are sometimes more than triple that of the existing computer. In the meantime, other measures can be tried such as optimizing the disk operating system through devising a 'RAM disk' or a 'disk cache', noting that no more necessary utility measures such as 'back tracking' and 'undo' have been cleared after the final program development phase for quicker spreadsheet processing.

The computer volatile memory and hard disk are quite satisfactory.

4.4.2. Software Package

Most common among application packages are the word processors, electronic spreadsheets and databases. Spreadsheets are intended for making repetitive calculations on interrelated variables. There are several spreadsheets packages in the market including Quattro Pro (QPRO), LOTUS, Excel, etc. Spreadsheets can generally perform certain database management. In most cases, spreadsheets have great power of plotting graphs. They have also the capabilities of interchanging data with other packages.

All above is found in QPRO 4. QPRO 4 is used for the purpose of the thesis since it has proved satisfactory to

Computer based information system is thought to be effected by the development history including proposal, design, implementation, and use by the organization.

Thus, implementation of computer based information systems does not only result in effecting technical changes but also organizational changes. Such changes include the organizational structure, job design, communication patterns, and inter-organizational relationships. In many organizations, such impacts are by large accidental. This means that changes are recognized only after having implemented the system.

4.5.2. Future Research

Further work will require research criterion measures which may include system-descriptive criteria such as response time of the computer system to process a menu command, task performance criteria such as total time it takes to produce the daily report, and human criteria such as time it takes to make a menu selection or to enter date, number of errors in entering text of in the remarks, strain resulting from mental work such as visual acuity, blink rate, or blood pressure, and subjective responses such as preferences. User speed and correct perception of graphical representation may be measured in terms of the latency and accuracy when extrapolating, or finding the proportion of several attributes in the graphical information for example.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

In my opinion, it was possible to apply recent HF principles. Also, as can be concluded from the evaluation stage, analysis implied a satisfactory system design. The system, thus, satisfied human performance requirements. The design also considered current technologies and costs. The development of the sample application program has been successful. As reliability and maintainability are important engineering measures, they have been considered, in parallel, carefully in the design.

In my opinion, the system is user friendly; the users will be motivated to do their part of operating the system and will have performance satisfaction. The pertinent health aspects of the users have also been considered. On the other hand, the timely, relevant and correct information and effective information displays should motivate the factory managers to implement the company strategies, and help them in planning and controlling for reaching higher production and timely delivery.

It is found that the computer storage capacity is sufficient. However, the processor will soon require upgrading. The software is found satisfactory to fulfill and comply with the information system requirements, HF guidelines, and data extraction from external database files. It is found easy to program because it is natural and interactive. This is in addition to its satisfactory capabilities in mathematical manipulations and graphical plotting.

The developed system, although as found in the scope of the thesis is not an integrated system, upgrades the prior system from operation level to management control level. However, the early system report format should periodically be revised. With the software and mathematical models capabilities, the system can always be developed further to include other crucial tasks such as a DSS.

With the system design process taking all the organizational and users' requirements and constraints into account in the definition stage, no major organizational changes are foreseen except for some modifications of the operators' jobs as a result of the added work modules. However, with this system and prior and subsequent systems care should be taken to control the change in order to cultivate their full benefits.

5.1. SUMMARY CONCLUSION

In my opinion, based on my experience in literature review, and system design and analysis, throughout this research, I have been able to use the HF guidelines in the design and development of the system satisfactorily and to a great extent. The designed MIS is capable of producing the proposed reports. This application will prove effective, less fatiguing and pleasant.

In my opinion, the objectives of the thesis have been satisfied within the scope and committed resources.

5.2. RECOMMENDATIONS

With reference to the above discussion and conclusions, and evaluation work performed at the final design stage, the following measures are recommended:

a-Use the production summary daily report for the factory management meeting , with respect to content and format, as shown and explained under the interface design subject matter.

b-Follow on the footsteps of the presented graphical displays design in order to prepare and present the monthly report.

c-It will become a good idea to shift to a higher speed computer in the future since their costs are rapidly declining.

d-The operator should pay attention to and control the luminance and contrast of the screens for better human performance and health considerations.

e-To reduce fatigue effects suffered by the computer user, filters should be added to the display, especially if glare is experienced. This is in addition to proper treatment of 'hot' sources such as windows and lighting, and the relative direction of the VDT.

f-The arrangement of the physical components, such as the display, mouse and keyboard, should be optimized within the work space envelop using the human sensory and anthropometric characteristics for better control of the pointing device, and better human performance using the keyboard in addition to the display legibility. Also, comfort of shoulders and neck should be considered from the ergonomic point of view.

g-As discussed earlier, the operators should not be continuously exposed to the CRT for more than one hour, especially when preparing the monthly report. This can be realized through alternative working of the two clerks or giving them some ten to fifteen minutes break.

h-In addition to the user guidance integrated in the system design, as discussed earlier, it will be beneficial, to refresh the operators on spreadsheets, preferably QPRO 4, provide them with the appropriate manuals, and train them on the job on system operation and on the techniques of good graphical displays design to let them concentrate on what is important and aid communicate the information effectively to the audience.

i-The different presentation alternatives should be occasionally re-evaluated and revised with respect to changing needs of users and economy of acquisition of new equipment, such as shifting to data show (overhead projectors connected directly to a computer).

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APPENDIX IV
DATABASE FILES
PL4 Database File

DATE	PR_CL_CLT	GR_CM_CT	DIS_CM_CT	STOCK_CM
08/01/92	650	320	459	9076
08/02/92	675	395	399	858
08/03/92	670	0	406	8666
08/04/92	480	635	443	8858
08/05/92	655	355	610	8607
08/06/92	650	365	361	8611
08/07/92	660	350	0	2678
08/08/92	670	360	377	8945
08/09/92	660	350	407	3462
08/10/92	655	365	624	8630
08/11/92	640	360	409	8440
08/12/92	640	365	588	8767
08/13/92	665	360	626	8501
08/14/92	665	360	0	8861
08/15/92	150	320	522	8659
08/16/92	605	345	525	8019
08/17/92	670	185	462	7742
08/18/92	665	640	430	7952
08/19/92	575	760	281	8931
08/20/92	670	1045	657	8819
08/21/92	685	765	0	9584
08/22/92	670	1075	861	9798
08/23/92	620	690	1045	9443
08/24/92	630	750	1071	9122
08/25/92	635	800	939	8983
08/26/92	635	1040	760	9263
08/27/92	320	1120	632	9751
08/28/92	625	660	0	10411
08/29/92	600	710	766	10355
08/30/92	630	1080	735	10700
08/31/92	335	1005	697	6992
09/01/92	340	870	682	11196
09/02/92	545	930	619	11507
09/03/92	645	380	692	11195
09/04/92	630	640	0	11835
09/05/92	630	870	683	12022
09/06/92	630	310	551	11781
09/07/92	615	0	570	11211
09/08/92	675	315	600	10926
09/09/92	685	1010	0	11936
09/10/92	490	845	574	12207
09/11/92	475	470	0	12677
09/12/92	0	340	477	12540
09/13/92	0	375	547	12368
09/14/92	0	335	620	12083
09/15/92	0	405	594	11894
09/16/92	0	350	514	11730
09/17/92	395	350	506	11574
	25510	26725	24321	458166

PL5 Database File

DATE	PR_CL_CLT	GR_CM_CT	DIS_CM_CT	STOCK_CM
08/01/92	1390	0	2237	12398
08/02/92	1305	215	2096	10773
08/03/92	1495	770	2446	11115
08/04/92	1385	1070	2179	10602
08/05/92	100	150	2341	10089
08/06/92	1210	340	2260	10859
08/07/92	1325	0	0	13260
08/08/92	1395	0	2417	11280
08/09/92	1445	0	2297	11280
08/10/92	1075	575	2405	11545
08/11/92	430	1025	0	14535
08/12/92	480	575	2160	12144
08/13/92	1280	875	2089	12141
08/14/92	1280	630	0	24927
08/15/92	1165	0	2761	12825
08/16/92	750	0	2645	11799
08/17/92	0	0	2655	9576
08/18/92	0	0	2554	7695
08/19/92	0	0	1641	7695
08/20/92	0	0	2528	4275
08/21/92	0	0	0	4275
08/22/92	0	0	395	3762
08/23/92	0	0	88	3674
08/24/92	0	1995	95	6639
08/25/92	0	2235	1752	11212
08/26/92	0	1860	3108	11184
08/27/92	555	1655	3689	8721
08/28/92	1280	1080	508	9576
08/29/92	1470	180	3408	9918
08/30/92	940	355	3152	9234
08/31/92	1100	450	2557	9832
09/01/92	1100	1210	2844	10089
09/02/92	620	1140	3255	10260
09/03/92	1485	2465	2529	10602
09/04/92	1470	1000	1273	10260
09/05/92	1210	640	3734	10773
09/06/92	1440	1165	3138	11799
09/07/92	1460	915	2652	11970
09/08/92	1525	1095	2994	11543
09/09/92	1510	2410	1645	11286
09/10/92	1480	1215	3577	9918
09/11/92	1440	2165	0	12141
09/12/92	1550	260	3722	12964
09/13/92	1505	0	3545	5985
09/14/92	1505	875	3428	9405
09/15/92	1530	2430	3495	9063
09/16/92	1430	2360	3123	8550
09/17/92	1440	2315	2708	12926
	46555	39695	106125	498374

PL6 Database File

DATE	PR_CL_CLT	GR_CM_CT	DIS_CM_CT	STOCK_CM
08/01/92	2750	1605	287	17461
08/02/92	2550	250	358	16857
08/03/92	2805	0	292	13047
08/04/92	2545	795	242	12219
08/05/92	1970	1610	267	10827
08/06/92	2715	2560	271	9502
08/07/92	1320	2230	0	9861
08/08/92	1170	1605	208	10820
08/09/92	550	2730	326	10927
08/10/92	2890	1480	135	10173
08/11/92	3140	2080	0	10288
08/12/92	2885	1340	148	11280
08/13/92	70	540	116	11471
08/14/92	0	0	0	10712
08/15/92	2820	1645	283	9668
08/16/92	2945	2910	108	13997
08/17/92	2815	1285	214	14636
08/18/92	2730	1555	92	15128
08/19/92	0	0	2	13485
08/20/92	0	0	0	14378
08/21/92	0	0	0	14378
08/22/92	0	0	0	14559
08/23/92	0	0	0	14559
08/24/92	0	1065	0	14559
08/25/92	0	4090	0	14559
08/26/92	0	1220	0	14559
08/27/92	0	0	0	14988
08/28/92	0	1480	0	16184
08/29/92	0	2535	0	15148
08/30/92	0	2740	43	15731
08/31/92	0	1895	142	12038
09/01/92	0	1980	172	13796
09/02/92	900	1635	289	12856
09/03/92	2665	2365	141	14674
09/04/92	2220	1200	0	15942
09/05/92	2655	2650	339	14646
09/06/92	2825	3430	221	14856
09/07/92	2925	3815	381	15382
09/08/92	2855	890	446	14355
09/09/92	2930	0	0	15378
09/10/92	2920	0	293	14092
09/11/92	2825	0	0	14034
09/12/92	1970	0	509	13240
09/13/92	2775	1540	219	13996
09/14/92	2830	3625	255	11393
09/15/92	1990	1510	207	11973
09/16/92	0	1320	211	12832
09/17/92	610	1225	167	13120
	74565	68430	7384	644564

PL7 Database File

DATE	PR_CL_CLT	GR_CM_CT	DIS_CM_CT	STOCK_CM
08/01/92	0	1425	3306	9384
08/02/92	0	1500	3212	7912
08/03/92	0	3035	2866	9581
08/04/92	0	1710	3304	8772
08/05/92	0	2395	3050	9170
08/06/92	0	1925	2659	9360
08/07/92	0	770	0	9600
08/08/92	0	1185	2634	8150
08/09/92	0	2440	2390	8200
08/10/92	0	2255	2508	7950
08/11/92	0	2500	0	10450
08/12/92	0	0	2836	7615
08/13/92	0	1395	2596	6441
08/14/92	0	3565	0	10200
08/15/92	0	1645	2524	9480
08/16/92	0	1330	2613	8642
08/17/92	0	2400	2642	8400
08/18/92	0	2515	2812	8400
08/19/92	0	0	0	8400
08/20/92	0	0	0	8400
08/21/92	0	0	0	8400
08/22/92	0	0	1617	6720
08/23/92	0	0	873	5848
08/24/92	0	0	1322	4526
08/25/92	0	0	857	3669
08/26/92	0	0	202	3467
08/27/92	0	1550	1230	4968
08/28/92	0	3260	1508	6720
08/29/92	0	2345	2106	6960
08/30/92	0	3215	2736	7440
08/31/92	0	2380	2982	6840
09/01/92	0	3375	3254	6960
09/02/92	0	2640	2715	6885
09/03/92	0	2795	2421	7259
09/04/92	0	2945	920	9285
09/05/92	0	2595	2785	9095
09/06/92	0	2385	2597	8883
09/07/92	0	2725	2407	9201
09/08/92	0	1555	2371	8385
09/09/92	0	1110	1367	8128
09/10/92	0	3455	2588	8995
09/11/92	0	2170	0	11165
09/12/92	0	690	2825	9030
09/13/92	0	1720	2939	7811
09/14/92	0	2605	2978	7438
09/15/92	0	3035	2856	7617
09/16/92	0	2465	3272	6810
09/17/92	0	3225	2966	7070
	0	88230	98646	380082

APPENDIX V

MACRO COMMAND PROGRAM

```
_start_macro    {CALC}
                {LET date1,@DATEVALUE(today)}
                {/ Block;Format}htable1~
                {/ Block;Format}htable2~
                {/ Block;Format}rtable3~
                {HOME}{PANELON}
_date_y_n       {GETLABEL "Change date (y/n)? ",_yes}
                {IF @UPPER(_yes)="y"}{_date_entry}
                {IF @UPPER(_yes)<>"y"}{IF @UPPER(_yes)<>"n"}{BRANCH _d
                {PUT table3,2,0,_plan_msg}
                {PUT table3,2,1,monthplan}
_plan_y_n       {PANELON}
                {INDICATE PLAN}
                {GETLABEL "Change monthly plan of clinker production (y/n)? ",_y
                {PANELOFF}{IF @UPPER(_yes)="y"}{_plan_entry}
                {IF @UPPER(_yes)<>"y"}{IF @UPPER(_yes)<>"n"}{BRANCH _pl
                {PUT table3,2,0,_frcst_msg}
                {PUT table3,2,1,forecast}
_frcst_y_n      {PANELON}
                {INDICATE FRCST}
                {GETLABEL "Change monthly forecast of cement dispatch (y/n)? ",
                {PANELOFF}{IF @UPPER(_yes)="y"}{_forecast_entry}
                {IF @UPPER(_yes)<>"y"}{IF @UPPER(_yes)<>"n"}{BRANCH _fr
                {BLANK table3}
                {BRANCH _main_sub}

_date_entry     {PANELOFF}
                {INDICATE DATE}
                {NUMON}
                {BLANK table3}
                {/ Block;Format}rtable3~
                {PANELON}
                {PUT table3,0,1,_date_message}
                {GOTO}date1~
                {/ Protection;Enable}
                {/ Block;Unprotect}date1~
```

```
                {/ Block;Unprotect}_...
                {/ Block;Unprotect}_error_message~
                {/ Block;Unprotect}_error_loc~
                {INDICATE INPUT}
                {/ Block;Input}title1~
                {NUMOFF}
                {/ Protection;Disable}
                {INDICATE WAIT}
                {IF date1=end4}{BRANCH _skip_ini}
                {_date_criteria}
                {_DB_extract}
                {_graph_insert}
_skip_ini       {BLANK table3}

_plan_entry     {INDICATE PLAN}
                {NUMON}
                {GETNUMBER "Enter the new monthly plan of clinker: ",monthplan
                {NUMOFF}
                {IF @CELL("contents",monthplan)<>"err"}{RETURN}
                {BEEP 2}
                {MESSAGE _plan_err,10,10,@NOW+@TIME(0,0,3)}
                {BRANCH _plan_entry}

_forecast_entry {INDICATE FRCST}
                {NUMON}
                {GETNUMBER "Enter the new monthly forecast of cement: ",foreca
                {NUMOFF}
                {IF @CELL("contents",forecast)<>"err"}{RETURN}
                {BEEP 2}
                {MESSAGE _forecast_err,10,10,@NOW+@TIME(0,0,3)}
                {BRANCH _forecast_entry}

_date_criteria  {PANELON}{BLANK TABLE3}
                {PUT TABLE3,1,1,_criteria_msg}
                {LET startdate,date1}
                {LET enddate,date1}
                {/ Publish;DataEntryDate}startdate~
                {WINDOWSOFF}{PANELOFF}
                {GOTO}startdate~
                {/ Block;Format}d1~{EDIT}{HOME}{DEL 2}1~
```

```
                  {/ Publish;DataEntryFormula}startdate~
                  {EDIT}{HOME}+date>=~
                  {GOTO}enddate~
                  {EDIT}{HOME}+date<=~
                  {HOME}
                  {LET end4,date1}
                  {LET end5,date1}
                  {LET end6,date1}
                  {LET end7,date1}
                  {LET endt,date1}

_DB_extract       {BLANK PI_tot1}
                  {/ Query;Reset}
                  {/ Query;Block}PI4.DBF~
                  {/ Query;CriteriaBlock}Crit_PI4:~
                  {/ Query;Output}PI4~
                  {/ Query;Extract}
                  {/ Query;Block}PI5.DBF~
                  {/ Query;CriteriaBlock}Crit_PI5:~
                  {/ Query;Output}PI5~
                  {/ Query;Extract}
                  {/ Query;Block}PI6.DBF~
                  {/ Query;CriteriaBlock}Crit_PI6:~
                  {/ Query;Output}PI6~
                  {/ Query;Extract}
                  {/ Query;Block}PI7.DBF~
                  {/ Query;CriteriaBlock}Crit_PI7:~
                  {/ Query;Output}PI7~
                  {/ Query;Extract}
                  {/ Query;Block}PI_tot.DBF~
                  {/ Query;CriteriaBlock}Crit_PIt:~
                  {/ Query;Output}PIt~
                  {/ Query;Extract}
                  {/ Query;CriteriaBlock}Crit_tot:~
                  {/ Query;Output}PI_tot~
                  {/ Query;Extract}

_graph_insert     {WINDOWSON}
                  {BLANK series111}
                  {GOTO}pr_cl~{END}{DOWN}{RIGHT 3}x~
```

```
               {GOTO}series11~{DOWN}
               +pr_cl/1000~
               {/ Block;Copy}~.{END}{DOWN}~
               {/ Name;Create}series11~
               {ESC}.{DOWN}{END}{DOWN}~
               {BLANK series211}
               {GOTO}dis_cm~{END}{DOWN}{RIGHT 4}x~
               {GOTO}series21~{DOWN}
               +dis_cm/1000~
               {/ Block;Copy}~.{END}{DOWN}~
               {/ Name;Create}series21~
               {ESC}.{DOWN}{END}{DOWN}~
               {BLANK table3}{HOME}
               {LET _print_flag,u}

_show_data     {PANELOFF}{WINDOWSOFF}
               {/ Graph;NameInsert}graph1~graph1~
               {/ Graph;NameInsert}graph2~graph2~
               {/ Block;Format}rtable1~
               {IF _print_flag="p"}{RETURN}
               {/ Color;Edit}{LEFT 12}~
               {/ ScreenHardware;TextScreenMode}b
               {LET _screen_flag,b}
               {PANELON}{WINDOWSON}

_screen_flag   a

_close         {PANELOFF}{WINDOWSOFF}
               {/ ScreenHardware;TextScreenMode}a
               {LET _screen_flag,a}
               {/ Block;Format}htable1~
               {/ Color;Edit}{RIGHT 12}~
               {PANELON}{WINDOWSON}{INDICATE}

_remarks_infor {BEEP 3}
               {MESSAGE _message2,10,10,@NOW+@TIME(0,0,4)}
               {RETURN}

_file2         33847
```

```
_remarks_insert  {CONTENTS _file2,date1,6,125}~
                 {GOTO}_file2~{EDIT}{BACKSPACE}~
                 {HOME}{GOTO}table1~
                 {/ Titles;Horizontal}
                 {GOTO}remrks1~
                 {PANELOFF}{WINDOWSOFF}
                 {/ Block;Format}rremrks1~
                 {IF @FILEEXISTS(_file1)}{BRANCH _copy1}
                 {BRANCH _remarks_inform}
_copy1           {DOWN 2}{/ File;CopyFile}
                 {CLEAR}
_file1           33847.WQ!
                 ~

_remarks_save    {PANELOFF}{WINDOWSOFF}{/ Protection;Disable}
                 {/ Block;Justify}remrks2~
                 {CONTENTS _file,date1,6,125}~
                 {/ File;ExtractFormulas}
                 {CLEAR}
_file            33847
                 ~remrks~{DOWN}~
                 {/ Titles;Clear}{HOME}
                 {PANELON}{WINDOWSON}
                 {BRANCH _main_sub}

_quit1           {GETLABEL "Press: N to return, Y if sure to exit; (y/n)? ",_yes}
                 {IF @UPPER(_yes)="y"}{BRANCH _quit2}
                 {BRANCH _main_sub}

_quit2           {_close}
                 {GOTO}_end_page~
                 {PLAY "THANKS",-256}
                 {PANELOFF}{/ Basics;Quit}y

_main_menu       Update Information
                 Update remarks, or the date, forecast or plan set points.
                 {BRANCH _update_sub}

_update_menu     Remarks
                 Enter new remarks or edit the current remarks.
```

```
                {BRANCH _remarks_sub}

_remarks_menu   Edit
                Change or correct current remarks
                {BRANCH _edit_sub}

_display_menu   Both
                Display both tables and plots.
                {BRANCH _both_sub}

_update_sub     {INDICATE "UPDATE"}
                {IF _screen_flag="b"}{_close}
                {HOME}
                {MENUBRANCH _update_menu}{BRANCH _program_secure}

_plan_sub       {PUT table3,2,0,_plan_msg}
                {PUT table3,2,1,monthplan}
                {/ Block;Format}rtable3~
                {_plan_entry}
                {BLANK table3}

_forecast_sub   {PUT table3,2,0,_frcst_msg}
                {PUT table3,2,1,forecast}
                {/ Block;Format}rtable3~
                {_forecast_entry}
                {BLANK table3}

_remarks_sub    {INDICATE "RMRKS"}
                {_remarks_insert}
                {PANELON}{WINDOWSON}
                {MENUBRANCH _remarks_menu}{BRANCH _program_secure}

_display_sub    {INDICATE "DSPLY"}
                {IF _screen_flag="a"}{_show_data}
                {MENUBRANCH _display_menu}{BRANCH _program_secure}
```

```
_print_flag      b
_print_sub       {INDICATE "PRINT"}
                 {IF _screen_flag="b"}{LET _print_flag,"b"}
                 {IF _print_flag="u"}{LET _print_flag,"p"}{_show_data}
                 {LET _print_flag,"b"}
                 {HOME}{GOTO}table1~
                 {/ Titles;Horizontal}
                 {GOTO}table4~
                 {/ Block;Format}rtable5~
                 {_break_check}
                 {WINDOWSON}
                 {PANELOFF}
                 {IF _screen_flag="a"}{/ Block;Format}rtable1~
                 {/ Block;Protect}print1~
                 {/ Print;OutputHQ}
                 {/ Print;Align}
                 {/ Print;Go}
_break_resume    {IF _screen_flag="a"}{/ Block;Format}htable1~
                 {/ Titles;Clear}
                 {/ Block;Format}htable5~
                 {HOME}
                 {PANELON}
                 {BRANCH _main_sub}

_edit_sub        {/ Block;Format}rtable4~
                 {/ Protection;Enable}
                 {/ Block;Unprotect}remrks~
                 {/ Publish;DataEntryLabel}remrks~ ~
                 {/ Block;Input}remrks3~
                 {/ Block;Format}htable4~
                 {BRANCH _remarks_save}

_tables_sub      {/ Titles;Clear}
                 {HOME}
                 {MENUBRANCH _display_menu}{BRANCH _program_secure}

_plots_sub       {/ Titles;Clear}
                 {HOME}{GOTO}table1~
                 {/ Titles;Horizontal}
                 {DOWN 27}
```

```
                 {MENUBRANCH _display_menu}{BRANCH _program_secure}

_both_sub        {/ Titles;Clear}
                 {PGDN}{GOTO}both~
                 {GOTO}table3~{DOWN}
                 {/ Titles;Horizontal}
                 {GOTO}graph1~
                 {PGDN}
                 {GOTO}graph1~
                 {MENUBRANCH _display_menu}{BRANCH _program_secure}

_remarks_disply  {/ Titles;Clear}
                 {HOME}{GOTO}table1~
                 {/ Titles;Horizontal}
                 {DOWN 44}
                 {MENUBRANCH _display_menu}{BRANCH _program_secure}

_quit_sub        {/ Titles;Clear}
                 {HOME}
                 {BRANCH _main_sub}

_save_sub        {INDICATE "SAVE"}{PANELOFF}
                 {IF _screen_flag="b"}{_close}
                 {GOTO}_title_page~
                 {/ File;SaveNow}r
                 {HOME}{PANELON}
                 {BRANCH _main_sub}

_exit_dos        {MESSAGE _message3,10,10,@NOW+@TIME(0,0,3)}
                 {INDICATE "EXIT"}{PANELOFF}
                 {IF _screen_flag="b"}{_close}
                 {BRANCH _quit1}


\d               {_error_check}{BRANCH _display_sub}

\e               {_error_check}{BRANCH _exit_dos}

\m               {BRANCH _main_sub}
```

```
\r              {BACKSPACE}{BRANCH _remarks_save}

\o              {PANELOFF}{DOWN}~{HOME}
                {_error_check}
                {NUMOFF}
                {GOTO}_title_page~
                {BRANCH _start_macro}

\p              {_error_check}{BRANCH _print_sub}

\s              {_error_check}{BRANCH _save_sub}

\u              {_error_check}{BRANCH _update_sub}

\w              {_error_check}{BRANCH _remarks_sub}


_program_secur  {BEEP 4}{BRANCH _quit_sub}

_error_sub      {BEEP 2}
                {MESSAGE _err_message,10,10,@NOW+@TIME(0,0,3)}
                {_error_check}
                {Branch @CELL("contents",_error_loc)}

_main_sub       {_error_check}
                {INDICATE MAIN}{MENUBRANCH _main_menu}{BRANCH _progr

_error_loc      [D1368132]B416

_error_check    {ONERROR _error_sub,_error_message,_error_loc}

_break_check    {ONERROR _break_sub,_error_message,_error_loc}

_break_sub      {BEEP 2}
                {MESSAGE _break_message,10,10,@NOW+@TIME(0,0,3)}
                {_error_check}
                {PANELOFF}{Branch _break_resume}
```

الملخـــــص

يوضح هذا البحث الاساليب المستخدمة في تصميم نظام معلومات اداري فعال في الصناعة الاردنية من خلال تطبيق مبادىء حقل العوامل البشرية التي تهدف الى زيادة الفعالية في العمل ورفع الكفاءة الانتاجية وتحسين ظروف العمل وسلامة الانسان، حيث تم السير على منهاج تصميم النظام الكلي، ويشكل العنصر البشري أحد المكونات الرئيسية لهذا النظام، حيث تشكل ادارة المصنع المستخدم الاول له، ويعتبر الكتبة في دائرة الانتاج - المشغلون له - المستخدم الثانوي، كما تشتمل مكونات النظام على الحاسوب أيضا".

تم القيام بدراسة مكثفة للادبيات والوثائق المتعلقة بموضوع البحث، حيث تم استخلاص المبادىء الاساسية للاداء البشري وعلاقته بالتصميم. كما تم الرجوع الى الاوراق البحثية والتجارب المخبرية حيث تم استخلاص النتائج المتعلقة بلوحات المعلومات المرئية والسطح البيني للانسان والحاسوب.

في المرحلة الاولى من عملية تصميم النظام تم تجميع المعلومات المتعلقة بالاحتياجات الخاصة بمستخدمي النظام بعد تحديد الهدف منه. كما تم وضع البدائل المختلفة للتصميم، فتبين أن البديل الانسب الذي يحقق اهداف النظام يتألف من تقرير يشتمل على ملخص للانتاج بما في ذلك الكميات الفعلية والمخططة من خلال ايرادها على شكل جداول ورسومات بيانية وملاحظات، ليتم تدويره وعرضه في اجتماع ادارة المصنع اليومي. كما يتم رسم نتائج الانتاج الشهرية وعرضها باستخدام الشفافيات وأجهزة العرض الخاصة بها. اما محتوى هذه الرسومات البيانية فهو تلخيص للمعلومات بحيث يدركها ويستطيع تفسيرها الحضور من المهندسين ذوي الخبرة، ولقد تبين أن الذين سوف يقومون على تشغيل النظام هم من المتمرسين في حسابات الانتاج بالطريقة اليدوية، كما أن لديهم خبرة ناجمة عن ممارسة متقطعة في استخدام الحاسوب.

يتم فحصه واعادة تقييمه بعد ذلك، علما" بأن البرامج قد اعدت بحيث يمكن ادامة النظام بما يتلاءم مع احتياجات المستخدمين المتجددة .