THE APPLICATION OF THE PRINCIPLES OF INTERIOR DESIGN IN THE FACTORY ENVIRONMENT

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THE APPLICATION OF

THE PRINCIPLES OF INTERIOR DESIGN

IN THE FACTORY ENVIRONMENT

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DECLARATION

I, Stephen Paul Fromage, hereby declare that the contents of this dissertation represent my own work. The opinions contained herein are my own and do not necessarily represent those of the Cape Technikon.

PREFACE

The origins of the research activities which constitute this dissertation can be traced to a proposal in 1991 to write a history assignment on the retrospective influence of interior design in the factory environment. A subsequent search for relevant information proved largely unsuccessful, resulting in the temporary suspension of further investigations into the topic.

However, these enquiries provoked a piquant interest in the feasibility of applying interior design principles in the factory environment. The challenge presented by the lack of reference to the role of interior design in the factory environment, in conjunction with a dearth of literature pertinent to the history of industrial architecture, served as impetus for the background investigation which led to a successful proposal that my National Higher Diploma be based on the practical design of factory interiors.

As part of the practical component for the National Higher Diploma during 1992, I was concerned with the design of industrial hives[i] on behalf of the Small Business Development Corporation as well as for Partnership De Villiers, a firm of consulting engineers.

These projects comprised the proposed conversion of a fruit drying store into industrial hive units in Robertson and a proposal submitted for tender to the Bellville Municipality for the development of an industrial hive complex in Cape Town's Northern Suburbs. A final project, submitted for the National Higher Diploma, constituted a proposal for a timber merchant's warehouse which incorporated a retail function.

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[i]The term "industrial hives" refers to instances where redundant factory buildings are sub-divided to form multiple cubicle "hive units", usually with a floor area not exceeding 150 square metres. These units are then leased to small manufacturing concerns. The ongoing development of this type of facility is a stated policy of the Small Business Development Corporation.

Experience gained through the execution of the projects served to highlight the lack of reference works suitable for use in the design of the factory environment. This factor, coupled with the growing awareness that interior design could play a positive role in the humanisation of the workplace with possible benefits to productivity, provided the motivation for this current work.

Continuing practical work during 1993, including the planning of a jewellery design workshop at the Cape Technikon, as well as the successful completion of a "micro factory" industrial complex[ii] as part of a professional team, has provided insight and experience useful for the selection and evaluation of the data which has been incorporated in my dissertation in the form of practical guidelines.

In this regard I would like to thank Johan Gildenhuys of the Small Business Development Corporation and Phillip Collins of Van Wyk and Louw Incorporated, both of whom afforded me design opportunities as well as providing advice.

Financial support was provided by a grant from the Foundation for Research Development as well as a bursary from the Cape Town Chamber of Commerce. Without this funding this investigation would not have been possible.

Finally, I am indebted to my supervisor, Mr Bev Gower, of the Cape Technikon's School of Design. His constant encouragement to explore the boundaries of interior design has provided the degree of academic freedom which has enabled me to strive towards my goals.

[ii]The complex comprises sixteen light industrial units with floor areas ranging from 90 to 150 square metres. Design aspects addressed included interior space planning, ventilation, lighting and finishes, as well as the building facades.

SYNOPSIS

The formulated intention of this research project was to ascertain the feasibility of applying interior design principles in the the factory environment. Objectives included establishing whether the design of the physical environment may influence productivity, as well as the setting out of reference material for future use by interior designers concerned with the design of factory interiors.

Research activities were of an exploratory nature and comprised the analysis of information gleaned from a wide field of literature. This information, supplemented by knowledge gained through consultation with others in their various fields of expertise, was compiled into a set of reference guidelines for future use by interior designers who may become concerned with designing in the factory environment.

The findings which have emerged as a result of this investigaiton are listed as follows:

- Historical evidence of concern for the potential effects of the interior working environment was noted. At the end of the nineteenth century this concern revolved around the need for improved production, but currently incorporates an interest in the general well-being of the worker. Several instances of recommendations by authors with regard to the need for practical research activity in the field of the working environment were noted.

- A literary review indicated that the design of the factory interior currently involves input from diverse disciplines such as engineering, architecture and ergonomics. However, it appeared that the diverging interests of these disciplines could, in some instances, result in the inefficient implementation of design solutions.

- A review of the history of Industrial Architecture revealed that the existence of industrial buildings could be traced back to periods as early as 5000 B.C. in Asia Minor. In the twentieth century Industrial Architecture has influenced contemporary developments such as the "Modern Movement" as well as styles such as "High Tech".

- A comparison of factory spaces and their functions with, for example, offices and service industry spaces, indicated that the physical elements which form the factory interior are essentially the same as those forming spaces in other contexts.

- Information contained in publications concerning subjects such as architecture, human psychology, engineering, corporate identity planning and office planning were found to be suitable for application by an interior designer in the factory interior.

- A general consensus of opinion was found to exist as regards the positive influence which the physical aspects of the interior environment can exert on productivity, both through efficient planning for activities as well as by designing the interior to accommodate human physical and mental attributes.

Evidence emanating as a consequence of the investigation suggests that the following conclusions be drawn:

- There is a need for the effective design of the factory Interior. The practical application of the principles of interior design by an interior designer can address this need. An interior designer may also be able to assist with the co-ordination of the various disciplines involved in the planning, design and construction of the factory, for example by acting as an interface between the client and architect.

- Opportunity exists for further research into the application of interior design principles to the factory interior. Research activities could encompass practical, scientific field experiments. An interdisciplinary approach could be incorporated where the practical and theoretical components of, for example, interior design and the social sciences are combined.

OPSOMMING

Hierdie navorsingsprojek poog om die uitvoerbaarheid van die toepassing van binne-ontwerpbeginsels op die ontwerp van die fabrieksinterieur te bepaal. Die doelstellings sluit in die bepaling of die ontwerp van die fisiese omgewing produktiwiteit kan beïnvloed asook die uiteensetting van naslaanwerk vir toekomstige gebruik deur binne-ontwerpers gemoeid met die ontwerp van fabrieksinterieurs.

Die navorsingsaktiwiteite is van verkennende aard. Die ondersoekprosedure omvat die evaluering, vertolking en samestelling van gegewens en inligting afkomstig uit 'n wye literatuurgebied wat nagevors is. Hierdie inligting is aangevul deur kennis uit eie praktiese ervaring en raadpleging van vakkundiges opgedoen.

Die volgende is die vernaamste bevindings van die navorsing:

Bewys is aangetref van 'n geskiedkundige besorgdheid oor die uitwerking van die binnenshuise werksomgewing op die mens. Teen die einde van die negentiende eeu het hierdie besorgdheid om die behoefte aan verbeterde produksie gedraai, maar tans behels dit ook 'n belangstelling in die algemene welsyn van die werker. Daar word kennis geneem van etlike gevalle waar outeurs aanbevelings oor die behoefte aan praktiese navorsing op die gebied van die werksomgewing gedoen het.

'n Literatuuroorsig toon dat die ontwerp van die fabrieksinterieur tans insette vannuit verskillende vakgebiede soos die Ingenieurswese, Argitektuur en Ergonomie betrek. Dit kom egter voor asof die uiteenlopende belangstellings van hierdie vakgebiede in party gevalle tot die ondoeltreffende implementering van ontwerpoplossings kan lei.

'n Oorsig van die geskiedenis van die Bedryfsargitektuur toon dat die bestaan van bedryfsgeboue tot so vroeg soos tydperke 5000 vC in Klein-Asië teruggevoer kan word. In die twintigste eeu het bedryfsargitekte tydgenootlike ontwikkelings soos die "Moderne Beweging" asook style soos die "Hoë tegnologie" beinvloed.

'n Vergelyking van fabrieksruimtes en hulle funksies met byvoorbeeld kantore en diensbedryfruimtes toon dat die fisiese elemente wat die fabrieksinterieur uitmaak wesenlik dieselfde is as dié wat ruimtes in 'n ander konteks uitmaak, en dus soortgelyke ontwerpoorwegings verg.

Inligting vervat in publikasies oor onderwerpe soos die Argitektuur, die Sielkunde van die mens, die Ingenieurswese, die beplanning van die korporaatidentiteit en kantoorbeplanning is vir toepassing deur 'n binne-ontwerper in die fabrieksinterieur geskik gevind.

Daar is gevind dat die algemene opinie bestaan dat die fisiese aspekte van die binne-omgewing 'n positiewe invloed op produktiwiteit kan uitoefen deur sowel doeltreffende beplanning van die aktiwiteite as die ontwerp van die interieur ten einde vir die mens geestelik en liggaamlik voorsiening te maak.

Op grond van die bevindings in hierdie navorsing word die volgende gevolgtrekkings gemaak:

Daar bestaan 'n behoefte aan die doeltreffende ontwerp van die fabrieksinterieur. Die praktiese toepassing van die binne-ontwerpbeginsels deur 'n binne-ontwerper kan in hierdie behoefte voorsien. Die binne-ontwerper kan moontlik ook behulpsaam wees met die koördinering van die verskillende vakgebiede wat gemoeid is met die beplanning, ontwerp en oprig van die fabriek, byvoorbeeld deur as 'n koppelvlak tussen die kliënt en die argitek op te tree.

Produktiwiteit kan bevorder word deur beplanning vir doeltreffendheid, byvoorbeeld bewegingsekonomie en ruimteplooibaarheid asook die ontwerp van die fisiese elemente van die ruimte ten einde vir die mens geestelik en liggaamlik voorsiening te maak.

Daar bestaan die geleentheid vir verdere navorsing oor die toepassing van binne-ontwerpbeginsels op die fabrieksinterieur. Navorsing kan praktiese, wetenskaplike veldproewe insluit. 'n Interdissiplinêre benadering kan verbande lê waardeur die praktiese en teoretiese komponente van byvoorbeeld binne-ontwerp en die sosiale wetenskappe gesamentlik betrek word.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Before the Industrial Revolution in the mid-eighteenth century, work other than farmwork was often carried out in the craftperson's or businessperson's home. With the advent of machinery and mass production, factories became feasible as efficient places of work.

Initially the only form of power was the water wheel and adequate lighting could only be provided by sunlight. The design of factory buildings was therefore dictated by these limitations to low-rise, narrow buildings, constructed of timber or stone.

According to Fisher et al, in their book on environmental psychology, "The advent of electricity and structural steel freed the building designers from these technological constraints and allowed designers, owners, managers and labour unions to focus on worker safety, health, productivity and job satisfaction "*(Fisher et al. 1984:318).*

In his review on the problems people have as they adapt to any working environment along with evolving concepts of the workplace, Sundstrom also infers an historical interest in the interior environment and maintains that throughout the history of offices and factories, a connection between the physical environment and: (1) comfort and efficiency of individuals, (2) communication and interpersonal relationships and (3) productivity and effectiveness of organisations, has commonly recurred *(Sundstrom 1986:40).*

A comparison of three studies *(Sundstrom 1986, Sutermeister 1976 and Fisher et al. 1984)* revealed that studies and theories regarding the effect that interior planning and the interior environment can have on productivity, have been carried out since the end of the nineteenth century. However, these studies have mainly been confined to the effect the environment has on productivity, not on the actual design of the environment itself.

There is evidence that a need has arisen for the study of the design of the workplace:

Fisher et al. posed the question "**Why study the design of the work environment?**". The suggested answer was that if productivity can be boosted by use of design, managers would be encouraged to take advantage of design principles *(Fisher et al. 1984:318)*. This implies that if design can be utilised to increase productivity and if the interior designer were in a position to apply these design principles, he could be utilised for this purpose.

In summarising Fisher et al's thinking regarding the design of workspace, the following dominating principles may be defined:

- The principle of workflow indicates that the **layout** of a factory should provide for the shortest possible distance between workstations along which the work moves

- The principle of providing **environments** which promote safety and **physical comfort** for the worker in the form of adequate **lighting, ventilation, noise reduction** and other physical and mental considerations. These are considered to be maintenance factors in human productivity in that a shortcoming in the **design of these elements** can reduce the human ability to perform

- The environment and job satisfaction: this is the concern that the **work environment** can contribute to job satisfaction which in turn leads to increased loyalty, lower absenteeism, better co-operation and other desirable qualities in the worker.

(Fisher et al. 1984:319)

The inclusion of elements such as the design of the layout and physical (working) environment in these principles, coupled with the fact that the principles of interior design are currently applied to these aspects of the interior, for example in office and hospital design, indicate that the interior designer should have a role to play in the design of the factory interior.

It is also apparent that these principles, although vital to productivity, are not currently being applied to the factory interior.

Becker points out that the individual employee's experience at work is critical to economic success and that productivity is driven, to a large extent, by how we organise work and workers. "Yet, if past experience is any guide, the potential for the most persuasive resource in the work environment, the physical setting, to contribute to these efforts, will be largely overlooked" ***(Becker 1981:v)***.

In commenting on the role of the industrial environment in the development of industrial systems Woodson et al. recommended that:

> "The role of the industrial environment ... should be to provide working conditions that will ensure that both the worker and the machine can function at maximum capacity" ***(Woodson et al. 1992:120).***

At the same time they make the observation:

> "It is often noted that planners are more concerned about machines than they are about workers e.g. air conditioning may be provided for the computers, while factory workers 'sweat' on the assembly line" ***(Woodson et al. 1992:120)***.

From the above it would appear that the factory interior can contribute to productivity and the interior designer should have a role to play in the design thereof. However, literature does not evidence an historical role for interior designers in this context. An interview (see Annexure J) with Professor Prinsloo, Director of the School of Architecture at the University of Cape Town, supported this observation.

The following contributory factors, based mainly on experience, are offered as reasons for the apparent omission of the factory interior from the general scope of Interior Design:

- Public perception that the primary function of the interior designer is purely to create a visually more attractive environment - People are not generally aware that the interior designer is concerned with the function of the space as well as decorative aspects. This issue is further confused by the fact that, in South Africa the entitlement "Interior Designer" is not controlled by a professional body or institute, with the result that unqualified persons may pretend to that title.

- Factory management is possibly unaware of the services which interior design can offer with regard to the design of manufacturing showrooms, factory restaurants, staff recreational facilities, public reception and waiting areas, offices and boardrooms as well as the need for corporate identity design, all of which are within the general scope of interior design. Currently much of this work is executed in-house or by shopfitters. This in turn implies that interior designers have probably not exploited the market of the factory interior design to the full.

- The term "Interior Design" is often confused with the term "Industrial Design", when applied to the industrial interior. This confusion can exist in the educational, professional or public arena. Although these design disciplines do overlap in various areas, it is Interior Design which deals primarily with the interior of the built environment.

- A shortage of accessible design reference material in respect of the factory interior could be a further restricting factor for the interior designer.

- It is possible that other professions will avoid utilising the skills of the interior designer as this may be seen to encroach upon their own professional sphere.

Addressing the subject of the attitude of various professions to the role of the physical setting, Becker points out that:

> "With the exception of the design professions, whose focus is on the built environment, most professions and trade unions tend to play down the physical setting's contribution to effective performance."

He reasons that this is because

> "... attributing successful performance to the nature of the environmental support system, especially if designed by other professionals, undermines the claim to special personal skills and autonomy central to the definition of 'professional'" *(Becker 1981:75).*

It can thus be seen that there is some evidence of an historical concern regarding the effect which the interior environment has on productivity in factories.

The principles currently embodied in workplace design theory continue to stress the role which the physical environment has to play in promoting productivity. They also refer to aspects commonly addressed by the interior designer in the design of, for example, offices and hospitals.

It appears, however, that these principles are not being practically applied to the physical factory environment to the extent that they should be. It also seems evident that interior designers are not yet as extensively involved in the design of factory interiors as they ought to be.

1.2 THE AIM OF THE STUDY

Firstly, to establish whether the principles of Interior Design can, and should, be applied in the factory environment, to the benefit of staff and management.

Secondly, to provide a body of information which can be utilised in the design of factory interiors in order to promote productivity. This will include reference to other professions, for example in consultation between the interior design and the human and social sciences, in order to establish the design criteria necessary for the development of effective design solutions.

Commenting on the relationship between the social sciences and design, Becker states:

> "As a result of the fragile bridge still being built between the social sciences and the design professions, changes in design practice have occurred. There is greater concern today ... for designing buildings that are sensitive to human requirements and preferences. There is little doubt that the ... 'enlightenment function' of policy research, in which concepts, ideas and information are filtered more or less unconsciously into policymakers' decisions, has occurred" ***(Becker 1981:2)***.

1.3 THE RELEVANCE OF THE STUDY

Van den Bogaerde breaks down the composition of South Africa's exports into two main sectors i.e. a strong primary sector (mining and agriculture) and a growing secondary sector (manufacturing). In order for this secondary sector to compete on overseas (export) markets the manufacturing industries have to remain abreast of international trends ***(Van den Bogaerde : 1982)***.

Current international trends in the manufacturing industries indicate a focus of attention on the improvement of the working environment. This has been reflected in the following areas:

1.3.1 FACTORY BUILDINGS AND ENVIRONMENTS

In a summary of current developments in the field of factory building design Macmillan refers to:

> "A desire to return to smaller factories with more natural environments due to experiences of centralised plants being closed for long periods through strikes, and increasing evidence that both improved productivity and labour relations result from care being taken in the design of the workspace" ***(Macmillan 1979:100).***

1.3.2 AUTOMATIC AND TECHNOLOGICAL ADVANCEMENT : CREATING A NEED FOR ENSURING WORKER SATISFACTION AND MOTIVATION

Weck et al. explain that as the cost of labour relative to total cost of production shrinks due to technological advances (currently averaging 25%), so the influence workers have on total production increases. In practical terms, as mechanisation and automation increase, people begin to control production rather than to physically produce the goods i.e. output per person increases. Thus the influence a single person has on productivity increases. It then becomes increasingly important to ensure worker motivation and satisfaction in order to promote productivity ***(Weck et al. 1991:115)***.

1.3.3 MANUFACTURING AND THE NEED FOR HUMANISING "UNDESIRABLE WORK"

Reflecting on the reluctance of the European workforce to enter into employment in the manufacturing industries, Blackenbury comments on the reasons, outcome and remedy for this problem:

> "The title 'humanisation of work' is taken from the program of work initiated by the West German government, which is continuing under the title of Work and Technology program.
>
> The Germans, along with others in Europe, have realised that society has evolved and is rejecting employment in 'industry' in favour of that in 'service industry'. Such a trend can be seen in the clothing and textile industries by the inability of firms to recruit staff, even in times of high unemployment. Such pressures on society have produced various outcomes including:

1. the movement of people into expanding service industries;

2. the movement of 'undesirable work' offshore;

3. growth of 'new technology' industries;

4. increased automation of processes.

> The Germans have been amongst the first to recognise that in a country whose wealth depends on the export of manufactured goods, such outcomes benefit a few but do not maintain a healthy economy. They recognised that it was important to reverse the move away from employment in the manufacturing industry by making it more attractive in terms of job satisfaction and esteem, while not decreasing productivity and quality of product"
>
> ***(Brackenbury 1992:150).***

Sundstrom's viewpoint supports the above when he proposes the following reasons for an increase in the standards of comfort:

> "(1) advances in the technologies of environmental control, (2) automation of jobs done in a hostile environment, (3) the need to maintain special conditions in certain industrial processes, and (4) the need to attract and maintain skilled workers" ***(Sundstrom 1986:381)***

1.3.4 TRENDS IN PRODUCTION SYSTEMS

In comparing observations of production system trends in the U.S.A. by Toffler in his book "The Third Wave" ***(Toffler 1981)*** with those of Blackenbury in the European Knitting Industries ***(Blackenbury 1992)***, it can be seen that since the 1980's market trends have shown rapid changes in demand. These changing demands have led many industries away from the mass production approach to one of small autonomous production units that depend on small orders, rapid response and multiskilled workers. Subsequently, increased flexibility in workplace design has become a requirement.

1.3.5 SUMMARY

The abovementioned trends show a common concern for the working environment and serve to substantiate the practical relevance of the study.

Sundstrom reinforces this viewpoint in his conclusions regarding priorities for future research:

> "Earlier research emphasised the laboratory over the workplace. The factory was particularly neglected. As a result, the literature contains ample evidence on questions that can be answered in the laboratory. Future research needs to emphasise the actual work environments, especially factories" ***(Sundstrom 1986:401).***

1.4 THE ROLE OF THE INTERIOR DESIGNER

Interior design, as defined in the study, outlines the primary role of the interior designer as the practical solving of three-dimensional problems primarily within the environment of buildings through the creative process of interior design.

When confronted with a problem in respect of a proposed design, it is necessary for an interior designer to assimilate theoretical and practical data in order to implement a practical solution. This data can be derived either from personal experience, experimentation, reference material or consultation with other experts. This body of information is then utilised in order to propose a practical solution to the problem.

Although the factory interior may be regarded as "new" to the scope of interior design, the role of the interior designer in the development of the factory working environment remains essentially the same as that for more established and accepted applications.

Apart from the need for approved reference material regarding the basic practical design of physical interior components, his role would include the assimilation and co-ordination of information and proposals from various fields, into practical solutions. This could involve direct co-operation with other experts in the fields of production, engineering, psychology, ergonomics, management science, architecture, environmental hygiene and safety (see Figure 1. for interaction with other specialists).
At present each of these separate fields has specific recognised data or systems which attempt to ensure that the working environment is adequate for their specific needs. However, conflicting interests and lack of co-ordination of this information can lead to ineffective implementation in terms of promoting productivity.

As an example, the Health and Safety Executive guideline "Lighting at Work", which interprets the Health and Safety at Work Act 1974 (United Kingdom), states in the introduction:

> "This guide does not explain how lighting can be used to maximise task performance or to enhance the appearance of the workplace, because although these are matters of good practise they are not relevant for health and safety" ***(H S/G Lighting at Work 1987).***

A lighting system designed in accordance with this guideline would be legal in terms of liability of the factory owner but it would not necessarily contribute to productivity.

Part of the interior designer's function may involve the evaluation of the client's requirements in respect of the factory interior. Professor Prinsloo (Annexure J) indicated that the interior designer could prove to be a valuable interface between the client and the architect in this regard.

Doctor Bridger (Annexure I) emphasises the importance of applying up-to-date ergonomic research information to the practical design of factory interiors and supports the view that the interior designer has a role to play in this process.

Doctor Birt (Annexure H) sees the role of the interior designer as that of "human orientated designer" as opposed to an engineering, or machine orientated designer.

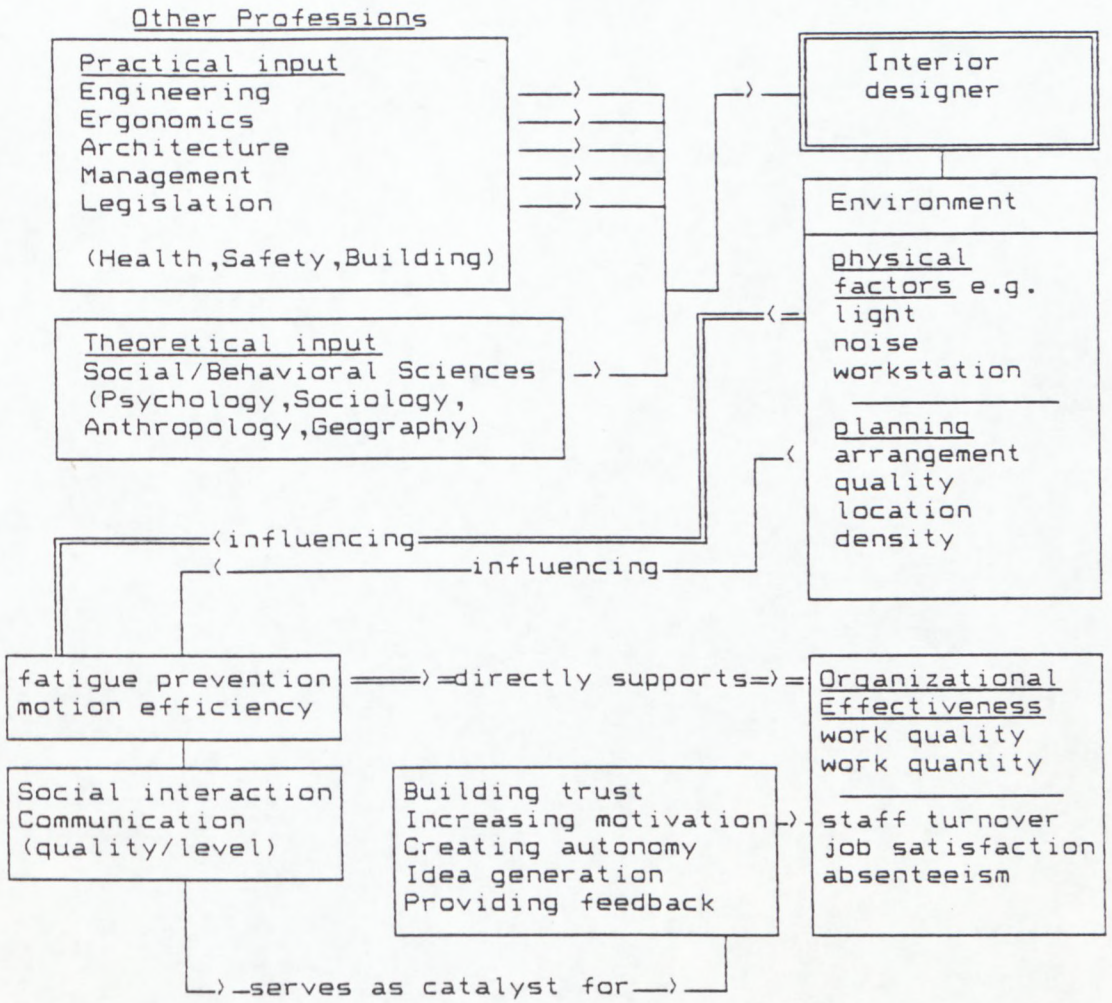

Figure 1. The role of the interior designer in the factory environment. Adapted from Becker *(Becker 1981:11)*

From the above it can be concluded that the primary role of the interior designer will be the humanistic approach to practical design of physical aspects of the factory interior with emphasis on worker comfort, congenial surroundings, optimal use of workspace and streamlining workflow. This could involve the co-ordination and incorporation of information from other fields of expertise. This information could be gained from personal experience, reference or consultation.

CHAPTER 2

THE PROBLEM AND ITS SETTING

2.1 THE STATEMENT OF THE PROBLEM

According to Leedy the problem is at the heart of every research project: "The problem is the axial centre around which the whole research effort turns. The statement of the problem must be expressed with utmost verbal precision. The problem is then fractionated into more manageable subproblems. So stated, we can see clearly the goal and the direction of the entire research effort" *(Leedy 1989:45).*

2.1.1 MAIN PROBLEM

The above definition was kept in mind when formulating the main problem, which is: **Can the principles of interior design be applied in the factory environment and, if so, could this have a beneficial effect on productivity?**

2.1.2 SUBPROBLEMS

The main problem was subsequently broken down into two components:

- the need to identify those elements of the factory interior to which the principles of interior design can be applied

- the need to extract and interpret data from various fields which, when utilised in the design process, will enhance each element's contribution to productivity.

It is by addressing these subproblems that the study proposes to solve the main problem.

2.2 DEFINITION OF TERMS

Although various definitions of these terms could be applied, the following have been chosen because they most closely describe the concepts used in the study.

Interior Design - The creative process applied to the practical solution of three dimensional problems, primarily within the environment of buildings *(Cape Technikon Design School Prospectus)*.

Interior Designer - A person with a minimum qualification M+4 in Interior Design[1] whose specialist knowledge and skills are applied to the practical solution of three dimensional problems, primarily within the environment of buildings.

Factory - "A factory comprises a defined set of spaces in which materials, energy and men are brought together for the purpose of producing a given set of end products" *(Mills:257)*.

Factory Interior - The physical environment inside a factory or factory related building.

Productivity - "... The effective utilisation of resources (inputs) in producing goods and/or services (outputs)" *(Sumanth 1984:4)*.

Production - "... the activity of producing goods or services" *(Sumanth 1984:4)*.

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[1]As measured by the Human Science Research Council in terms of the Department of National Education publication "Formal Technikon Instructional Programmes in the Republic of South Africa"

2.3 THE DELIMITATIONS

The study will concentrate on the design of the factory interior and not the exterior envelope (building) or development of the site. This delimitation is based on the assumption that the interior designer would be part of a team of professionals including architects and engineers whose function would include the design of these aspects.

It has not been the intention to quantify the extent of potential improvements in productivity resulting from the application of interior design principles as this would involve extensive field and laboratory tests/experiments. For example, the repainting of a factory in order to evaluate the effects of colour changes on productivity represents a considerable financial outlay, which is beyond the financial scope of this study.

CHAPTER 3

LITERATURE REVIEW

3.1 INTRODUCTION

According to Leedy the literature review's function "derives from a fundamental position among researchers that the more one knows about the peripheral germane to one's own study, the more knowledgeably one can approach the problems inherent in one's own area of investigation. Such exploration and discussion occupies the section ... in the research report known as the review of the related literature" *(Leedy 1989:66)*.

A survey of general literary works pertinent to factories indicated that little research literature related to factory interiors has been generated in the field of interior design.

Perspective to the study was therefore gained primarily through the revue of general literature from the following fields:

3.2 INTERIOR DESIGN

Reference information pertaining to the design of domestic and commercial interiors such as ablution facilities, restaurant design, office design, lighting, display lighting, colour and materials and finishes is equally applicable to the design of factory interiors, as wherever people gather, their surroundings influence their comfort and convenience.

3.3 ENGINEERING

Engineering reference manuals were consulted in order to gain insight into the production planning and processes of the factory. Upon reviewing this literature it became apparent that the engineer frequently acts as the designer of the factory environment (often inclusive of design of the building). The following were points of focus:

Mechanical engineering - Production processes as well as environmental control i.e. ventilation, cooling and heating were reviewed.

Chemical engineering - The specific problems which are encountered in the chemical industry e.g. pollution and are inherent in the production of chemical products i.e. pollution and corrosion were studied because the knowledge gained could also be applied to other categories of industry.

Electrical engineering - Reference to all factors of production including physical environment, ergonomics, planning and processes were examined.

Production engineering - The main area of focus was on lighting of the workplace.

Industrial engineering - This subject served as a source of background information in respect of system specification, development and implementation. An analogy can be drawn between the comparison of the mechanical engineer/industrial designer and industrial engineer/interior designer.

3.4 APPROACHES TO THE PSYCHOLOGY OF THE WORKPLACE

The following approaches were studied and appraised:

Industrial/Organisational psychology - A branch of applied psychology which focuses on the physical environment as a component of job satisfaction.

Human factors psychology (also referred to as Engineering psychology or Ergonomics) - This branch of psychology deals with the interface between the human and his environment. The literature review concentrated on the design of equipment and the ambient environment.

Environmental psychology - Here the focus is on the workspace as total environment and includes aspects such as social systems and the workspace as a reflection of the organisation.

Cognitive psychology - Insight was sought regarding the interaction between the human and his environment.

Bullock et al. define this as:

> "A branch of psychology defined partly by its subject matter i.e. Cognition, partly by its point of view. With respect to point of view, its main presupposition is that any interaction between an organism and its environment changes not only its overt behaviour or physiological condition, but also its knowledge of or information about the environment, and that this latter change may affect not only present response but also future orientation to the environment" ***(Bullock et al. 1988:138).***

3.5 MANAGEMENT SCIENCE

There is a possible relationship between management models and the physical environment in that different approaches to management may demand differing approaches to the design of the interior environment.

Sundstrom *(1986:42)* points out that Scientific Management, Organisation Theory and the Systems Approach are the three approaches representing the history of management. The differing management models were served by differing physical environments, especially in offices, and it is possible that the evolution of management created new demands on office planners resulting in, for example, the concept of open planning.

Production Management - This management approach is based on scientific models, for example work study methodology and ergonomics, employed mainly in the manufacturing industries. Methodology employed by specialists in this field must be understood by the interior designer as statistics gained through these methods may serve as motivation for layout planning.

3.6 ARCHITECTURE

Architectural reference works were a source of information with regard to planning of appropriate and harmonious internal building components, definition of activities envisaged and services to be rendered, prior to occupancy.

3.7 ERGONOMICS OR HUMAN FACTORS ENGINEERING

Literature on this subject reflects information regarding the human interface with the environment, both physical and mental.

This study focussed on data which could be utilised in practical design work - typically light, sound, temperature, cognitive processes and conservation of energy.

3.8 CATERING

Catering for employees in industry is a specialised field often utilising contracted-in services. Planning for factory catering facilities is based on criteria different to those of a commercial restaurant. Professional catering literature contains guidelines in this respect.

3.9 CORPORATE IDENTITY PLANNING

Corporate identity planning could potentially be carried through to the factory workspace. A literature survey was carried out in order to establish the feasibility of this assumption.

3.10 SECURITY

Guidelines for planning of security areas including pay office and visitor security were obtained from literature relevant to the security service industries.

3.11 BACKGROUND OF VARIOUS CATEGORIES OF INDUSTRY

In order to gain a general background to the various categories of industry, general literature was reviewed under the following headings (see Section 6.2 of this study for further explanation).

Food and Food Processing
Electrical and Electronics
Automobile and Transportation
Hardware, Plumbing, Heating and Cooling
Construction
Furniture and Woodwork
Textile
Stone, Shell, Clay and Glass products
Primary
Secondary
Tertiary
Mass Production
Moderate Production
Job Lot Production

CHAPTER 4

A LITERARY REVIEW OF THE HISTORY OF INDUSTRIAL ARCHITECTURE

4.1 INTRODUCTION

A literary review of the historical background is included in the study in order to provide insight into the subject of factory design and the structures upon which it is based.

For example, it serves to highlight the historical concern for social and working conditions. A comparison of Macmillan and Davies, indicated that factory design has exerted a strong influence on the Modern Movement in architecture as well as style such as "High Tech" *(Davies 1988:15, Macmillan 1979:88).*

4.2 HISTORICAL INFLUENCES

According to Macmillan's Encyclopedia of Architecture and Technological Change, the earliest examples of factories as we know them, were Basilican buildings developed by monastic orders during the twelfth century and subsequently taken over by wealthy families as manufacturing centres. The taking over of the Abbey of Fontanay in Burgundy by the Montgolfier family in the 17th century for the papermaking, is cited as an example.

Figure 2a. Interior view of the Stanley Mill, Gloucestershire, built in 1813. Note the circular bearing shells which carried the gaint turning shafts carrying mechanical power to the machinery. *(Source : MacMillan 1979).*

Macmillan makes the point however, that mills which were used to split grain in Asia-Minor from 5000 B.C. could be considered to have been the first factories, with millers being the first factory engineers *(Macmillan 1979:94)*. The millers pioneered development in shaft drives, gearing, belt drives and mechanical handling equipment. This was due to the fact that milling was one of the first industries to employ the water wheel as a power source. Up to the time of the mid-eighteenth century (Industrial Revolution) this remained the only form of power and was used to power cloth mills, forges and wire drawing and boring processes.

Mill structures were the first industrial buildings to develop strong timber frames clad with weather boarding, while brick mills only appeared in the 17th century.

A comparison of Sundstrom and Macmillan indicates the following to be significant dates in factory development *(Macmillan 1979:95, Sundstrom 1986:18)*:

TABLE 1 : Some key developments in the evolution of the factory

Date	Development
5000 BC	Mills used to split grain
1272 - 212 AD	Mills make use of Archimedes Screw
4 AD	Utilisation of the overshot waterway
31 AD	Chinese mill used to power bellows
1719	First factory building (Lombe silk-throwing mill, England)
1776	Watt steam engine in industrial use
1798	Interchangeable parts
1831	Electric motor (Michael Faraday)
1835	Assembly line (Colt pistol)
1860	Iron construction of buildings
1879	Electric light bulb (Edison)
1880	Steel frame construction
1899	Oldsmobile assembly line
1930	Refrigerated air conditioning
1960	Programmable computerised controllers

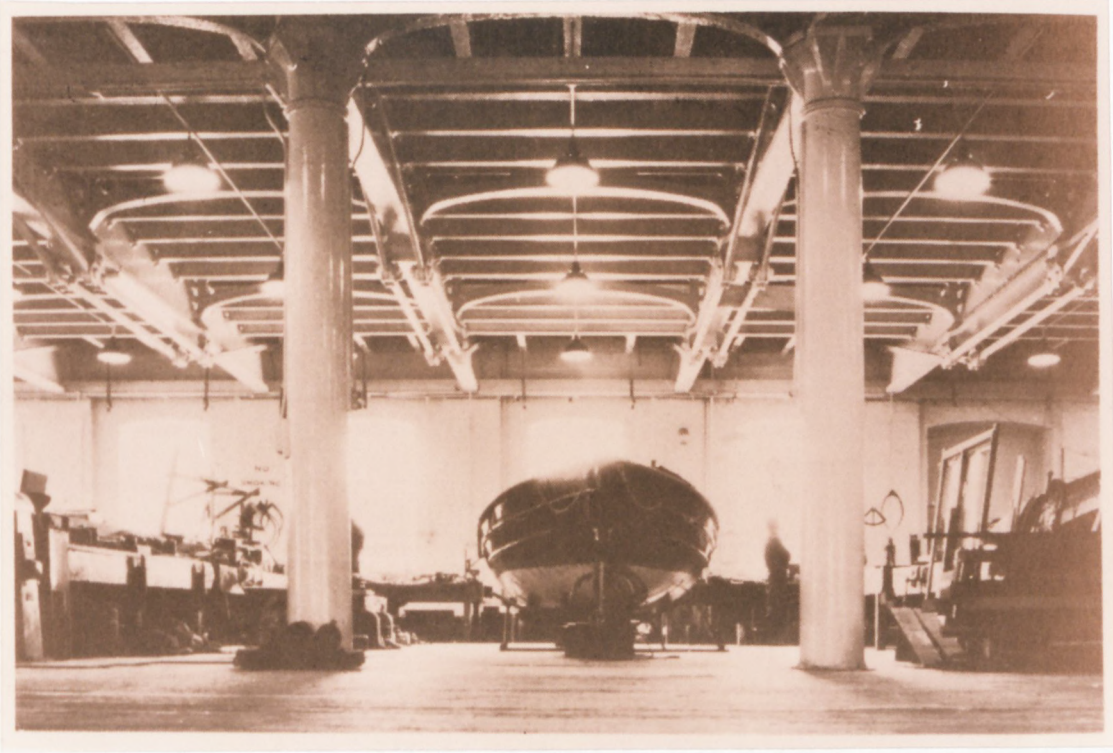


Figure 2b. Interior of what used to be a boot factory erected in 1854 showing use of columns and relatively wide spans. *(Source : Macmillan 1979)*

4.3 EXAMPLES OF INDUSTRIES IN BRITAIN, EUROPE AND AMERICA

4.3.1 BRITISH MILLS

By the mid 18th century, due to technical developments in spinning technology, mills were being built consisting typically of a five-storey building measuring 34 metres x 12 metres with 400 windows and employing 300 workers. Power was delivered by machine wheels activated by a 5-metre waterwheel. These buildings were constructed of wood and were lit by appliances containing naked flames, which posed a fire hazard.

Working conditions were often poor. Child labour was used extensively and long working hours, bad ventilation and inadequate rendered the workplace miserable. Unguarded machinery was a further hazard along with chronic ill-health.

Since the mid-eighteenth century factory building design had been influenced by the introduction of steam power to manufacturing processes (1783) and the use of cast iron beams and columns in building construction (1796).

By the mid-1880's factory design had improved to such an extent that, according to Macmillan, a well-designed multi-storeyed mill in Britain featured:

- Wrought iron floor joist structure for improved fire resistance
- Flat roofs of same construction as floors
- Brick external masonry walls with piers incorporated to carry beam loads and give wider openings for windows allowing deeper plans
- Stair towers external to main buildings
- Fire doors separating each level
- Toilets and other facilities on half-landings with good ventilation
- In many cases, provision of fire hydrants
- Fire escapes
- Provision of ventilation and heating
- Structures based on a regular grid to provide modular space

(Macmillan 1979:96).

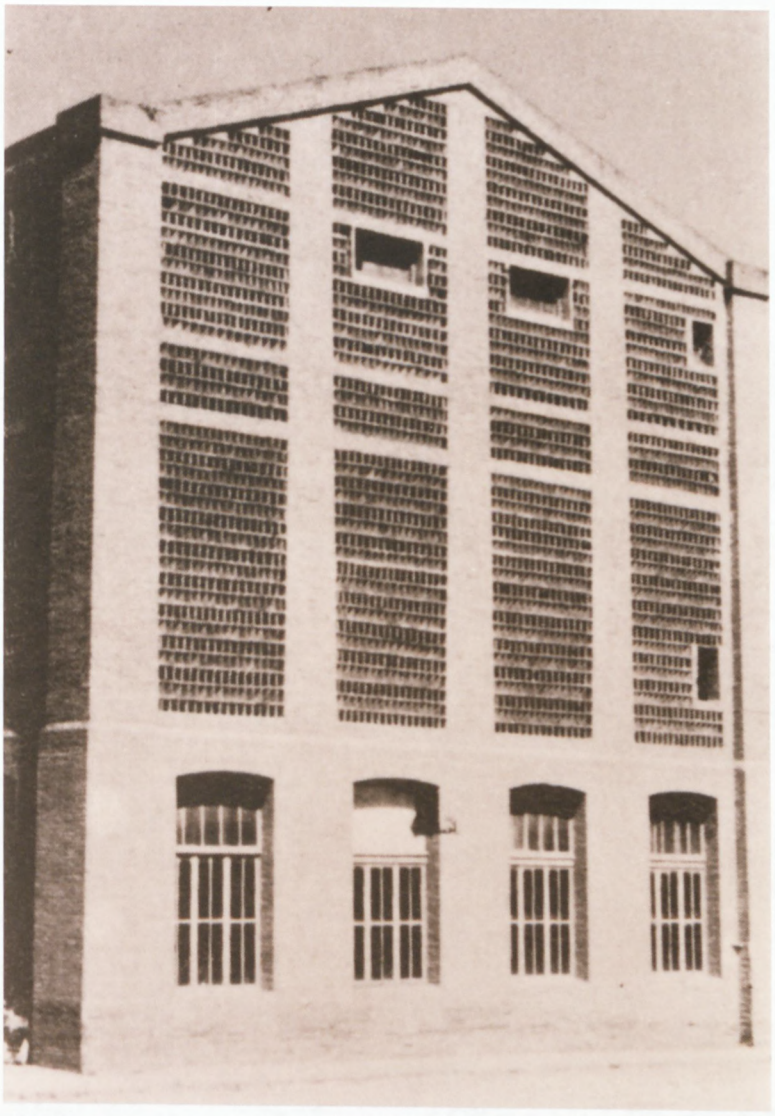


Figure 2c Example of a late 19th Century industrial building. This is the facade of a drying shed at the Guele textile mill, Barcelona.
(Source : Macmillan 1979)

4.3.2 EUROPEAN FACTORIES

The British, as pioneers in industrial design, strongly influenced the design of European factories. The Europeans, however, showed that factory buildings could be utilised in a manner different to that of the British mill for example:

The saltworks plant designed in 1776 by Claude-Nicolas Ledouw (1736 - 1806) was an early example of interrelated buildings on, or near, site. These buildings formed a community in that they served various industrial, housing and social functions.

In designing the Menior Chocolate Mill in 1872 Jules Saulnier (1817 - 1881) broke with the tradition of load-bearing walls. Instead the building was designed on four piers and straddled a river like a bridge (see Figure 2e).

Later European factory buildings followed trends in the United States of America such as multi-storeyed steel skeletal structures and use of reinforced concrete.

> "The AEG Turbine Factory at Berlin (1908 - 1909) by Peter Behrens (1868 - 1940) and the Fages Factory at Alfeld (1911) by Walter Gropius (1883 - 1969) and Adolf Meyer (1881 - 1929) were both forward-looking buildings (see Figure 2f) which were to become very influential to the European Modern Movement architects. Before World War I the avante garde architects began to admire the forms of American industrial buildings often built by little known engineers and these were published as examples of the direction architects should take" ***(Macmillan 1979:98)***.

> "Peter Behrens (1868 - 1940) considered that industrial tasks should be seen as the essential ones of the time. The factory thus took on a far greater significance than it had previously possessed" ***(Curtis 1982:63)***.

> "Walter Gropius (1883 - 1969): Gropius' architecture was an attempt, not only at accommodating the functions of the modern world, but at symbolising that world as well. This was the type of "factory aesthetic" which would eventually influence the universal machine style of a decade later" ***(Curtis 1982:66)***.

Figure 2d. Menier chocolate mill (1872). This was an early example of a framed structure with non-load bearing walls.
(Source : Macmillan 1979)

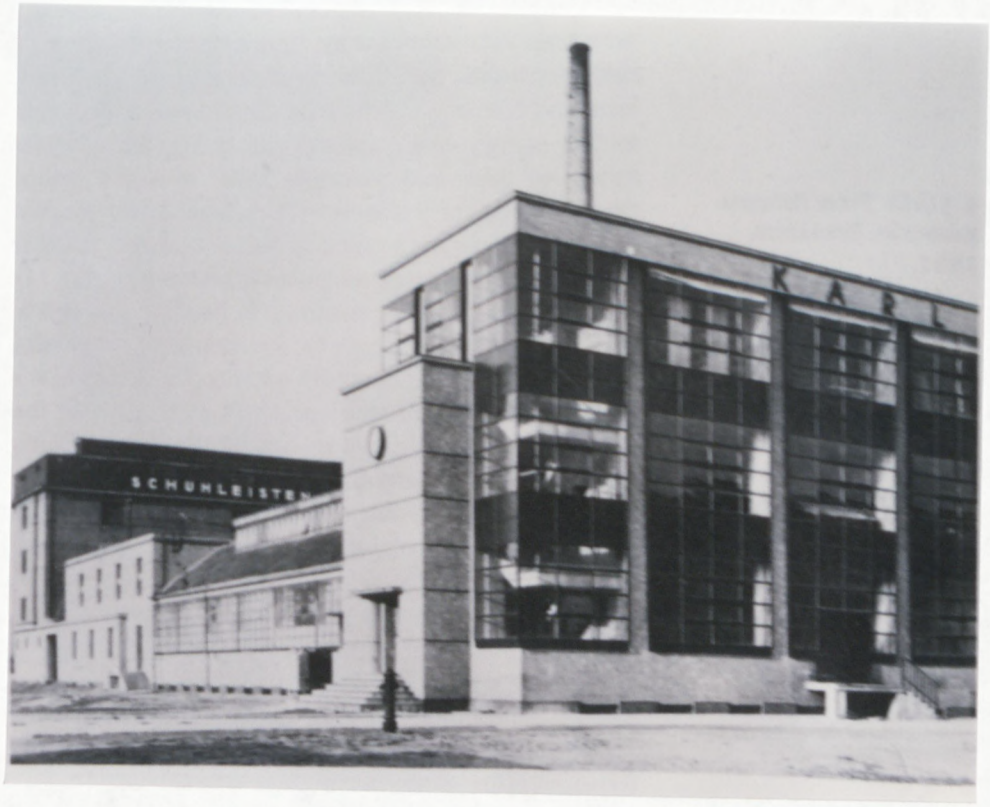


Figure 2e. Fagus shoe-last factory at Alfeld (1911).
(Source : Macmillan 1979).

4.3.3 FACTORIES IN THE UNITED STATES OF AMERICA

Until 1810 practically all American mills were timber framed. Developments paralleled those in Britain and Europe up to the mid-1850s but thereafter the growth rate of the economy and size of American industries enabled them to lead the way in factory building and system design.

Labour saving devices were an early concern and rapid industrialisation led to vast industrial complexes.

Large scale disasters involving collapsed buildings and fires forced insurance companies to lobby for stricter building control. From the mid-1850s cast iron frames were utilised for construction with reinforced concrete being pioneered by the early 1880s.

By 1912 the continuous moving assembly line had been perfected; the relationship between factory structure, bay size, materials flow and production organisation were known; skylights were used for dialoguing; reinforced concrete had increased column spacing; similar units were linked together to form open and closed courts; broad front lawns and shrubs were incorporated in order to create a more natural environment so that workers would feel less confined.

After the First World War most of the changes regarding factory buildings have been in terms of accommodating increasing automation and to a certain extent improving working conditions.

Figure 2f. Ford Motor Company storage area at the Highland Park Plant Michigan (1909). *(Source : Ferry 1970).*

Figure 2g. Company headquarters of the Fisher Body Company at Portland Ohio (1921). *(Source : Ferry 1970).*

4.4 20TH CENTURY DEVELOPMENTS

Albert Khan (1869 - 1942), as quoted by Ferry, commented on the influence of industrial architecture, in a speech shortly before his death, saying

> "Industrial Architecture is continuing its forward march, contributing not only its share to the general welfare of the worker but winning recognition even in the field of art ... who would deny that large expanses of glass, for instance, essential in modern industrial buildings have not exerted their influence on everyday buildings even in residential work? Or who would question that the entire field of architecture has been influenced by today's common sense solution of factory buildings" *(Ferry 1970:27)*.

Macmillan outlines current trends in building design as those revolving around flexibility of space for optimising production layout and materials flow, low-cost, speed of erection and energy conservation *(Macmillan 1979:100)*.

As previously explained in this study, there is also evidence of a shift away from the "machine" aesthetic towards a more human approach.

4.5 "HIGH TECH" STYLE OF ARCHITECTURE

According to Davies in his book on "high tech" architecture, industrial buildings, because of their exposed workings and structure, are naturally amenable to the expression of this style of architecture and it therefore may appear that this style is derived from factory buildings.

The origins of this style can however be traced back to early structures constructed of cast iron or steel framework for example **Decimus Burton's Palm House** at Kew Gardens (1848); **Eiffel's Tower** and Contamin and Duterts **Galerie des Machines** built for the Paris Exhibition of 1889 as well as Paxton's **Crystal Palace** built for the great exhibition of 1851.

Figure 2h. Albert Khan 1869 - 1942. Considered by many to be the first great contributor to modern industrial architecture. *(Source : Ferry 1970)*

The Modernists' use of reinforced concrete (a material which the "High Tech" architect avoids) was the **preferred** method of construction for the first half of the twentieth century thus ensuring that High Tech remained an alternative form of architecture for this period.

According to Davies, during the late 1960s work by architects such as Rogers, Foster and Stirling popularised the concept "High Tech" once more, for example the Immos Microprocessor Factory, Newport, Virginia, by Richard Rogers Partnership, 1982.

Figure 2j. Immos Microprocessor factory. Newport Virginia, 1982. By Richard Rogers Partnership. *(Source : Davies, 1988).*

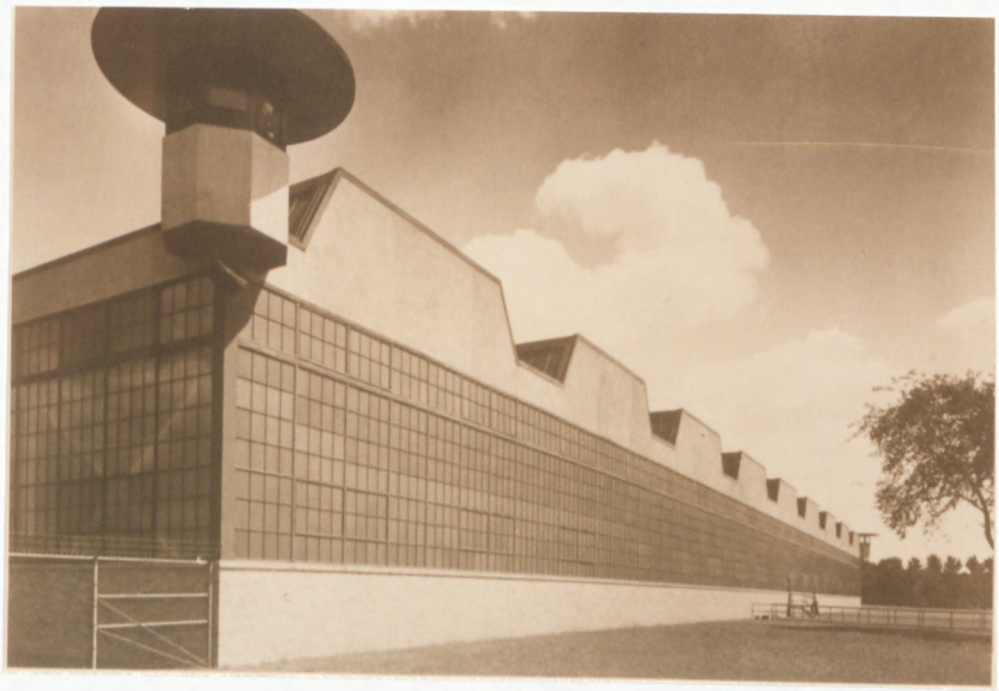


Figure 2i. The American Ordnance Plant/Torpedo Plant. Chicago, Illinois, 1942. By Albert Khan 1969 - 1942. *(Source : Ferry 1970).*

CHAPTER 5

IDENTIFICATION, EXTRACTION AND INTERPRETATION OF DESIGN DATA

5.1 IDENTIFICATION OF ELEMENTS OF THE FACTORY INTERIOR TO WHICH INTERIOR DESIGN PRINCIPLES CAN BE APPLIED

This section of the study was concerned with determining: (1) the elements comprising the factory interior and (2) to which of these elements the principles of interior design could be applied. The definition by Woodson of the industrial environment as an "... **architectural/mechanical/human interface.**" was utilised as a guideline in compiling a schematic model (shown below) which indicates the main areas of investigation of the study. *(Woodson et al. 1992:58)*.

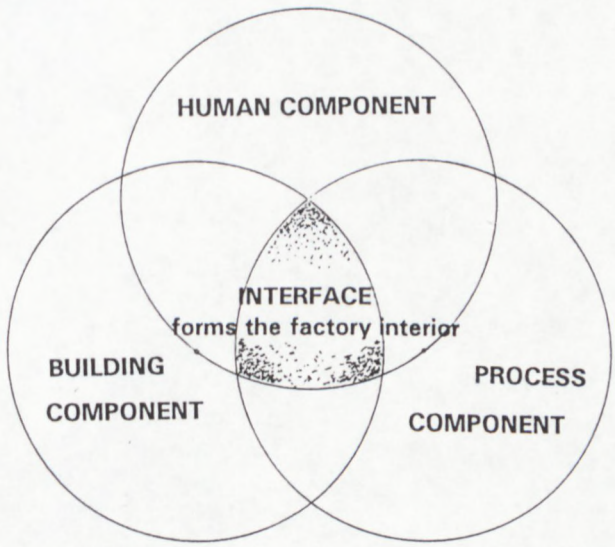


Figure 3: **Diagram showing the formation of the factory interior by the interfacing of human, production and building elements.**

5.1.1 LOCATION AND CATEGORISING OF DATA

With the abovementioned definition/diagram serving as a guideline, a literature study was carried out in order to determine those elements and their categories which comprise the factory interior. The information thus gained formed the basis for further investigation as follows:

5.1.2 COMPARISON OF ELEMENTS OF THE FACTORY INTERIOR WITH THOSE FOUND IN MORE TRADITIONAL APPLICATIONS OF INTERIOR DESIGN

A comparison was then made between elements identified as those comprising the factory interior and those forming interiors which traditionally fall within the scope of interior design, for example, in offices, restaurants and hospitals.

These included: Planning for spaces and activities; application of ergonomic principles; water and electrical services supply; lighting; ventilation and noise control; fixtures, fittings and finishes; attention to aesthetics e.g. colour.

5.1.3 SUMMARY

The results of these comparisons can be summarised as follows:
The elements comprising the factory interior were found to be essentially the same as those comprising, for example, office, hospital and restaurant interiors. However, when evaluated in the context of the factory interior the functional emphasis of these elements were found, in some instances, to differ from those emphasised in other interiors. For example, colour may serve a primarily aesthetic function in restaurant design whereas in the factory interior, the emphasis may be on improving light reflectance.

5.2 THE EXTRACTION AND INTERPRETATION OF DESIGN DATA

This section of the study concerned the location and interpretation of design data, both practical and theoretical, which could be applied by the interior designer to the practical design of the factory interior with emphasis placed on the improvement of productivity.

5.2.1 LOCATION AND INTERPRETATION OF DATA

The process of data location and interpretation involved the perusal of the literature as reflected under the sections "Literature Review" and "Bibliography" of this study.

This data was collected, evaluated and compiled into a set of reference guidelines for practical use by the interior designer for the design of factory interiors. The evaluation process, criteria and compiled results form the main body of the dissertation.

CHAPTER 6

DESIGNING THE FACTORY INTERIOR

6.1 INTRODUCTION

This chapter attempts to offer practical design guidelines for use by the interior designer in the design of factory interiors and represents a compilation of the information which was collected and evaluated as part of the study.

In dealing with the various elements, each section addresses aspects such as planning considerations, practical and theoretical design information and designing to promote productivity. Where applicable, reference is also made to other sources of information which could supplement examples cited in the study.

6.2 CLASSIFICATION OF INDUSTRIES

It was found that various categories of industry tend to place differing emphasis on certain aspects of factory design.

The chemical industry for instance, places emphasis on pollution control and the ability of finishes to withstand attacks from corrosive chemical compounds whereas the food processing industry places emphasis on efficient cleansing and surfaces which do not harbour harmful agents. In this instance the concerns are a direct result of the product which is being manufactured.

It was noted that three main factors tend to influence these areas of concern i.e.

- production systems
- processes
- the product manufactured.

For ease of later reference industries may therefore be classified as follows:

6.2.1 CLASSIFICATION BY EXTENT OF PRODUCTION:

- **Mass production** - products are produced continuously at high volume for a considerable period of time; typically 100 000 units per year, for example bottles.

- **Moderate production** - output is variable, usually in accordance with sales; typically 2 500 to 100 000 units per year for example ships' navigational equipment.

- **Job lot production** - these types of jobs tend to be "one-off" type work, for example vintage car restoration where each project has special requirements unique to that job.

6.2.2 CLASSIFICATION BY PROCESS:

- **Primary industry** (also referred to as heavy industry) - those processes which require plant, machinery and transpiration facilities of such scale that these parts must be built in-situ; e.g. steelworks, mines or mass production systems.
  In this type of production process there may be intensive demands for overhead production and environmental services (such as overhead cranes and ventilation) as well as extensive materials handling equipment, for example fork lift trucks and mechanical conveyor belts.

- **Secondary industry** (also referred to as medium industry) - processes requiring special or fixed facilities of plant, building, services or environmental conditions, for example batch production of engineering components.
  These production processes are usually arranged in a given production sequence. Although this implies some structural demands on the building, allowance is usually made for flexibility of production and storage layout.

- **Tertiary** (also referred to as light industry) - Those processes which require only general facilities for example shoe repair.

- **High technology processes** - this usually implies a "high quality" personnel/process environment. It can also demand extensive floor or roof zone services routing. Bulk loading and handling of powders, liquids and gases may also be implied, for instance in the manufacture of medicines. These industries tend to deal in volatile markets and this factor, coupled with the rapid changes in technology, create a high demand for flexibility/ interchangeability of the workplace.

6.2.3 CLASSIFICATION BY PRODUCT (AS EXAMPLES):

- Food and food processing industries
- Electrical and electronics industries
- Automobile and transportation industries
- Hardware, plumbing, heating and cooling industries
- Construction industry
- Furniture and woodwork industries
- Stone, shell, clay and glass products industries
- Chemical industries
- Clothing and knitwear industries.

6.3 PLANNING THE FACTORY LAYOUT

According to Riggs, a given layout affects all production functions and integrates most production subjects. He offers the following symptoms of a poor layout:

Lack of control; congestion of men and materials; excessive re-handling; long transportation lines; accidents; low worker performance; production line bottlenecks *(Riggs 1981:282)*.

These symptoms serve to highlight the extent to which layout planning can affect productivity.

Szokolay emphasises the point that if the brief is inadequate in terms of space requirement specifications, it should be completed by the designer. This may be done by interviewing the client or the future user of the building, but the designer may have to carry out a study to discover how the organisation or processes to be accommodated really work, and thus what the real space requirements are *(Szokolay 1980:31)*.

The following sections present topics for general consideration and methods for use in the design of factory layouts.

6.3.1 GENERAL CONSIDERATIONS

In order to be effective, the layout should be able to accommodate each process and its flow through the factory system.

This "process flow" can be broken down into two components: **(1) operations** and **(2) work elements**; operations meaning processes and work elements being manpower, materials and energy. Each of these factors can then be quantified in terms of space requirements and relative placement.

Mills utilises a design process flow chart (overleaf) which suggests a suitable order for the securing of design input data for the purpose of designing the factory interior.

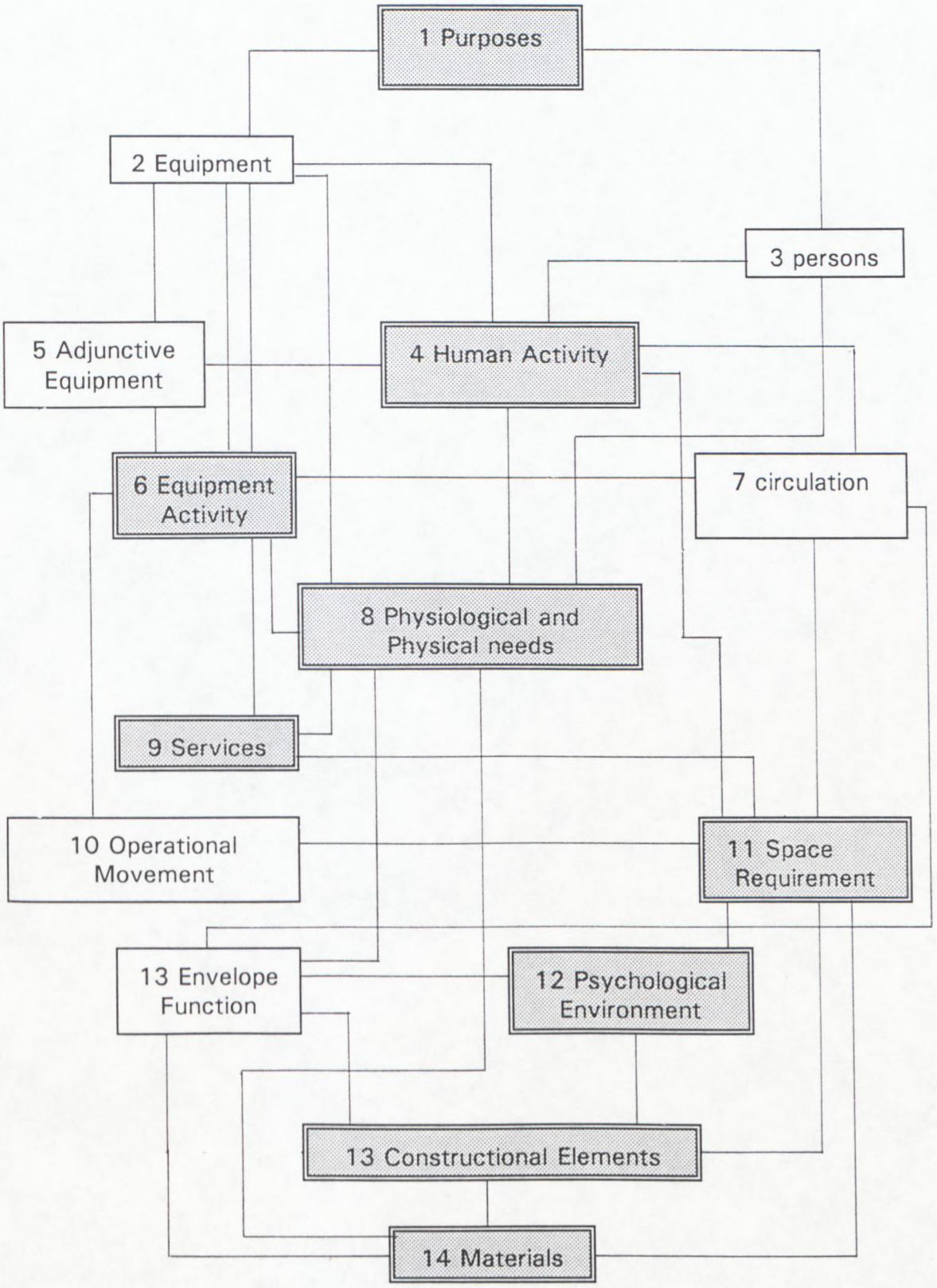


Figure 4. Design process information flow. The highlighted aspects indicate main data collection points. Adapted from Mills *(Mills 1985:figure 11.3)*.

A comparison of Carson, Mills, Neufert, Riggs and Szolokay revealed a common concern for those factors or considerations which could affect the potential efficiency of the layout *(Carson:1972, Mills:1985, Neufert:1980, Riggs:1981, Szolokay:1980).*

Carson's recommendations concerning factors for consideration in **layout selection** were found to be comprehensive in this regard. The following guidelines were compiled using these criteria as source information *(Carson 1972:16.39)*:-

6.3.1.1 Working conditions and employees' "job satisfaction" (the extent to which the layout contributes to making areas pleasant places in which to work). This includes:

- The effect of the layout on attitude, performance, or general morale of the employees

- The suitability of the layout's arrangement and space allocation to personnel requirements

- Contribution of the layout to the physical environment

- The ability of the layout to contribute to a healthy mental environment, for example freedom from features causing workers to feel afraid, embarrassed or discriminated against.

6.3.1.2 Safety and housekeeping (the effect of the layout and its features on accidents or damage to employees and facilities, and on the general cleanliness of the area involved). These include:

- Regularity of the aisles and work areas with clear aisles, minimum congestion and the avoidance of blind corners

- The adherence of the layout to safety codes and regulations

- The availability of, and ease of access to, exits, escapeways, first aid and firefighting equipment

- The layout's ability to segregate or protect the worker from dangerous or unsightly processes.

6.3.1.3 Appearance, promotional value, public or community relations (the ability of the layout to promote the corporate identity). This implies:

- an ability to serve as showplace or reflect reliability, progressiveness or other company traits for example through regularity, the use of clean lines, symmetry and a generally organised appearance.

6.3.1.4 Ease of supervision and control (the ease with which supervisors and managers are able to direct and control operations). The layout could affects management's:

- Ability to see the area fully and easily

- Ease of area access and mobility.

6.3.1.5 Adaptability to the company organisational structure (the degree to which the layout matches the organisational structure). This implies:

- That the layout may contribute to a reduction, or streamlining, of supervisory staff and the alignment of managerial personnel, for example by placing areas with similar supervisory requirements in close proximity to one another

- That the layout may contribute to changing production organisation, for example a change from a traditional isolated machine operator/assembly line organisation, to one promoting teamwork.

6.3.1.6 Utilisation of natural conditions, buildings, or surroundings (the extent to which the layout takes advantage of the natural conditions of the site, physical surroundings and building structure). This implies:

- Utilisation of existing levels
- Taking solar penetration and wind direction into account
- Orientation in relation to access routes, for example from road and rail transportation systems
- Exploitation of the building features, for example structures, shapes, heights, docks, doors, windows, walls, columns and lifts.

6.3.1.7 Flow or movement effectiveness (the effectiveness of sequenced working operations or steps). This refers to the layout's contribution to motion efficiency. Considerations include:

- The incorporation of the greatest flows with minimum distances
- A general consistency or regularity in flow patterns
- The proximity between related areas
- The access to, from and between major areas such as receiving, manufacturing and despatch areas
- Making provision for access and flow of auxiliary services, for example waste and scrap removal
- Planning for access and flow of visitors, delivery personnel and service personnel.

6.3.1.8 Space utilisation (the degree to which the layout utilises floor area and cubic space). This implies:

- The conservation of floor and cubic space
- The avoidance of waste or idle space caused by split, divided, cornered, scattered or otherwise honeycombed structures, too-close columns, or too frequent partitioning of walls
- The utilisation of less desirable space for slow, dead areas; convenient space for fast, active areas.

6.3.1.9 Building considerations (height and section restrictions) which the layout could have to take into account include the following:

- The heights required by transportation systems, for example overhead cranes and conveyers
- The working heights of processes
- Space required for access and maintenance, for example work on service lines above process equipment
- The utilisation of gravity feed systems
- Height level of supervision workstations.

6.3.1.10 Flexibility and ease of expansion of the layout (the ease with which the layout can be physically rearranged/expanded/reduced in order to accommodate changes in operations). Considerations include:

- The machinery, equipment or workplace's relative size, level of standardisation and freedom from fixture to, or support by the building
- The independence of self-sufficiency of the system to be moved from the support of other systems

- The ease of access to, and the flexibility of service lines, for example power, heating and ventilation services

- The ability of the proposed layout to spread to adjacent areas

- The degree to which components and spaces have been planned round modular systems

- The degree to which changes will interrupt production.

6.3.1.11 Storage effectiveness (the effectiveness of "holding" required stocks of materials, parts, products and service:

- The storage of: raw materials; in-process and finished goods; supplies; tools; scrap or waste as well as trash and equipment or materials not in current use

- Ease of access, location and identification of stock

- Protection of stock from fire, moisture, dust, dirt, heat, cold, pilferage and deterioration.

6.3.1.12 Quality of product or material (the extent to which the layout affects quality of the product, material or their workmanship). Considerations include:

- The potential damage or risk to materials caused by the nature of the layout or its transport facilities

- The encouragement by the layout of quality control activities, for example by virtue of proximity to manufacturing processes.

6.3.1.13 Maintenance (the extent to which the layout will benefit or hinder maintenance work) in respect of:

- The adequacy of facilities for maintenance and repair work, for example ease of access and minimum disruption of manufacturing processes

- The provision of appropriate janitorial facilities.

6.3.1.14 Integration of supporting services (the manner in which supporting services, for example waste collection, serve the operating area). This can include:

- The ability of support systems to carry out their function in relationship to the layout

- The proximity of related support services to the layout.

6.3.1.15 Equipment utilisation (the extent to which machinery and equipment is utilised). Considerations include:

- The degree to which equipment will be utilised

- The encouragement of group use of equipment thereby avoiding duplication of equipment, or the necessity of overcapacity equipment due to "occasional use" demands.

6.3.1.16 Materials' handling effectiveness (the efficiency of the handling systems, equipment and containers). Considerations include:

- Ease of integration with external handling systems, for example road or rail transport

- The use of gravity for moving materials where possible

- Promoting the use of handling equipment for more than one purpose, for example by placing operations which use the same containers in the same areas.

6.3.2 PLANNING METHODS

This section of the study suggests methods which may be employed in quantifying design layout proposals. This suggests the conversion of design input data into practical dimensional and organisational space requirements.

6.3.2.1 **Dimensions and Space Quantification**

The results of a comparison of methods recommended in the fields of engineering, production management and environmental planning for quantifying space requirements, signified that methods employed in these fields involve, where possible, reference to reliable sources of planning guidelines pertaining to the spaces occupied by furniture, equipment, machinery and processes.

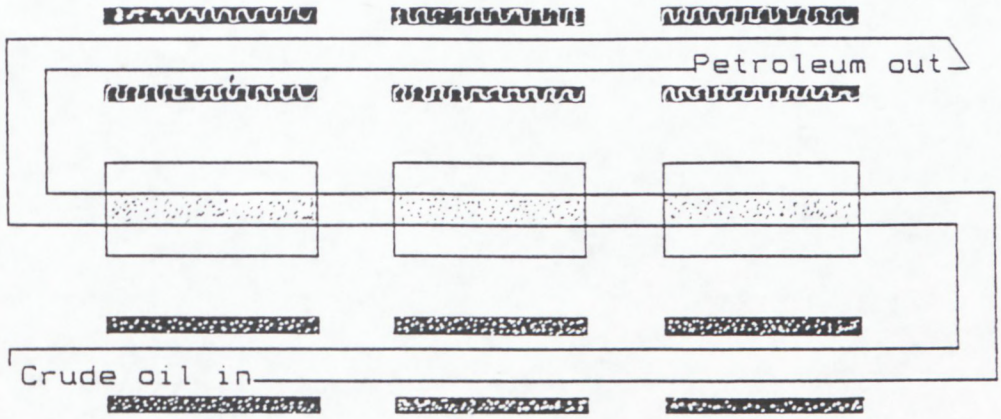
Examples of available guidelines in this regard are reflected as Figure 11.

6.3.2.2 **Layout Analysis**

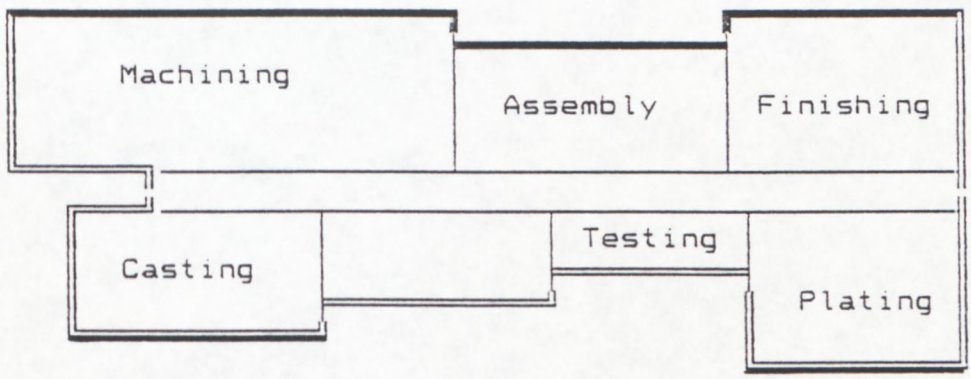
An evaluation of methods for determining the organisation of space and its contents, generated the conclusion that layout analysis could be governed by the limitations imposed by either the product, or the process (see Figure 5).

The term "**product layout**" usually implies that the production process is organised in a certain manner due to the nature of the product. For example, the manufacture of petroleum products requires that the product be processed in a fixed sequence. According to Riggs this layout is characteristic of mass or continuous production *(Riggs:1981:282)*. This production process, because of its reliance on fixed sequential operations, tends to be inflexible.

The term "**process layout**" typically refers to a situation where similar processes are grouped together into "departments" and that these departments produce a number



Product orientated layout



Process orientated layout

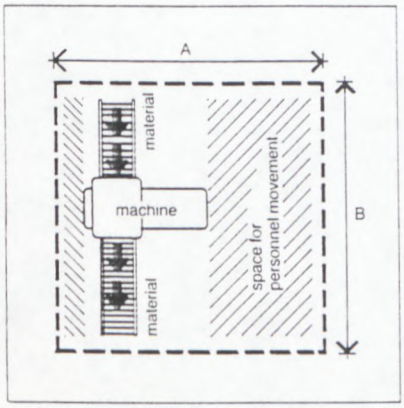
Figure 5. Layouts according to product and process.

WORKSHOPS: EQUIPMENT SPACE

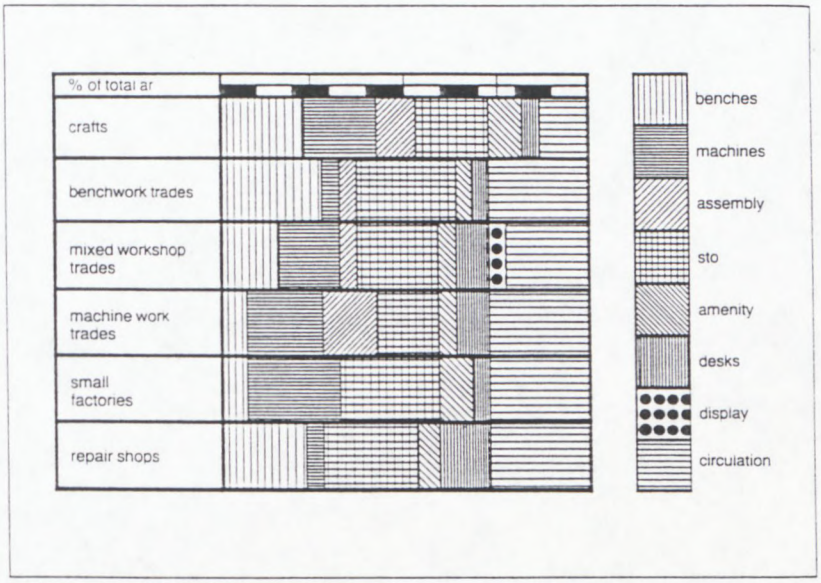
→(1) shows requirements for some suitable handling eqp for small premises. →(2)(3) show typical space needed per machine in tightly planned layout: does not necessarily allow for general circulation, process sto or initial installation of machinery. →(4) shows percentage of total area required for operations in various types of workshop.

type	passengers	heavy goods	light goods	machine rm	pit	external fittings	access
el elevators	yes	yes	yes	yes	yes	yes	3 sides
hydraulic lift	yes	yes	yes	no	yes	yes	3 sides
manually operated lift	yes	no	yes	no	yes	yes	3 sides
platform hoist	no	yes	yes	no	no	yes	2 sides
el service lift	no	no	yes	no	no	yes	3 sides
scissors lift	no	yes	yes	no	yes	no	4 sides
dock leveller	no	yes	yes	no	no	yes	2 sides
el belt conveyor	no	yes	yes	no	yes	no	2 sides
gravity conveyors	no	yes	yes	no	no	yes	2 sides
el winch	no	yes	yes	no	no	yes	4 sides
manual winch	no	no	yes	no	no	yes	4 sides
manual floor crane	no	no	yes	no	no	mobile	mobile

1 Suitable handling eqp for small premises



2 Eqp space →(3)



4 Space budgetting by technology types

eqp in common use	A × B →(2) working space per item
metal work	
machining centre	6.0 × 4.0
jig boring & milling machine	3.0 × 3.0
turret drill	2.6 × 3.2
surface grinding machine	2.6 × 2.2
capstan lathe	3.0 × 4.0
bar & billet shears	2.5 × 3.0
press brake	3.0 × 6.0
engraver	2.2 × 3.0
die sinker	1.8 × 2.2
welding plant	2.8 × 2.5
tool grinder	1.1 × 1.2
shaper	1.7 × 2.1
power hack saw	4.0 × 1.2
punch press	1.5 × 1.3
slip roll	1.1 × 2.1
nibbler	2.3 × 1.2
shear clamp head	2.1 × 1.5
band saw	2.3 × 3.1
workbench	2.7 × 1.9
plastics	
extruder	2.8 × 2.8
vacuum former	2.8 × 2.8
blow moulder	3.0 × 4.5
acrylic saw	3.0 × 5.0
heating oven	0.6 × 1.1
woodwork	
band saw	3.0 × 5.0
circular saw	4.8 × 7.9
surface planer	2.6 × 5.0
knot hole drill	2.2 × 4.2
milling machine	4.0 × 5.0
slot boring machine	2.2 × 5.0
dove-tailer	2.2 × 4.3
jointer	1.4 × 8.3
scroll saw	1.6 × 1.9
drill press	1.6 × 1.6
wood shaper	2.9 × 1.6
radial arm saw	6.5 × 1.8
belt sander	4.4 × 4.8
veneer press	5.0 × 4.2
lathe	2.0 × 3.0
polisher	2.2 × 2.6
carpenter's bench	3.0 × 4.5
printing	
lithographic press	2.5 × 5.0
plate maker	1.5 × 1.8
folder	1.2 × 1.5
drill	1.2 × 1.5
guillotine	1.5 × 3.0
gluing belt	2.0 × 4.2
photographic	
developing tank	2.4 × max length print
enlarger	1.5 × max length print/2
clothing	
laying up machine	7.0 × 14.0
sewing machine	1.2 × 2.2
steam press	2.0 × 2.0
ironing bar	2.0 × 2.0
steam boiler	1.2 × 1.2
footwear	
nailer	1.5 × 2.2
sole press	1.5 × 2.2
heel press	1.5 × 2.2
shaping machine	2.0 × 2.5
leather cutter	3.0 × 3.5
pattern stamper	1.5 × 1.7
electronics	
instrument bench	1.5 × 4.5
motor repairs	
each bay	3.0 × 6.0
general	
compressor	0.75 × 1.2
dust collector	1.5 × 2.0
furnace	1.5 × 3.0
hot dip tank	1.7 × 2.2
drying cabinet	3.0 × 7.0
upholstery press	2.5 × 3.5
forge	0.9 × 2.1
kiln	0.9 × 2.1
potter's wheel	1.8 × 1.7

3 Typical space required per machine in tightly packed layout

Figure 11. Examples of space quantification tables. ***(Neufert 1980:288).***

of different components which may be assembled at various sites. For example the manufacture of motor vehicle components. Riggs states that this arrangement is characteristic of batch or job-lot production *(Riggs 1981:82)*. It generally allows good flexibility but increases space requirements.

A third layout, termed a **"fixed position layout"** can also be identified because of the necessity for all equipment and materials to be brought to the product, for example the building of a ship or the construction of a building.

6.3.2.3 Analysis tools

Facility planners often employ analytical tools to determine the optimal theoretical "flow" and "proximity" of people, objects and space for the purpose of planning the layout. These requirements are usually evaluated by assigning a value or level of importance to each element under consideration in order to form a theoretical relationship between these elements. An example of this is the use of the "bubble diagram".

However, Szolokay, referring to the use of the bubble diagram states that "these are only a slightly improved version of the architect's doodles" *(Szolokay 1980:32)*.

He ventures the opinion that, in an only modestly complicated design task, memory can no longer be relied on and advocates the use of interaction matrices (or association charts), work study methods and graphic methods.

He further proposes that "these techniques can help to clarify the designer's thinking by the sheer fact of externalising his thoughts. They can positively assist in discovering relationships and producing a satisfactory space organisation" *(Szolokay 1980:31)*.

In comparing the works of Carson, Mills, Neufert, Riggs and Szolokay it was noted that significant emphasis was placed on layout analysis techniques. This implies that the use of these techniques forms a common tool of communication in the layout planning of factory interiors. *(Carson:1972, Mills:1985, Neufert:1980, Szolokay:1980)*.

Common terms for these tools include:

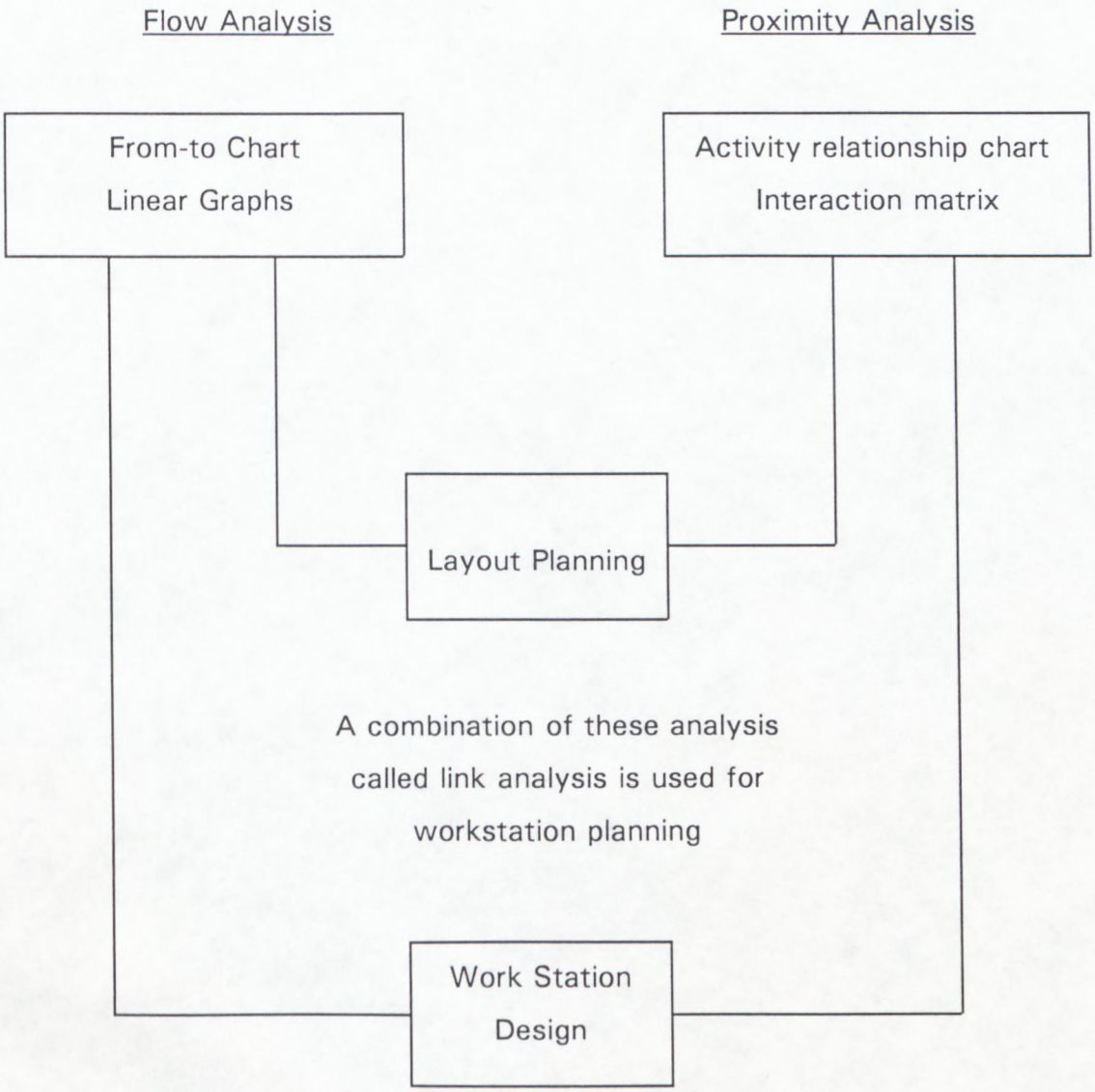


Figure 6. Chart showing layout analysis tools and applications.

Examples of the use of these analysis include:

- Making comparisons of distances between departments
- Calculating the number of trips made per day, for example to fetch materials
- Evaluating the importance of department proximity in terms of use of the same personnel, materials flow, information flow, ease of supervision, use of the same equipment.
- Designing the workstation in terms of operator-to-operator proximity and operator-to-machine interface proximity.

A control tower is manned by three or four controllers, depending on the amount of traffic. As depicted in Figure 9.9, position number 1 is occupied by the team leader responsible for final decisions. Operators 2 and 4 are assisted by relief help from operator 3 when traffic is heavy.

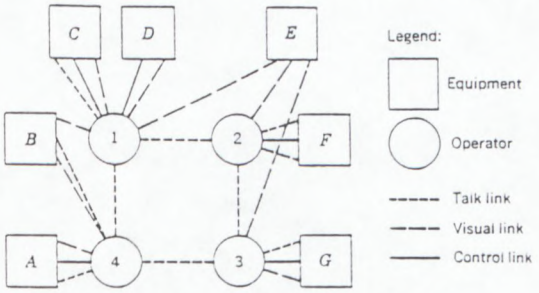


Figure 9.9 Present control tower arrangement.

Each operator has control of a given traffic sector. Audio communication with the traffic is by radio. Other talk links are between controllers. Visual communications are comprised of television screens, digital readouts, and on-off lights. Most controls are switches and buttons.

The link analysis of the existing system is conducted by having "experts" agree on a consensus rating for each observable link from operator to operator and from operator to equipment. Links between equipments are not usually included in an initial evaluation. After rating the frequency and importance of use, a composite value is obtained for each link, as represented below for operator 1.

The layout is evaluated according to the way it facilitates the links. Views should not be obstructed by equipment or operators. The effect of distance and illumination on visual performance is considered. Distance is also a factor in auditory communications; shouting should never be necessary. The postural set of operators should accommodate easy visual or vocal communication. There must be sufficient room for convenient and accurate manipulation of controls.

If it is necessary to redesign the arrangement, attention is given first to the highest valued links. A mock-up may be required. Attention is given to proper ventilation, protective safety devices, noise control, and other maintenance or convenience features that will assure smoother operations by lessening physical and mental fatigue among operators.

A possible revised layout for the control tower is shown in Figure 9.10. Link values are shown in small circles for each link. The elevation of operator 1 is raised with respect to the other operators. A more thorough study would indicate the vertical placement of equipment; exact scaling would be used. Before finalizing a new design, thought should be devoted to unusual or emergency operating conditions. Care taken to assure a workable design distinguishes a craftsman from a journeyman, a design that anticipates the unexpected marks a master.

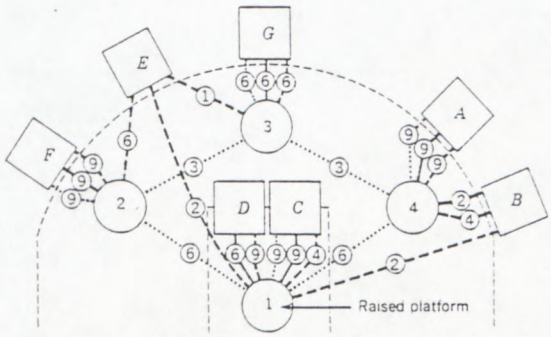


Figure 9.10 Revised control tower arrangement (composite link values are noted in small circles).

Operator	Link	Equipment or Operator	Frequency Rating	×	Importance Rating	=	Composite Rating
1	– – – – – –	②	2	×	3	=	6
	– – – – – –	④	2	×	3	=	6
	– – – – – –	C	3	×	3	=	9
	— — — — —	D	3	×	3	=	9
	— — — — —	C	2	×	2	=	4
	— — — — —	B	1	×	2	=	2
	— — — — —	E	1	×	2	=	2
	— — — — —	C	3	×	3	=	9
	— — — — —	D	3	×	2	=	6

Figure 7. Examples of the use of layout analysis. ***(Riggs 1981:293)***

Whichever method is employed, the approach remains essentially the same and usually incorporates the following steps:

- List all significant factors involved in the selection

- Weigh the relative importance of the factors

- Analyse the results.

Examples of these analysis tools are included as Figures 7 to 12 for reference purposes and the reader is referred to works by ***Riggs (1981)*** and ***Szolokay (1980)*** for further information.

6.3.3 WORK STUDY METHODS

In work study methods a series of standard symbols is used to designate various activities. The most common ones are shown in Figure 8. These symbols can be used, for example, in conjunction with graphs, or in place of vertices (y axis of linear flow graph).

The example depicted in Figure 9a shows a generalised flow diagram of goods in a factory shop. Figure 9b indicates the flow of customers. The points of contact between the two flows can then be identified and the two diagrams can be combined, as in Figure 9c. This combined format graphically illustrates a shape that is very close to an actual layout. The final step would be to establish dimensions, i.e. shelving runs, aisles and shelving widths, and translate the combined flow diagram into an actual plan.

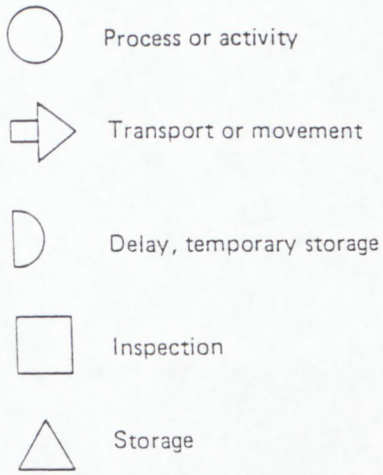


Figure 8. Examples of workstudy symbols. ***(Szolokay 1980:37)***

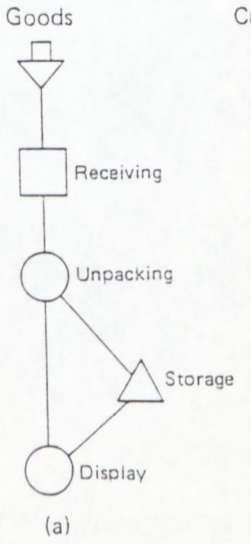


Figure 9a. Goods flow diagram.

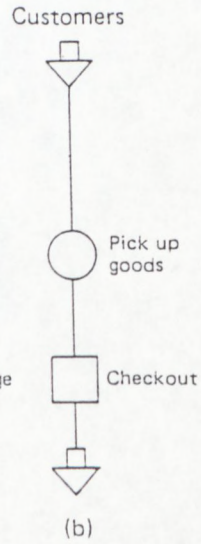


Figure 9b. Customer flow diagram.

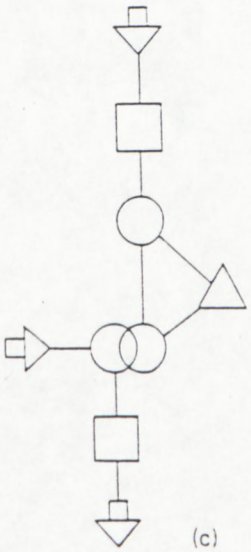


Figure 9c. Combined customer and goods flow diagram.

Figure 9. Examples of flow diagrams. ***(Szolokay 1980:37)***

Department	from \ to	#1	#2	#3	#4	#5
Shipping & receiving	#1		30	71	98	10
Assembly area A	#2	30		41*	68	80
Assembly area B	#3	82	52*		27	39
Inspection	#4	109	79	27		12
Packaging	#5	10	91	39	12	

(a)

*The distance between two departments differ if there are one-way lanes or obstacles in the flow pattern.

from \ to	#1	#2	#3	#4	#5
#1		14		1	3
#2			22	6	
#3		10		18	
#4					13
#5	25				

(b)

from \ to	#1	#2	#3	#4	#5
#1		23		2	3
#2			53	21	
#3		27		28	
#4					11
#5	16				

(c)

Figure 9.2 (*a*) From-to chart showing distances between departments, (*b*) From-to chart showing the number of material handling trips per day. (c) From-to chart showing material-handling cost per day. These costs reflect the distance travelled, quantity moved, and transportation charge rate.

Figure 10. Example of sequence of use analysis.
(Riggs 1981:293).

FACILITIES LAYOUT FOR A SHELTERED WORKSHOP

The purposes of a sheltered workshop are to assist in the rehabilitation of handicapped people by providing employment, counseling, and vocational training. Hope Center is an established sheltered workshop that requires additional space in order to be able to serve more clients. A building of adequate size can be leased at an attractive price. In order to evaluate the structure, a preliminary layout conforming to the building dimensions is needed.

The proposed building will house only production departments; administrative offices and a cafeteria-classroom will be in an adjacent structure. The dimensions of the production building are 150 by 125 feet, with a railroad siding along a 150-foot side and truck-loading space on a short side.

Departments in the Center are named according to the type of work performed. An activity relationship chart that also records the space requirements is shown in Figure 9.4.

The relationships defined in the chart are converted to a

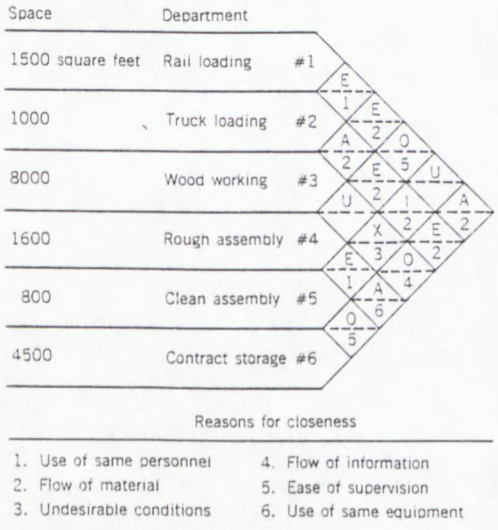


Figure 9.4 Activity relationship chart for a sheltered workshop layout. The loading departments include shipping, receiving, and storage facilities. Contract storage involves receiving materials for a commercial firm and holding them until the firm wants them converted to assemblies in the rough assembly department.

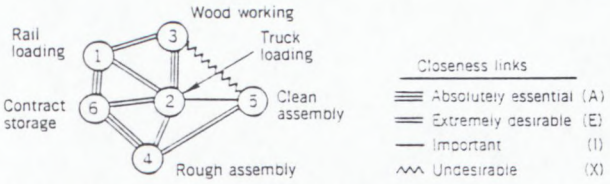


Figure 9.5 Activity relationship diagram as a layout guide for the sheltered workshop floor plan.

layout format by an activity relationship diagram, as shown in Figure 9.5. This simple diagram, constructed by trial and error, suggests the relative positions departments should take in the layout. The truck-loading area (no. 2) appears to be the key department to locate because it has strong closeness links (*A-E-I*) to all other departments. It is therefore a logical choice to be placed first in the floor plan. Physical conditions decree that it has to be located on the side of the building where the truck ramps are now located. Other departments are clustered near it in an arrangement that agrees as nearly as possible to the closeness ratings.

A tentative layout is shown in Figure 9.6. Departmental areas are dimensioned to conform to the required space and shaped to accommodate the departments within the building

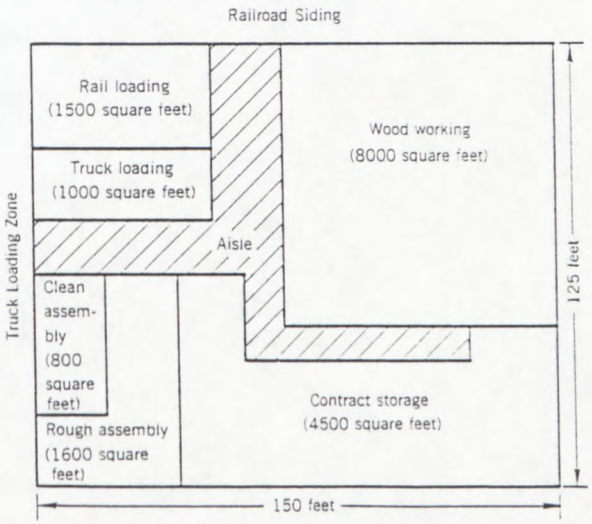


Figure 9.6 Preliminary workshop layout.

Figure 12. Example of activity relationship charts. ***(Riggs 1981:287).***

6.4 PRACTICAL APPLICATION OF ERGONOMIC PRINCIPLES

The National Institute for Personnel Research's Ergonomic Division, as stated in their publication "Ergonomics - an aid to Industry" found that:

> "Ergonomics is the scientific study of human factors in the working environment; the interaction between man and machine or user and product ... Like workstudy it is concerned with improving productivity and efficiency, in addition it takes into account many other factors of the work environment which may have a bearing upon the performance of the operator" ***(N.I.P.R/PERS 713:1).***

In their research project entitled "How successfully can non-ergonomists recognise and apply ergonomic principles", J.D.Weston and R.A.Haslam investigated the ability of persons with ergonimic training to evaluate designs as opposed to the abilities of persons with no ergonomic background training.

They concluded that: "The results show that for the tasks studied, the ergonomists performed better than the non-ergonomists: ***(Lovesey 1991:334)***. They also point out that the use of common-sense alone proved disadvantageous when evaluating a design in terms of ergonomic principles.

Findings such as these serve to illustrate the need for the practical application of ergonomic principles to the design of the factory interior, by persons with a suitable ergonomics background, in order to improve productivity.

With the above in mind and taking an interior designer's knowledge of ergonomic principles into account, an attempt was made to establish aspects of ergonomic design principles which may be particularly relevant for practical application in the design of factory interiors as follows.

6.4.1 VISUAL

A comparison of Carlton, Murrel, Sanders and Woodson showed a common concern for the effects that lighting levels, glare and task-to-background brightness ratios could have on human vision ***(Carlton:1980, Murrel: 1965, Sanders:1987, Woodson:1992)***.

The concern for attaining maximum efficiency of human vision in the factory environment may in part be explained by the fact that up to 80% of the information required to carry out a job is perceived visually *(International Labour Office 1974:55)*.

The findings of the study indicate that the following factors may contribute to efficient human visual performance (see also illumination of the factory interior Section 6.10.2):

6.4.1.1 Lighting Levels

A comparison of recommended general lighting levels by the British Lighting Council, the Health and Safety Executive, Neufert and the National Building Research Institute revealed that, in general, consensus has not been reached as to what constitutes "adequate" lighting levels *(British Lighting Council:1967, Health and Safety Executive:1987, Neufert:1980, National Building Research Institute:1982)*.

Examples of tables contained in the Interior Lighting Design Handbook (1967) are included as Annexure L due to their comprehensive nature and their inclusion of a limiting glare index[2]. In addition, these lighting levels reflect a standard for the attainment of 90% of the maximum possible visual efficiency for the particular job concerned.

This standard of lighting is claimed to be financially justifiable in that the monetary outlay for the lighting which would have to be specified in order to attain the recommended levels, will result in improved human efficiency to the point where the extra money spent will be recovered *(Interior Lighting Design Handbook 1967:12)*.

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[2]Glare Index - the glare index is a numerical figure which is a product of the four factors which most affect glare i.e. the brightness of the light source; and the angle of the source relative to the direction in which the eye is looking. In effect it is a measurement glare discomfort. In the design of a lighting scheme, the standard lux method is carried out and a provisional arrangement of fittings established. This arrangement remains provisional until the evaluation of the glare index has established that the visual comfort is acceptable i.e. the limiting glare index is under that as specified. If not, remedial steps are taken for example a new light fitting layout or re-specification of wall surface finishes in order to improve reflectance values.

It was found that general concern exists for the differentiation between the requirements of **general** and **task** lighting for the following reasons.

- A reduction in general lighting coupled with more attention being placed on task lighting can effectively reduce/control glare factors
- A task/general lighting system can reduce operating costs due to the lower level of general illuminance required by such systems.
- Task lighting can be more flexible than general lighting systems
- Task lighting can be designed to give the worker individual control over his lighting level.

6.4.1.2 Brightness Ratios within the Visual Field

According to Woodson, "Good seeing is also affected by the brightness relationships between all elements within the visual field ... It is desirable to maintain different brightness relationships between the primary visual task and immediate and distant visual phenomena" *(Woodson 1992:662)*.

The following table is presented as a suggested guideline in this regard:

Areas (in the factory)	Recommended Maximum Luminance Ratio
Task and adjacent darker surroundings	3:1
Task and adjacent lighter surroundings	1:3
Task and more remote darker surfaces	10:1
Task and more remote lighter surfaces	1:10
Luminaires (or windows) and adjacent surfaces	20:1
Areas normally within field of view	40:1

Table 2 Recommended brightness ratios within the visual field.
Adapted from *(Woodson 1992:662)*.

For the design of workstations, Woodson emphasises the effects of glare, and those of the relationship between contrast, visual angle, and brightness, on human vision. The three-dimensional chart shown in Figure 13 illustrates the relationship between three critical areas that determine whether a person sees an object or not. When the combination of variables intersects behind the curve, the eye cannot discriminate, whereas any intersection point in front of the curve provides good seeing conditions. Contrast refers to the difference in brightness between the object and the background. This factor can be affected by illuminance as well as colour reflectance factors. Visual angle refers to the angle of the surface being viewed relative to the direction in which the eye is looking; brightness refers to the surface illuminance level of the object.

Woodson emphasises the importance of considering glare in workstation design and lists the following effects of glare on the visual function:

- **Visibility** - glare can cause the object not to be seen (disability glare)

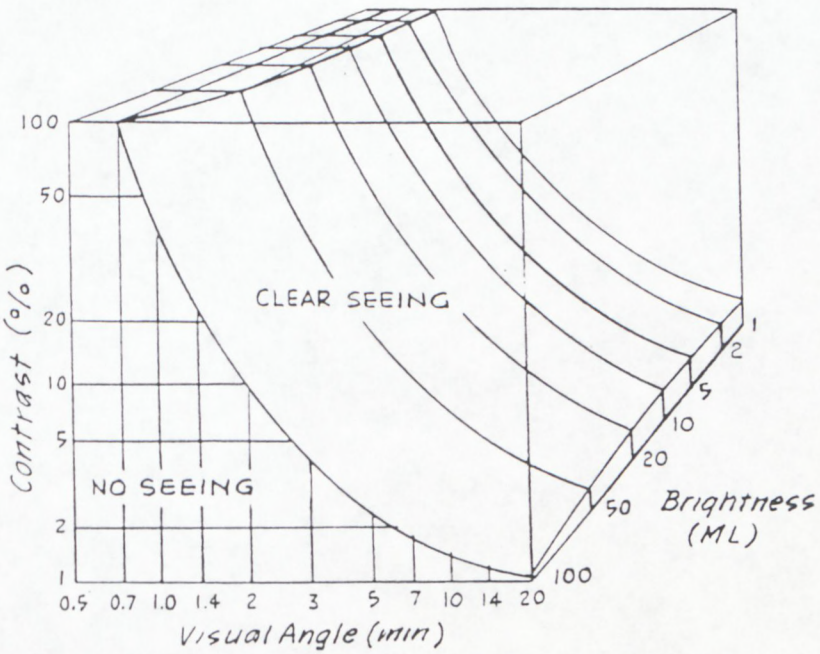
- **Size threshold** - glare can cause smaller objects not to be seen

- **Contrast threshold** - glare can make it necessary for contrast to be increased in order to restore vision

- **Muscular tension** - glare significantly increases muscular tension - in some cases up to 30%

- **Vision through eyeglasses** - the number of persons wearing spectacles is sufficiently large and the glare effect sufficiently severe to cause this to be a factor for consideration in placing light sources. When the light source is behind the head, no glare from eyeglasses will exist if the light source is 30° or more above the line of vision, 40° or more below the line of vision, or at an angle of 15° or more with the axis of symmetry of the head.

(Woodson 1992:667)



RELATIONSHIP OF CONTRAST, VISUAL ANGLE, AND BRIGHTNESS TO SEEING

Figure 13. Relationship between contrast, visual angle and brightness. *(Woodson 1992:662).*

6.4.1.3 The effects of lenses in direct uplighting (LIL) and parabolic downlighting (PBL) on video display terminal (VDT) work

The increase in computer use in the workplace over the past decade has been accompanied by increasing concerns about the relationship of workplace conditions to computer workers productivity.

The results of a comparative study by A Hedges on lighting for VDT work is cited for consideration:

> "This study showed that office lighting significantly affects the visual health and related problems experienced by computer users. Both the LIL[3] and PBL systems created better lighting than that from prismatic diffusers. The LIL workers consistently reported fewer visual health problems, fewer lighting related problems, and better productivity than PBL workers. Over all, reactions to the LIL system were significantly more favourable than those to the PBL system, and workers said they preferred working under the LIL system" *(Lovesey 1990:300)*.

6.4.2 AUDITORY

A comparison of literature regarding human hearing in the factory environment showed that the primary threat to human hearing is noise. Noise contributes to environmental pollution and may also contribute to fatigue, annoyance and cause breakdowns/difficulties in communication *(Irwin:1979, Mullholland:1981, Reynolds:1975, Woodson:1992)*.

Although sound measurement is a specialised field, an interior designer may be briefed to generate design solutions in conjunction with an acoustics specialist. In order to accomplish this he may require knowledge of the potential effects of various noise levels on human hearing, the physical properties of noise transmittance, and practical methods to reduce noise transmission. The following guidelines are a synthesis of the data found in the abovementioned literature.

---

[3]The LIL system has ceiling suspended luminaires which provides upward light which is then reflected down to the workplace by the ceiling and the walls. The PBL system has ceiling recessed luminaires which are shielded with a grid of parabolic louvres to provide direct lighting to the workplace.

6.4.2.1 The effects of noise levels on performance

Information summarised in the table may be used by an interior designer when planning the layout, for example placing tasks which require greater concentration in areas with lower noise levels.

Noise levels, performance and communication		
Noise level, dB	Typically generated by	Effects
100	Jet engine Heavy machinery	Serious reduction in alertness. Most people will find this level unacceptable.
95		Considered to be the upper acceptance level for areas where people expect the environment to be noisy
90	Protective clothing recommended	Temporary hearing loss may occur. At least half the people in a given group will judge this level to be too noisy. Skill errors and mental deterioration will be frequent
85		Commonly recommended as the upper limit over which damage will occur to hearing
80	Average for factory operational areas employing mechanised processes	Conversation is difficult and complaints will be received from persons in confined spaces
75	Average for factory operational areas employing mechanised processes	Upper limit for direct verbal communication and too noisy for telephone conversation
65	Office processes	Frequent telephone and direct communication
55	Drafting rooms, laboratories, conference rooms, offices	No difficulty with conversation or telephone use
45	Sleeping areas	

Table 3. Noise levels, performance and communicaiton.

6.4.2.2 The effect of noise on computer operators

Neil Morris and Dylan M Jones, in a study conducted in order to examine the effects of noise on the human ability to transcribe information from a video display terminal, found that the presence of background speech was sufficient reason for a significant increase in errors *(Lovesey 1990:185)*.

The reduction of noise levels in environments where production is controlled by means of video display information may therefore be a matter for consideration.

6.4.2.3 Reduction of noise transmission

The reduction of noise transmission is effected by impeding or interrupting or absorbing the transmission of the noise (energy) through the air or through a structure. The following approaches may be considered.

i. *AIRBORNE NOISE*

- Utilise distance as a noise reduction measure i.e. place the noise source and susceptible receiving point as far apart as possible.
- Positioning noisy machinery close to walls thus giving scope for sound absorbing treatment to be applied to the walls.
- Group noisy machinery/rooms together.
- Obtain machinery sound level specifications from manufacturers for use in layout planning.
- Plan for isolating enclosures.
- Instruct that direct plane noises (air intakes/exhausts) are directed away from the work area.

ii. *STRUCTURE BORNE NOISE*

It may be necessary for the specification of a separate foundation, or floor slab, to be built to accommodate machinery which could transmit vibration and noise via the building foundations. A separate floor slab for the equipment causing the vibration will ensure that the vibration is not

transferred by the general building foundations.

As a general rule, heavy plant and equipment should be placed as low as possible in tall buildings as the lower level structural elements are normally more massive and can absorb more vibration than upper level structures. There is also a shorter connecting path to the mass of the subsoil which acts as a damper to vibration and noise.

iii *SCREENING OR SHIELDING (ACOUSTIC INSULATION)*

Consideration can be given to the sound absorption/reflectance properties of materials used for construction of ceilings and drywall partitioning.

Drywall partitioning should be constructed with alternating support battens supporting alternate wall skins so that the vibration from one side of the wall is not transferred structurally to the other side (see figure 14 for example). Drywalls may also be filled with sound absorbing material.

Openings in otherwise soundly designed screening will radically reduce sound insulation properties. An opening of ,1% of the total wall area can reduce the sound insulation properties by 30%. Enclosures generally take the form of either a machine enclosure featuring both thick and massive material (sound insulation) with soft, fibrous or porous material (sound absorbing) on the inside or the enclosure may enclose a human. In either instance attention should be given to lighting, ventilation and access without compromising noise insulation.

Whichever methods are employed the following order of action was recommended in the literature with regard to controlling noise:

- If possible, remove the hazard
- If this is not possible, remove the individual from exposure
- The next course of action, if the previous two were not possible, is to isolate the hazard and lastly
- if the previous actions are not viable then protect the individual.

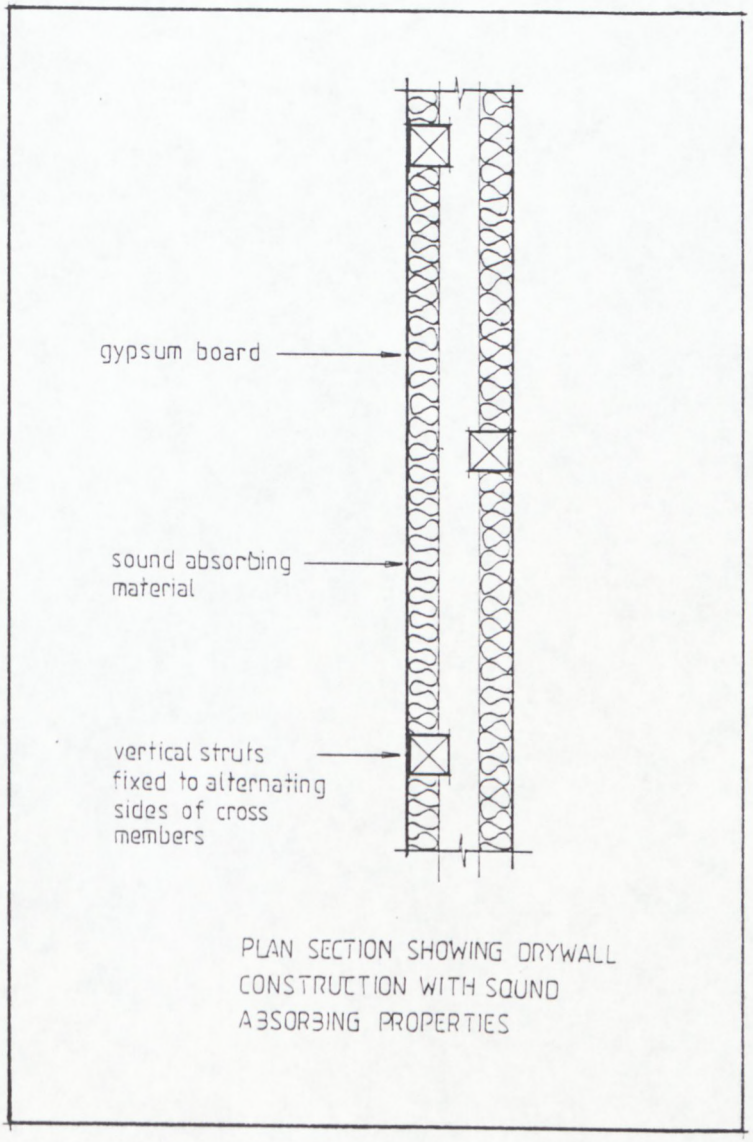


Figure 14. Example of sound inhibiting drywall construction.

iv. *CEILINGS*

According to the National Building Research Institute, the general noise level of any room can be reduced by three to four decibels by the installation of a sound absorbing ceiling ***(National Building Research Institute 1982:138)***

v. THE DESIGN OF MACHINES FOR QUIETNESS

Although the design of machinery is usually the domain of the engineer it may be of interest to note that machinery can be designed, to a certain extent, to operate quietly.

Before recommending expenditure on screening, an interior designer could enquire whether:

- the equipment employed in the operation has its impacting parts enclosed

- in the case of rotating or impacting machines, whether they are fixed to antivibration mountings

- in the case of internal combustion engines, whether they are effectively silenced

- all rigid connections such as water, electricity and gas supplies to vibrating equipment should have vibration decouplers.

6.4.3 BIOMECHANICAL

Because the concern of an interior designer revolves largely around man and his spatial needs, much of his planning includes the utilisation of dimensional and spatial planning information relating to human activities.

When referring to the static, or rigid dimensions of the human body these dimensions are often referred to as "anthropometrics" while the application of these dimensions to, for example chair design, is referred to as "ergonomics".

The following information is a synthesis representing the works of Kantowitz, Woodson, Mekjavic and Sanders *(Kantowitz 1983, Woodson 1992, Makjavic 1988, Sanders 1987)*.

6.4.3.1 The use of Static and Dynamic Data

The design of a workstation involves inter alia the translation of anthropometric (static) data into dynamic information through the application of biomechanical function/limitations to the anthropometric data.

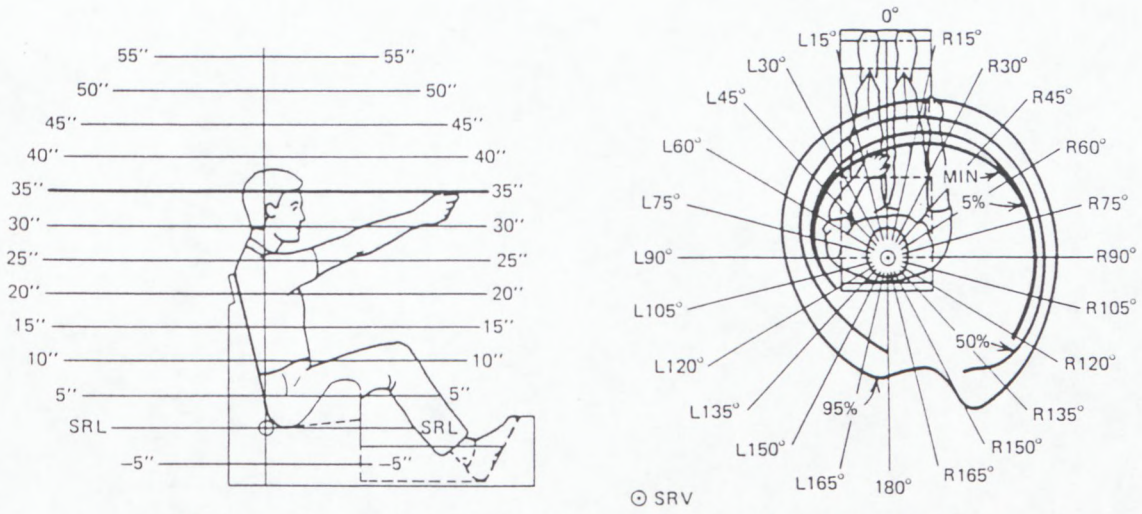
In effect this means that a designer may utilise static dimension of the human body and, taking the limitations of mobility and function imposed by, for example skeletal hinge-point locations, can predict a dynamic three-dimensional "space envelope" of movement for the body part in question. Consideration should also be given to factor such as:

- Potential physiological strain/fatigue caused by the proposed movement/ repetition of the proposed movement

- Minimising of physiological strain by designing for correct weight distribution and working posture.

Figures 15 and 16 illustrate the difference between static and dynamic design data and gives examples of correct weight distribution and posture applications.

Figure 17 reflects the preferable ergonomic operator/machine relationship for a computer operator.



Men's grasping reach to a horizontal plane 35 inches above the seat reference point.

Figure 15. Examples of static and dynamic design data.

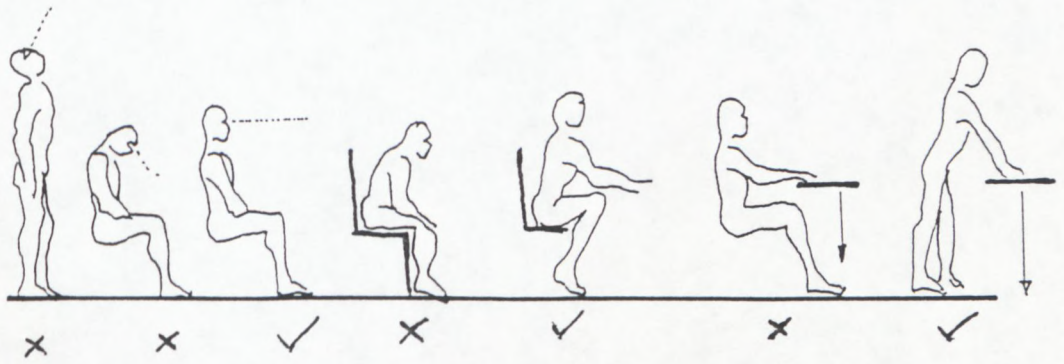


Figure 16. Example of correct weight distribution and posture.

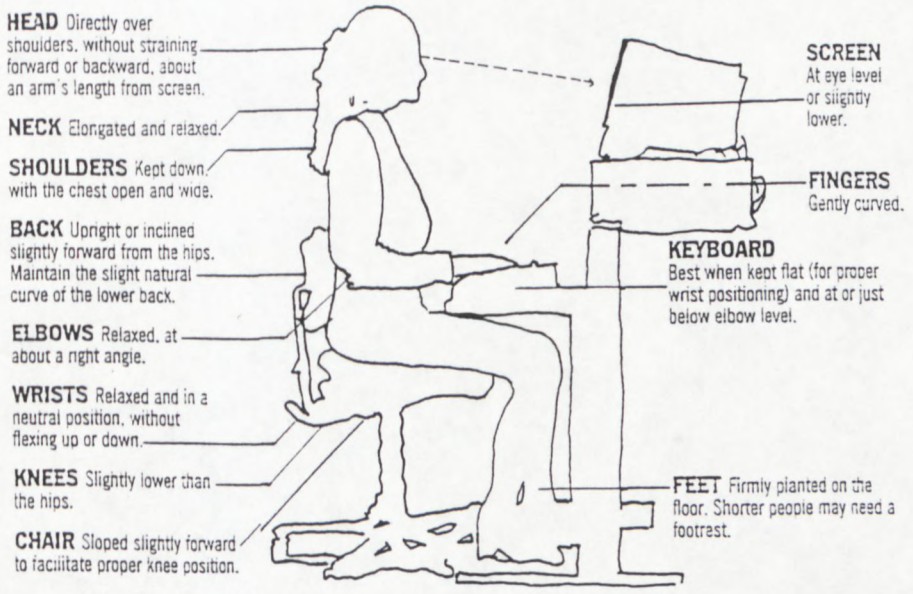


Figure 17. Example of ergonomic requirements for a computer operator. (Horowitz 1992:62)

6.4.3.2 General considerations

The following guideline serves to highlight considerations which could contribute to satisfactory workstation design.

If possible:

- Allow operators to sit rather than stand
- Provision should be made for changes in position
- Keep movements symmetrical
- Provide adequate dynamic working space
- Ensure comfortable working heights
- Use machanical devices to hold work where applicable
- Provide arm and feet supports especially if there are long periods of time between control lever depressions by the hands or feet.

Avoid:

- Workstation layouts that require the operator to perform many similar operations constantly repeated over long periods of time.
- Workstation layouts that require operators to sit in a skewed position relative to an operating control, especially a foot control.
- Workstation layouts that require operators to constantly move their heads from side to side.
- Workplace layouts that require operators to step up and down for long periods of time.

6.4.4 COGNITIVE PROCESSES

The term "cognitive processes" in the context of Ergonomics or Human Factors Engineering was, for the purpose of the study, determined to be "those typical human expectancies and mental capacity for comprehension which the physical features of the facility are designed to be compatible with" *(Woodson 1992:58)*.

The practical task for the designer is to make better use of spontaneous and stereotype responses (closing the eyes at the sound of loud explosive noises; expecting the colour red to mean STOP as opposed to expecting the colour green to mean GO) as well as avoiding unnecessary information recall effort (for example direction colour coding in a building to "remind" a person where one is and where to go).

A much used term "user friendly", can perhaps be utilised to describe a design which successfully addresses the human cognitive processes and physical attributes. It can therefore be deduced that if the design is easy to use, or that the manner in which it is to be used/operated is obvious to the user, the design is more efficient than a design which requires more time to learn how to operate.

According to Sundstrom, this concept is utilised by ergonomists, but is applied mainly to the design of displays, controls and workstations *(Sundstrom 1986:52)*.

The following are examples of various stereotyped and spontaneous responses which may be considered for workstation design purposes:

Position - control switches are best placed near to the display of the function that is controlled by that switch.

Size - An "important function" switch should be larger than a "less important function" switch.

Shape - A different shape for a different function can assist the operator in identifying the correct control when the control is out of the line of vision.

Colour - Colour can be used for function coding or functional differentiation of switches on a complex panel. However, because of the possibility of colour blindness or in the event of lighting failure, colour should be considered a secondary cue for vital functions.

Legend - A written or graphic legend, although useful, should also be considered a secondary cue due to the possibility of illiteracy or misinterpretation of a graphic symbol.

6.4.4.1 Control stereotypes

Humans learn that certain components operate in a certain manner. When, for instance in an emergency, they are confronted with the need to operate these components they will do so on a control stereotype basis and, if the component does not operate as per "normal", they may not be able to peform a vital function such as opening a door.

The following are some common control sterotypes:

Speed - A control that modifies speed will generally be considered to increase the speed by being moved up, forward or clockwise relative to the operator. Reversing these directions is related to slowing or stopping.

On/Off - The up or down function of electrical switches differs from country to country.

Guidelines such as these, although used mainly in equipment design, could be used by an interior designer in, for example, the design of emergency exit doors to ensure that release mechanisms, locks and opening direction are suited to the function.

6.4.4.2 Spaces and the human cognition processes

The question may be posed **"If the function or operation of the space were evident to the user, would this not imply that the space is more efficient?"**

Practical examples would be a goods delivery truck driver entering a delivery point (space) and immediately understanding what to do, where to do it and in what sequence to carry out these operations; or a person sitting at the factory restaurant who is encouraged by the environment to make social contact with fellow workers thereby enhancing co-operation in the workplace.

As reflected in the literature review of the study, it was found that much has been written about the human/working environment relationship but pertinent practical design guidelines with which to translate these observations into practical designs were not readily available. For example Sundstrom, in his book on workplaces, states "This book explores psychological and social-psychological influences of the physical environment in offices and factories ... (it) should interest professional designers, but it makes no attempt to provide practical guidelines or standards for offices or factories" *(Sundstrom 1986:xi)*.

The following synthesis[4] of information is not intended to represent a professional psychologist's opinion but rather the writer's impression of how humans understand space. As such, this information may assist an interior designer, for example, when having to provide practical solutions in collaboration with an industrial psychologist. It may also serve as a supplementary frame of reference when seeking a practical design solution.

The accompanying chart (Figure 18) (overleaf) represents three aspects of the human understanding of space; the **analysis** of, the **experience** and **processing** of information regarding the physcial environment.

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[4]In order to facilitate the writer's understanding of subjects such as experimental psychology, engineeering psychology, industrial psychology, behavioural psychology, industrial organisational psychology, occupations psychology and social psychology, a study was made of works by: *(Becker 1981, Bloomer 1976, Fisher etal, 1984, Goshen 1961, Jordaan W & Jordaan J 9184, Matlin 1983, Maer 1983, Osgood 1957, Sundstrom 1986, Sutermeister 1976, Viljoen et al. 1987)*

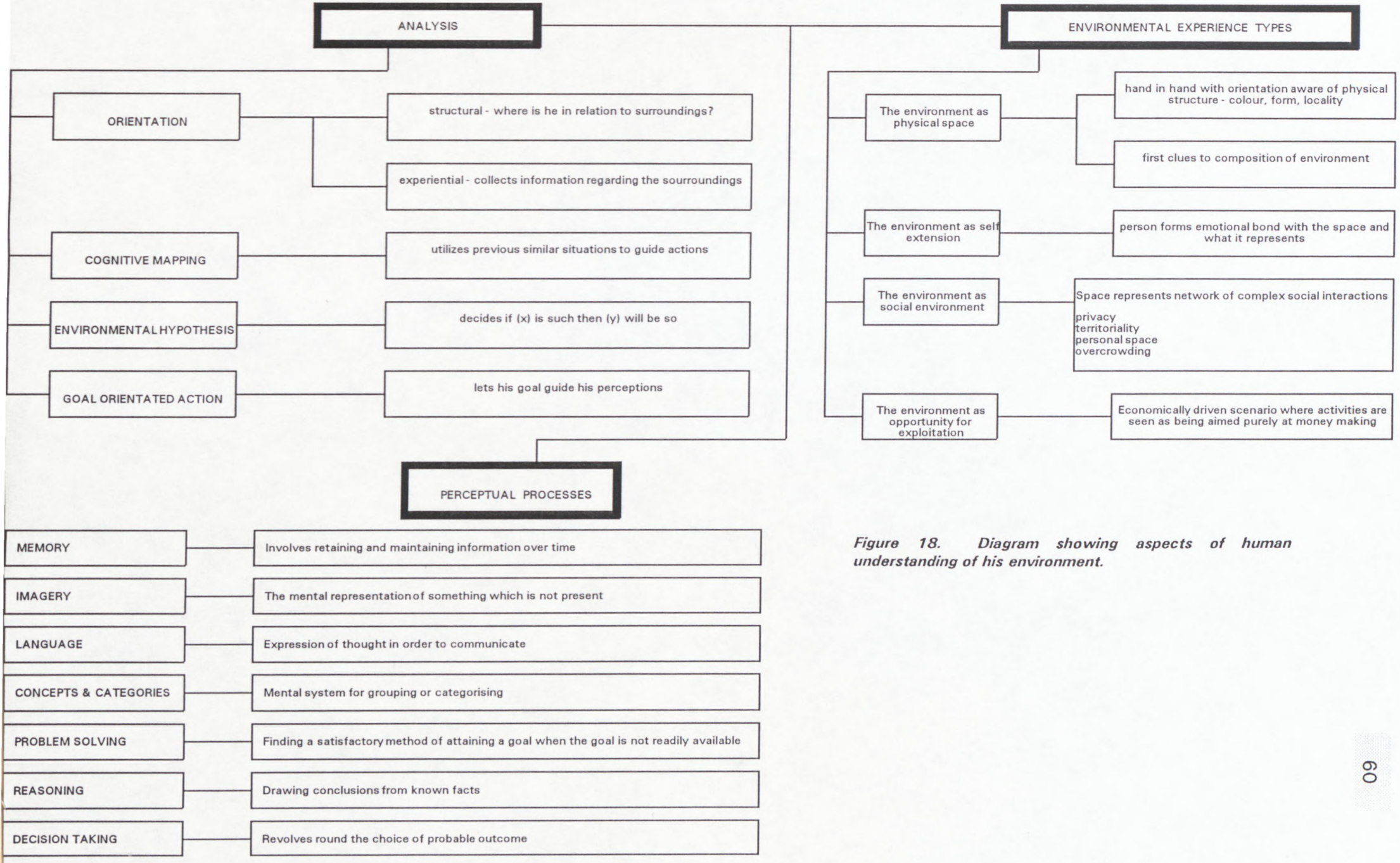

Figure 18. Diagram showing aspects of human understanding of his environment.

The **analysis** aspect refers typically to a situation where the human finds himself in a new environment or perhaps one which he has not visited for a long period of time.

The **environmental experience** aspect refers typically to a situation where the human finds himself in the same space for a relatively longer period of time, for example his office.

The third aspect, **perceptual processes**, refers to the human (mental) information processing system.

These aspects are now discussed in more detail.

ANALYSIS OF THE SPACE

In order to analyse the space, the human uses processes which can be divided into four categories

i. *ORIENTATION*

The first task for the newcomer is to determine where he is in relation to other places in order to plan his next action. He orientates himself using both structural references and other visual clues such as signage. A practical design example of catering for structural orientation would be to plan the floors of a multi storey building according to similar layout patterns. In this way the lift shaft could serve as a common structural orientation reference point on every floor. In this way a person would "know" where he is in relation to the lift shaft on every floor. An example of the use of signage would be the provision of adequate signage in a building entrance foyer indicating to the visitor where he is and showing how he can get to where he wants to go. The newcomer will usually be reluctant to carry out further actions until he has orientated himself.

ii. *COGNITIVE MAPPING*

In a "new" environment a person will use his existing knowledge (cognitive maps) of similar environments in order to make sense of the new one. For example upon entering a new branch of a bank he will use his knowledge of existing bank queuing systems in order to recognise the new place to queue. The designer can cater for this process by analysing typically common visual or other clues to the function of the space and applying them to his design. These clues will then assist the newcomer in orientating himself.

iii. *FORMATION OF THE ENVIRONMENTAL HYPOTHESIS*

This process follows that of cognitive mapping and takes the format "if ...., then .....". For example, IF he sees the sign over a desk saying "information" THEN he will surmise that this will be where information can be obtained. Or, if the reception desk is placed before the office, then perhaps the visitor will stop at the reception desk before entering the office. In other words, the designer can attempt to ensure that "cues" which are supplied to guide the newcomer's action, are as unambiguous as possible.

iv. *GOAL-ORIENTED ACTIONS*

The way in which a person analyses space is dependent upon the reason for that analysis. For example a bank robber "sees" the banking hall differently to the bank's clients, as he has a different purpose in mind. Similarly, an interviewer and interviewee may see an office space differently. The interior designer may have to design the space in order to put the interviewee at ease as well as to accommodate the interviewer's administrative processes i.e. the space may have to accommodate more than one role.

THE ENVIRONMENTAL EXPERIENCE

The following types of environmental experience are, to a large degree, interdependent and differing types will dominate for differing circumstances.

i. *THE ENVIRONMENT AS PHYSICAL SPACE*

Initially people perceive the environment as "that which is not me" i.e. something which is outside and independent from themselves. This can be equated with the aformentioned orientation phase of environmental analysis. At this stage of orientation, people are acutely aware of colour, form, locality and appearance of physical structures as these are the first clues to the composition of the environment.

As time passes these elements will "gel" to form an "atmosphere" which, in the long term, will form the **environmental space experience**. Thus separate elemements such as lighting, colour, spatial features, noise and temperature have long-term effects on the environment due, not only to their individual contributions, but also to their **combined** contributions.

ii. *THE ENVIRONMENT AS SELF EXTENSION*

After a certain amount of time in an environment, a person can develop a sense of ownership over the space. The person actually becomes emotionally attached (or perhaps repulsed) by the space and what it has come to represent. This is not always obvious to an outsider. For these reasons, an interior designer may find that, in spite of the offer of better surroundings, many workers could show a great reluctance to move. Therefore, those involved should be kept well informed of impending moves and what their roles in the new environment will be, so as to minimise possible disruptive effects.

iii. *THE ENVIRONMENT AS SOCIAL CLIMATE*

People experience space in a social context i.e. as a network of social interactions. This network of social interaction is a complex one and is affected by a number of related concepts for example privacy territoriality and overcrowding. An interior designer's task in this regard may involve designing the space in order to enhance or de-emphasise certain elements, for example leadership (design to reinforce status). This can be accomplished through the use of accepted status symbols, such as large furniture and slightly higher levels of luxury.

iv. *PRIVACY*

The protection of privacy in the working environment can be interpreted to mean **making provison for a person to control when and how he interacts with others**. A practical solution may entail the inclusion of a door which can be closed for privacy, the provision of an eye-level screen behind which the individual can "hide" simply by lowering his eyes, or the concept of auditory privacy which may necessitate the use of acoustic screening. A dearth of privacy can result in the stress known as "crowding", whereas excess privacy can bring feelings of isolation.

v. *TERRITORIALITY*

The concept of territoriality is tied in with the concept of space as self extension, and the personalisation of space. The person perceives the space as a zone of control, or territory, and may feel a sense of responsibility for "their" workplace. These feelings may be encouraged/discouraged by the extent to which the person can personalise the space, whether he has to share the space and how often, and for what purpose he uses the space.

vi. *OVERPOPULATION OR CROWDING*

Under these conditions a person is subjected to more social interaction than he wants or can control. This is a subjective experience and can vary according to the circumstances. For example, 40 000 people at a sports stadium may be crowded together just as densely as 12 people in a lift but the overcrowding experiences are totally different.

vii. THE ENVIRONMENT AS OPPORTUNITY FOR EXPLOITATION

In this situation people (management, workers or general public) experience the workplace as a place where an exploitative action, usually economically driven, has taken place. This usually implies that activities were aimed purely at making money without consideration of the importance of the environment to the life of the inhabitant/occupants of that environment. This can often be observed as a conflict between labour and management.

PERCEPTUAL PROCESSES

Just as the human body has the physical facilities to see, hear, feel, touch, taste and smell, the brain has various "methods" for acquiring, storing, retrieving and using knowledge. This can be termed "human information processing".

Popular belief holds that the brain records everything which the eye sees and later recalls this information for further use. In fact the brain is spontaneously selective regarding the information which it processes and subsequently stores.

Carolyn Bloomer, in her book on the principles of visual perception points, explains that "the study of visual perception clearly reveals that perceptual processes are not structured to **record** data but rather to **organise meaning**" *(Bloomer 1976:122)*. This process is subjective and can be used to explain, for example, why two people seeing the same occurrence from the same vantage point, can report different versions of the same incident. It can therefore be deduced that two people in the same environment can have differing perceptions of that environment.

Current understanding of these processes suggests that the format in which information is presented may enhance/detract from the perceiver's ability to process this information. It therefore follows that a design which caters for these processes will be more functional than one which does not.

The following definitions of processes and possible design considerations may therefore be of interest to an interior designer:

i. *MEMORY*

This involves maintaining information over time. A designer may assist in the retention of information by emphasising the importance of the information or by providing "reminders". For example a "no smoking" notice may be placed at the entrance to a large manufacturing area and be supplemented by smaller reminder symbols at intervals around the room.

ii. *IMAGERY*

This process involves the mental representation of something which is not physically present. These mental images are used in guiding future actions, for example the use of a mental map to guide one's direction.

A mental image is manipulated in the same way that a real object is in that it has to be rotated, measured, transported or otherwise positioned for use. Similarly to real objects, the more the mental image has to be manipulated for use, the higher the likelihood that it will be "damaged" in the process. Practically, this implies, for example, that orientating directional signage such as floor plans and directional arrows correctly in relation to the physical plan will assist in the interpretation of this information by the viewer.

iii. *LANGUAGE*

Language is a method of communicating information. It can take many forms ranging from universal sign language to complex scientific or mechanical language. Decisions regarding the appropriateness of the form in which information is visually presented may influence the efficiency of the communication process. For example a graphic symbol may, in certain circumstances, convey a message more effectively than the equivalent written message.

iv. *CONCEPTS AND CATEGORIES*

These are systems for organising individual items into groups so that the members of each group share one or more characteristics. A design can assist in this process by, for example, grouping functions visually by proximity, colour or form.

v. *PROBLEM SOLVING*

Problem solving involves finding satisfactory methods of reaching a goal when that goal is not readily available. If the goal and relevant methods for achievement are ones with which a person is familiar it becomes "easy" to solve the problem, for example stepping on to an escalator. But a person from a rural area who

has not used an escalator before may be confused and show trepidation when faced with this form of transport.

vi. *REASONING*

This process involves drawing conclusions from known facts; if a person wants to exit a building he may follow a sign saying "exit". In a multi-storey building he may assume that the main entrance/exit to the building is on the ground floor. This assumption is based on a generally known fact that the main entrance to buildings is on the ground floor. When a design does not conform to the norm, consideration may be given to informing people of this fact in order to prevent the drawing of incorrect conclusions.

vii. *DECISION TAKING*

This process is concerned with choices about the likelihood of uncertain events. For example, if there is only one visible entrance to a building then decision taking regarding entering that building is limited. If there are three identical entrances it will be difficult to determine which one is the main entrance. If one of the entrances is twice as large and is positioned on the main street then this design feature may help a person to decide that this is the main entrance.

6.4.5 ENERGY CONSUMPTION

In the context of ergonomics, energy consumption refers to the physical and mental effort which the worker exerts in order to accomplish a task. Energy conservation is attained through task based productivity improvement.

Sumanth, in his book on productivity engineering presents seven methods for consideration, namely:

- Methods engineering/work simplification
- Work measurement
- Job evaluation
- Job design

- Job safety design
- Human factors engineering
- Production scheduling

(Sumanth 1984:452)

Although these are fields of expertise which an interior designer may have to consult concerning specific production process layouts and their effects on workstation design, the following general guidelines advocated by Woodson for individual workstation planning may be considered in order to promote motion economy *(Woodson 1992:122)*:-

- Provide a definite, fixed place for all tools and materials.

- Locate tools, materials and machine controls and displays close to the point of use.

- Wherever a specific movement requires a repetitive or precise control, assign the motion to the hand or digit that provides the required degree of strength and dexterity, but avoid overloading a particular hand or finger unnecessarily.

- Provide jigs, fixtures and foot-operated aids to relieve the hands of unnecessary tasks.

- Pre-position tools and materials as much as possible.

- Provide auditory signals for long duration processes so that the worker can carry on with other tasks whilst listening for a completed cycle signal.

- Place controls and displays where they require the least excess movement of torso, head, limbs or eyes.

- Arrange machines, workbenches, etc, so that work can be passed directly and naturally from one to the other i.e. not across aisles, around corners or past an intervening workstation.

The distance which workers have to traverse to fetch tools and materials, deliver finished products, communicate with co-workers and use ablution facilities can also be considered for motion economy purposes.

6.4.6 ENVIRONMENTAL FACTORS

Certain environmental factors such as temperature and air quality can be affected by manufacturing processes or by the external environment. This could have an effect on both humans and materials. The following aspects may require assessment in this regard.

6.4.6.1 **Temperature**

Commenting on the effect that climatic conditions can have on the worker, The International Labour Office states that "if productivity is to be maintained, climatic conditions at the workplace must not place an extra burden on the worker; this is also a factor in safeguarding the workers' health and comfort" ***(International Labour Office 1974:62)***.

This observation is supported by the findings of the National Building Research Institute: "... it is already clear that measurable improvements in productivity can be obtained by control of the factory environment ..." ***(National Building Research Institute 1982:19)***.

Regulations issued in terms of The Factories, Machinery and Building Work Act, place limits on the maximum temperatures permissible in the factory interior for specific types of work as 30° Celsius for continuous light work and 25° Celsius for heavy work[5].

However, these are maximum temperatures beyond which definite discomfort or damage to health may be experienced.

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[5]These are wet-bulb globe thermometer indexes and therefore take into account air temperature, radiant heat, air humidity and air movement.

A survey of temperature recommendations indicated that the optimum temperature for sedentary work is 22° Celsius, decreasing as the workload increases *(National Building Research Institute 1981:11, Sundstrom 1986:111, International Labour Office 1974:66)*.

Various environmental conditions were found to be inherent to certain categories of industry as follows:

Hot work - In a hot working environment the most effective way of body heat dissipation is by sweat vapourisation. This process is facilitated by adequate ventilation and inhibited by humid conditions. Examples of humid conditions can be found in spinning and weaving mills, in sugar refineries, laundries, canning plants and, in general, in all work entailing exposure to hot, humid conditions, especially in tropical countries.

A combination of radiant heat and high temperature processes in dry climates can also produce unfavourable working conditions, for example in iron and steel works, glass works, hot rolling mills and forges.

Cold work - Work such as cold storage packing has to be carried out in cold conditions and therefore protective clothing is the method generally employed for maintaining body heat.

Wet work - steam can contribute to high levels of humidity as well as increased temperatures. Ventilation may be used to reduce temperatures and exhaust ventilation may be used for extracting steam.

6.4.6.2 Ventilation

The design of a factory building, its ventilation system, and the nature and layout of its processes can ensure that the composition and quality of the air in the factory is controlled, to the benefit of the worker and his productivity, and that pollution of the air outside is restricted "... A whole industry has emerged to cater for the monitoring of factory air ..." *(National Building Research Institute 1982:Synopsis)*.

The function of ventilation in a factory include:

- The dispersion of heat generated by men and machines at work. Consequently, where men and machines or workers are grouped together, ventilation should be increased.

- The provision of fresh air and maintaining the feeling of air freshness

- The dilution/removal of atmospheric contaminants.

Methods of providing ventilation include:

- Natural ventilation, obtained by opening windows, or wall or roof air vents and promoted by, for example the stack effect inherent in certain building types.

- Where natural ventilation is inadequate, it becomes necessary to use mechanical ventilation. Systems comprise blown-air, exhaust-air, or a combination of both. In the case of large emissions of gas, vapours, fumes and dust, exhaust-air systems may be preferable due to this system's abilities to prevent the spread of contaminants to adjacent areas in the workplace.

- Where general ventilation is inadequate, local exhaust ventilation is required, by means of exhaust hoods or other devices.

6.4.6.3 **Occupational Health and Safety**

Ergonomic considerations are included in a broad sense in legislation regarding the environment and occupational health and safety. Thus, for example, the minimum volume of space, minimum ceiling heights, minimum floor area per worker and minimum ventilation standards may be regulated by legislation. Reference to this legislation is provided in Annexure K.

6.5 PRODUCTION PROCESSES AND THEIR IMPLICATIONS WITH REGARD TO THE WORKING ENVIRONMENT

This section of the study presents a brief outline of typical manufacturing processing and the hazards which they may present to humans and materials. This information may be used at the planning stage to assist in planning for measures to combat these hazards.

6.5.1 MANUFACTURING (CASTING, CUTTING, FORMING, TREATING, DRILLING)

The manufacturing process can be broadly divided into the following sub-sections:

Processes used to change the shape of material including:	
Process:	**Implies:**
Extraction from ore	Dust, noise, vibration, abrasion, hazardous chemicals.
Casting	Fumes, radiant heat.
Hot and cold working	Fumes, radiant heat, impact, vibration, noise.
Powder metallurgy forming	Fumes, radiant heat, dust.
Plastics moulding	Fumes
Chemical processing	Air pollutants, water pollutants, corrosive products.
Textile manufacturing	Air pollutants, corrosive liquids and gases, steam, noise, radiant heat, vibration.
Food processing	Odours, chemicals, water, steam, radiant heat, dust.

Table 4

Processes for machining to specified dimensions	
Traditional machining e.g. turning and milling	Reciprocating machinery, noise, screening, machinery guards.
Non traditional machining e.g. ultrasonic, electrical discharge, laser cutting	Specific to process.

Table 5

Processes for joining parts or materials	
Welding, brazing, soldering	Fumes, eye protection, screening, radiant heat, noise, explosive gases.
Riveting, sintering and pressing	Noise, vibration.
Adhesive joining	Fumes.

Table 6

Processes for obtaining surface finishes	
Process:	**Implies:**
Paint dipping and spraypainting	Fumes, spillage, explosive flammable and corrosive chemicals.
Polishing and grinding	Noise, fumes, dust, abrasive compounds, vibration.
Electroplating and Metal spraying, anodizing	Air pollutants, spillage, solvents and toxic liquids.

Table 7

6.6 THE PLANNING AND DESIGN OF PRODUCTION RELATED ACCOMMODATION

This section of the work presents planning considerations regarding the receiving, despatching and accommodation of raw materials, partially-completed and completed products and the inspection and testing of products for the production process. This can perhaps be considered as production related storage as opposed to bulk storage or warehousing.

6.6.1 PRELIMINARY STORAGE OF GOODS/MATERIALS, WORK IN PROGRESS AND PRE-DELIVERY STORAGE OF PRODUCTS

Preliminary and pre-delivery storage accommodation refers to the areas planned for the storage of goods/materials in the interim period between receiving/ production and production/delivery. (This excludes bulk storage/warehousing which is usually considered to be a separate function to the production process.).

The design of these storage areas could require the incorporation of counterspace and computer terminals for the accommodation of administrative processes at these points. Floorspace requirements may vary widely according to product or process category as well as production volumes.

Work in progress accommodation, implies a space requirement in the production process in which partially manufactured goods are temporarily stored while awaiting subsequent work operations. For efficient use of machine tools, the amount of partially completed work stored must be adequate to permit a maximum working throughput. The storage space may have to be flexible so as to act as a buffer in the production process. Particularly in batch processing, where a batch of items have to be completed before the work is passed to the next stage, work in process can take up a large proportion of floor area.

Because of the importance of utilising a minimum of storage space for the maximum of working time for the worker and machines, these areas should be calculated in collaboration with production management.

6.6.2 INSPECTION AND TESTING

Inspection and testing of goods and materials may be necessary at either receiving or despatching points.

Provision may have to be made for, inter alia:

- The physical examination of goods, for example under adequate or special lighting conditions.

- The weighing of goods on scales, weighing platforms or weighbridges.

- The counting and sorting of goods, for example at sorting tables.

- The measuring of goods with tape measures or specialist measuring equipment.

6.6.3 STORAGE AND HANDLING COMPONENTS

Components which may be utilised in both production and storage areas, for example as part of a work station, are listed in annexure G.

6.6.4 LOADING BAYS

The findings of the study indicated that, because the loading area forms a vital link between transport (distribution) and process (storage or manufacturing), efficient planning of the area can contribute to the reduction of production costs. *(Mills 1985:264, Neufert 1980:282).*

The following guidelines may be applicable, and are typical of those found in engineering and architectural planning handbooks:

- Raised level loading docks are suitable for use with box bodied vehicles and end loading containers; ground level loading docks are suitable for use with flat bed, curtain sided and side loading vehicles/containers.

- Separate loading and receiving bays may be required for large distributors (high volumes) or where goods receiving docks suit ground level compared to those for despatch suiting raised dock levels.

- Spacing and layout of the areas surrounding the actual dock should take into account the accommodation of the goods received/despatched as well as the area required for the manoeuvring and parking of vehicles; see for example Figure 19.

- Mechanical means for altering raised dock heights (dock levellers) may facilitate the transfer of goods between vehicle and loading dock.

- Energy consumption may be conserved by facing loading bay openings away from prevailing winds, the use of dock shelters if the loading area is external to the building, and the use of roller shutter doors to seal loading areas not being used.

- Security planning may prevent visiting drivers from requiring access to the general manufacturing area, for example by providing separate toilet facilities.

Examples of guidelines for the design of loading bays as contained in Neufert Architects Data are reflected as Figure 19.

6.6.4.1 **Rail Transport : Loading Bays**

Rail loading docks are serviced by a spur track from a main railway line. The docks are usually raised to standard rolling stock bed height. Design considerations may include vehicle-to-building clearance dimensioning, fencing enclosures and compliance with municipal/rail transport system regulations. Early consultation with the relevant authorities may therefore be necessary in this regard.

6.6.5 PREVENTION OF PERSONAL INJURY

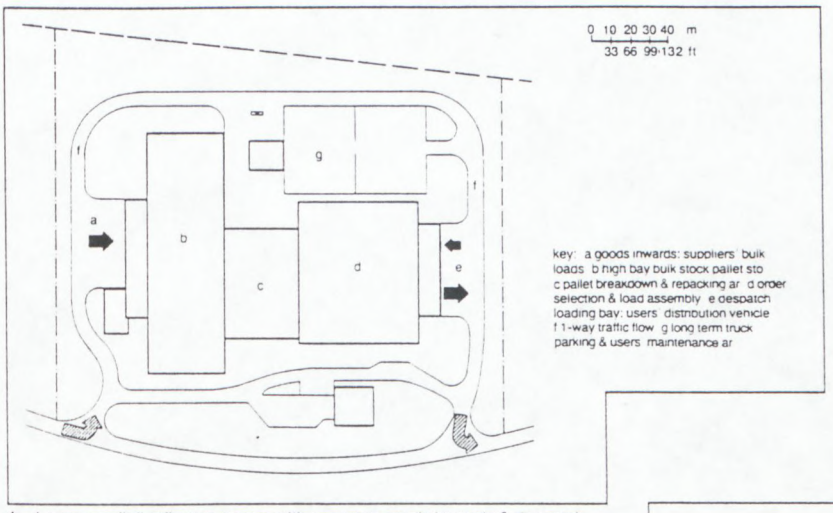
The results of the investigation indicated that although loading and storage areas are designed towards the efficient handling of goods and materials, each phase of goods handling and storage involves human input. The following would be typical areas in materials handling where personal injury could occur:

- Direct interface with raw materials that are heavy, sharp, rough, toxic, breakable or explosive. Careful planning and demarcation of pedestrian/vehicle aisles and storage areas may assist in preventing accidental contact with these types of goods or materials.

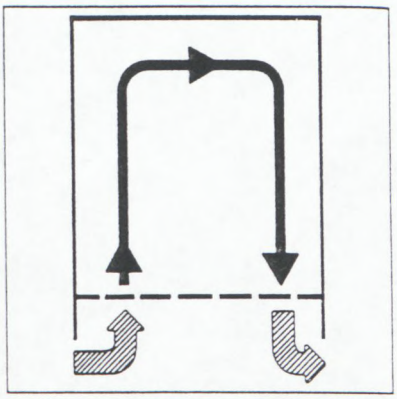
- The specification of inefficient storage and stacking systems may cause materials to fall, causing damage or injury.

- The sharing of the same areas by both people and automated handling systems (for example an overhead conveyer) can cause persons who are unaware of impending movements of goods to be struck or become entangled.

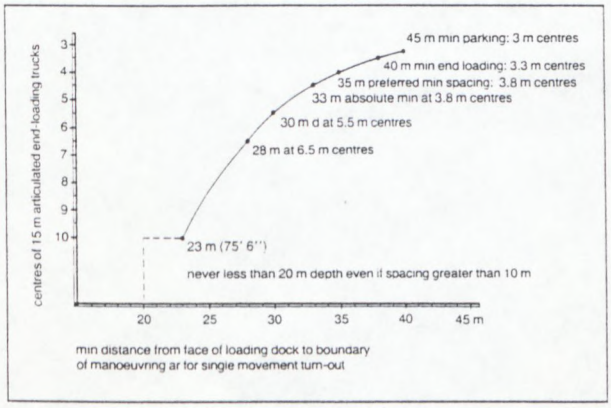
- In instances where tracks are utilised to guide trollies, barriers or other forms of demarcations may be employed to prevent persons stepping onto tracks.



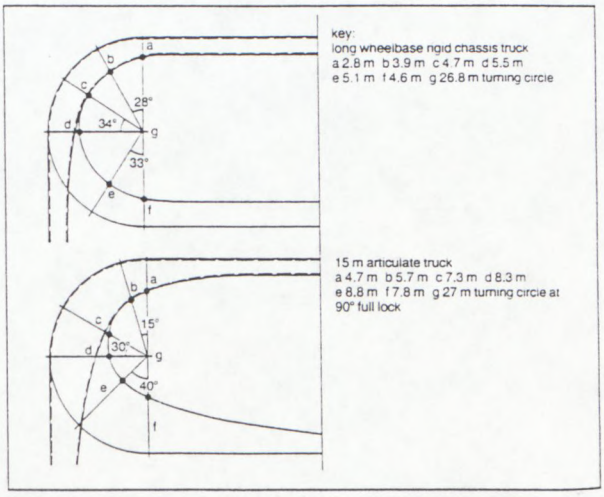
1 Large retail distribution centre with separate goods inwards & despatch loading bays



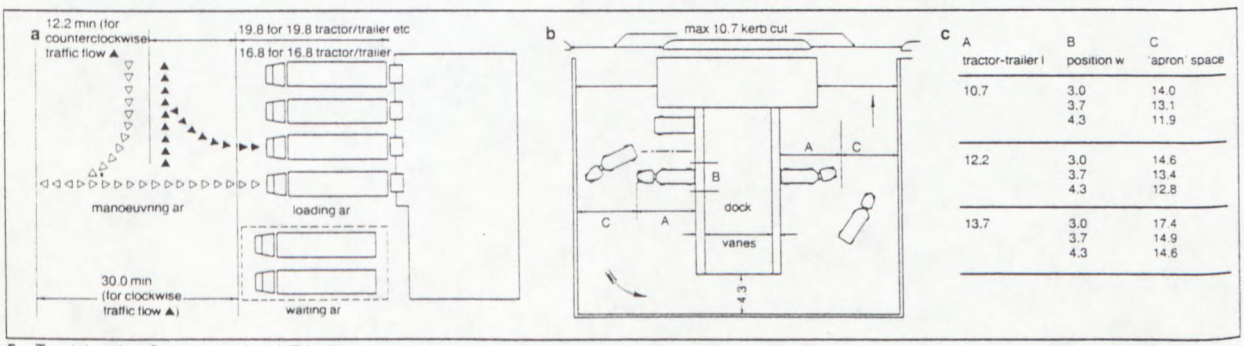
2 Many warehouses can use dock for incoming & despatch goods: in factories sharing type of loading bay may not be possible but goods vehicle manoeuvring ar can be common



3 Calculating yard depth & loading bay spacing for 15 m articulated trucks parked at 90° to dock



4 Typical turning dimensions for rigid chassis & articulated trucks



5 Truck loading & manoeuvring, USA dimensions **a** loading, manoeuvring and waiting ar **b** & **c** apron space required for 1 move into or out of position

Figure 19. Examples of loading bay planning guidelines.
(Neufert 1980:282).

- When planning the materials handling area for materials handling vehicles, for example forklift trucks, consideration may given to positioning the loading operations so that the vehicle operator can view both the load transfer and the vehicle instruments.

6.7 THE PLANNING AND DESIGN OF ANCILLARY AND STAFF ACCOMMODATION

6.7.1 OFFICE ACCOMMODATION

A comparison of handbooks (Ernst & Young, Hodgett, Lock, Mills, Neufert and Pile) for office planning, management, plant layout and architectural/interior design revealed no significant differences in approach to the design of factory office accommodation as opposed to offices in other contexts *(Ernst & Young 1986, Hodgett 1987, Lock 1973, Mills 1985, Neufert 1980, Pile 1976,1978)*.

For example, Paul Darrington, writing on the planning of offices in factories advises that "The design of offices usually offers no special problems once the type and extent have been established" *(Mills 1985:269)*. Neufert Architect's Data handbook, under sections dealing with industry and those addressing office planning, does not differentiate between office planning for factories as opposed to planning for the general context "offices" *(Neufert 1980)*.

As practical office planning/design is an aspect of interior design with which an interior designer would be familiar, and taking into account the quantity of reference material which is available on the subject, further investigation was limited to those aspects not commonly reflected in office design reference manuals but which may be applicable in factories.

6.7.1.1 Location

Factory offices are usually separated from the production areas so as to avoid spill-over of production associated environmental factors such as noise; except for shop floor (supervision) offices, which are located at or near production operations.

Offices may be located in a separate multi-storey building in order to utilise the cost saving afforded by multi-storey construction, as opposed to the advantages of housing production in a single-storey structure.

Historically, factory offices present the "best" view to the visitor, in that this section of the building probably receives the best architectural/interior design attention to decorative elements. As a result, offices are often orientated to face public view. This tendency is pointed out by Ferry in his biography on Albert Khan. *(Ferry 1970:8)*.

6.7.1.2 Improving standards by applying the open office concept

Assuming that one of the reasons for employing an interior designer to design office space would be with the aim of improving office conditions or "standards", a comparison of literature related to the field of environmental psychology was made in order to ascertain whether specific office layouts were perceived to show any greater or lesser overall contribution to the raising of general office standards. The following findings may be of value in this regard.

As pointed out by Becker, "a crucial variable in office standards appears to be the spatial proximity of the individuals in the organisational hierarchy" *(Becker 1981:38)*. This implies that the closer an individual is situated (physically) to top management, the better the working environment is likely to be.

This phenomenon can be tabled thus:

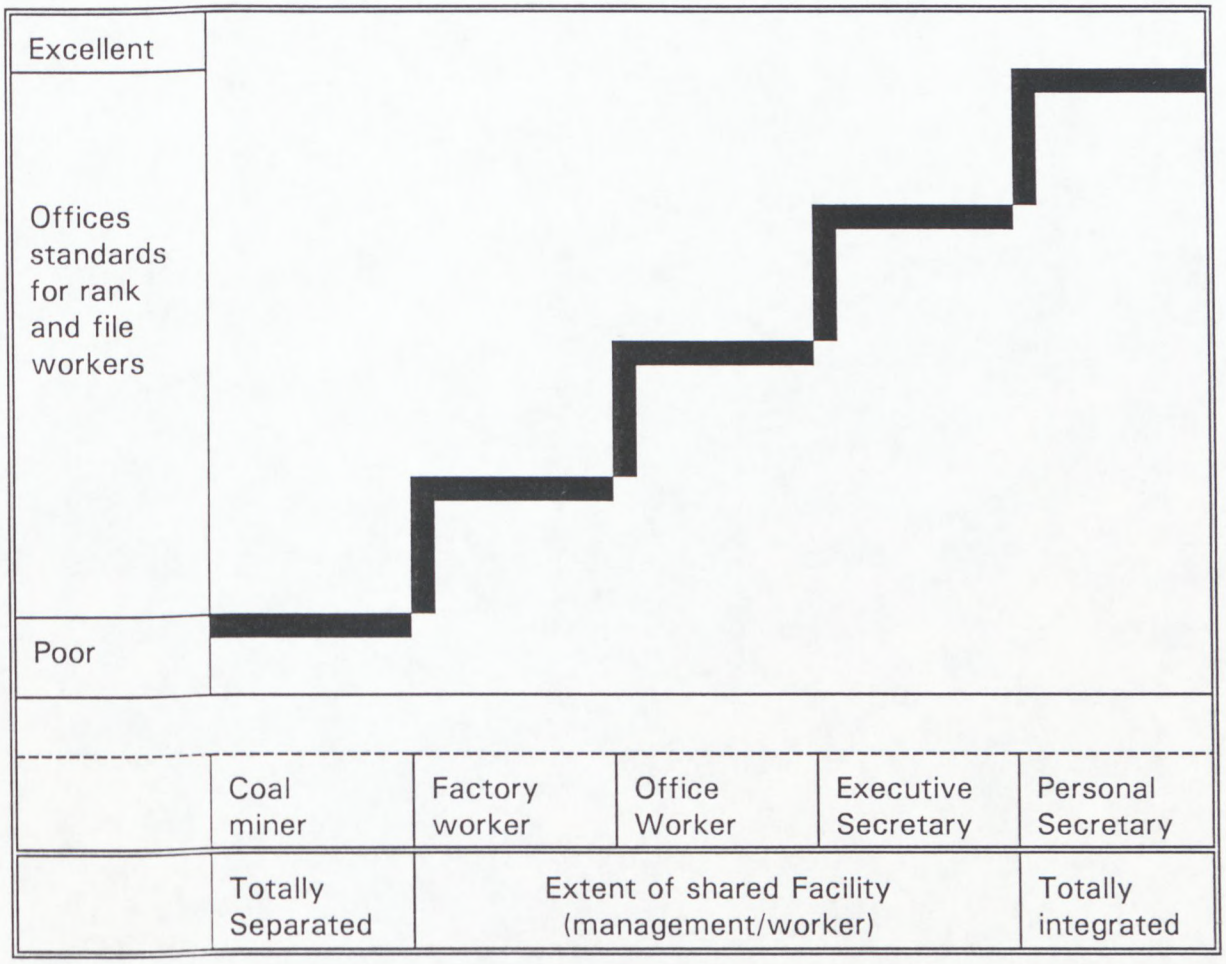


Table 8. Office Standards (as adapted from Becker). ***(Becker 1981:140).***

As depicted by the table, the conditions under which the coalminer works bears absolutely no relationship to the working conditions of those who own and manage the mines, hence the attention given to the miner's "office" is low.

At the other extreme, the personal secretary often works in conditions that overlap and essentially mirror those of her boss, hence her working condition standards are usually high.

The practical value of this phenomenon to an interior designer may be that, by incorporating a system whereby a majority of the hierarchy shares the same space and is subjected to the same conditions, improved office standards may be encouraged.

Becker is of the opinion that "the differences (in conditions) diminish even further in

the case of workers in landscaped offices because the environment, although designed to express subtle differences among levels (in the hierarchy), are essentially designed within a common framework or design vocabulary" *(Becker 1981:141)*.

This factor could be combined with other "plus" factors such as relatively low cost and high degree of flexibility when weighing the positive contributions of open plan office design against the negative aspects, such as lack of privacy and noise intrusion.

6.7.1.3 Management approach as an influence on office planning

Office planning usually incorporates the dynamics of the organisation by evaluating the physical manner in which administrative/management functions are carried out and incorporating the data regarding the organisation's information flow, communication levels and the like, into a physical layout.

However the management approach can also be viewed in a broader sense as being a "philosophy", or "approach".

The evolution of the management approach during the 20th century can be shown thus *(Megginson et al 1938)* :-

Management approach	Attends to	Typical application
1900 - Mechanistic/ Scientific	Motion study, adequate light and ventilation	Time is a critical factor in task accomplishment. High density of humans relative to the process.
1950 - Humanistic approach	The importance of social relationships in the working environment	Projects such as space programs (costs are "no problem"); Research projects, Charity organisations or organisations where workers are highly self-motivated.
1960 - Human Resources/ Systems approach	Utilise human skills. Attention to social needs	Seen as universal approach using what resources are available.

Table 9. Summary of management approaches

Sundstrom points out that office based organisations, such as insurance companies, have adapted their management approach in accordance with these tendencies and that office planning services have, due to market demand, supplied office systems to support the changes in management approaches. He cites an example of the Burolandschaft (Office Landscape) of the 1960's as perhaps having grown from the human relations movement in the philosophy of management *(Sundstrom 1986:42)*.

In their work on management concepts and applications, Megginson et al. adopt the viewpoint that scientific management is still the easiest, though not necessarily the best, for factory production where the managers' main responsibilities are to plan, direct and control the actions of their subordinates to obtain the highest output from them *(Megginson et al. 1983)*.

For an interior designer the implication may be that current office planning practice, although viewed as essentially the same for both office-based and factory-based organisations, may not be addressing the same management approaches in all instances. In a factory environment it is possible that office accommodation will have to cater for several, sometimes "old-fashioned", management approaches, such as the scientific approach listed in the above table.

The Engineer's Handbook in its section on the planning of office space warns:

> "One of the commonest errors in office planning is to decide which type of layout will be used without reference to the specific needs of each function. It is now usual to find companies that have taken an arbitrary decision to introduce landscaped layouts into their offices regardless of whether it is appropriate for either organisation or building" *(Lock 1973:251)*.

In order to avoid making recommendations on an arbitrary basis the following types of table may be used for evaluating the needs of each function. A rating of one to three is applied to the type of office layout and its main characteristic, as well as the importance of this characteristic to the proposed occupants of the space.

Characteristic	Open space	Open plan	Cellular		Half height partition	Carrel	Impor-tance
			Indivi-dual	Shared			
Privacy	2	-	3	1	1	2	-
Freedom from distraction	2	1	3	-	1	2	3
Communication	3	3	-	1	2	1	3
Flexibility	3	2	-	-	1	1	3
Supervision	2	3	-	1	1	-	-
Workflow	3	3	-	1	1	-	1
Space utilisation	3	3	-	1	1	2	-

Table 10. Office Planning Evaluation.

The above, which evaluates the office needs of a product development team, the value given to freedom from distraction, communication and flexibility are high. The order of choice in office planning could then be 1. open space, 2. Open plan, 3. Half height partition.

6.7.1.4 Office function types

A list of office types typically found in factories was compiled and is included for reference purposes.

- Boardroom
- Executive offices
- Management offices
- Design office
- Accounting and Finance

- General administrative offices (also for stores, maintenance shops, despatch and receiving points etc.)
- Data processing
- Production supervision offices
- Cashier's office
- Personnel (Interviewing and training)
- Reception
- Gatehouse (security) office.

6.7.2 STAFF FACILITIES

6.7.2.1 **Ablution Facilities**

This section of the study investigated differences between typical staff facilities found in factories and those found, for example, in large office buildings. Apart from differences in "luxury" standards, fittings and materials used were found to be essentially the same. Considerations may include:

i. *LOCKERS/CHANGING ROOMS*

Where staff have to wear clothing other than that which they wear en route to the workplace, for example protective clothing for dirty processes, lockers and changing rooms will be required. The following factors may affect the design of these facilities:

- Proximity to toilets - It is generally convenient to place lockers/changing rooms adjoining lavatories and wash facilities.
- Where shift work is the rule, locker facilities will be related to the total number of workers whereas toilet/washing facilities will relate to number of workers per shift.
- It may be usual to find a larger percentage of males on a night shift compared to a day shift which may affect planning.
- Catering staff will require separate facilities, usually in accordance with health regulations.
- Storage of soiled protective clothing for laundering as well as issue of clean clothing may be a requirement.

- For "dirty work" it may be necessary to supply two lockers per person or to partition lockers so as to prevent cross contamination between work and private clothing.
- According to Neufert, .5 m² per person for the changing area, should be allotted *(Neufert 1980:280)*.

ii. *TOILET FACILITIES*

The number of toilets required can vary according to the levels of hygiene specified by regulations governing the manufacturing process, for example food preparation industries require stricter control of toilet facilities than engineering industries.

In the absence of legislative guidelines, scales of provision such as those contained in the following table may be consulted.

Population (Male or Female)	Number of WCs and washbasins required. Urinals not provided
1 - 15	1
16 - 30	2
31 - 50	3
51 - 75	4
76 - 100	5
More than 100	Add 1 per 25
Population Male	**Number of WCs required, urinals provided**
1 - 20	1
21 - 45	2
46 - 75	3
76 - 100	4
More than 100	Add 1 per 25; 1 in 4 may be urinals
Population Male	**Number of urinals required**
1 - 15	0
16 - 30	1
31 - 60	2
61 - 90	3
91 - 100	4
More than 100	See above

Table 11. Scale of Provisions (ablution facilities). ***(Wise 1986:Table 11.1)***.

According to Darrington, it is better to have lavatory/washing facilities dispersed in large complexes in order to reduce loss of manhours (walking to and from facilities) and crowded conditions at peak times, for example at change of shifts *(Mills 1985:269)*.

iii. *SAFETY CONSIDERATIONS FOR ABLUTION FACILITY DESIGNS*

Some features in bathrooms are potentially unsafe. The following factors should be guarded against:

- Door swing should be planned to avoid the situation where a person entering is struck by the door being opened from within the room. Similarly, a person standing in the room should be in a position clear of the door swing.

- Light switches and electric outlets should be positioned out of reach of persons in contact with water.

- Non-structural towelracks should not be positioned so as to act as a potential supporting handrail.

- Fixtures, cabinets, controls, spouts and towel racks should have rounded edges so as to minimise the chance of cutting.

- The use of slippery floor materials in an effort to provide shiny, attractive surfaces should be avoided.

- The positioning of cabinets which causes people, when bending over, for example a washbasin, and leaving the door open, to bump their heads, should be avoided.

iv. *MAINTENANCE AND HOUSEKEEPING CONSIDERATIONS*

The following features may be considered in order to facilitate ease of cleaning and maintenance of ablution facilities:

- Surfaces should be as seamless as possible to avoid the trapping of dirt.

- Hardware and fittings should be as "smooth" as possible, as a filigree entraps water, soap and dirt and is difficult to clean.

- Hardware choice should include consideration for replacement parts availability.

- Suspended cabinets are preferable to floor mounted features as floor mounted features tend to collect dirt at the base which is difficult to clean with conventional broom or mop.

- If the design accommodates plumbing within walls, care should be taken in the initial planning phase to provide adequate access points for servicing.

- Toilet seats invariably become damaged. Fixtures which feature easy/economic replacement may be a consideration.

- Toilet cisterns with fast refill cycles, or flushvalves, should be specified as this can be a critical factor in efficient toilet operation especially in high demand conditions.

- Finishes in factory ablution facilities should make provision for "heavy" use. Finishes such as vinyl sheeting or tiles can usually be specified for differing levels of use. Painted surfaces should be washable. Consideration should be given to future availability of fittings/finishes for repair purposes.

Personal experience has shown that most manufacturers of fixtures and fittings for ablution/toilet facilities produce an "industrial range". Generally speaking, these ranges are lower priced, but do not necessarily reflect features, either functional or aesthetic, which contribute to effective interior design in factories. For example, industrial range toilet bowls are invariably mounted with slowly refilling, wall mounted cisterns. Frustration at not being able to flush the toilet results in continual cranking of the flushing handle which subsequently breaks.

Items such as toilet seats, toilet door latches, ceramic tiles, mirrors and coat hooks cannot be designed to be unbreakable. The next best course of action may therefore be to design so that these types of items are readily replaceable.

6.7.2.2 **Medical Facilities**

Medical facilities in the factory can range from first-aid boxes (usually required by legislation) to small hospitals, usually found at mines. A compromise which may be found in most medium-to-heavy industry factory buildings is the "first-aid room".

Planning of this type of space may include the following typical features:

- Natural lighting and suitable ventilation.
- A glazed sink with hot and cold running water.
- Toilet facilities should be within close proximity or else could be provided adjacent to the room.
- Smooth-surfaced table tops, or counterspace.
- A means for sterilizing instruments.
- Space for a couch and stretcher.
- Suitable storage place for medical supplies and equipment.
- There may be separate facilities for males and females.
- The first-aid facility is often positioned close to the personnel office as personnel staff are usually required to be trained in first aid.
- In the case of a full-time nurse being employed, a suitable workstation for administrative duties may be provided.
- Generally, the fittings, finishes and colours in the sickroom may be designed so as to project an image of modernity, or progressiveness, so as to inspire confidence on the part of the patient *(Becker 1981:101)*.

6.7.2.3 Restrooms/smoking rooms

If smoking is not permitted in process areas, provision for designated smoking areas with suitable fire safety/anti-contamination precautions may be necessary. In large processing operations this type of accommodation could be distributed locally to users so as to reduce time spent travelling to them. Where processes demanding high concentration or worker fatigue are carried out, the opportunity to relax at intervals may be provided in the form of "rest" rooms or areas.

6.7.2.4 Restaurant and catering facilities

According to Jones, in his book on the topic of food services operations, the first world war was the main contributing factor to the employment of the food services industry in factories. A severe rationing of foodstuff at a domestic level meant that industry had to provide nourishment to its workers in order to maintain productivity *(Jones 1983:12)*.

He is of the opinion that industrial workers (in the U.S.A.) currently consume 40% of the food processed by the catering industry and that 30% of people who eat out do so at the workplace *(Jones 1983:75)*.

The implication, therefore, is that the eating facility designed for the factory staff may be the only "eating out" opportunity experienced by a large percentage of the population.

As this factor may have social significance for the designer in South Africa, telephonic enquiries were directed to various catering industry sources such as "Fedics". However, statistics for South African conditions were unavailable and it can therefore only be speculated that the abovementioned percentages may be higher in South Africa.

i. *FOOD SERVICE METHODS*

A comparison of literature by Carson, Jones and Terrel on the subject of food service methods, costs to the company and speed of service, revealed that four main service methods are used, sometimes in combination, with various advantages/ disadvantages inherent in each type ***(Carson 1972, Jones 1983, Terrel 1979)***.

This information was compiled into the following guideline:

Cafeterias - feature a full meal (menu) service, with seated eating areas. These facilities can be either company run, or the work can be contracted out to professional caterers.

Snack Bars - Take-away facility with limited seating.

Lunch Wagons - Serve limited meals or take-aways at, or near the main production area.

Vending Machines - Usually automatic machines serving snacks and cold/hot beverages.

The advantages and disadvantages of various systems are tabled as follows:

	CAFETERIA		SNACK BAR	LUNCH WAGONS	VENDING MACHINES
	COMPANY	CONTRACT			
FOOD					
Quality	varies	uniformed	varies	varies	uniform
Variety	unlimited	slightly limited	somewhat limited	limited	limited
Sanitation	difficult	-	easier	difficult	easier
Price	low if subsidised	low if subsidised	low if subsidised	medium	low
Nutrition value	good	good	fair	fair	poor
COMPANY COSTS					
Installation	high	variable	moderate	low	low
Space	high	high	moderate	little	little
Subsidy	high	high	moderate	moderate	little
Cleaning	high	-	moderate	moderate	moderate
Janitor	many employees	-	few employees	some employees	-
SERVICE					
Speed	slow	slow	faster	fast	fast
"Open" period	limited	limited	limited	limited	always
Distance from workspace	remote	remote	remote	local	local
Personal touch	yes	yes	yes	maybe	no
Reliability	good	good	good	good	varies

Table 12. Comparison of food service methods.

ii. *PLANNING OF ON-SITE CAFETERIA FACILITIES*

In comparing the designs of factory cafeteria facilities and those of commercial restaurants, it was apparent that the factory facility shared a common goal with some commercial ventures in terms of designing for a fast entry/service/eat/exit time cycle. In a commercial venture this may reflect the need for fast customer turnover in order to boost profits.

In the factory environment the motive, although economic, was found to be slightly different in that, firstly, the more efficient the space (in terms of service time), the smaller the space required to cater for a fixed number of people - hence lower space costs. Secondly the higher the turnover per unit space, the lower the costs per person served will be, and therefore the lower the prices of the food would have to be in order to meet budget figures.

This emphasis on fast service was the only significant difference found between the practical design of factory facilities and those of a commercial nature. Due to the quantity of reference material which is available regarding the design of catering facilities, the remainder of this section of the work was limited to aspects of cafeteria design which may facilitate faster service cycles.

iii. *GENERAL DESIGN CONSIDERATIONS*

These may include:

- Menus and prices should be displayed prominently and as early as possible so that the decision-making process regarding menu choice is at least partially completed before reaching the actual service point.

- Menus should be designed so that availability of foods can be indicated.

- Self-service should be promoted where possible.

- Non-consumable items such as cutlery should be positioned after the service process is completed, usually after the cashier (this is to prevent crowding).

- Seating must be adequate.

- The design may encourage cleaning by the client, for example tray collection points.

- Staggered lunch hours will mean an even demand on catering facilities as demand will be more evenly spread.

iv. CAFETERIA LAYOUT TYPES AND CHARACTERISTICS

"In-line" counter plan

"In-line" counters (Figure 20) comprise a single counter along which a customer passes to select food and beverages. The process efficiency may be enhanced by:

- Keeping the single counter in a straight, continuous line. Customers tend to chat as they move their trays along and there is a tendency to push the tray off the counter at corners.

- Food serving facilities should be arranged along the counter in menu order.

- Limit counter length to the minimum. Because the effect of one person stopping in the queue system means that everyone has to stop, it follows that the longer the queue, the slower it will move.

"In-line, double queue" counter

By dividing the single counter into two equal sides (See Figure 21) a double queue can be formed. This arrangement will require a duplication of service at the counter, as well as a duplication of cashiers but will double the service speed.

"Free-flow" system

Split single counter plans and parallel counter plans would service approximately four to eight customers per minute.

In order to double this quantity it becomes necessary to incorporate a "free-flow" system (See Figure 22) where several counters serve different meal items, for example

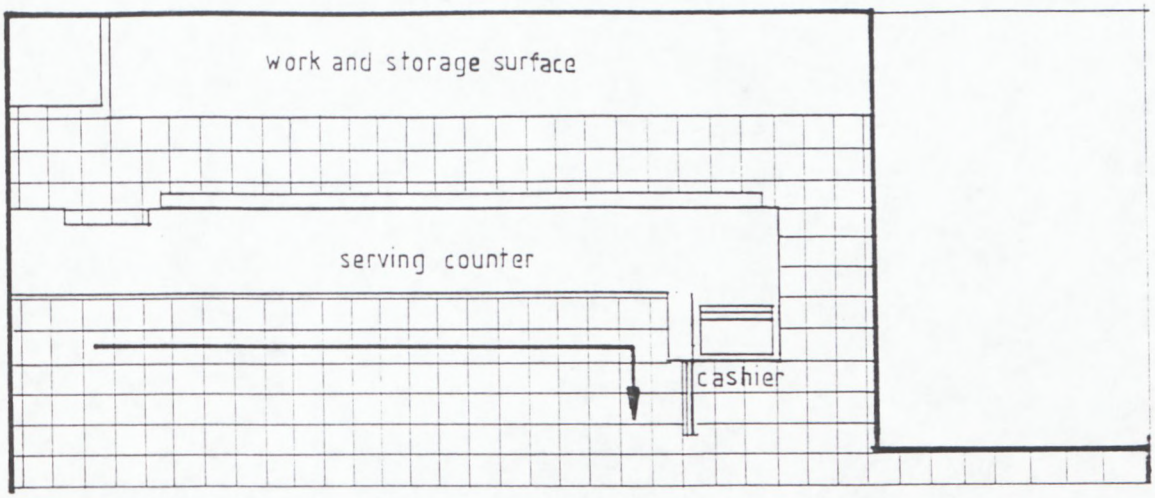


Figure 20. "In-line" restaurant counter plan.

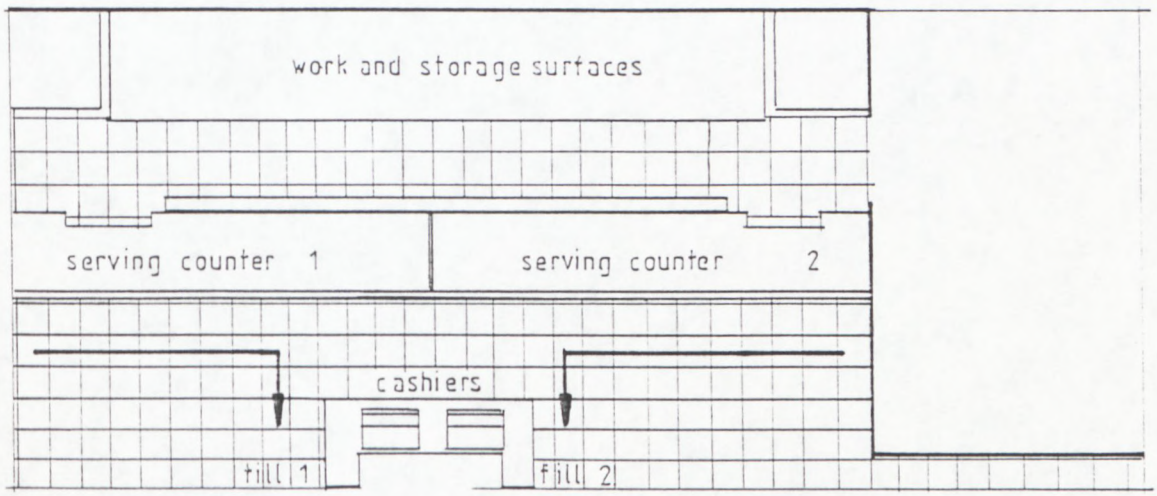


Figure 21. "In-line double queue" restaurant counter plan.

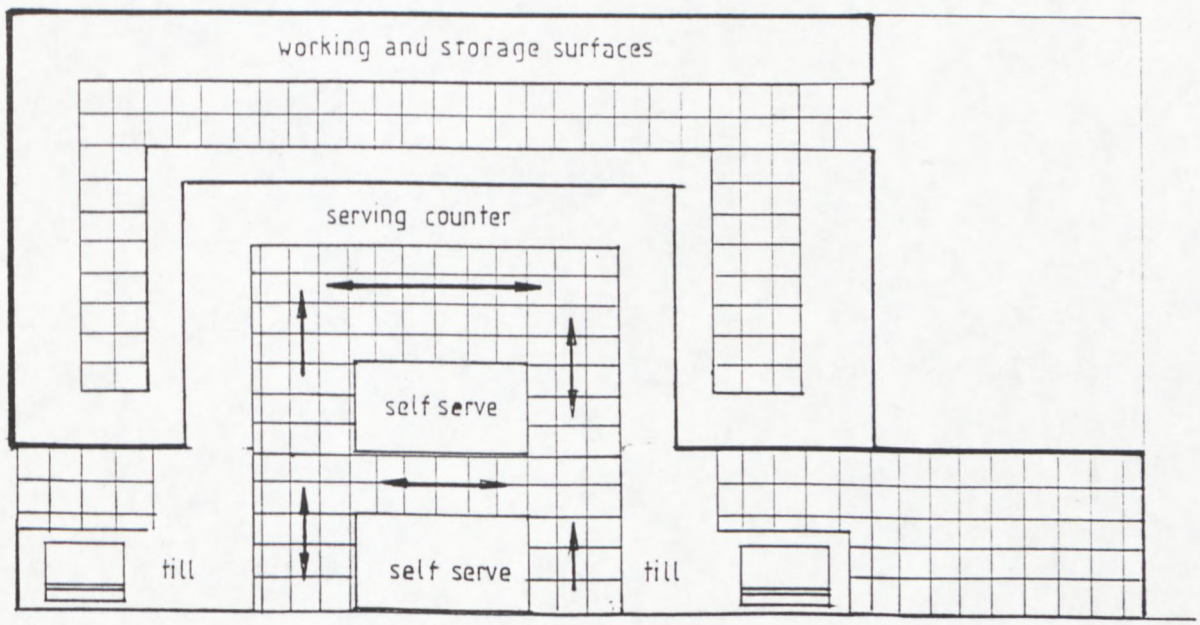


Figure 22. "Free-flow" restaurant counter plan

salad bar, hot foods, beverages, breads and cheeses etc. This arrangement requires more space but is more efficient for the following reason:

- Customers wanting limited items such as snacks or salads do not have to wait in the main food service queue.

- Queues will generally be shorter resulting in faster general movement.

- A separate call order counter for grills can be operated. Customers waiting for their orders do not then hold up the queue for other men items.

- Selected counters can be closed down during slack period.

- A main plate can be served with additional items such as salads, breads and beverages being self-serve items.

v. CALCULATION OF SEATING REQUIREMENTS

A recommendation regarding the space requirements of a staff cafeteria may have to be made at the planning stage of a factory layout. Jones recommends that a figure of 30% of the workforce be used as a base figure for estimating space requirements *(Jones 1983:82)*.

For example, if the total workforce is 900 then the total clientele will be 300. If the lunchbreak is staggered in three shifts then each shift will produce 100 potential clients.

If the lunchbreak is not staggered in steps of time which are longer than the average duration of a meal consumption, then seating accommodation will have to be doubled or trebled. For example, a continuous demand, served at a rate of 15 persons per minute, eating for an average time of 15 minutes each, will require 225 seats in order to prevent queuing. Once the estimated seating requirement is known, the figure can be quantified into floor area using standard design procedures.

A list of areas which may have to be planned for is included for reference purposes:

Kitchen	Receiving area	Manager's office
Employees' Facilities	Storage areas	Salads & fruit preparation area
Cooking centre	Baking centre	Sandwich centre
Cleaning centre	Dining area	Serving areas.

6.7.3 QUALITY CONTROL LABORATORIES

Quality control laboratories in the factory context function as part of the inspection and testing process for checking both functions and appearance of the product.

From the literature review it was evident that reference guidelines such as Neufert Architects Data contained information specifically for the design of laboratories, but that they referred mainly to science facilities such as those found in a chemistry laboratory.

A comparison of related literature by Lockyear, Herzog and Roseler resulted in the establishment of the following design considerations which could supplement the information contained in design reference handbooks *(Lockyear:1974, Herzog:1985, Rosaler:1983)*.

6.7.3.1 A dry bulb temperature of 68 degrees Fahrenheit, plus/minus two degrees, is required for the use of some calibrated measuring instruments. For example, measuring instruments manufactured from metals will deliver differing readings according to temperature.

6.7.3.2 Air filtration may be necessary in, for example, food or chemical testing laboratories.

6.7.3.3 In rooms where high standards of measuring accuracy is required, the laminar air flow should be as even as possible. This usually implies multiple air delivery and exhaust points.

6.7.3.4 Vibration sensitive measuring equipment should be positioned away from high traffic areas and may require anti-vibration mountings.

6.7.3.5 Lighting should be sufficient for the task at hand. Attention may be given to lighting levels, modelling characteristics, colour rendering and special lighting such as black or ultraviolet lighting. The potential effects of radiant heat from lighting on sensitive measuring instruments may also be a consideration.

6.7.3.6 Cleanliness will usually be a consideration in the design of quality testing facilities. This implies attention being given to finishes in terms of ease of cleaning, smoothness and minimum joints/seams, as well as colour and its ability to show up dirt and dust.

6.7.3.7 Planning may include providing for individual workstations as well as facilities for administrative processes.

6.8 WASTE GENERATION, STORAGE AND DISPOSAL

Waste disposal can range in complexity from the collection and disposal of a few unserviceable components in an electronics assembly area to the management of hazardous waste generated at a nuclear power station. A study of plant management, engineering and architectural handbooks was made in order to establish potential elements of waste management which an interior designer may have to plan for in the factory interior *(Birrer:1966, Clark;1983, De Chiara:1974, Kemper:1979, Perry:1984)*.

The following table lists various professions and their related contributions to waste management. As indicated by the table, an interior designer's role would generally be restricted to planning for the management of human waste and waste generated by both human and process at the workstation.

FIELD	WASTE MANAGEMENT PLANNING
Production/Plant Engineer	- Process waste
Civil/Structural Engineer	- Site drainage - Underground storage tanks - Main sewer connections
Designer (interior/architect) and Engineer	- Human waste - Building planning for human, natural and process waste transportation - Workstation waste generation and storage
Cartage contractor	- Collection and transportation from site

Table 13. Waste Management Planning.

Waste products are subject to a cycle which may include the following steps: waste generation; temporary storage at point of generation; removal for sorting/processing/recovering/decontamination, longer term storage and, finally, cartage off site.

Solid, liquid and gaseous wastes in the factory context may be generated either by **humans/human related activities** or by **processes used to manufacture a product.**

6.8.1 HUMAN RELATED WASTES

These can include:

- **Smoke** - Caused by cigarette smoke and cooking
- **"Domestic" wastewater** - from washing facilities
- **Food waste** - generated by both workers and cafeterias
- **Rubbish** - solids other than food
- **Waterborne/solid waste** - toilet outlets.

The collection, storage and disposal of these waste products may be dealt with in the same manner as for domestic housing, restaurant design or office building design. Certain aspects of both human waste and process waste disposal may be combined for cost saving purposes, but this possibility will have to be evaluated for specific variables, probably in consultation with the architect, civil engineering consultants and the relevant local authorities.

6.8.2 PROCESS RELATED EFFLUENTS AND WASTES

6.8.2.1 **Air Pollution**

These pollutants are produced in gaseous and particulate forms. Gases include true gases such as sulphur dioxide, as well as vapours such as petroleum vapour. Particulates include divided solids (dust) and divided liquids (mist).

Air pollutants which are harmful to humans are usually dealt with by two methods. The first, and probably most important method, is local exhaust ventilation. The second control measure is good housekeeping.

i. LOCAL EXHAUST VENTILATION

Local exhaust ventilation involves the trapping and carrying off of dusts fumes or vapours. Methods employed include extractor hoods, plenums and other forms of collectors which are placed at the source of pollution generation in order to extract/filter/trap the polluted air.

These devices are designed, usually by specialists, so that the volume of air which they treat is matched to the volume of pollution which is produced. It is important that these devices operate in such a way that the harmful substances are removed **before** being inhaled by the worker, or damaging equipment and finishes.

From experience, it has been noted that an interior designer should give consideration to design of these devices for the following reasons

- Ergonomics - because the extraction of air pollutants is often a mechanical engineering problem, the design of extraction equipment will often be a mechanically orientated process, rather than human, orientated exercise.

  Thus it may occur that an overhead extractor hood is placed close to a bath of volatile liquid in order to prevent toxic fumes escaping. This positioning may prevent the operator from observing the process without inserting his head below the hood thereby being exposed to the fumes.

- Extractor hoods invariably have to be surface treated in order to prevent corrosion. When developing an interior colour scheme, extractor hoods and exposed ducting may be treated as decorative elements.

ii. *HOUSEKEEPING*

Dust which is allowed to accumulate on floors and machinery can be disseminated to other parts of the plant. Interior surface treatments may assist in the prevention of dust accumulation, for example the use of smooth surfaces, anti-static finishes or paint finishes in colours that will show up dust and dirt.

6.8.2.2 Waste Water

Industrial waste water usually results from either the manufacturing process or from a cooling process.

i. *PROCESS WASTE WATER*

Processes such as product washing, plating and chemical bathing, or washing down of the production areas as in food processing, can produce waste water. The collection, storage and disposal of this type of waste would form part of the production process and would therefore generally form part of the engineer's design.

An interior designer may however, have to consider the likelihood of spills and leakages when specifying finishes for the areas where these accidents may occur.

Also, interior partitioning/entrances/exits/windows may have to be designed so as to prevent cross contamination, for example where toxic matter is washed down in an area adjacent to another space occupied by humans.

ii. *COOLING WASTE WATER*

"One pass" cooling water, unless contaminated, is often returned to the environment as, for example, in the case of nuclear power stations. In some instances the use of cooling water for the heating of the workspace (energy conservation) may be employed. Contaminated water is either stored in storage tanks for later removal, or it may be processed in order to decontaminate it.

6.8.2.3 **Solid Waste**

A graphic representation of the management of waste generation, storage and collection is shown overleaf.

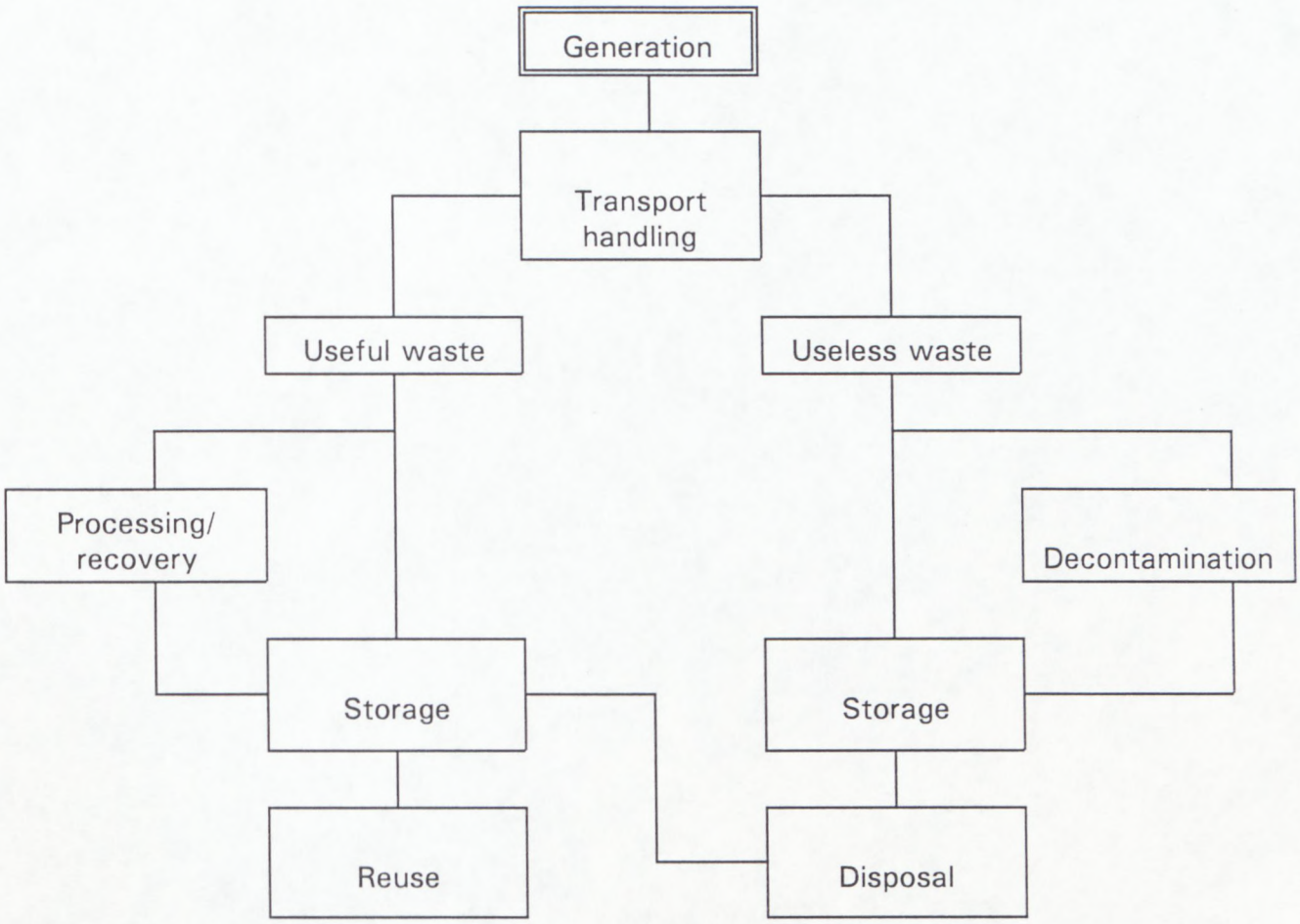


Figure 23. Diagram showing waste generation, storage and disposal sequence.

In the context of the factory interior, designing for solid waste management may encompass: planning for the collection of solid waste at the point of generation; the temporary storage of waste at the workstation; the subsequent transporting of waste out of the building.

Consideration may include:

- Access for removal of the waste should be planned so as to minimise disruptions in the work process.
- Some machinery may incorporate a waste collecting mechanism which may have to be incorporated into the general waste disposal system.
- Separate containers may have to be provided for the presorting of waste at the point of generation; for example sorting metals into ferrous and non-ferrous waste.

- Hazardous waste will generally be handled by specialist personnel and will be stored and transported in special containers. The physical features of such a system may have to be accommodated in a workstation design.
- Storage bins should be easy to clean and finishes should be durable.

6.9 SERVICES

The planning and installation of water, gas ventilation, heating and cooling services in the factory were found to be congruous to applications in the office building or commercial shopping centre context.

However, as pointed out in the Architects Handbook:

> "Increasing building costs, stricter control on building construction, greater demands for better internal environments, increasing energy costs, the need for flexibility to provide for changing uses of the building, all point to early analysis of building services ... Increasingly the benefit of closer integration of the specialists (involved in planning the factory) are being realized, in terms of both design and construction.
>
> The integration of services in the factory context implies the incorporation of services into the factory building so that they form part of the factory building and are not 'tacked on' after the building is built. In order to obtain a high level of integration it becomes necessary to co-ordinate the planning of services so that their installation does not interfere with existing services or with the building structure and finishes"
> *(Mills 1985:131).*

This need for integration and co-ordination can be coupled with the need for system flexibility[6] and may be promoted through factors such as:

- The design of the building structure should facilitate ease of access to services with a minimum of damage to the structure and finishes, for example through the use of removable panels in the case of above-ceiling or under-floor services.

- Ducting and piping should be fastened to the building structure so that it is easily removable.

- Systems should be as standardised as possible so that future alterations can be carried out using standard components.

- Equipment needed to operate the systems, such as cooling plants, compressors, flow capacities of ducts and pipes etcetera, should have sufficient capacity to supply future service requirements.

- Consideration should be given to the possibility of a decrease, as well as an increase, in the demand for services.

- Consideration should be given to the flexibility of the actual system, for example, an unused branch of an air conditioning system could be shut down if the correct gear had been specified at installation.

6.9.1 SERVICES PLANNING

Although the findings of the study indicate that planning for services in the factory context is essentially the same as that for buildings in other contexts and should, therefore, from part of an interior designer's experience, further guidelines in respect of water services, gas services, cooling services, space heating services and ventilation services are included in Annexures A to E.

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[6]Flexibility of operation is seen as a desirable feature in industrial-type buildings ***(Macmillan 1979:100, Carson et al 1972:16.37, Neufert 1980:264)***.

The rationale for this inclusion is that some of the service requirements may have to serve both human and process requirements (for example ventilation), hence specifications may have to be co-ordinated.

Also, the checklist refers to certain process related services which would not normally appear in the specification for a building outside the factory context. For example, in the case of distilled water supply, an interior designer may need to address the problem of indicating which taps are for drinking water, as opposed to distilled water supply.

6.10 INSTALLATIONS

In this part of the study, a comparison was made between specifications for typical installations in the factory interior and those specified for spaces which traditionally fall within the scope of interior design resulting in the following findings:

6.10.1 ELECTRICAL POWER SUPPLY

For large industrial developments where electrical current requirements are high, or more complex in nature than that which can be supplied by normal public mains, specialist consultants may be appointed to carry out the required estimates and planning in respect of power supply and generation.

For conventional power supply systems drawing supplies from public electricity mains, planning considerations were found to be essentially the same as for commercial or domestic buildings.

Although these aspects may already form part of an interior designer's design experience, typical planning considerations[7] for electrical power supply installations are reflected in Annexure F.

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[7]Planning considerations were synthesized from information reflected in publications by ***(Bates:1978, Henderson:1972, Keyte:1981, Lyons:1959, Mills:1985, National Building Research Institute:1982, Neufort:1980, Rosaler:1983)***

6.10.2 ILLUMINATION OF THE FACTORY INTERIOR

The purpose and benefits of good industrial lighting are summarised in the following figure.

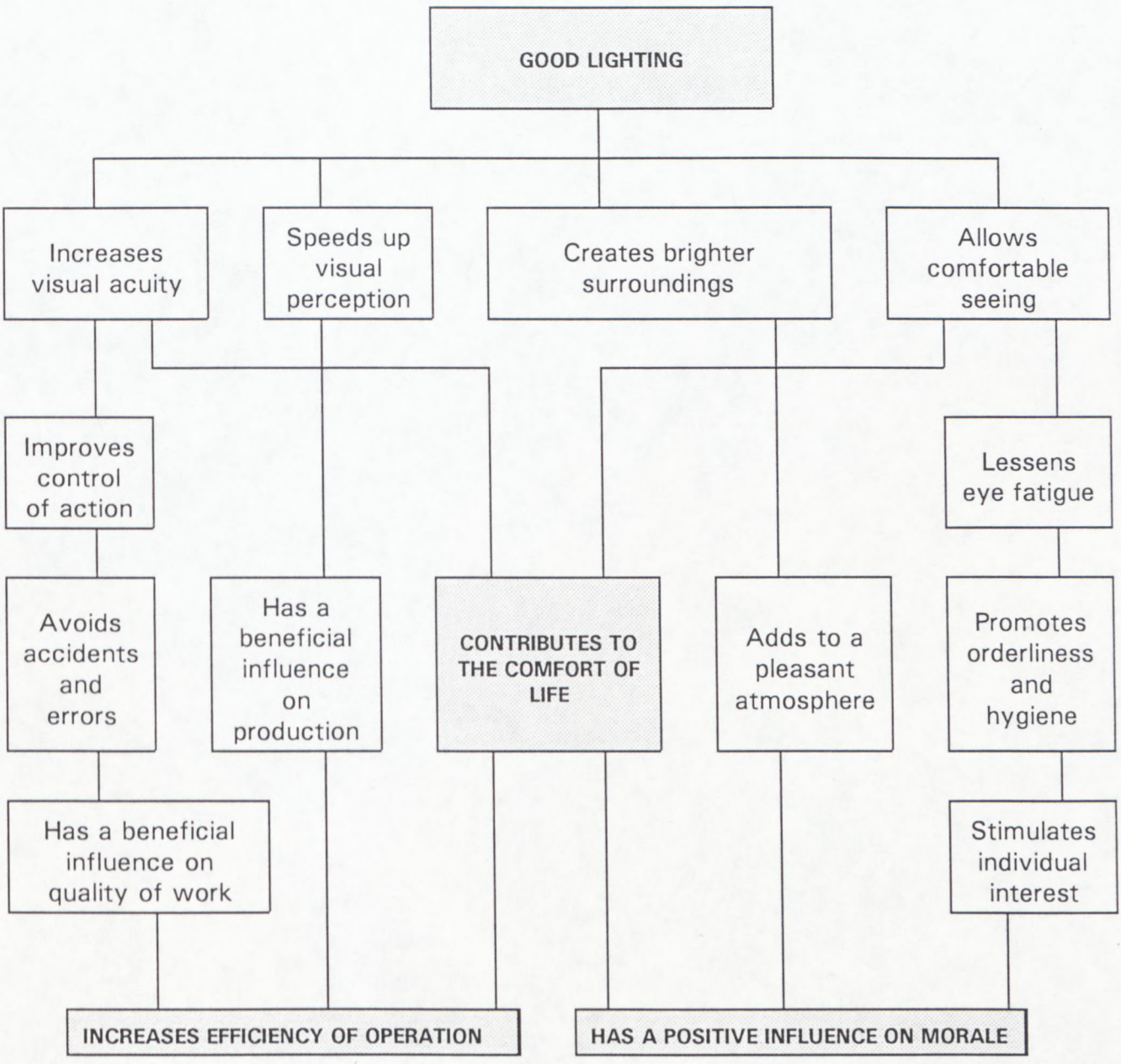


Figure 24 Purpose and benefits of good lighting ***(Verhey 1976:32)*****.**

A comparison of publications pertaining to the illumination of the workplace, revealed that lighting system selection and application principles were congruous for both factory and other types of interiors such as offices.

However, opinion as to existing factory lighting conditions indicated that factories are poorly illuminated in comparison with offices, with no apparent reason other than the possibility that people have lower expectations for factory conditions.

Verhey, in his paper delivered to the East Cape Regional Industrial Co-ordinating Committee, stated "For reading clear black printing on white paper, one requires less lighting than to read an oil-stained blueprint, despite which there is a tendency to provide better illumination in offices than on the factory floor" (*Verhey 1976:32*).

Boyce, commenting on ergonomics in lighting, is of the opinion that

> "Emphasis in factory lighting is on the effect it has on work and not comfort ... criteria relating to comfort, for example Glare Indices, are much less stringent than is the case for offices. There is no logical reason why this difference in criteria should occur. People who work in factories are not different from those who work in offices. Once again it is a matter of expectations" (*Boyce 1981:325*).

An interior designer, whose training and experience regarding lighting would be based on the "higher standards" required of installations in workplaces such as offices, may note the tendency for poorer illumination in factories and utilise his experience in order to improve factory lighting conditions.

Further aspects of factory lighting which were identified during the investigation into the subject of illumination and which may require consideration (see also section 6.4.1.1) include:

6.10.2.1 Artificial Lighting Installations

Based on guidelines by Verhey and the National Building Research Institute, the following list of lamp types, typical characteristics and conditions for economic use were compiled for reference use *(Verhey 1976:33, National Building Research Institute 1982:90)*. These guidelines refer to general lighting only, as task lighting would have to be designed for specific needs.

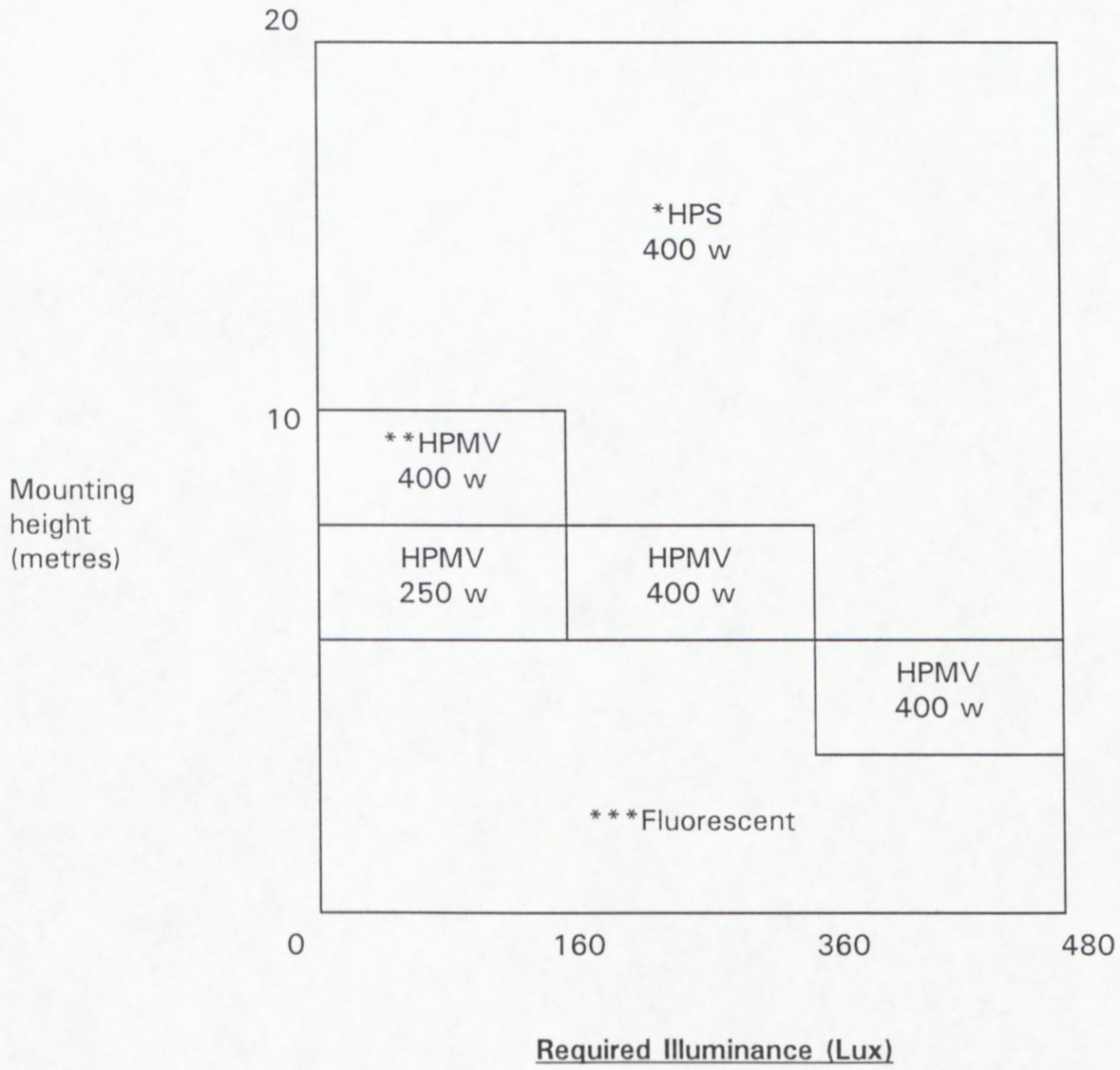
Light Source	Output range lm/lamp	Control gear loss %	Rated life h	Lamp efficacy lm/W
GLS incandescent	200 - 27500	-	1000	8 - 18
Tungsten halogen incandescent	200 - 3300	-	1000 -	15 - 22
Low voltage incandescent	100 - 800	-	2000	15 - 18
High efficacy fluorescent	800 - 8700	20	350 - 1000	55 - 80
Improved colour fluorescent	400 - 6500	20	7500	25 - 55
Colour-corrected mercury	1800 - 54000	7 - 30	7500	36 - 54
Tungsten-ballasted mercury	2500 - 11500	-	7500	16 - 23
High pressure mercury	24000-280000	14 - 22	6000	60 - 80
Phosphor-coated metal halide	27000 - 85000	14	7500	68 - 85
Low pressure sodium	4500 - 27500	20 - 80	7500	105 - 160
High pressure sodium	19500 - 38000	12 - 20	6000 6000	78 - 95

Light Source	Relative source size	Relative lamp cost	Colour rendering (1 - 4)	Recommended for use in factory interior:
GLS incandescent	Small	Low	3	No
Tungsten halogen incandescent	Small	Medium	4	No
Low voltage incandescent	Very Small	Low	3	No
High efficacy fluorescent	Large	Low	2	Yes
Improved colour fluorescent	Large	Low	4	Yes
Colour-corrected mercury	Medium	Medium	2	No
Tungsten-ballasted mercury	Medium	Medium	2	No
High pressure mercury	Small	Quite high	2	Yes
Phosphor-coated metal halide	Medium	Quite high	4	Yes
Low pressure sodium	Large	Medium	1	No
High pressure sodium	Medium	High	2	Yes

Table 14. Comparison of light sources for industrial lighting.

From the above table it can be deduced that low efficacy, poor colour rendering and short lamp life, limit the choice for economic factory lighting to the use of fluorescent, high pressure mercury vapour and high pressure sodium lamps.

This information can be summarised in the form of a table representing the established place of the fluorescent tube for low level factory lighting, and the growing importance of the high pressure sodium lamp as follows:



*HPS : High pressure sodium lamps
**HPMV : High pressure mercury vapour lamps
***Fluorescent : Fluorescent tube lighting

Table 15. Economic use of indoor industrial light fittings ***(National Building Research Institute 1982:93).***

Mention should also be made of the potential stroboscopic effects of fluorescent lighting. This phenomenon, induced by the cyclic heating and cooling of fluorescent tubes (100 cycle flicker) may cause rotating or reciprocating machinery to appear to be running at speeds other than actual speed.

As pointed out in the Interior Design Lighting Handbook, this is "a danger more apparent than real, since there is no known report of an accident due to this cause" *(Design Lighting Handbook 1967:44)*.

6.10.2.2 Fixture Servicing

The efficiency of the lighting system may be enhanced if the proposed installation is easy to clean and maintain, as explained by Woodson et al. :

> "The ease with which light fixtures can be cleaned and relamped is perhaps as important as the overall lighting system design concept. It has been estimated that a typical lighting system output is reduced by 25 percent six weeks following its installation" *(Woodson et al. 1992:323)*.

The following service features are summarised from Woodson for consideration:

- Where possible, fixtures should be accessible by means of a stepladder. Crawl space access, excessive heights and the use of specialist access mechanisms should be avoided.

- Intervening panels (reflectors, diffusers, louvres) should facilitate removal for servicing without the use of specialist tools.

- Light filtering or light distributing panels or covers should be made of materials that do not discolour with age.

- Fixture housings should be designed so that there is sufficient clearance to manipulate lamps for removal/replacement.

- Fixtures which allow dust to drop through naturally, or are sealed against dust and dirt collection may maintain lamp efficacy for longer periods of time.

(Woodson 1992:323).

6.10.2.3 Energy Saving

The following considerations for facilitating energy saving in lighting installations are summarised from Woodson:

- Design of circuits so that selected components of the lighting system can be turned off; the remaining components should still create a balanced, but less intense, light distribution.

- Provide a central switching component with which the "last person to leave" can turn off the main lighting circuit.

- Light sensitive photo-electric cells may be utilised to automatically switch off selected circuits if natural lighting levels are adequate.

- The use of task lighting to supplement general lighting can reduce the total light output required, as the higher luminance levels necessary for carrying out the task is limited to the work area.

(Woodson 1992:323).

6.10.2.4 Natural Lighting

Natural lighting is provided by openings in the building envelope such as doors, windows and various forms of rooflight. For the purposes of the study it was assumed that, although an interior designer may have to make recommendations regarding the positioning of windows and doors to, for example the architect, the final decision regarding the design of the building envelope would rest with the building envelope designer.

The following factors may require consideration by an interior designer, either because a recommendation is required regarding the positioning of windows in a new building, or in order to make better use of existing natural lighting conditions.

i. *THE EFFECT OF WINDOW POSITION ON NATURAL LIGHTING*

The effect of various types of window opening on surface luminance in the factory interior are illustrated in Figure 25. These factors may be taken into consideration when making recommendations regarding either window, or equipment positioning.

Machinery types may also be orientated relative to natural light sources so that the "workface" receives the most natural light for example:

- Shapers - The working side should face the light source (rooflight or sidelight).

- Milling machines - at right angles to the light source.

- Planers - with the axis at right angles to the light source.

- Lathes - with the axis at right angles to the light source and with the chuck facing the source.

- Where there are rows of racking or equipment, these should be placed at right angles to light sources so that the rows do not shade one another.

ii. *REFLECTANCE RANGES OF INTERIOR SURFACES*

An important aspect of the lighting of interior spaces is the use of interior surfaces that provide adequate reflectance.

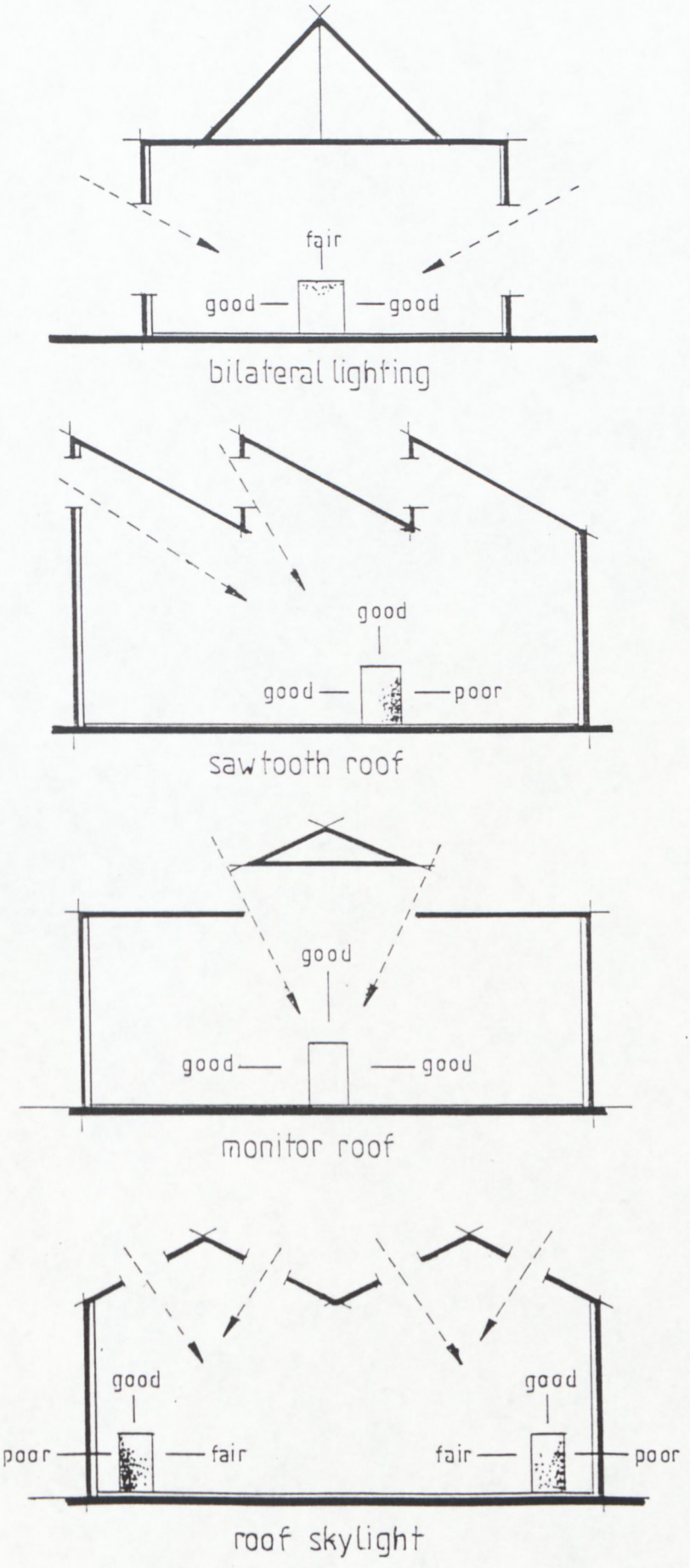


Figure 25. Effects of window light on surface illuminance.

The following table of suggested reflectance factors was compiled from recommendations by Woodson and others. *(Timesaver standards for interior design 1991:1013, Interior lighting design handbook 1967:15).*

Interior surface or element	Percentage reflectance required
Ceilings	60 - 90%. Surface should have a white, pale tint or reflective finish that is compatible with the proposed colour scheme. A minimum of 80% reflectance is required for effective visual performance of indirect lighting methods.
Walls	50 - 85%. When the wall consist of two different reflectance values (i.e. a lower "dado" is used to reduce the expected soiling of the lower wall) a higher value reflectance may be applied from the waist up.
Window covering (e.g. blinds)	Fabric or other drapery provisions should maintain an average reflectance factor of at least 15 - 45%.
Furnishing	30 - 40%. Working plane surfaces may have higher reflectance ranges in order to avoid high contrast between task and working surface.
Floors	15 - 35%. Middle values may assist visual detection of possible obstructions on the floor which might otherwise cause tripping.

Table 16. Reflectance levels.

The handbook "Timesaver standards for interior design and space planning" gives reflectance values for various interior finishes as follows:

Colour	Approximate percentage reflection
White, matt	78 - 85
White, gloss	85 - 90
Light tints	
Cream or eggshell	79
Ivory	75
Pale pink and pale yellow	75 - 80
Light green, light blue, light orchid	70 - 75
Soft pink, light peach	69
Light beige, pale grey	70
Medium tones	
Apricot	
Pink	56 - 62
Tan, yellow gold	64
Light greys	55
Medium turquoise	35 - 50
Medium light blue	44
Yellow green	42
Old gold, pumpkin	45
Rose	34
	29
Deep tones	
Cocoa brown, mauve	
Medium green, medium blue	
	24
Dark colours	21
Dark brown, dark grey	
Olive green	
Dark blue, blue green	10 - 15
Forest green	12
	5 - 10
Natural wood tones	7
Birch and beech	
Light maple	
Light oak	35 - 50
Dark oak, cherry	25 - 35
Redwood	25 - 35
Black walnut, mahogany	10 - 15
	10 - 15
	5 - 15

Table 17. Reflective Values ***(Timesaver Standards for Interior Design and Space Planning 1991:1013).***

Neufert and Gloag are of the opinion that terminology such as "pumpkin" and "forest green" should be avoided when referring to hue, chroma and value, and that a scientifically based colour system, such as the Munsell system, should be employed when calculating reflectance values. A formula for the "reflectance value to Munsell value" ratio is given in the Interior Design Lighting Handbook as: Munsell value (V) multiplied by Munsell value minus one (V-1) i.e. Reflectance value = V (V - 1).

(Neufert 1980:17, Gloag 1961:4) (Interior design lighting handbook 1956:15).

The results can be tabled thus:

Value	Munsell Value	Reflectance factor
Very light	9 - 9,25	72 - 84%
Light	7 - 8	42 - 56%
Middle	5 - 6	20 - 30%
Dark	3 - 4	6 - 12%
Very dark	1 - 2	1.5 - 2%

Table 18. Reflectance factor equivalents to Munsell value *(Neufert 1980:17).*

iii. PSYCHOLOGICAL RESPONSE TO LIGHT

Woodson, in referring to possible differences in illuminance level specification for good seeing versus desired psychological response points out that:

> "The designer of interiors, in particular, must accommodate in terms of both aspects, i.e. good seeing is essential to ensure adequate visual task performance, but it is also necessary to create a lighting environment that produces a desired psychological response" ***(Woodson 1992:674).***

Two of the possible psychological responses which may be influenced by lighting i.e. **"alertness level"** and **"atmosphere"** were investigated with the following results (see also section 6.4.1.1).

6.10.2.5 Effects of light on alertness

Woodson proposes that "although little quantitative evidence exists regarding the psychological effect of light levels on general alertness, the accompanying table indicates suggested requirements" *(Woodson 1992:674)*.

Alertness level requirements	Average Light Level, fL
Maximum mental alertness required for highly complex mental task performance	50 and above
Medium mental alertness required for routine, manual tasks, leisure reading, and/or stimulating social activity	40
Minimum mental alertness required for nondemanding social intercourse and/or perceptual-motor performance (dining dressing etc.)	30
Rest, mental alertness for minimal interaction with other people (bar, intimate restaurant)	15
Sleep	Below 3

Table 19. Effects of light on performance *(Woodson 1992:674)*.

6.10.2.6 Subjective impressions of "atmosphere"

Flyn, in a study of subjective responses to low energy and non uniform lighting systems, found that lighting may influence a person's impression of the "atmosphere" in a space as follows:

- **Impression of perceptual clarity**

  This impression is created by bright, uniform lighting. Peripheral emphasis such as that created by high wall reflectance values or wall lighting may enhance this impression.

- **Impression of spaciousness**

  The impression of spaciousness may be created by the use of peripheral lighting. Brightness may be a reinforcing factor.

- **Impression of relaxation**

  An impression of relaxation may be formed by the use of non uniform lighting. A combination of low light intensity in the immediate locale of the observer, with remote areas being brighter could enhance the effect. Wall mounted lighting may also have a contributing effect.

(Flyn 1977:6)

6.10.3 COMMUNICATION INSTALLATION PLANNING

According to Carson et al. the following communication systems may be found in the factory:

- Voice communication systems including: Telephones (both private and P.A.B.X. systems), two-way radios and public address systems.
- Mechanical communication systems, for example pneumatic tube systems.
- Instantaneous printed communication; this type of communication may take the form of "telex" or "fax" machines.
- Computer systems; including modems and printers.
- Pictorial systems; include television an d computer (VDT) screens.
- Reproduction methods; these include diazo reproduction, photocopiers and mechanical printers.
- Alarm systems, both audio and visual.
- Directional and instructional signs.

(Carson et al. 1972:3.93)

Woodson offers guidelines regarding communication system planning which may be summarised thus *(From Woodson 1993:131)*:

6.10.3.1 General considerations

- Plan for the total proposed array of communications i.e. person-to-person speech and visual contact as well as electromechanical communication systems and signage.

- Establish requirements concerning privacy and prevention of annoyance.

- Determine both inside and outside communication interference possibilities and identify the exact nature of these in terms of loudness, frequency distribution etc.

- Examine and determine potential physical interaction between each type of communication mode and the physical environment. Reverberation, echoes, sound time lag, sound shadows, visual barriers, effect on sound localisation, visual glare, seeing distance, illumination level etc. may all be influenced by the physical environment.

6.10.3.2 Physical environment features which may affect auditory communication

These include:

- The shape and size of interior spaces.

- The surface texture and mass of floors, walls, ceilings and furnishings.

- The physical positioning of communication components (people, speakers, telephones etc.)

- The volumetric density of noise absorbing objects relative to the space. For example, the more people present in a room the more sound they will absorb.

6.10.3.3 Physical environment features which may affect visual communication

These include:

- Viewing distances.
- Ambient lighting effects.
- Decorative lighting effects (bright lights, coloured or flashing lights).
- Day versus night ambient artificial lighting, and their influence on internal seeing conditions.

6.11 WINDOWS AND DOORWAYS

6.11.1 WINDOWS

The comprehensive design guidelines recommended by Woodson for window systems were found to be suitable for use in the factory interior/building context *(Woodson 1992:161)*.

The following is a summary of these guidelines:

6.11.1.1 Window Functions

The function of the window should be the main consideration when selecting a window system. The primary functions include:

- To provide a visual communication link, or view.
- To provide natural light.
- To provide ventilation.

- To provide an auxiliary escape route.
- To provide an aesthetic function.
- To provide weather protection.

The auxiliary functions of windows may also include the following:

- Light filtration (solar screening)
- To provide an environmental or acoustic control or barrier.

6.11.1.2 **Window Location and Size**

Decisions concerning the location of windows may be influenced by considerations such as:

- Location so as to maximise viewing angles.
- Locate windows so as to effectively distribute natural light.
- Positioning should promote cross-ventilation.
- Avoid positioning which may form potential hazards.
- Accessibility for cleaning and repair.
- Locate windows so as to minimise the risk of fire transfer between buildings.

The size of the window opening and the number of window openings should be balanced so that:

- The desired quality of natural lighting is obtained.
- The function of the wall in which window openings are located is not impaired.
- Control is exercised over solar penetration and noise transfer.

6.11.1.3 **Selection of window types**

Considerations in window type selection may include:

- The extent of the required viewing
- The area of the openings required for ventilation purposes.
- The extent to which the opening must be burglar proofed.

- The type of cleaning method which is envisaged.
- The window may have to accept various forms of screens such as blinds or insect screens.

6.11.1.4 The window as a decorative feature

The aesthetic function of the window may require attention to details such and compatibility with building style, or the use of the window as a focal point or as a symbol.

6.11.1.5 Safety considerations

- The use of safety or tempered glass is recommended for use in windows where the sill height is less than 400 millimetres from finished floor level. Local building codes should be consulted in this regard.

- Avoid the positioning of large glazed areas where objects may inadvertently be pushed into them.

- Avoid the placing of large glazed areas at stair landings or close to the bottom of a flight of stairs. Should a person trip on the stairs at these points it may cause them to fall against the glazing.

- Window cleaning methods, especially for the exterior where high heights may be involved, should be considered.

- Windows which are meant to be opened and closed should be positioned so that a person can do so in a safe manner i.e. without having to lean over obstructions or by having to climb a ladder.

- Windows which intrude (jut out) into a space when open, especially those below head height, can be hazardous to both sighted and blind persons.

6.11.1.6 General characteristics of window types

Window types and their characteristics may be summarised as follows:

Window type	Percentage opening	Weather protection when open	Hazard close to walkways	Diverts incoming draughts
Double-hung (sash)	50%	No	No	No
Casement opening out	100%	No	Yes	Yes
Casement opening in	100%	No	Yes	Yes
Awning	100%	Yes	Yes	Yes
Pivoted vertical	100%	No	Yes	Yes
Pivoted horizontal	100%	Yes	Yes	Yes
Top hinged	100%	Yes	Yes	Yes
Bottom hinged (in)	100%	Yes	No	Yes
Louvred	100%	Yes	No	Yes
Horizontal sliding	50%	No	No	No

Window type	Structural members obstruct view	Dust sealing efficient	Screen fitting possible	Suitable for burglar proofing
Double-hung (sash)	Yes	Erratic	Yes	Outside
Casement opening out	Yes	Yes	Yes	Outside
Casement opening in	Yes	Yes	Yes	Inside
Awning	Yes	Yes	Yes	Inside
Pivoted vertical	No	Yes	No	In/Outside
Pivoted horizontal	No	Yes	No	In/Outside
Top hinged	No	Yes	Yes	Inside
Bottom hinged (in)	No	Yes	Yes	Outside
Louvred	Yes	No	Yes	Limited
Horizontal sliding	Limited	Erratic	Yes	Outside

Table 20. Window types and characteristics.

6.11.2 DOORS AND DOORWAYS

The primary functions provided by doors and doorways include:

- Access from one side of an enclosure to another.
- Acting as a security barrier.
- Acting as a privacy shield.
- Acting as an environmental barrier.

From experience, the following observations have been made with regard to doors in the factory context:

- Doors and entrance units are often "abused" in that they may be kicked or bumped open by persons or vehicles. Apart from damage to the door material, these actions may stress the door hinge and frame components.

- Doors may require a fire rating; metal doors may be a solution in these cases.

- Wooden doors in high traffic areas may require metal kickplates in order to protect those areas of the door which may be subjected to kicking or bumping.

- Doorway heights and widths should be planned around the activities which the doorway will have to accommodate. Factors such as vehicle widths, load heights and possible automatic opening mechanisms may require evaluation.

- Doorways form relatively large openings in the building envelope. The length of time during which they remain open can affect planning factors in terms of potential interior heat loss or gain as well as weather penetration.

The design guideline recommended by Woodson for doors and doorways was also found to be suitable for use in the factory interior/building context *(Woodson 1992:145)*.

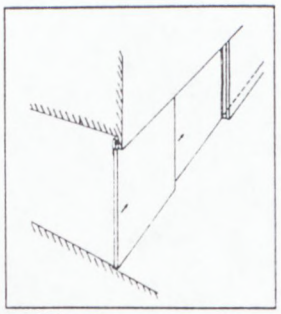
The following is a summary of these guidelines:

- Large or heavy doors may require mechanically assisted opening mechanisms.
- The inclusion of viewports into a free-swinging door may prevent a person "walking into" an opening door.
- Separate entryways should be provided for vehicles and pedestrians.
- Metal edges should be radiussed.
- In certain areas, weather conditions may cause swelling or shrinking of the door material which could result in inefficient operation such as "sticking" or rattling.
- Where possible, floor levels on either side of the doorway should be equal.
- Doors should not open into corridors because of the possibility that someone may be struck by a door that is being opened.
- Door hardware should indicate to the user whether to push, pull or turn a handle to open a door.
- Doors located at the corner of a room should open (swing) towards the corner.

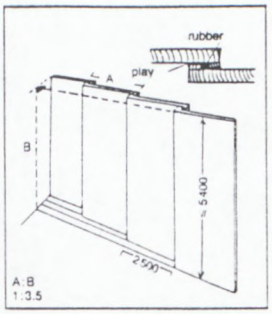
6.11.2.1 Door Types - industrial doors comprise the following typical types and uses:

Door type	Used for	Typical example
Sliding Slide-folding Concertina folding	For large openings	Multiple vehicle access
Folding Sectional Roller	For vehicle access	Usually single vehicle access
Special designs	Specialist buildings	Aircraft Hangar
Impact resistant	Goods movement	Where constant "impact opening" stress is envisaged, for example storeroom-to-sales counter accessway
Air curtains	Thermal barrier	Where exterior temperature is higher or lower than a maintained interior temperature
Weatherproof	Environmental barrier	Vehicle loading dock

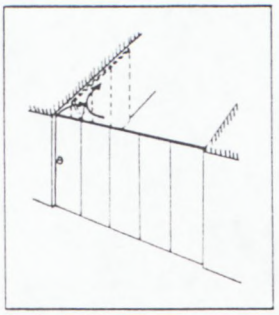
Table 21. Industrial door types and uses.



1 Sliding door



2 Telescopic sliding door



3 Angle sliding doors (cornaway)

INDUSTRIAL TYPES

For large openings (partitions) sliding, sliding-folding, concertina-folding →(1)–(8).

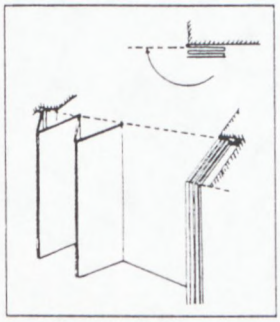
Private garage doors (folding, sectional, roller) →p102(7)–(10).

For very large and high bldg (*eg* aircraft hangers) special design with lifting corner or section supports →(9).

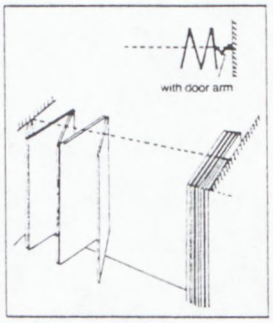
Access way doors of impact resistant plastics →(10); also plastics strip curtain →(11).

Air doors: injection of spanning air curtain →(12)–(13).

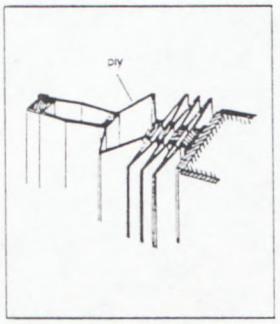
Door frames of weather-proof rubber edging →(14); all-round wired rubber segments →(15).



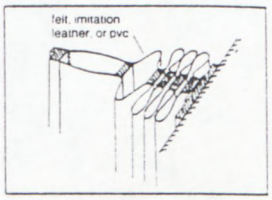
4 Folding doors (foldaway)



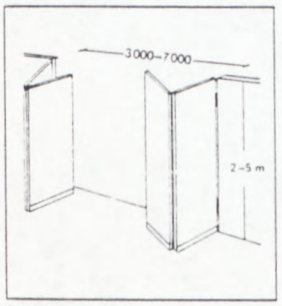
5 Folding doors (centafold)



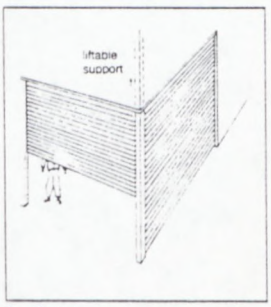
6 Concertina folding doors (plywood)



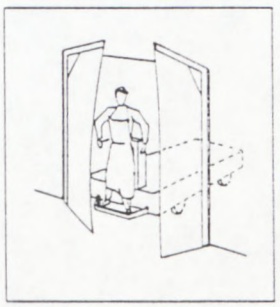
7 Concertina folding doors (plastics fabrics)



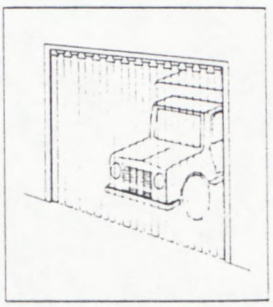
8 Power-operated folding door



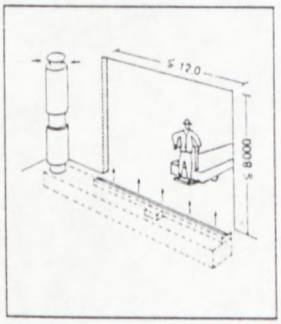
9 Roll shutter door over corner or with sectional supports (h reach possibilities)



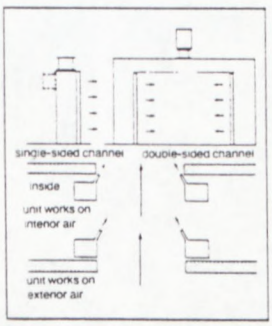
10 Rubber swing door



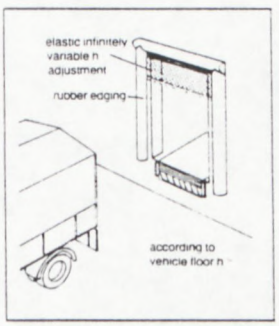
11 Strip curtain (pvc) for wide access



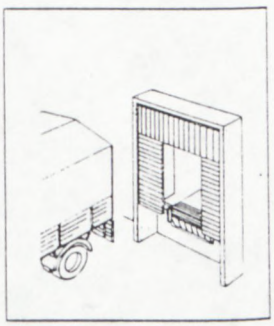
12 Air curtain system



13 Air curtain for small doors



14 Rubber edging door seal



15 Wired rubber segments door seal

Figure 26. Examples of industrial door types.
(Neufert 1980:402).

Further typical examples contained in Neuferts Architect's Data are shown in Figure 26.

6.11.3 RAMPS, STAIRS AND LADDERS

Requirements regarding the design of ramps, stairs and ladders may be governed by occupational health, safety or municipal regulations.

Preferred structures for typical ascent angles are shown as Figure 27.

Recommended dimensions for stair-ladder (i.e. stepladder) and rung ladder designs are contained in the following tables:

Stair-Ladder Design Requirements			
Dimensions	Minimum	Maximum	Recommended
Tread depth range: For 50° rise For 75° rise (open ladder)	 150mm 75mm	 250mm 140mm	 215mm 100mm
Riser height	180mm	300mm	230mm
Width (handrail to handrail)	530mm	610mm	560mm
Overhead clearance	1730mm	-	1930mm
Height of handrail at leading edge of tread	860mm	940mm	890mm
Handrail diameter	32mm	75mm	38mm
Handrail clearance from wall	50mm	-	75mm

Table 22. Stair-ladder design requirements ***(Woodson 1992:186)***

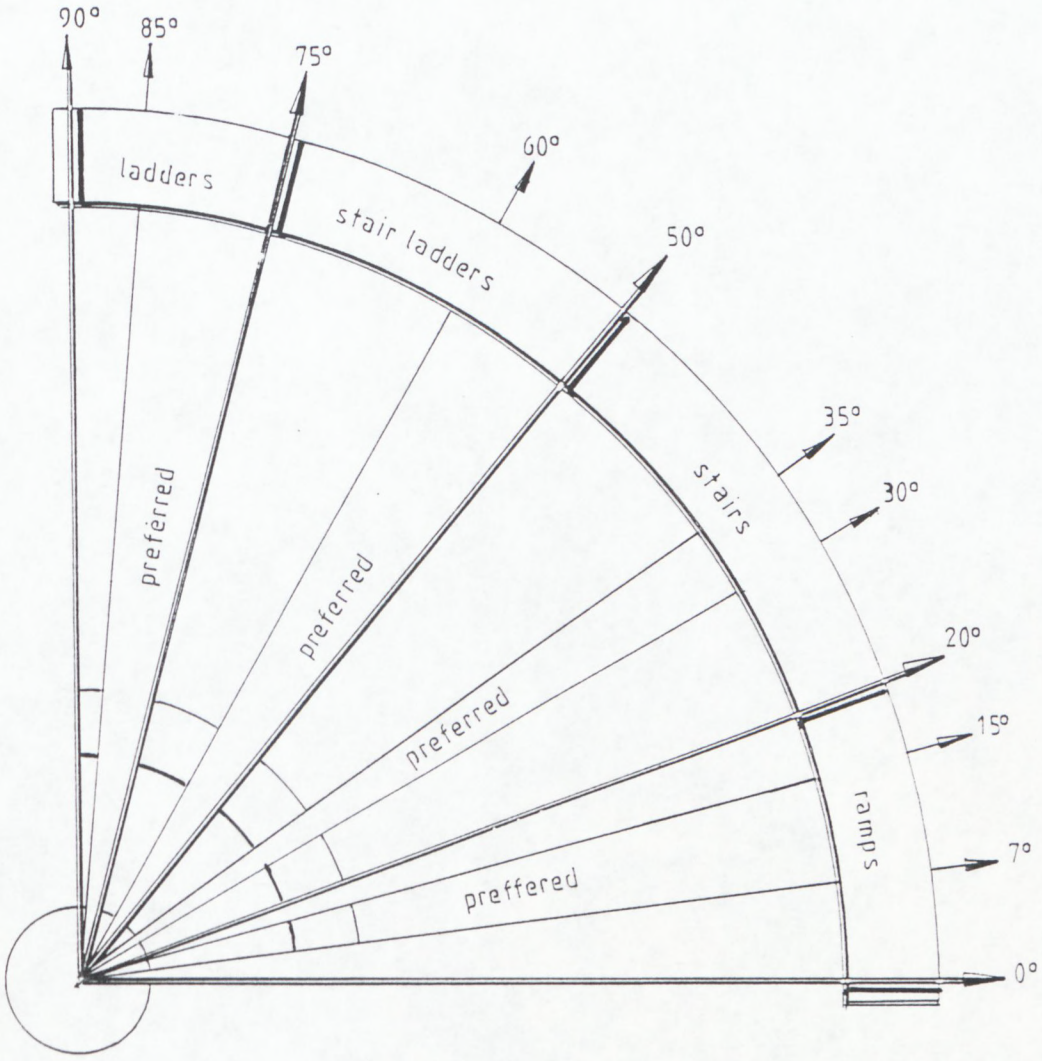


Figure 27. Preferred structures for typical stair angles. *(Woodson 1992:185).*

Fixed (rung) ladder design requirements			
Dimensions	Minimum	Maximum	Recommended
Rung thickness: Wood Protected metal Corrosive metal	 32mm 19mm 25mm	 38mm 38mm 38mm	 35mm 35mm 35mm
Rung spacing	230mm	380mm	300mm
Height (last rung before landing)	150mm	380mm	380mm
Width between stringers	300mm	-	460 - 530mm
Clearance from ladder to wall	150mm	-	200mm
Clearance at back of person	910mm for 75° to 760mm for 90°		
Height of stringer above landing	840mm	-	910mm
Height from floor level to first rung	-	380mm	-

Table 23. Fixed ladder design requirements ***(Woodson 1992:186).***

6.11.3.1 Industrial stairway requirements

The design of industrial stairways was found to be the same as that for stairways in general as regards rise-and-run dimensioning, widths, handrail heights, landing location and head clearance. Handbooks such as Neufert Architects' Data may be referred to for further detail.

6.11.4 FLOOR FINISHES

An investigation into factory flooring indicated that floor finish selection is an important consideration in factory design ***(Rosaler 1983:2-71, Neufert 1980:264).***

Although steel and aluminium flooring may be used in factory buildings for mezzanine levels and raised walkways, it is concrete which forms the basis for heavy duty factory flooring. By proper use of mix designs and admixtures, with careful control of the water/cement ratio and careful attention to laying, finishing and curing techniques, concrete itself can serve as a highly durable flooring finish.

However, irrespective of how well it has been laid, concrete has poor resistance to staining and attack by acids and many other chemicals. Where spillage of such materials is envisaged, or where an increase in light reflectance levels is required, or for aesthetic purposes, a protective coating may be applied to the concrete.

The following guidelines in this regard, are based on a paper delivered by J.D.N.Shaw, "Special finishes for concrete floors" at the international Conference on Advances in Concrete Slab Technology at Dundee University in 1979 *(Shaw 1980:505-515)*.

6.11.4.1 Selection of flooring required

Service conditions which may be considered include:

- Service temperature and extreme changes in temperature which may cause surface cracking.

- Nature and concentration of any materials likely to come into contact with the floor.

- The laying of floors to levels, for example in order to facilitate drainage.

- Grade and condition of concrete sub floor.

- Nature of traffic (maximum loads and type of wheels using floor).

- Degree and ease of cleaning required.

- Non-slip characteristics required.

6.11.4.2 Requirements of concrete substrate

If, at the specification stage, it is decided that a protective finish is to be applied to the concrete floor the following factors may be considered:

- Spray-applied concrete curing membranes could seriously affect the adhesion of any protective flooring application. Overlapping polythene sheeting could be used instead.

- Although the concrete laid by the contractor may have cube strengths well in excess of that specified, it is the top few microns of the concrete to which the protective coating will be applied. It is therefore essential that any surface weaknesses be removed by a method appropriate to the type of finish being applied.

- As a general rule, any concrete base which will subsequently be treated with a special flooring should not be subject to rising damp.

- Attention should be given to (expansion) joint filling in order to prevent, for example, edge spalling, dirt collection and damage to vehicle wheels.

6.11.4.3 **Finishes**

Various types of finishes are available for concrete floors including, in order of increasing cost:

- Thin applied hardeners and sealers
- Floor paints
- Self levelling epoxy, polyester or reactive acrylic resin systems
- Heavy duty flooring.

These categories may include the following types of finishes:

i. *THIN APPLIED HARDENERS AND SEALERS*

- Sodium silicate and silicon fluoride solutions as concrete surface hardeners:

These solutions are applied to clean, dry, sound concrete floors as dilute aqueous (10 - 15% solids) in two to three applications. The silicate or silicon fluoride reacts with the small amount of free lime in the cement to form glassy, inert material at the surface. This improves the surface resistance to wear, mild aqueous chemicals and oils at a relatively low cost.

This treatment is less effective on modern concrete floors which tend to be dense with low-porosity.

- Low-viscosity, resin-based, penetrating in-surface finishes.

These resin-based systems, like the chemical surface hardeners, penetrate into the surface of the concrete finish and form a hard surface layer which protects the concrete from acid attack, wear and at the same time facilitates easier cleaning.

- Non-reactive and semi-reactive resin solutions:

These substances act as sealers as opposed to hardeners. Acrylic resin solutions are more durable and offer better protection to chemical and oil spillages than concrete surface hardeners. Because they penetrate the floor surface they can be used to "rescue" poor-quality floors and offer marked improvements in abrasion resistance.

Types include:

Air-drying alkyds (similar to resins in gloss paints);
Styrene butadiene resins;
Urethane oils;
Styrene acrylates.

All such resin solutions are based on flammable solvents and are becoming increasingly less acceptable on health and safety grounds. There is therefore increased interest in water-based polymer dispersion floor sealers but they may not offer the same improvements to flooring.

- Polymer dispersions:

Polyvinyl acetate (PVA), acrylic and other polymer dispersions have been widely used as anti-dust treatments. Until recently they have tended to be based on dispersions of relatively large polymer particles, similar to those used in emulsion paints.

Dispersions are now becoming available which offer superior performance as floor sealers; mainly due to the demand created by problems associated with polymer solutions based on hydrocarbon solvents.

- Epoxy resin dispersions:

Two component epoxy resin dispersions (water thinned), may be used as floor sealers. They have good adhesion to concrete and good chemical resistance. They have relatively large particle size and consequently penetration into good-quality concrete is minimal i.e. an "on-surface" seal is obtained. However, with porous low-quality concrete, considerable binding and strengthening of the surface can be achieved.

ii. *FLOOR PAINTS*

Floor paints, in a wide range of colours and based on a number of different binder systems, are used extensively for concrete floors in light industrial applications. Types include:

- Chlorinated rubber paints:

Chlorinated rubber paints are probably the most common of the lower-cost floor paints. They produce tough, chemically resistant coatings but surface adhesion varies. They tend to wear in patches and are therefore not suitable for heavy traffic areas. Application is simple and floors can easily be maintained during shutdown periods. Similar paints based on other resins include acrylics, vinyls and styrene butadiene.

- Polyurethane floor paints and multi-coat treatments:

  Moisture-cured or two-pack polyurethane resin paints are used extensively. They combine excellent abrasion resistance with good chemical resistance. In addition moisture-cured polyurethane resin solutions are used for durable decorative floorings.

  In multi-coat treatments, several coats of resin are applied to the prepared substrate, with one or more coats being dressed with coloured paint flakes which are sealed in by the next coat. Applications may include reception areas, kitchens and toilets.

- Epoxy resin high-build floor paints:

  Solvent-free high-build floor paints are available which can be applied by brush, roller or spray to a prepared concrete surface to give a thickness of 0.10 mm to 0.20 mm per coat. Normally two coats are applied and the first is often dressed with fine sand or carborandum dust to give a non-slip, chemically resistant and durable coloured floor, ideal for light industrial traffic conditions (for example, rubber-shod wheels).

iii. *SELF-LEVELLING EPOXY, POLYESTER OR REACTIVE ACRYLIC RESIN SYSTEMS*

These are solvent-free low-viscosity systems which are readily applied onto a prepared level surface to provide a thin (1.5 mm - 3.5 mm) chemical resistant flooring in a single application. Before the system is cured, the surface is normally lightly dressed with fine, abrasion-resistant grit. Without a non-slip dressing there is a tendency to produce a gloss surface which is slippery and scratches easily. This problem may also be overcome by the application of slip inhibiting industrial floor polish.

This type of flooring is widely used in laboratories, pharmaceutical factories and food-processing areas where easily cleaned, chemically resistant durable floors are required.

iv. *HEAVY DUTY FLOORING*

A considerable range of different toppings are available for heavy-duty service. In general, heavy duty toppings require a sound (preferably 35 N/mm² strength) concrete substrate types include:

- Granolithic toppings:

  In effect, granolithic toppings are just a method of producing a high cement content concrete wearing surface on a concrete substrate. A suitable surface could be achieved by direct finishing of a high cement content, high strength concrete. Where it is considered necessary to apply a granolithic topping onto an existing concrete substrate the danger of debonding can occur. The danger of debonding can be reduced by the use of polymer based bonding aids including:

  Epoxy resins specially formulated for bonding;

  A bond coat of polymer latex (also called polymer emulsions or dispersions) such as styrene butadiene (SBR), Polyvinyl acetate (PVA) acrylics or modified acrylics;

  The so-called "universal" PVA bonding aids are not recommended for external or wet service conditions, as there is a danger of the polymer breaking down.

- Bitumen emulsion-modified cementitious floors:

  The use of specially formulated bitumen emulsions as the gauging liquid for graded aggregate/sand/cement screeds can produce a dustless, self-healing, jointless surface for industrial areas subject to heavy wheeled traffic under normally dry conditions, for example large warehouses.

  Loading levels above 8 N/mm² for long periods are not recommended for emulsion-modified cementious floors due to a tendency to indent at these loads.

- Mastic asphalt floors:

Hot applied mastic floors are not commonly used in factory interiors due to a tendency to become plastic when warm.

- Polymer-modified cementitious floor toppings:

Polymer-modified cementitious floor toppings are widely used instead of granolithic toppings. The polymers are supplied as milky white dispersions in water and are used to gauge the topping mix.

The polymer latex acts in several ways including:

It functions as a water reducing plasticiser, producing a flooring composition with good workability at low water/cement ratios.
It ensures a good bond between the topping and the concrete substrate.
It produces a topping with good tensile strength and toughness.
It can, depending on the polymer latex, produce a topping with good water and chemical resistance.
It acts as an integral curing aid.

Polymer-modified cementious floor toppings are normally laid 6 - 12mm thick.

This type of flooring is commonly used in the food-processing industry, particularly meat processing, as well as the printing industries because it can be cleaned with steam cleaning techniques without problems of thermal shock breakdown.

- Epoxy resin mortar flooring:

Trowelled epoxy resin flooring approximately 6mm thick is used extensively where a combination of excellent chemical resistance and good mechanical properties are required, particularly abrasion and impact resistance as well as resistance to very heavy rolling loads. Epoxy toppings are available with compressive strengths up to 100 N/mm^2 and tensile strengths up to 30 N/mm^2.

- Reactive acrylic resins:

Reactive acrylic resins are ise for heavy duty flooring. The high filler content of these re .ne danger of shrinkage (as exhibited by polyester resin). Thes usually used in abattoirs, dairies and food processing plants.

- Industrial tile flooring:

There are industrial flooring situations where the service requirements or the time allowed for laying do not permit the use of jointless floor toppings. For such applications a wide range of industrial tiles are available which will meet most requirements in terms of either mechanical properties or chemical resistance. When tiles are used in aggressive chemical environments the main problem is the performance of the grout between the tiles. Grout systems based on specially formulated furane resins (which resist strong acids) and epoxy resins are available for this purpose.

6.12 FIRE PREVENTION AND PROTECTION

Fire prevention and fire protection are often differentiated with **prevention** meaning the elimination or reduction of the fire risk with **protection** meaning measures taken to mitigate the control the consequences of fire.

Experience has shown that fire protection and prevention is a complex problem and it is essential that the relevant authorities be consulted at the initial stages of any design project in order to determine measures to be taken in terms of existing legislation.

An investigation into fire prevention and protection, indicated this topic to be a specialised field and that comprehensive guidelines are available, such as those contained in the National Building Research Institute's publication Part 5, "Guidelines for Factory Building Design" ***(National Building Research Institute 1985)***.

It is therefore recommended that these and similar reference works be consulted in conjunction with advice obtained from the local authority.

CHAPTER 7

VISUAL CONSIDERATIONS

This section of the investigation was concerned with visual aspects of the factory interior which may be subject to creative interpretation. From experience it has been noted that, when faced with a design problem in the factory context, it may be difficult to explore abstract ideas or "design concepts", perhaps because there appear to be few examples from which to draw inspiration.

However, it has been found that many elements may serve as a source for generating creative ideas, such as the building envelope, physical surroundings, manufactured product image or use, manufacturing process or process requirements, colour schemes,. corporate identity planning, environmental impact, use of modular systems, the interpretation styles such as "High Tech", the carrying through of a related operations image into the factory interior, or perhaps an interpretation of management ideals.

Two of these aspects, namely colour and corporate identity planning, serve as examples where visual considerations may be applied to the factory interior as follows:

7.1 THE APPLICATION OF COLOUR IN THE FACTORY INTERIOR

While recommendations with regard to specific colour use in the factory cannot be made, an awareness of the contribution which colour can make to various aspects of the environment may assist an interior designer in the planning of a suitable colour scheme.

The following guideline in this regard was compiled from recommendations by various authorities on the subject of colour and the application of colour in the factory *(Birren 1969, Carson et al. 1972:16.63, Gerritsen 1974, Gloag 1961, Osgood et al. 1957:299-302, Woodson 1992:671)*.

7.1.1 THE FUNCTION OF COLOUR IN FACTORIES

The properties of colour may be used in order:

- To aid vision
- To assist in developing an "atmosphere", for example invigorating, pleasant or relaxing
- To create a sense of orderliness
- To assist with good housekeeping (shows up dirt).

7.1.2 COLOUR AS AN AID TO VISION

An important function of colour is the aiding of vision. By combining the properties of colour with the human sight process, more effective vision may be facilitated.

The principal governing work, colour, light, and seeing can be summarised thus:

- The smaller the detail)
- The slighter the contrast) The greater the light required
- The darker the colours)

7.1.2.1 Colour and light reflection

Lighting becomes indirect when reflected from walls, floors and ceilings. The effectiveness of coloured surfaced as reflectors depends on their value. This implies that large surface areas such as floors, walls, ceilings and tall or bulky machinery should be light, or high value, colours.

7.1.2.2 Colour contrast between work and background

Work that is dark in colour, or lacks clear contrast with its background may be made easier by incorporating a screen of contrasting colour behind the work, for example a coloured desk top or coloured partition.

7.1.2.3 Control of brightness contrast (glare)

Because different hues having differing reflectance values they can be used to control brightness contrasts in the working environment, for example:

- Interior window frames and bars with a value of 9 and a chroma of 1 on the munsell scale will be less noticeable.
- Surfaces receiving direct sunlight may have a lower value than those receiving indirect lighting in order to balance the brightness contrasts.
- Highly polished or glossy surfaces should be avoided because of their high reflectance values.
- Sloped ceilings on southlights may have a high reflectance value in order to increase the amount of reflected indirect lighting.

7.1.2.4 Focussing of attention on the work

The eyes are naturally attracted to the brightest and most colourful object in view. Therefore, attention is naturally focussed on the work when the background hue is one or two steps darker in value than the object being viewed.

7.1.3 COLOUR AS A FORM OF CODING

Colour may be used to symbolise function. The following serve as examples:

- Exit doors, or fire doors may have fixed hues to indicate their function.

- Different signage systems may be designated specific colour ranges, for example directional green, warning red.

- Colour may act as an identity code, for example British Petroleum may be associated with green and yellow.

- Colour may act as a map code. For example, the use of an instruction such as "Follow red arrows to ground floor".

- Colour may serve as a warning or safety code. The following recommendations are summarised from the handbook "Time saver standards interior design and space planning".

PHYSICAL HAZARDS:

Red: Fire protection equipment and apparatus; danger; stop.

Orange: Dangerous parts of moving machinery; dangerous materials (non-flammable) such as acids, alkalis, toxic materials; oxygen.

Yellow: Physical hazards that might cause stumbling, falling etc; Dangerous materials (flammable) such as fuel oil, gasoline, kerosene, alcohol, propane, butane, acetylene, hydrogen and solvents.

Green: Safety - first aid dispensary or kits, stretchers, safety deluge showers etc.; Safe materials such as drinking water.

Violet: Valuable materials.

Black: Electrical conduit; traffic direction.

White: Sanitation.

(Timesaver Standards for Interior Design and Space Planning 1991:1013).

7.1.4 PSYCHOLOGICAL RESPONSE TO COLOUR

Although no evidence of successful scientific quantification of the precise effects of colour or lighting levels on human beings was found, it would appear that colour may elicit typical repeatable reactions as follows:

- Certain colours may make a space appear larger than it actually is, while others cause a space to "close in" on the observer.

- Certain colours may appear "warmer" while others appear "cooler".

- Colours seem to symbolise "moods", for example stimulating, or depressing.

- Certain colours seem to "recede" while others "advance".

- Some colours seem to "clash" with each other and therefore produce a feeling of irritation in observers who are especially sensitive to colour incompatibilities.

A summary of observations by Woodson et al. of typical colours[8] and their possible effects on humans is reflected on the following page.

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[8]The term "taste" as used in the table, refers to physical and not aesthetic taste.

Description	Response
RED	Warm feeling, stimulating, generally exciting, but calm to the extent of indicating a protective quality, pleasing to the appetite, associated with danger.
Pale Pink	Slightly warm feeling, pleasing when associated with odors.
Pink	Warm, soft, pleasing when associated with odours and taste.
Reddish-pink	Warm feeling, slightly stimulating, pleasing association with taste.
Scarlet	Very warm feeling, stimulating and exciting.
Reddish-orange	Warm, stimulating, exciting, cheerful, pleasing association with taste.
ORANGE	Warm, stimulating, exciting, cheerful, pleasing association with taste.
Any of the above reflect light that is flattering to skin and complexion, thus making people appear healthy and normal (as opposed to cool colors with create an appearance of being pale). Scarlet through ORANGE colors advance slightly towards the observer.	
Yellowish-orange	Warm, somewhat exciting, cheerful, express a feeling of comfort, associated with pleasing taste.
YELLOW	Warm, somewhat exciting, cheerful, comfortable, associated with pleasing taste.
Pale yellow	Warm, cheerful, associated with pleasing odor and taste, softness and comfort.
Greenish-yellow	May be associated with feeling of slight warmth or coolness depending on other colors used, not associated with good taste.
Yellowish-green	May be associated with feeling of slight warmth or coolness depending on other colors used, calming, somewhat neutral, may or may not be associated with good taste.
GREEN	Generally cool, slightly cheerful, comfortable, calming, associated with pleasing refreshing odor.
Bluish-green	Cool, calming, associated with good taste.
BLUE	Cool, comfort, protective, calming, although may be slightly depressing if other colors are dark, associated with bad taste.
Green through blue	Will advance toward observer if dark shades are used.
Pale blue	Cool, soft, calming, tends to neutralize if other colors are pale, reflected light makes skin appear pale.
Lavender	Slightly cool, calming, soft, associated with pleasing odor, but with bad taste.
Violet	Slightly warm, calming, associated with bad taste.
Royal blue	Rich, substantial, may be slightly depressing if used with other dark colors, associated with bad taste.
Purple	Rich, protective, calming, may be depressing, associated with pleasing odor, but bad taste.
Violet through Purple will advance toward observer, creates a feeling of heaviness.	
MISCELLANEOUS:	
Hot pink (a yellowish cast)	Very warm, stimulating, exciting, cheerful.
Rose (bluish cast in pink range)	Neutral relative to warmth, comfortable, calm, associated with pleasing odor.
Fluorescent orange	Warm, stimulating, exciting, cheerful, extremely conspicuous
Fluorescent red	Warm, stimulating, exciting, cheerful, extremely conspicuous.
Fluorescent yellow	Warm, stimulating, slightly irritating but cheerful.
Chartreuse	Slightly warm, cheerful, associated with bad taste.
Olive	Warm, comfortable, slightly depressing, associated with bad taste.
Cream	Slightly warm, comfortable, calming, clean, reflected light enhances skin tone.
Buff	Warm, comfortable, calm, soft; good blend with other colors
Tan	Warm, very comfortable; good blend with other colors.
Reddish-brown	Warm, comfortable, cheerful, slightly stimulating.
Brown	Warm, comfortable, rich, substantial, protective, may be slightly depressing.
Fluorescent colours advance toward observer.	
WHITE	Neutral, sterile, clean, fresh, stark, crisp; may appear hard or soft depending on lighting color, may appear harsh, glaring.
Off-white	Neutral, a clean, fresh.
Light gray	Neutral, clean, fresh, calming, soft, comfortable; critical that the tint is compatible with other colors (e.g. bluish, pinkish, yellowish, etc.)
GRAY	Neutral, comfortable, calming, slightly hard; critical that the tint is compatible with other colors used (e.g. bluish, pinkish, yellowish, etc.)
Dark gray	Neutral, comfortable, may be depressing; critical that the tint is compatible with other colors used (e.g. bluish, pinkish, yellowish, etc.) substantial, heavy, advances toward the observer.
Flat black	Solid, heavy, comfortable, generally neutral, advances toward the observer, gives the impression of being dirty, vagueness, recedes.
Deep black	Protective, depressing, heavy, substantial, advances toward observer in small amounts, but may recede in large amounts (e.g. painting a ceiling black).
Gold/Brass	Rich, comfortable, warm (tint important for compatibility with other colors); slightly advancing.
Silver/aluminium	Neutral, cold, hard, clean, stiff and uncomfortable, sterile, lifeless, recedes.
Light wood grain	Warm , comfortable, quiet.
Dark wood grain	Warm, comfortable, quiet, protective, slightly depressing.
Light leather grain	Warm, comfortable, cheerful, soft.
Dark leather grain	Warm, comfortable, protective, soft, slightly depressing, advancing.

Table 24. Typical colour responses ***(Woodson et al. 1992:673).***

7.1.5 COLOUR AND GOOD HOUSEKEEPING

Colour may be utilised to show up dirt and dust. It may also be utilised to highlight potential deposits of toxic matter. For example, if a toxic powder is known to be green, then a red working surface will show spillages more easily because of the colour contrast.

7.2 THE FACTORY AS AN EXPRESSION OF CORPORATE IDENTITY

"Corporate Identity" may be interpreted to mean the identity which is portrayed by the various images of an organisation The "identity" is formed from a composition of "images" ranging from the graphic symbols to efficiency of service.

A study of literature pertaining to Corporate Identity planning and design was made in order to ascertain whether this concept could be incorporated into the factory environment. The findings of this investigation are summarised as follows:

7.2.1 REASONS FOR EMPLOYING CORPORATE IDENTITY PROGRAMMES

James Pilditch in his study of corporate identity is of the opinion that:

> "As workers cease to live in the shadow of their factory their loyalty to it diminishes. The need grows to build loyalty by other means ... Curiously, it may be that the corporation or, at an executive level, profession, is becoming the new focal point for self-identification. This is noticeable in the big international companies. A Unilever man may be a Unilever man first and a resident of Rotterdam, London, New York or Paris second. He will often be more at home with a Shell man than with a compatriot in a small business. ... In a sense there is a new need to provide sheet-anchors in an increasingly uncertain world" ***(Pilditch 1970:5)***

According to Kogan in his book on strategies for effective identity programmes *(Kogan 1990:43)*, the reasons for implementing corporate identity programmes include:

- A company that projects a strong corporate identity (for example Sony) can launch a new product where the "Sony" name adds value and reduces uncertainty about the new product for both distributors and consumers.

- It is a method for standing out from competitors.

- It facilitates the decentralisation of production. For example, a "Sony" television is acceptable because it is a Sony and not because it was produced in Taiwan, Malaysia or South Africa. A well-known company may "buy out" a competitor and by "lending" its name to the new company it can give instant identity to the new products.

- Because of rapid changes in demand, product lifecycles are getting shorter. A strong corporate identity may enable a product to get a bigger "chunk" of the market in a shorter time.

From the above it can be deduced that corporate identity planning can be motivated on the grounds of worker loyalty as well as good business practice. In an historic context, the A.E.G. Corporation serves as a well-known example of the effective implementation of a corporate identity programme embracing products, architecture and publicity material by talents such as Peter Behrens, Walter Gropius, Mies van der Rohe and Adolf Meyer.

7.2.2 CORPORATE IDENTITY TYPES

Certain types of identity may be defined, for example:

- **Monolithic identity**

  this type of identity incorporates one name and visual style throughout the organisation, for example "Shell".

- **Endorsed identity**

  This identity type is applied to a group of diverse companies which may have their own separate identities but operate under one "umbrella" identity. Examples are the "Rembrandt" group or the "Barlows" group of companies.

- **Branded identity**

  This is where a company operates through a series of brands which may be unrelated to one another or to the companies' corporate identity.

  An example would be a company which manufactures washing detergents under several brand names, none of which reflects the corporate images of the **manufacturer's** corporate identity.

The creation of a corporate identity may be broken up into four general phases namely:

- Investigations and recommendation.

- Creation of the identity including aspects such as two and three-dimensional design guidelines as well as prescribed behaviour and communication patterns.

- Development of guidelines (usually incorporated into some form of manual).

- Implementing and launching the corporate identity.

Assuming that an interior designer may be involved with the implementation of the programme, i.e. the application of the corporate identity images to the factory interior, the following aspects may be considered:

- Manuals or guidelines pertaining to the implementation of the corporate identity should be obtained.

- Identify specified logos and where they may be applied.

- Identify colour schemes and ascertain where and how they may be applied to the factory interior in the form of materials and finishes.

- Check for prescribed typefaces and where they may be applied.

- Check prescribed layouts of documents and signage for possible application in factory operations.

- Three-dimensional features from related buildings (for example retail outlets) may be incorporated in the factory building.

- Ensure that prescribed behaviour patterns and communication methods can be accommodated in areas to which the public have access. For example, if the prescribed greeting in the form of "A personal handshake and a verbal welcome" is projected by the mass media and at retail outlets, then similar actions should be made possible at public reception areas in the factory.

While the above considerations are mainly aimed at implementing the "public" corporate identity, Olins, in his book "Corporate identity : making business strategy through design" is of the opinion that management may assist in portraying an identity to the worker which indicates that they (management) "know which way the world is moving and that they feel the corporation to be an integral part of society" by the implementation of "physical interior design changes such as common spaces and more informal relaxation areas" *(Olins 1989:206)*.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Much of the research activities engaged in during the course of this investigation were of an exploratory nature in that the qualitative and quantitative parameters of the problem were unknown.

This may be attributed to the fact that as far as could be ascertained, the problems associated with the application of the principles of interior design in the factory environment have not previously been clearly defined or agreed upon.

In order to gain adequate insight into the issues which may be associated with designing in the factory context, qualitative data pertinent to the application of interior design principles in the factory environment were assimilated and analysed. Leedy, commenting on the nature of data, is of the opinion that qualitative data is largely concerned with "what the researcher sees, observes, with what can be described in words and can be concluded from these words" (*Leedy 1989:173*).

This assimilation and analysis process encompassed the exploration of a broad spectrum of concepts ranging from matters involving largely practical considerations such as space quantification, to theories more usually associated with for example, the social or business sciences.

Evidence which has emerged as a result of this research work suggests the following conclusions:

Because of the influence and control which people can exert over production, the effect which the interior environment may have on their attitudes and physical well-being should be taken into account when designing the spaces in which they work. It would seem that past practice with regard to the design of factory interiors involved a machine orientated approach in that interior planning and conditions were provided which most suited the production process and did not necessarily cater for human needs.

However, as noted in the introduction to this dissertation, a need has arisen for a human orientated design approach where the "system" is adapted to suit human needs rather than the human having to constantly adapt to conditions imposed by the production process. This need has been evidenced by an increasing concern for the design of building interiors which are sensitive to human requirements and preferences. This concern has been further motivated by mounting evidence that both improved productivity and labour relations may result from care being taken in the design of the workspace.

There has also been an indication of a growing awareness that the characteristic disparity between the quality of working conditions typically found in factories and those experienced in for example offices, is largely due to differing levels of expectations. Although person working in the factory are no different from those working in the office, traditionally accepted norms have meant that the factory worker has been subjected to generally lower standards. This imbalance may have contributed to the phenomena where, even in times of unemployment in certain countries, people are unwilling to accept employment in manufacturing industries which traditionally imply a poorer quality of working environment.

As has been highlighted in this investigation, the application of interior design principles can address the need for an effective human orientated strategy for the design of the factory interior, in that it inherently encompasses an approach which endeavours to solve the problems associated with the design of those elements constituting the physical environment, (for example, building components and ergonomic requirements such as lighting, ventilation and colour), which could assist the human in interfacing with both the machine process and the physical environment.

Also, although the functional emphasis with regard to the elements which constitute the factory environment, may differ from those of for example, domestic, office, commercial and service industry spaces, these elements exhibit correlative characteristics and consequently require similar design considerations.

With regard to practitioners in fields such as the social biological or business sciences, where the opportunity for the implementation of theoretical "models" into the workplace may be inhibited by a lack of practical designing skills, the findings of the study support the possibility that by incorporating input from these fields into the brief, ideas and concepts from various disciplines may be given physical expression via the interior design process.

Significant reference has been noted throughout the investigation regarding the influence which the physical environment can exert on productivity. Here the term productivity refers to the effective utilisation of resources in producing goods and services rather than simply the activity of producing, or production. In other words the term productivity is used in a broader context than production and includes diverse aspects ranging from the well-being of the worker to the quality of the product.

As evidenced by the findings of the investigation, the causal relationship between the physical environment and productivity may be influenced by the application of interior design principles through:

Firstly, the implementation of planning concepts such as motion economy, energy conservation and space flexibility all of which encourage efficiency and secondly, by taking human physical and mental attributes as well as preferences into consideration, thus creating an environment which is conducive to both the maintenance of human productivity and the enhancement of labour relations.

A further issue which has emerged is the necessity for the facilitation and co-ordination of design activities associated with the development of the factory environment. This need arises as a consequence of the different disciplines involved in the planning and development of a factory, who may not necessarily form a cohesive team, having diverging or conflicting interests.

In order to make the best use of the available resources, it may be desirable for the interior designer to act as an intermediary, for example between management, engineer and architect in establishing the design brief in respect of both pre and post occupancy design requirements.

To illustrate the above point, the contents of this dissertation's chapters six and seven along with their design implications, were compiled from literature sources generated by a diverse field of disciplines and professions representing disparate interests. By harnessing these diverging and conflicting interests into a cohesive design approach, more efficient use may be made of available resources.

Finally, in response to the main problem posed in the study, i.e. "Can the principles of interior design be applied to the factory interior, and if so, could this have an effect on productivity?" :

It can be concluded that the objectives of the research project have been achieved in that the results of this investigation suggest that interior design principles can, and should, be applied to the factory interior, and that by doing so, productivity could be positively influenced.

8.2 RECOMMENDATIONS

In order to further investigate and measure the consequences of changes made to the physical working environment through the application of interior design principles, it may be necessary to accumulate suitable data for interpretation. These data could be assimilated through research activities based on observation and employing descriptive survey methods such as the use of questionnaires.

It is probable that future accumulated data will be of a qualitative, or descriptive, rather than quantitative or analytical nature. This probability is suggested by the results of this investigation in that, for example, little evidence relevant to the application of interior design principles was found where essential causal relationships were known

and agreed upon and where critical variables and interrelationships have been quantitatively reduced and manipulated.

In this regard Aaron Sloman, Professor of Artificial Intelligence and Cognitive Science, School of Cognitive Science, University of Sussex, writing in the Fontana Dictionary of Modern Thought proposed that "It is arguable that much research effort has been wasted ... in attempting to force non-quantifiable processes into quantitative molds, instead of searching for more relevant mathematical representation *(Bullock et al. 1988:709)*.

A future research approach which is suggested by the findings of this investigation (cf. the reference to Becker 1981:2 in the introduction to this dissertation in conjunction with paragraph 6.4.4.2) could comprise an interdisciplinary collaboration between interior design and the social sciences. By adopting a policy of co-operation it may be possible to combine the practical components of one of the social sciences with possible benefit to both disciplines as well as a strengthening of ties between design and the sciences.

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ANNEXURE A

1. WATER SERVICES

1.1 AREAS OF GENERAL CONCERN:

- Protection of public health
- Maintenance of potability of public water supply
- Water conservation.

1.2 PLANNING CONSIDERATIONS

1.2.1 EXTERNAL FACTORS

- Mains pressure range.
- Quantities available - daily/rates/limits.
- Location depth and size of mains and connection methods.
- Quantities to be supplied from other sources e.g. borehole.
- Chemical and biological characteristics of available supplies.

1.2.2 INTERNAL FACTORS

- Water requirements of processes/services/occupants.
- Water temperature requirements of processes/services/occupants.
- Statutory requirements, for example emergency storage.

1.2.3 BUILDING FACTORS

- Height to be pumped.
- Structures influencing layout, for example weight of storage tanks may require structural reinforcing.

1.3 AREAS OF GENERAL CONCERN

- Protection of public health.
- Maintenance of potability of public water supply.
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1.4.3 BUILDING FACTORS

- Height to be pumped.
- Structures influencing layout, for example weight of storage tanks may require structural reinforcing.

1.5 LOCATION AND SPACE REQUIREMENTS

1.5.1 INCOMING SUPPLIES AND METERS

- Meters usually required for inspection by authorities.
- Mains water supply should be accessible for inspection/repair.
- Mains supply cannot normally be buried under floor slabs.

1.5.2 PUMPING AND/OR PRESSURISATION OF WATER SUPPLY

- Required where mains pressure is insufficient.
- Pressurisation usually comprises a compressor and pressure vessel which is connected to the pipework system. Space requirements considerations for equipment, control gear and maintenance work. The operation of pressurising systems may entail high noise and vibration levels.

1.5.3 COLD WATER SUPPLIES

- Fire mains and potable water services are usually connected directly to the mains.
- Other supplies are usually drawn from storage or break tanks.
- Distribution pipework is usually laid level or preferably to falls.
- Consider access to isolating valves, drain cocks and air release valves.
- Consider implications of overflow pipes, for example flooding.
- Check statutory requirements regarding the marking of drinking water supply points.

1.5.4 HOT WATER SUPPLIED FROM:

- Calorifiers indirectly heated using primary steam or hot water from the building heating systems.
- Electric emulsion heaters.
- Small gas fired or local hot water cylinders may be used These are normally supplied by local cold water pipework.

1.5.5 PROCESSING OF WATER

- Incoming supplies, or used water, may require the use of filter beds, cooling ponds, pumps and storage tanks.

1.6 SOIL AND WASTE SYSTEMS

- Soil - W.C.'s, urinals, slop sinks.
- Waste - Wash handbasins, basins, baths, showers.
- Kitchen waste - Greasetraps.
- Process waste - cooling, processing, storage.

1.6.1 PLANNING ABOVE GROUND

- Locate and group system to give shortest pipe runs.
- Local authority ventilation requirements to be considered.
- Ventilation of the pipework to the atmosphere to be considered in terms of cross contamination of incoming air.
- Horizontal runs and vertical stacks should be avoided in occupied spaces due to the noise generated by the pipework.
- Pipework should not be subject to excessive heat/cold.

1.6.2 ACCESS ABOVE GROUND

- Pipework should not be built into the structure. For example pipework should be chased into walls rather than installed between the leaves of a cavity wall.
- Inspection points should be provided at the foot of each stack and on main junctions at ends of branch runs.

1.6.3 PLANNING BELOW GROUND PIPEWORK

- All branch connections are usually made at manholes.
- Underground drainpipes should run in straight lines between manholes (for ease of tracing pipework in the event of repairs).
- Manholes within the building must be sealed with double access covers over open channels.

1.6.4 SOIL AND WASTE STORAGE BELOW GROUND

- Usually required where waste is treated on site and stored for removal by a contractor. This may imply the use of specially designed storage tanks which are taken away or emptied by a contractor.

For further guidelines relating to Water Services, reference can be made to publications such as "Water, Sanitary and Waste Services for Buildings" by Wise, 1986 and "Planning: The Architects' Handbook" edited by Mills, 1985.

ANNEXURE B

1. GAS SERVICES

Gas supplies can be used for the following purposes:

- **Fuel** - for heating furnaces, hot water, air.

- **Power** - for running combustion type engines.

- **Process gases** - for welding and brazing.

- **Medical gases** - in the factory this usually implies "medical quality" gases, or example oxygen, often for use in a laboratory.

Gas services will usually be supplied by a specialist company such as "Afrox". The installation should be subject to municipal regulations and inspection. Planning aspects may include:

- Suitable storage space for gas containers incorporating:
  - ventilation
  - security
  - weather, heat and cold protection
  - warning signage such as "no smoking".

- Space allocation will depend on quantity of gas containers to be stored/used.

- Storage should be located to the exterior of the building.

- Supply pipework may be laid underfloor, carried above the ceiling or suspended from the ceiling.

- Main pressure valves in the interior pipework system should be vented to the outside of the building.

- Liquid Petroleum Gas may be supplied from a town mains connection.

- Work areas incorporating the use of process gas must be adequately ventilated so as to reduce the chance of inhalation of gas in the event of leakage as well as the prevention of explosions.

- Flammable Gas Detectors may be a requirement in areas where the use of flammable gas constitutes a fire risk.

Further guidelines with regard to Gas Services can be referred to in publications such as "Planning: The Architects' Handbook", edited by Mills, 1985.

ANNEXURE C

1. COOLING SERVICES

The process of cooling air and liquids usually incorporates the use of both cooling towers and air-cooled condenser sets. Planning factors may include:

1.1 The effect of location on the performance of cooling components in that:

- There should be free access for air movement so that fresh cooling air can replace spent cooling air.

- The possibility of contamination of refrigerated air by tower-cooling air should be avoided.

- Ducting of incoming air may reduce cooling fan performance if the ducting is restrictive to fan airflow.

- Height restrictions imposed by the building may affect cooling tower performance.

1.2 The effects which cooling towers and sets may have on the adjacent areas include:

- Air temperatures around the cooling component areas will be increased due to the cooling process. This implies avoiding the positioning of air intakes for ventilation in these areas.

- Moist air discharged by the system may condense. This could cause vapour clouds which could drift downward or be carried by wind into adjacent areas.

- Cooling components generate fan and water noise.

- The weight and vibration caused by the cooling equipment may have structural implications.

- Accidental leakage may cause flooding unless suitable overflow mechanisms have been included in the system.

- Tall cooling towers and other cooling components may require aesthetic planning.

For further guidelines regarding Cooling Services, reference can be made to publications such as "Planning: The Architects' Handbook" edited by Mills, 1985.

ANNEXURE D

1. SPACE HEATING SERVICES

1.1 HEATING PLANT

The heating plant usually comprises oil, electric or solid fuel boilers. Planning factors may include:

- Rating for capacity, possibly including future or standby requirements
- Clear heights for installation
- Space/access for maintenance
- Space for auxiliary components such as pumps, valves, tanks, and storage of chemicals
- Air supply for both fuel combustion and ventilation
- Space for flues and chimneys as well as storage of burnt fuel residues
- Boiler attendant's office and ablution facilities
- The effect which the weight of the installation may exert on the building structure
- The noise generated by the equipment
- Proximity of boiler fuel supplies to the installation.

1.2 FUEL STORAGE

Consideration may be given to factors such as area requirements, weight of fuel, special storage facilities, fire and security risks.

1.3 DISTRIBUTION SYSTEMS

Hot water, steam, or oil distribution systems will normally distribute to local distribution terminals via pipework. Planning considerations may include:

- Insulation of piping for heat retention and sound absorption.

- Space requirements and access for supports, anchors and expansion loops.

- Access to valves for balancing, isolating, drainage and temperature measurement.

- Type of system to be employed, for example one, two, three or four pipe systems.

- Single-storey distribution systems may be incorporated under-floor.

- In multi-storey buildings riser ducts will almost certainly be required; positioning may be a critical factor in interior planning

- Pipework should be laid to falls.

1.4 WARM AIR SYSTEM CONSIDERATIONS

These considerations may include:

- Warm air ductwork should be heat insulated.
- Positioning of supply grills in terms of both function and aesthetics.
- Fire compartmentalises, thus specification of fire dampers could be included in order tog prevent the spread of smoke and fumes between compartments of the building.
- Noise attenuation: air velocity may cause noise at, for example, supply grills. Specifications for the system may include noise level limiting.

1.5 TERMINAL UNITS

Terminal units are heat exchangers which change heat carried by water, steam or oil, into radiant heat, warm air, or a combination of the two. Planning considerations include:

- Finishes: these can affect the performance of the unit as some finishes inhibit heat transfer.
- Planning for fitting of terminals include aspects such as height, area and support/fixing requirements.
- Pipe runs could be overhead, under-floor or behind finishes.
- Fan convectors may be duct mounted in either ceilings or walls. This implies planning for supply grills.
- Access for maintenance and future changes to the system.

1.6 LOCAL HEATING SYSTEMS

Local systems usually comprise gas or electric units. Gas fired units will require a gas supply and a venting flue. Electrical units will require an adequate electrical supply.

1.7 WASTE HEAT SYSTEMS

In these systems some form of heat exchanger transfer the heat generated by, for example a process-cooling or process-heating operation to the space heating system. Typically, the pipework will be the same as that of a boiler system with the heat exchanger replacing or supplementing the boiler.

1.8 HEAT PUMPS

"Heat Pumps" are systems which pump (or flow) natural heat sources through a system in order to heat a space/process. Examples include the use of natural hot-spring water, or ventilating cool interior areas with air from warmer (exterior) areas.

1.9 SOLAR HEATING

Solar heating components usually require relatively large, sunny areas for effective operation. Specialist advice should be sought for these types of systems.

1.10 SURFACE HEATING

Surface heating refers to underfloor piped or electrical heating. Correct insulation (minimum heat loss) is usually critical to the effective operation of these systems.

For further guidelines regarding Space Heating Services reference can be made to publications such as "Planning: The Architects' Handbook, edited by Mills, 1985.

ANNEXURE E

1. VENTILATION SERVICES

Ventilation services provide fresh air and remove stale air, water vapour, odours, excess heat and other unwanted airborne contaminants. This action is carried out by the ingress or egress of air, or a combination of these factors. This air movement may be natural or mechanically assisted.

1.1 NATURAL VENTILATION

Natural ventilation is facilitated by openings in the building envelope and the air movement caused by positive and negative air pressures inside and outside the building.

Cross ventilation and the avoidance of "dead areas" i.e. areas with little airflow, are desirable characteristics which should be incorporated in the building envelope design. An interior designer may consider the effects of interior elements such as partitioning, on the crossflow of air in the factory interior.

1.2 MECHANICAL VENTILATION

A mechanical system comprises intake, fan, distribution and exhaust components. Planning considerations include:

- Air inlets and filters should be situated away from potential pollution sources.

- Ventilation ductwork may require noise insulation/attenuators.

- Fire dampers and volume control dampers may be required.

- Air supply points may feature controls which have to be positioned for human use.

- Transfer ducts may have to be introduced in partitioning to make effective use of limited supply points.

- The possible spreading of noise via shared ductwork should be avoided by suitable pipework baffling.

1.3 TOILET VENTILATION

Natural ventilation is preferable if possible. In the case of air extraction, the placing of fan units close to outlets will prevent pressurisation of the ductwork thereby lessening the chances of air leakages occurring.

2. EMPLOYMENT OF AIR CONDITIONING SERVICES

Reasons for employing air conditioning services could include:

- Natural conditions not suitable for human comfort or performance.

- The processes carried out may require controlled temperatures for accuracy purposes, for example quality testing facilities.

- Air conditioning may serve to enhance "prestige" value.

- The building may have to be insulated from the external environment due to noise or air pollution.

2.1 SYSTEM CHARACTERISTICS

- Air conditioning systems occupy relatively large areas with resulting high cost implications.

- Basic components of the system comprise methods of cleaning, heating, cooling, humidifying and distributing air.

2.2 PLANNING IMPLICATIONS

Initial planning considerations may include plant room layout, cooling tower location, distribution ductwork routing and final delivery method.

2.3 PLANT ROOM LAYOUT

Components to be planned for include: air intakes; filters; fans; ductwork; refrigeration machinery; boilers; fuel supplies; pumps; water treatment equipment; and system controls. These components are connected to form a "package" for conditioning the air.

2.4 COOLING TOWERS AND AIR COOLED CONDENSER SETS

See Annexure C.

2.5 TERMINAL DISTRIBUTION UNITS

See Annexure Section 1.5.

2.6 DUCTWORK SUPPLY SYSTEM

Conditioned air ducting system requirements are essentially the same as those for mechanical ventilation systems (See Section 1.2). However, because the delivered air may be heated or cooled, the ductwork may require insulation for improving temperature retention. Also, the conditioned air may be recirculated a number of times before being exhausted to the exterior environment. This process will require a return air system. Return air systems may make use of false ceiling spaces or other building cavities for return air channelling.

2.7 HEAT RECLAMATION SYSTEMS

In winter, these types of systems may collect air which has been preheated by the lighting installation or other processes for the warm air supply.

In summer the system may use external, pre-cooled night air to combat the effects of building heat storage during the night.

2.8 LOCAL SELF-CONTAINED UNITS

These are units which do not depend on a central plant, but are self-contained in terms of ability to supply cooled/heated air usually only requiring an electrical supply point.

These units are relatively bulky and location thereof may require careful consideration. Condensation caused by air cooling may require drainage.

Further guidelines to Ventilation Services can be referred to in publications such as the National Building Research Institute's "Guidelines to Factory Building Design", 1982 as well as "Planning: The Architects' Handbook", edited by Mills, 1985.

ANNEXURE F

1. PLANNING CONSIDERATIONS FOR ELECTRICAL POWER SUPPLY

1.1 INTERNAL FACTORS

- The gross supply capacity is estimated by ascertaining interior activities and quantifying these in terms of power requirements. These estimates will normally be compiled by an electrical engineering consultant using proposed activity details supplied by the client's brief.

- Special attention should be given to power supply requirements for computers, alarm systems and communication system installations as these may require "clean" or continuous power supplies.

1.2 EXTERNAL FACTORS

Initial planning typically involves establishing the capacity, voltage, location and security of the nearest public electrical supply.

1.3 BUILDING FACTORS

High load areas such as furnaces or boilers may influence distribution planning, for example in terms of locating of distribution boards and heavy cabling.

1.4 SPACE REQUIREMENTS AND LOCATIONS FOR POWER SUPPLY SERVICES

The main components of the system which will have to be planned for will include some or all of the following:

- Mains intake, metering and distribution equipment/system.
- High and low voltage distribution system.
- Local switch and distribution fuseboards.
- Local distribution wiring and power outlets.

1.4.1 MAINS INTAKE AND DISTRIBUTION SUBSTATION

Due to the size and need for air cooling these components are normally externally located.

1.4.2 HIGH AND LOW VOLTAGE DISTRIBUTION SYSTEMS

This refers to the distribution system from the main substation to the high/low voltage distribution boards.

1.4.2.1 The routing plan should take into account:

- Access for drawing of cables
- Cable diameters and minimum bending radii
- Cable supports
- Heat dissipation for the cables
- Possible electrical interference with other systems
- Protection of cable from damage caused by impact, heat or fluids.

1.4.2.2 Specification for insulation and fire stops may be required in the case of shared ducting.

1.4.3 LOCAL SWITCH AND DISTRIBUTION FUSEBOARDS

The function of the local switch and distribution boards is to "split" electrical current into suitable circuits for equipment as well as provide protection devices in the event of system overload or earth leakage. Planning considerations include:

- Location: may be located in any suitable space such as a cupboard or in a riser duct. No special construction is required except in hazardous atmospheres.

- The prime considerations for location is access for testing, maintenance, switching and rewiring purposes.

- Positioning of the fuseboards should be related to main cable routes and their supply capabilities.

1.4.4 LOCAL DISTRIBUTION WIRING AND POWER OUTLETS

Local distribution wiring connects the local distribution boards to power outlets, fittings and equipment. Planning considerations include:

- Larger power distribution systems may be accommodated in cast conduits.

- Smaller systems may be located underfloor, above-ceiling, on wall surfaces or in power skirting.

1.5 EMERGENCY AND MAINTAINED SUPPLIES

Planning may include:

- Emergency lights for
  - public access routes
  - escape routes
  - security lighting

- Maintained power for
  - pumps lifts, smoke ventilation systems
  - security services
  - fire alarms
  - computer systems.

Emergency and maintained electric power supplies comprise a combination of generator and/or battery storage.

Further guidelines to Electrical Supply Planning can be referred to in, for example, the publication "Planning: The Architects' Handbook" edited by Mills, 1985.

ANNEXURE G

1. HANDLING AND STORAGE COMPONENTS

HANDLING EQUIPMENT	USED FOR
Common wheelbarrow	Sand, gravel, loose matter
Sack barrows	Bagged goods
Stillage truck	Lifts a container with legs
Pallet truck	Lifts pallets
Hand stacker	Lifting a platform
Pulley Blocks	Lift heavy objects
Monorail	Overhead transporting
Chutes	Gravity transport
Roller conveyors and belt conveyors	Horizontal transportation

POWER DRIVEN VEHICLES AND CRANES

Forklift trucks
Platform trucks
Tractors
Overhead electric cranes.

STORAGE COMPONENTS	USED FOR
Adjustable steel shelving:	
Open type	Packaged items e.g. boxes
Closed type	Loose items e.g. bolts
Stocking	Bolted together to form rows
Multi tier	Storage above 2 metres high
Trays	Usually for specialised items e.g. jewellery
Pallets	Storage and transportation
Two-way pallet	Forklift can lift from two directions
Four-way pallet	Forklift can lift from four directions
Full perimeter base	Can be used by both forklift and hand pallet truck
Box pallet	Pallet with box sides capable of stacking.

Timber pallets offer more surface-to-surface friction for lifting equipment, are "softer" than metal, therefore less damaging to goods, are cheaper and do not rust. Steel pallets are usually only used when structurally necessary, or when there is a fire risk.

Racks: Racks are a generic name given to any type of storage fitting which is not classified as shelving or binning. Its application is wide and usually refers to storage of pallets, tubing, timber etc.

General Tools:

Wire or banding equipment
Hand-operated or powered saws
Hand-operated or powered guillotines.

ANNEXURE H

REPORT OF AN INFORMAL INTERVIEW WITH DOCTOR MARTIN BIRT, SENIOR LECTURER AT THE DEPARTMENT OF BUSINESS SCIENCE, UNIVERSITY OF CAPE TOWN

1. TERMS OF REFERENCE

On 26 August 1993 Doctor Birt was interviewed in order to obtain his opinion regarding the future role which an interior designer could play in the design of factory interiors and any relevance which this role may have in terms of management philosophy.

2. PROCEDURE

Doctor Birt was interviewed informally, by telphone.

3. TOPICS DISCUSSED AND CONSLUSIONS DRAWN

Doctor Birt pointed out that the interior designer's approach to the design of the factory interior could be seen from management's point of view to be a human orientated approach as opposed to the engineer's machine orientated approach.

He also recommended further investigation into what has become known as "social technology" or the "socio-techno systems" approach. This is a broad-based subject and derives from the idea that science-based technological thinking can be used to address social problems. In the context of interior design this implies the incorporation of science-based thinking into the creative problem-solving process.

ANNEXURE I

REPORT OF AN INFORMAL INTERVIEW WITH DOCTOR BRIDGER, HEAD OF THE ERGONOMICS GROUP AT THE DEPARTMENT OF BIOMEDICAL ENGINEERING, UNIVERSITY OF CAPE TOWN AND GROOTE SCHUUR HOSPITAL

1. TERMS OF REFERENCE

On 26 August 1993 Doctor Bridger was interviewed in order to obtain his opinion as to the future role which an interior designer could serve in the design of factory interiors.

2. PROCEDURE

Doctor Bridger was telephoned and interviewed on an informal basis.

3. TOPICS DISCUSSED AND CONCLUSIONS DRAWN

3.1 Doctor Bridger offered the following advice with regard to the future role of the interior designer in the design of factory interiors:

> "The interior designer must furnish himself with the latest information and guidelines pertaining to Ergonomics. He should not limit himself to South African standards as these are limited, but should obtain up-to-date information from Europe and the United States of America. He will then be able to incorporate the best available advice into his design."

ANNEXURE J

REPORT OF AN INFORMAL INTERVIEW WITH PROFESSOR I. PRINSLOO, DIRECTOR OF THE SCHOOL OF ARCHITECTURE AT THE UNIVERSITY OF CAPE TOWN

1. TERMS OF REFERENCE

On 25 August 1993 Dr Prinsloo was interviewed in order to obtain his opinion regarding the role which an interior designer could play in the design of the factory interior.

2. PROCEDURE

Professor Prinsloo was telephoned and the topic was discussed informally.

3. TOPICS DISCUSSED AND CONCLUSIONS DRAWN

The possible future role of the interior designer in the design of factories was discussed. Professor Prinsloo's opinions are summarised as follows:

3.1 HUMANISING THE WORKPLACE

The interior designer's approach to the design of the workplace should be characterised by a striving for the humanisation of the environment.

3.2 INTERFACE BETWEEN CLIENT AND ARCHITECT

The interior designer could act as an interface, from the architect's point of view, between the client and the architect as regards the client's requirements in terms of the building envelope.

3.3 CURRENT STATUS AS REGARDS PROFESSIONS CATERING TO THE NEED FOR A HUMAN ORIENTATED APPROACH TO THE DESIGN OF THE FACTORY INTERIOR

Professor Prinsloo indicated that he was not aware of an existing approach by a design profession which caters for the design of factory interiors. (Seen in the context of the conversation, this does not imply that architects do not address the interior environment as part of the design process or that ergonomic considerations are not implemented by, for example, the plant engineer).

ANNEXURE K

ALPHABETICAL INDEX TO SHORT TITLE REFERENCES TO SOUTH AFRICAN LEGISLATION WHICH MAY BE OF PARTICULAR RELEVANCE TO THE DESIGN OF FACTORY INTERIORS

SUBJECT	SHORT TITLE REFERENCE
- Atmospheric pollution prevention	PUBLIC HEALTH
- Atomic energy and nuclear installations	MINING AND MINERALS
- Building regulations and building standards, national	TRADE AND INDUSTRY
- Electrical wiremen and contractors	ELECTRICITY
- Environmental conservation act	LAND
- Factories, machinery and building work	MINES, WORKS AND FACTORIES
- Hazardous substances	PUBLIC HEALTH
- Health	PUBLIC HEALTH
- Labour	LABOUR
- Liquid fuel and oil	MINING AND MINERALS
- Livestock and meat industries	ANIMALS
- Machinery and occupational safety	MINES, WORKS AND FACTORIES
- National building regulations and building standards	TRADE AND INDUSTRY
- Occupational diseases in mines and works	MINING AND MINERALS
- Shops and Offices	LABOUR
- Water	WATER

See also:

South African Bureau of Standards for summaries of standards for building materials as well as standards for lighting codes etc.

Recommendations made by the National Building Research Institute - Council for Scientific and Industrial Research.

ANNEXURE L

LIGHTING TABLES

RECOMMENDED VALUES OF ILLUMINATION AND LIMITING VALUES OF GLARE INDEX

This Schedule is taken from the Code of the Illuminating Engineering Society, by courtesy of the Society. The basis on which the illumination values have been worked out is explained in para. 60.

This Schedule gives values of illumination and limiting values of Glare Index commensurate with the general standards of lighting described in the Code and related to many occupations and buildings. The great variety of visual tasks makes it impossible to list them all and those given should be regarded as representing types of task.

The different locations and tasks are grouped alphabetically within four sections:

Industrial buildings and processes;
Offices, schools and public buildings;
Surgeries and hospitals;
Hotels, restaurants, shops and homes.

The illumination values recommended are those to be maintained at all times on the task. They represent good modern practice and should be regarded as giving the order of illumination commonly required rather than as having some absolute significance. They can be exceeded where standards of visual performance or amenity higher than those set in the Code are called for, provided that other requirements of the Code (such as freedom from visual discomfort) are satisfied.

The recommended values increase by steps each of which is fairly large because it is related to a corresponding step in visual difficulty as between one class of scheduled task and the next. The series is:

1, 2, 3, 5, 7, 10, 15, 20, 30, 45, 70, 100, 150, 200, 300 . . .

Where work takes place throughout an interior, general illumination to the recommended value is necessary; where the precise height and location of the tasks is not known or cannot be easily specified, the recommended value is that on a horizontal plane 3 ft. above floor level.

Where the work is localized, the recommended value is that for the task only; it need not, and sometimes should not, be the level of illumination used throughout the interior. Some processes—such as industrial inspection processes—call for lighting of specialised design, where the level of illumination is only one of several factors to be taken into account.

The value of Glare Index for a particular lighting installation when computed by the method given in the Code should not exceed the limiting value recommended in this Schedule for the appropriate location. The recommended limiting values of the Glare Index form a series whose steps indicate noticeable changes in glare. The series is:

10, 13, 16, 19, 22, 25, 28.

The recommended limiting values of Glare Index apply to the *location* and not to the task; little glare is normally experienced when attention is concentrated on the task. They represent the maximum degree of glare which is acceptable for the room or building in which the particular occupation is carried on. Where different occupations are carried on in the same room, the installation should be designed to the lowest value of Glare Index recommended for the different occupations.

INDUSTRIAL BUILDINGS AND PROCESSES

	Recommended Illumination lm./ft.²	*Limiting Glare Index*
General Factory Areas:		
Canteens	15	
Cloakrooms	10	
Entrances, corridors, stairs	10	
Factory Outdoor Areas:		
Stockyards, main entrance and exit roads, car parks	2	
Internal factory roads	In accordance with BS CP1004 Part 2	
Aircraft Factories and Maintenance Hangars:		
Stock parts production	45	25
Drilling, riveting, screw fastening, sheet aluminium layout and template work; wing sections, cowling, etc., welding, sub-assembly, final assembly, inspection	30	25
Maintenance and repairs (hangars)	30	25
Assembly Shops:		
Rough work, e.g., frame assembly, assembly of heavy machinery	15	28
Medium work, e.g., machined parts, engine assembly, vehicle body assembly	30	25
Fine work, e.g., radio and telephone equipment, typewriter and office machinery assembly	70	22
Very fine work, e.g., assembly of very small precision mechanisms, instruments	*150	19
* Optical aids should be used where necessary.		
Bakeries:		
Mixing and make-up rooms, oven rooms, wrapping rooms	15	25
Decorating and icing	30	25
Boiler Houses (Industrial):		
Coal and ash handling	10	
Boiler rooms:		
Boiler fronts and operating areas	*10	
Other areas	2 to 5	
Outdoor plants:		
Catwalks	2	
Platforms	5	
* Supplementary local lighting may be required for gauge glasses and instrument panels.		
Bookbinding:		
Folding, pasting, punching, stitching	30	22
Cutting, assembling, embossing	45	22
Boot and Shoe Factories:		
Sorting and grading	*100	19
Clicking and closing:		
Preparatory operations	70	22
Cutting tables and presses, stitching	100	22
Bottom stock preparation, lasting and bottoming, finishing	70	22
Shoe rooms	70	22
* Special attention should be paid to the colour quality of the light.		
Breweries and Distilleries:		
General working areas	15	25
Brewhouse, bottling and canning plants	20	25
Bottle inspection	Special lighting	
Canning and Preserving Factories:		
Inspection of beans, rice, barley, etc.	45	22
Preparation:		
Kettle areas, mechanical cleaning, dicing, trimming	30	25
Canned and bottled goods:		
Retorts	20	25
High speed labelling lines	30	25
Can inspection	45	

	Recommended Illumination lm./ft.²	Limiting Glare Index
Carpet Factories:		
Winding, beaming	20	25
Designing, Jacquard card cutting, setting pattern, tufting, topping, cutting, hemming, fringing	30	22
Weaving, mending, inspection	45	22
Ceramics: (See *Pottery*).		
Chemical Works:		
Hand furnaces, boiling tanks, stationary driers, stationary or gravity crystallisers, mechanical driers, evaporators, filtration plants, mechanical crystallising, bleaching, extractors, percolators, nitrators, electrolytic cells	15	28
Controls, gauges, valves, etc.	*10	
Control rooms:		
Vertical control panels	20 to 30	19
Control desks	30	19
* Supplementary local lighting may be required for gauge glasses and instrument panels.		
Chocolate and Confectionery Factories:		
Mixing, blending, boiling	15	28
Chocolate husking, winnowing, fat extraction, crushing and refining, feeding, bean cleaning, sorting, milling, cream making	20	25
Hand decorating, inspection, wrapping, packing	30	22
Clothing Factories:		
Matching-up	*45	19
Cutting, sewing:		
Light	30	22
Medium	45	22
Dark	70	22
Pressing	30	22
Inspection:		
Light	45	19
Medium	100	19
Dark	150	19
Hand tailoring:		
Light	45	19
Medium	100	19
Dark	150	19
* Special attention should be paid to the colour quality of the light.		
Collieries (Surface Buildings):		
Coal preparation plants:		
Working areas	15	
Other areas	10	
Picking belts	30	
Winding houses	15	
Lamp rooms:		
Main areas	10	
Repair sections	15	
Weigh cabins	15	
Fan houses	10	
Dairies:		
General working areas	*20	25
Bottle inspection	Special lighting	
Bottle filling	45	25
* Supplementary local lighting may be required for sight glasses.		
Die Sinking:		
General	30	
Fine	100	19
Dye Works:		
Reception, "grey" perching	70	
Wet Processes	*15	28
Dry processes	*20	28
Dyers' offices	†70	19
Final perching	†200	
* Supplementary local lighting should be used where necessary.		
† Special attention should be paid to the colour quality of the light.		

	Recommended Illumination lm./ft.²	Limiting Glare Index
Electricity Generating Stations: Indoor Locations:		
Turbine halls	20	25
Auxiliary equipment:		
Battery rooms, blowers, auxiliary generators, switchgear and transformer chambers	10	
Boiler houses (including operating floors), platforms, coal conveyors, pulverisers, feeders, precipitators, soot and slag blowers	7 to 10	
Boiler house and turbine house basements	10	
Conveyor houses	7	
Conveyor gantries, junction towers	7 to 10	
Control rooms:		
Vertical control panels	20 to 30	19
Control desks	30	19
Rear of control panels	15	19
Switch houses	15	25
Nuclear reactors and steam raising plants:		
Reactor areas, boilers, galleries	15	25
Gas circulator bays	15	25
Reactor charge/discharge face	20	25
Electricity Generating Stations: Outdoor Locations:		
Coal unloading areas	0·5	
Coal storage areas	0·1	
Conveyors	1	
Fuel oil delivery headers	5	
Oil storage tanks	1	
Catwalks	2	
Platforms, boiler and turbine decks	5	
Transformers and outdoor switchgear	2	
Engraving:		
Hand	100	19
Machine	See *Die Sinking*	
Farm Buildings:		
Barns:		
Storage, granary	5	
Food preparation	15	25
Cow houses:		
At udder level and drain channels	15	
Feeding passages (trough level)	2	
Dairies:		
Boiler houses	5	
Milk rooms	15	25
Washing and sterilising rooms	15	25
Drying, grass or grain:		
Control points	15	
General	5	
Fertiliser stores	5	
Implement stores	5	
Implement maintenance	15	25
Loose boxes:		
Bull, calf	5	
Isolation, calving	10	
Stables	5	
Milking parlours	15	25
Piggeries:		
Pig houses, boiler houses	5	
Farrowing pens	10	
Poultry:		
General	5	
Extended hours	2	
Stockyards (covered)	2	
Flour Mills:		
Roller, purifier, silks and packing floors	15	25
Wetting tables	30	25
Forges:		
General	15	28

	Recommended Illumination lm./ft.²	Limiting Glare Index
Foundries:		
Charging floors, tumbling, cleaning, pouring, shaking out, rough moulding and rough core making	15	28
Fine moulding and core making, inspection	30	25
Garages:		
Parking areas (interior)	7	28
Washing and polishing, greasing, general servicing pits	15	28
Repairs	30	25
Gas Works:		
Retort houses, oil gas plants, water gas plants, purifiers, coke screening and coke handling plants (indoors)	*3 to 5	28
Governor-, meter-, compressor-, booster- and exhauster-houses	10	25
Open type plants:		
Catwalks	*2	
Platforms	*5	
* Supplementary local lighting should be used at important points		
Gauge and Tool Rooms:		
General	*70	19
* Supplementary local lighting and optical aids should be used where necessary.		
Glass Works and Processes:		
Furnace rooms, bending, annealing lehrs	10	28
Mixing rooms, forming (blowing, drawing, pressing, rolling)	15	28
Cutting to size, grinding, polishing, toughening	20	25
Finishing (bevelling, decorating, etching, silvering)	30	22
Brilliant cutting	70	19
Inspection:		
General	20	19
Fine	70	19
Glove Making:		
Pressing, knitting, sorting, cutting	30	22
Sewing:		
Light	30	22
Medium	45	22
Dark	70	22
Inspection:		
Light	45	19
Medium	100	19
Dark	150	19
Hat Making:		
Stiffening, braiding, cleaning, refining, forming, sizing, pouncing, flanging, finishing, ironing	15	22
Sewing:		
Light	30	22
Medium	45	22
Dark	70	22
Hosiery and Knitwear:		
Circular and flat knitting machines, universal winders, cutting out, folding and pressing	30	22
Lock stitch and overlocking machines:		
Light	30	22
Medium	45	22
Dark	70	22
Mending	150	19
Examining, and hand finishing, light, medium, dark	70	19
Linking or running on	45	19
Inspection Shops (Engineering):		
Rough work, e.g., counting, rough checking of stock parts, etc.	15	28
Medium work, e.g., "Go" and "No-go" gauges, sub-assemblies	30	25
Fine work, e.g., radio and telecommunication equipment, calibrated scales, precision mechanisms, instruments	70	22
Very fine work, e.g., gauging and inspection of small intricate parts	150	19
Minute work, e.g., very small instruments	*300	10
* Optical aids should be used where necessary.		
Iron and Steel Works:		
Marshalling and outdoor stockyards	1 to 2	
Stairs, gangways, basements, quarries, loading docks	10	
Slab yards, melting shops, ingot stripping, soaking pits, blast furnace working areas, pickling and cleaning lines, mechanical plant, pump houses	10	28
Mould preparation, rolling and wire mills, mill motor rooms, power and blower houses	15	28
Slab inspection and conditioning, cold strip mills, sheet and plate finishing, tinning, galvanising, machine and roll shops	20	28
Plate inspection	30	
Tinplate inspection	Special lighting	
Jewellery and Watchmaking:		
Fine processes	*70	19
Minute processes	*300	10
Gem cutting, polishing, setting	†*150	
* Optical aids should be used where necessary.		
† Special attention to colour quality of light may be necessary.		
Laboratories and Test Rooms:		
General laboratories, balance rooms	30	19
Electrical and instrument laboratories	45	19
Laundries and Dry Cleaning Works:		
Receiving, sorting, washing, drying, ironing (calendering), despatch	20	25
Dry cleaning, bulk machine work	20	25
Fine hand ironing, pressing, inspection, mending, spotting	30	25
Leather Dressing:		
Vats, cleaning, tanning, stretching, cutting, fleshing and stuffing	15	28
Finishing, staking, splitting and scarfing	20	28
Leather Working:		
Pressing and glazing	45	22
Cutting, scarfing, sewing	70	22
Grading and matching	*100	19
* Special attention should be paid to the colour quality of the light.		
Machine and Fitting Shops:		
Rough bench and machine work	15	28
Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	30	25
Fine bench and machine work, fine automatic machines, medium grinding, fine buffing and polishing	70	22
Motor Vehicle Plants:		
General sub-assemblies, chassis assembly, car assembly	30	25
Final inspection	45	25
Trim shops, body sub-assemblies, body assembly	30	25
Spray booths	45	
Paint Works:		
General, automatic processes	20	25
Special batch mixing	45	22
Colour matching	*70	19
* Special attention should be paid to the colour quality of the light.		

	Recommended Illumination lm./ft.²	Limiting Glare Index
Paint Shops and Spraying Booths:		
Dipping, firing, rough spraying	15	25
Rubbing, ordinary painting, spraying and finishing	30	25
Fine painting, spraying and finishing	45	25
Retouching and matching	*70	19
* Special attention should be paid to the colour quality of the light.		
Paper Works:		
Paper and board making:		
Machine houses, calendering, pulp mills, preparation plants, cutting, finishing, trimming	20	25
Inspection and sorting (overhauling)	30	22
Paper converting processes:		
Corrugated board, cartons, containers and paper sack manufacture, coating and laminating processes	20	25
Associated printing	30	25
Pharmaceutical and Fine Chemical Works:		
Raw material storage	20	28
Control laboratories and testing	30	19
Pharmaceuticals manufacture:		
Grinding, granulating, mixing and drying, tableting, sterilising and washing, preparation of solutions and filling, labelling, capping, cartoning and wrapping, inspection	30	25
Fine chemical manufacture:		
Plant processing	20	25
Fine chemical finishing	30	25
Plastics Works:		
Manufacture	See *Chemical Works*	
Processing:		
Calendering, extrusion	30	25
Moulding—compression, injection	20	25
Sheet fabrication—shaping	20	25
trimming, machining, polishing	30	25
cementing	20	25
Plating Shops:		
Vats and baths, buffing, polishing, burnishing	15	25
Final buffing and polishing	Special lighting	
Pottery and Clay Products:		
Grinding, filter pressing, kiln rooms, moulding, pressing, cleaning, trimming, glazing, firing	15	28
Enamelling, colouring, decorating	*45	19
* Special attention should be paid to the colour quality of the light.		
Printing Works:		
Type foundries:		
Matrix making, dressing type, hand and machine casting	20	25
Fount assembly, sorting	45	22
Printing plants:		
Machine composition, imposing stones	20	25
Presses	30	25
Composing room	45	19
Proof reading	30	19
Electrotyping:		
Block-making, electroplating, washing, backing	20	25
Moulding, finishing, routing	30	25
Photo-engraving:		
Block-making, etching, masking	20	25
Finishing, routing	30	25
Colour printing:		
Inspection area	*70	19
* Special attention should be paid to the colour quality of the light.		

	Recommended Illumination lm./ft.²	Limiting Glare Index
Rubber Processing:		
Fabric preparation creels	20	25
Dipping, moulding, compounding, calenders	15	25
Tyre and tube making	20	25
Sheet Metal Works:		
Benchwork, scribing, pressing, punching, shearing, stamping, spinning, folding	20	25
Sheet inspection	Special lighting	
Soap Factories:		
Kettle houses and ancillaries, glycerine evaporation and distillation, continuous indoor soap making plants:		
General areas	15	25
Control panels	20 to 30	25
Batch or continuous soap cooling, cutting and drying, soap milling, plodding:		
General areas	15	25
Control panels, key equipment	20 to 30	25
Soap stamping, wrapping and packing, granules making, granules storage and handling, filling and packing granules:		
General areas	15	25
Control panels, machines	20 to 30	25
Edible products processing and packing	20	25
Structural Steel Fabrication Plants:		
General	15	28
Marking off	30	28
Textile Mills (Cotton or Linen):		
Bale breaking, blowing, carding, roving, slubbing, spinning (ordinary counts), winding, hackling, spreading, cabling	15	25
Warping, slashing, dressing and dyeing, doubling (fancy), spinning (fine counts)	20	25
Healding (drawing in)	70	
Weaving:		
Patterned cloths, fine counts dark	70	19
Patterned cloths, fine counts light	30	19
Plain "grey" cloth	20	19
Cloth inspection	*70	19
* Special attention should be paid to the colour quality of the light.		
Textile Mills (Silk or Synthetic):		
Soaking, fugitive tinting, conditioning or setting of twist	20	25
Spinning	45	25
Winding, twisting, rewinding and coning, quilling, slashing:		
Light thread	20	25
Dark thread	30	25
Warping	30	25
Healding (drawing in)	70	
Weaving	70	19
Inspection	*100	19
* Special attention should be paid to the colour quality of the light.		
Textile Mills (Woollen):		
Scouring, carbonising, teasing, preparing, raising, brushing, pressing, backwashing, gilling, crabbing and blowing	15	25
Blending, carding, combing (white), tentering, drying, cropping	20	25
Spinning, roving, winding, warping, combing (coloured), twisting	45	25
Healding (drawing in)	70	
Weaving:		
Fine worsteds	70	19
Medium worsteds, fine woollens	45	19
Heavy woollens	30	19
Burling and mending	70	19
Perching:		
"Grey"	70	
Final	*200	
* Special attention should be paid to the colour quality of the light.		

	Recommended Illumination lm./ft.²	Limiting Glare Index
Textile Mills (Jute):		
Weaving, spinning flat, Jacquard carpet looms, cop winding	20	25
Yarn calender	15	25
Tobacco Factories:		
All processes	*30	22
* Attention should be paid to the colour quality of the light in all processing areas.		
Upholstering:		
Furniture and vehicles	30	22
Warehouses and Bulk Stores:		
Large material, loading bays	10	28
Small material, racks	15	25
Packing and despatch	15	25
Welding and Soldering:		
Gas and arc welding, rough spot welding	15	28
Medium soldering, brazing and spot welding, e.g. domestic hardware	30	25
Fine soldering and spot welding, e.g. instruments, radio set assembly	70	22
Very fine soldering and spot welding, e.g. radio valves	150	19
Woodworking Shops:		
Rough sawing and bench work	15	22
Sizing, planing, rough sanding, medium machine and bench work, gluing, veneering, cooperage	20	22
Fine bench and machine work, fine sanding and finishing	30	22

OFFICES, SCHOOLS AND PUBLIC BUILDINGS

Airport Buildings:		
Reception areas (desks)	30	22
Customs and immigration halls	30	22
Circulation areas, lounges	15	
Assembly and Concert Halls:		
Foyers, auditoria	10 to 15	
Platforms	45	
Corridors	7	
Stairs	10	
Banks:		
Counters, typing, accounting, book areas	30	19
Public areas	15	19
Churches:		
Body of church	5 to 10	13
Pulpit and lectern areas, chancel, choir	10 to 15	
Altar, communion table	*20 to 30	
Vestries	10	
* The value will depend on circumstances but should be sufficient to give appropriate emphasis.		
Cinemas:		
Foyers	15	
Auditoria	5	
Corridors	7	
Stairs	10	
Libraries:		
Shelves (stacks)	*5 to 10	
Reading rooms (newspapers and magazines)	20	19
Reading tables	30	19
Binding	45	22
Cataloguing, sorting, stock rooms	30	22
* On vertical surface.		

	Recommended Illumination lm./ft.²	Limiting Glare Index
Museums and Art Galleries:		
Museums:		
General	15	16
Displays	Special	16
Art galleries:		
General	*10	10
Paintings	†20	10
* For galleries with separate picture lighting. In small galleries without wall lighting the illumination should be increased to 20 lm./ft.²		
† On vertical surface. Special attention should be paid to colour quality of the light.		
Offices:		
Entrance halls and reception areas	15	
Conference rooms, executive offices	30	19
General offices	30	19
Business machine operation	45	19
Drawing offices:		
General	30	16
Boards and tracing	45	16
Corridors and lifts	7	
Stairs	10	
Lift lobbies	15	
Telephone exchanges:		
Manual exchange rooms (on desk)	*20	16
Main distribution frame rooms	15	16
* Special lighting will be required for switchboards.		
Schools and Colleges:		
Assembly halls:		
General	15	16
When used for examinations	30	16
Platforms	30	16
Class and lecture rooms:		
Desks	30	16
Chalk boards	*20 to 30	
Embroidery and sewing rooms	70	10
Art rooms	†45	16
Laboratories	30	16
Libraries:		
Shelves, stacks	*5 to 10	
Reading tables	30	16
Manual training	See *Appropriate Trade*	
Offices	30	19
Staff rooms, common rooms	15	16
Corridors	7	
Stairs	10	
* On vertical surface.		
† Special attention should be paid to the direction and colour quality of the light.		
Theatres:		
Foyers	15	
Auditoria	7	
Corridors	7	
Stairs	10	

SURGERIES AND HOSPITALS

Dental Surgeries:		
Waiting rooms	15	
Surgeries:		
General	30	
Chairs	Special lighting	
Laboratories	30	
Doctors' Surgeries:		
Waiting rooms, consulting rooms	15	
Corridors	7	
Stairs	10	
Sight testing (acuity) wall charts and near vision types	*45	
* The charts should be so illuminated that their brightness is substantially uniform over their whole area.		