DESIGN CONSIDERATIONS IN INDUSTRIAL ARCHITECTURE

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A Thesis Submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the Degree of Master of Architecture.

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PREFACE

The planning of this study started with the author's personal observations from available reading material that in industry, some problems appear to be persistent. For instance:

(a) rapid market and technological changes constantly tend to render many manufacturing plants economically and technically obsolete;

(b) great economic losses are sustained every year through fire destruction, and chemical and dust explosions; and,

(c) the full potential of human contributions to industrial efficiency and prosperity is not being attained, as judged by the frequency, extent, and proliferation of labour conflicts.

Accessed by the myriad of issues which confront an industrial enterprise every day, these problems may be distant, but they are none-the-less important.

Realizing that extensive studies have been carried out on various aspects of industrial buildings, and also that industrial plant designers architects, engineers, constructors and various technical experts - among them, already know, or possess adequate information about the technical, constructional, and servicing skills necessary to make an industrial plant function, this author believed it would be rewarding to examine the nature of the problems mentioned above from an architectural point of view alone.

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This work is therefore an attempt to explore some basic economic, technical and human problems related to industrial buildings to which architectural solutions may be provided, but which do not appear to have been given much attention. It is based on the hypothesis that where fragmentation of the huge mass of an industrial plant by articulation of the main component activities is used as a framework for the design approach of industrial buildings, certain economic, technical and human advantages will be obtained.

The study is organized into three sections.

The first section discusses the scope of Industrial Architecture, and the objectives of typical manufacturing enterprise, and from these, the nature of the architectural problems.

The second section, the main body of this work, is organized into three parts:

Part One deals with the economic considerations of change and obsolescence, and security of industrial assets from fire hazard;

Part Two deals with the technical considerations of production process selection, and the physical layout of plant facilities and services;

Part Three deals with the human considerations of worker motivation, satisfaction, and higher productivity in industry.

The third section, the conclusion, deals with the synthesis of the considerations examined, and suggests a framework for an architectural design approach to these problems. It ends with the evaluation of the architect's role in the interpretation and expression of such an approach, and the extent of professional collaboration necessary to attain it.

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This study has been made possible by the assistance rendered by many people to whom the author now wishes to express his gratitude. Professor Norbert Schoenauer, the author's director, showed great understanding and encouragement, and provided good guidance, criticisms and suggestions. Professor John Bland, the Director of the School of Architecture, showed a keen interest by helping to correct the manuscripts several times with important suggestions. Professor J. Cherna of the Mechanical Engineering Department granted a series of stimulating and useful interviews. Mr. B. Saskin, Chief Architect (Montreal Branch), of the T. Pringle Industrial Project Design Company offered a deep insight into practical situations. The librarians at the Commerce, Engineering, Blackader, and Redpath Libraries afforded great facilities and privileges in the use of library material.

To many other people who have helped to make the production of this work possible, the author wishes to express his gratitude.

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SECTIONONE Introduction

CHAPTER 1

THE SCOPE OF INDUSTRIAL ARCHITECTURE

Industrial production consists of three basic aspects:¹

- (a) the extraction of raw materials, Primary Industry;
- (b) the manufacture of products, Secondary Industry; and
- (c) the distribution of materials and products, Tertiary Industry.

These three aspects require one type of physical facilities or another, depending on the nature and extent of the operations. Most generally, however, the extraction or raw materials does not usually require a building in which to operate. The distribution industry merges into the commercial and business operations of industrial enterprise. Strictly speaking, therefore, it is the manufacturing aspect of industrial production - whether it is processing, fabricating or assembly, or all three combined - which usually requires buildings. Industrial architecture may therefore be considered to involve the provision of adequate and appropriate physical facilities for the manufacturing aspect of industrial production.

The scope of what is adequate and appropriate will normally be defined by the objectives of a given enterprise.

¹James F. Munce, <u>Industrial Architecture</u>, F. W. Dodge Corporation, New York, 1960. p.180.

The Objectives of Manufacturing Enterprise

Different industrial establishments have different sets of goals. It would be safe, however, to state that in a "free enterprise economy", there are two main objectives: economic and social.

The economic objectives are the desire (a) to stay in business, and (b) to make money.² Many manufacturing companies publish a long list of high-sounding objectives, but if they fail to stay in business the other objectives do not matter; and if some officers continue to loss money for very long, they are likely to be replaced; or if some products are not selling well, they too are sure to be abandoned. These economic objectives of survival and profit necessarily introduce the normal operational objectives of improved efficiency and higher productivity.

While broad social objectives may result from the role industry is expected to play in promoting social progress and strengthening the economic foundations of human well-being,³ the immediate social objectives concern the workers' comfort, welfare and motivation.

Architectural Objectives

In architectural terms, the economic and social objectives of industry would be met by the provision of:

- 1. Operational efficiency of plant facilities. This calls for:
 - (a) efficiency of the physical plant, of labour, and of management,

²F. G. Moore: <u>Manufacturing Management</u>, Irwin Inc. Illinois, 1958, p.25.

³International Labour Office: <u>Higher Productivity in Manufacturing</u> <u>Industries</u>, Geneva, 1954, p.11

- (b) thwarting of obsolescence, and
- (c) adequate security of life and property; and
- 2. Pleasant physical environment. This requires:
 - (a) the provision of adequate physical amenities for the workers.
 - (b) physiological appropriateness within the plant environment.
 - (c) the avoidance or abatement of obnoxious infussion into the environment.
 - (d) the orderly development of physical facilities to provide proper scale, stimulus and perception of work situation to workers.
 - (e) the recognition of, and provision for other individual and group needs of workers.

Prevalent Design Concept

Although little architectural development of a valuable philosophical content in the industrial field occurred between the beginning of the Industrial Revolution era in the eighteenth century and the dawn of the twentieth century,⁴ great strides have been taken in industrialized building techniques, especially in the structural and constructional aspects, since the second World War.⁵

Rapid progress in technological developments, the use of complex mechanization in production systems, and the increasing demand for controlled atmosphere for machines, equipment and products, and in some cases for

⁴Henry J. Cowan, "Industrialized Architecture," (Reprinted from the Australian Journal of Science, Vol.26, No.7, Jan. 1964, pp.206-213), Reprint No.30 privately circulated.

⁵ibid.; see also K. Wachsmann, <u>The Turning Point of Building</u>, Structure and Design, Reinhold Publishing Corporation, New York, 1961. people, have resulted in the introduction and increasing use of artificially controlled environment,⁶ the culmination of which is the notion of the "windowless factory."

However, these developments together with the introduction of the principle of mass production technique to the production system which of started in the automobile industry, the development/horizontal handling methods, the availability of spacious land in the suburban areas, and the realization of rapidly changing conditions in industry, have led to the evolution of a design concept which concentrates most or all of the manufacturing activities of an industrial enterprise within one huge building.⁷ More than by any other feature, the contemporary industrial plant is now recognized by its colossal size. Undoubtedly, the "concentration" concept appears adequate from a "machine-logic" point of view, but it creates a number of other problems, while leaving unresolved some of the issues it explicitly sets out to resolved.

It is therefore the adequacy of prevalent trends in plant building that this study wishes to examine in the light of changing economic technical and human values.

The next chapter will introduce the economic considerations which the existing system does not fully satisfy.

⁶Frank L. Whitney, "A New Measure of Construction Costs," Architectural <u>Record</u>, March, 1961, p.155. See also a study on Mechanical and Electrical Installations by the Walter Kidde Constructors, Inc. U.S.A., <u>Architectural</u> <u>Record</u>, July, 1964, pp.168-171.

For a penetrating argument against this trend, see Lewis Mumford, "The Case Against 'Modern Architecture'", Architectural Record, April, 1962. pp.155-162.

⁷George Nelson, Industrial Architecture of Albert Kahn, Inc. (Architectural Book Publishing Co. Inc., New York, 1939), pp.11-12.

SECTION TWO Part One

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CHAPTER 2

INTRODUCTION TO ECONOMIC CONSIDERATIONS

"The industrial building cannot be created or intelligently located except by economic analysis. When it is built, it is usually built in a hurry. Before it is finished, it may have to be expanded. In the end, its failure or success can be measured only by what it contributes to the productivity and profitability of the industrial process."¹

While profitability is strongly affected by the design and construction of the physical plant, it is also seriously affected by other complex factors that involve the architect, but occur well in advance of the decision to build. For example, the objective of profit must take into consideration the problems of plant location and site selection; the assembly of adequate land on which to build the plant; area transportation system; water resources; local tax rates; the characteristics of the market for the product to be manufactured; technological change and the question of plant specialization or flexibility; operational obsolescence and the problem of plant disposal; security of assets from fire hazard.



¹J. Roy Carroll, "Industrial Architecture: Proving Ground for Comprehensive Services," <u>Architectural Record</u>, July, 1964.

An analysis of these and many other economic planning problems are needed to determine whether the plant facility should be built at all, and if it is built, whether the manufacturer should own all of it or lease a part of it to other manufacturers. The answers to these questions will greatly influence the nature of the architect's design.

Beyond the question of plant location, for an architect, the important considerations for the design of industrial buildings are the phenomenon of change and particular plant characteristics, the problem of obsolescence and plant disposal, and the security of industrial assets from all varieties of hazards. These will be the issues to be examined in Chapters 3, 4 and 5 respectively.

Throughout this SECTION, that is Parts One, Two and Three, drawings indicating the "concentrated" design concept of figures 1 and 2, and the fragmented design concept of figures 3 and 4 will be used to illustrate the essence of the arguments produced on each topic.



Volkswagenwerk AG factory in Hanover, Germany Design and contract work by the Volks-wagen AG Building Department, Wolfsburg Above: Aerial view of the whole plant; in the fore ground, the presswork department, on the left the Mittelland Canal Below: Schematic representation of the factor floor plan with the most important departments





FIGURE 1 - "CONCENTRATED" DESIGN CONCEPT Volkswagen Factory, Hanover, Germany. (Walter Henn, II, p. 132).



Architects: Albert Kahn Inc., Detroit (Walter Henn, II, p. 134).



View from the north-west towards the department for baby products



Johnson & Johnson surgical-dressing factory in North Brunswick, USA Architects: Walter Kidde Constructors Inc. North Brunswick, NJ, USA

Layout: Scale 1 : 10 000 1 Finished goods store

2 Baby products 3 Surgical-plaster mili 4 Ancillary plants 5 Canteen 6 Car park

W R STREET R . . .

FIGURE 3 - "FRAGMENTED" DESIGN CONCEPT (Walter Henn, II, p. 283).



International Business Machines Corp. in Rochester, Minn., USA Architects: Eero Saarinen Assoc., Hamden, Conn.

Two requirements led to a cheeseboardpatterned works installation: first, that there should be great flexibility with regard to facilities for extension; and secondly, that work positions should be arranged in the greatest interests of the operatives' welfare. Research work indicated that the optimum size for a production department at IBM was about 5,500 square metres, and the optimum size for an administration unit, about 3,700 square metres. Departments of these dimensions form an easily supervised unit for the personnel working in them, and normal human comfort is given full consideration. The focal point of the whole works is a building containing dining rooms and two large entrance halls-the whole plant is accessible from two opposite sides. On one side of this structure are the office and training buildings, each two-storey and 24 - 76 metres in area; and on the other side are the 76 · 76 metre production buildings. Two main gangways running parallel to one another yield access to the whole complex. Each building has a centre portion with the sanitary rooms and air-conditioning sysbehind the other, as seen from the south

tem. The garden courts situated between the various buildings serve as recreation areas for personnel. Each building has its own large car park.

In the first building section four office buildings and four production units have been erected. A gradual extension to eight offices and 11 production buildings is planned. The power station, the water tower and a storage building with a railway siding are situated at the end of the production area.

Office and production buildings are built on steel frames and form an artistic unity. An aluminium curtain wall with perpendicular continuous profiles with 1-20 metre axis



FIGURE 4 - "FRAGMENTED" DESIGN CONCEPT

(Walter Henn, II, p. 164).

CHAPTER 3

THE PHENOMENON OF CHANGE AND PLANT CHARACTERISTICS

The Process of Change in Industry:

The economic and social climate in which industry operates is constantly changing.¹ Changes within the economic system that affect an industrial enterprise include new products and services, technological improvements, business cycles, changes in costs, and changes resulting from action by competitors.

These changes present special problems of adjustment to every industrial enterprise. Instability in the economy causes instability in the individual firms. A period of rapid growth means that most firms must increase production, employ more workers, obtain new capital and facilities, and increase sales. A period of contraction means that most firms must curtail expenditures, decrease production, and lay off workers. While such changes are commonly associated with booms and depressions, they are actually occurring all the time.² New products, new methods, and new ideas appear continually; the competition they foster and the failures they cause are both a part of the never-ending process of change.

¹H. C. Thole and C. C. Gibbons (Ed). <u>Business Action in a Changing World</u> Public Administration Service, Chicago, Ill. 1956, p.1.

²ibid.

Change, as such, is not new; but the pace of change is now increasing rapidly. Big opportunities that formerly occurred perhaps once in a life time may now confront an industrial manager any day; and if the chance of success comes often, the chance to miss an opportunity and thus to fail, comes equally often.

Long-range Planning

Because of this process of change, dynamic economic planning which anticipates future conditions becomes important in manufacturing management.³ Today there is a trend for management planning to become more long-range in character. Increasing population and rising standards of living mean that there will be a greater demand for products in the future. Managers are motivated to increase or at least maintain their share in the market. Long-range requirements for buildings, equipment and manpower must therefore be established.

Another factor which makes long-range planning necessary is that most manufacturing industries require large capital outlays. Automation and increasing labour costs tend to make it profitable to increase capital expenditures still further. Recovery of these costs must be spread over a long period of time and it is therefore necessary to plan far ahead.

Specialization or Flexibility ?

One factor which requires careful long-range planning is the vital question of whether an industrial enterprise should have specialized or flexible physical facilities, or the right balance of both in its estab-

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³ibid., p.2.



lishment.4

Many companies are at a serious competitive disadvantage today merely because their facilities are so highly specialized.⁵ To keep pace with technological progress which has substantially improved competitive products, they find that they must spend unusually large sums of money for building and layout changes. More astute facilities planning in the past would have saved them much of that expense.

Admittedly, there are some industries which can operate successfully only with the use of highly specialized facilities.⁶ Petroleum refining and cement manufacturing are typical examples in which the possibility of designing truely flexible facilities is limited and is accepted largely as a characteristic of the industry.

The problem of facilities planning, therefore appears to have no definite solutions. The degree of flexibility that is ideal for one product-situation may be totally inadequate or ineffectual to another. Each probelm would have to be individually studied to determine the effects of flexibility and specialization on the current and long-term profit position. This requires obviously that marketing research findings should be carefully analysed during the design programming stage. For example: if the sale of a product depends on its price, which leaves a very small profit margin, it may be imperative to plan highly specialized facilities so that manufacturing costs can be kept to the absolute minimum. Here the need for the lowest possible current operating cost may be so

⁴Robert P. Neuschel, "<u>How Flexible Shall We Make Our Plant and Facilities</u>", <u>Advanced Management</u>, 16th January, 1951, p.16.

⁵ibid., p.17. ⁶ibid.

vital that designing flexible facilities is out of the question.⁷

Often, however, the spread between manufacturing costs and selling price will permit some loss of current efficiency in expectation of greater long-term gains from flexibility. If the higher manufacturing costs do not seriously affect the current competitive position of the company, long-term profits may be greatly enhanced by designing highly flexible facilities.

Moreover, an industry for fine chemicals, electronics, electrical appliances, or pharmaceuticals, that is plagued with constant changes in products and process and also with rapid expansion possibilities, will probably thwart the adverse effect of change by designing flexible buildings which would be adaptable to changing requirements.

The Nature of Plant Flexibility

At this juncture, it is important to observe that the issue of plant flexibility has generally been regarded as resolved when large unobstructed space for all the plant facilities can be provided under one roof.⁸ Figure 5 shows the typical application of this philosophy.

The property of plant flexibility, in its fundamental form, requires that the plant facilities, as a system, should be capable of adjusting to satisfy any demands of the process of change. It should be an adaptive system in which various constituent elements or components are free to respond to change individually or collectively without danger or obstruction to one another's existence or proper functioning.

⁸George Nelson: <u>Industrial Architecture of Albert Kahn, Inc.</u>, (Architectural Book Publishing Co. Inc., New York, 1939), p.11.

⁷ibid., p.18.



FIGURE 5 - TYPICAL INDUSTRIAL SCENE (All major activities under one roof). Volkswagen Factory, Hanover, Germany.

(Walter Henn, II, p. 133).

If we assume a state where all the components are contained within a single body, we might equally assume that there would develop, at some time, possible areas of conflict or friction which may result in consequent incapacitation, see figure 6 at (a).

There would, of course, be some form of relationship among the components resulting in different degrees of cohesion, size groupings, independence, inter-dependence and internal activity. If the various main components which may now be differentiated are set free in space, it is possible that the phenomenon of change will be more easily absorbed. The economic advantage of flexibility within, and expandability of each major component in the system may more readily be obtained.

FIGURE 6

Practical Application of this Concept

This concept of differentiating and setting free in space the main components within a plant system can take various forms. Figures 7 and 8 illustrate two of the possible variations, depending on the nature of plant operations, and the internal activity and relationships that the components are required to satisfy for the proper functioning of the system.



Johnson & Johnson Surgical-dressing Factory in North Brunswick, U.S.A.

Architects: Walter Kidde Constructors Inc. North Brunswick, N.J. U.S.A. (W. Henn, II,p.282.)

FIGURE 7



International Business Machines Corp. in Rochester, Minn., U.S.A.

Architects: Eero Saarinen Assoc., Hamden, Conn. (W. Henn, II, p.164).

PLANT FLEXIBILITY

These dynamic plant forms have an intrinsic capacity to respond to the demands of dynamic change.

FIGURE 8



Volkswagenwerk AG Factory in Hanover, Germany.

Design and contract work by the Volkswagen AG Building Department, Wolfsburg.

(W. Henn, II, p.132).

FIGURE 9



Chrysler Corporation Assembly Plant in Fenton Missouri, U.S.A.

Architects: Albert Kahn Inc., Detroit. (W. Henn, II, p.136).

FIGURE 10

PLANT FLEXIBILITY

But these virtually static forms are incapable of responding to dynamic change. In either of the two examples, the main components are differentiated and set free in space so that any one component can adjust within itself or expand outwards without creating friction or disturbing the proper functioning of other components, and from an architectural point of view, without disturbing the visual form of the system.

In figures 9 and 10 where the components are contained within the system, any demand for flexibility or expansion of any one of the components will most likely produce some conflict with or disturbance to other adjacent components. Expansion of any one component part in isolation detracts from the established visual form.

It would appear therefore that where the main components are not contained within one enclosing body, but are separated in space, some economic advantage of flexibility and expandability will result.

Summary:

There is a constant process of change in industry. It affects all of the aspects of industrial enterprise, and demands that business administrators must constantly be planning ahead to forestall the economic disadvantages which it may bring. Industrial managers must plan ahead for various types of change, not the least of which is the effect of change on plant facilities. The ability to make changes in a plant, process, or product when required certainly has a great economic advantage. But this advantage is not likely to be realized if the required flexibility or expansion of any main part of the system cannot be made without great loss, conflict, or disturbance to the efficient running of the plant.

A tentative suggestion is made that by fragmenting what would have been a huge mass of a plant in such a way that the main component parts are isolated one from another, as far as it is possible, but without endangering the integrity of the system, the economic advantages of flexibility and expandability will be obtained. How the functioning integrity of the system can be maintained will be discussed in Section Three.

Meanwhile, in the next chapter we shall examine another economic problem - that of obsolescence and plant disposal - which is a result of the effect of change on plant facilities.

CHAPTER 4

PLANT OBSOLESCENCE AND DISPOSAL

Closely related to the phenomenon of change, and in fact prompted by it, is the problem of plant obsolescence. Only when management executives consciously try to visualize the future of the product and the processing equipment, and the effects which these have on plant buildings or equipment layout, can they hope to foresee and offset the effects of product obsolescence on plant facilities. In this respect, market research should provide suitable answers to the following type of questions:

- (a) How often will the raw materials, makeup, and other aspects of the product change ?
- (b) What will be the nature and extent of those changes?
- (c) What effect will they have on equipment layout and building structure ?
- (d) What strong or new substitute products are appearing in other related industries ?¹

Today, many companies are making important plant planning and design decisions without adequately considering what might happen to the product or its process in the future.

Robert P. Neuschel, op.cit., p.17.

Moreover, whether to provide flexibility in plant and layout design depends not only on the likelihood of changes in the present product but also on the possibility of complete obsolescence.² Is the product apt to become obsolete before the plant investment has been written off? Can some other product be made as a replacement ?

Here again, the product's history and its current market position, and the research and development programme of a company should indicate possible answers to these types of questions.

Almost as important as trying to make the actual prediction, however, is the constant awareness that changing technology and changing markets may some day force the company to make new and different product or even abandon the plant for a new site.

Possibility of Plant Disposal

Important as the issue of flexibility is in thwarting product obsolescence, it does not solve the great economic problem of plant disposal in the event of complete plant obsolescence. Even discounting complete business failure, a company will find it advantageous to have a readily saleable plant for various reasons.³ Should the company outgrow present plant facilities, the best course of action might be to construct a new plant. Should the company have to use raw materials, it might be desirable to relocate a plant nearer the source of supply. Should there be a major shift in market geographically, the company might find it advisable to move the plant closer to the market.

²op.cit., p.18.

³H. C. Thole and Charles C. Gibbons, (Ed), <u>Business Action In A Changing</u> <u>World</u>, p.206.

Many other reasons might be added, but the important architectural implication is that the nature of plant facilities where possible should not prevent a company from changing factory location merely because its plant cannot be sold or leased without great sacrifice.

A single large plant building(Figure 11a) probably the size of a football field is not easy to sell or lease to another company. To lease it to a number of smaller firms would require extensive internal reconstruction. There would also be many servicing problems in co-tenancy. But if we consider the building facilities as composed of smaller units (figure 11b), it would be reasonable to assume that to sell or lease them to different companies would not prove so great a problem, neither would it be at a great economic loss.





Application of Concept

From the point of view of plant disposal with relative ease and at reasonable price, the advantage of the fragmented plant buildings in figures 12 and 13 over and above those of the monolithic types in figures 14 and 15 appears obvious.

It would appear, then, that where the market analysis of a product and the technological characteristics of the process indicate the possibility of complete obsolescence of product or plant facilities at a foreseeable future as is expected in many electronic and pharmaceutical industries, the concept of fragmentation of the plant building might well



Johnson & Johnson Surgical-dressing Factory in North Brunswick, U.S.A.

Architects: Walter Kidde Constructors Inc. North Brunswick, N.J. U.S.A. (W. Henn, II,p.282.)

FIGURE 12



International Business Machines Corp. in Rochester, Minn., U.S.A.

Architects: Eero Saarinen Assoc., Hamden, Conn. (W. Henn, II, p.164).

PLANT DISPOSAL

It will be a lot easier and less involved to lease or sell small units of property to smaller companies since these small units will be able to function independently and with relatively little conflicts.

FIGURE 13



Volkswagenwerk AG Factory in Hanover, Germany.

Design and contract work by the Volkswagen AG Building Department, Wolfsburg.

(W. Henn, II, p.132).

FIGURE 14



Chrysler Corporation Assembly Plant in Fenton Missouri, U.S.A.

Architects: Albert Kahn Inc., Detroit. (W. Henn, II, p.136).

FIGURE 15

PLANT DISPOSAL

It may not be easy to find companies willing to buy large obsolete properties at a good price. The margin of loss or economic sacrifice will be wider here than in the former examples.
be adopted, other things being equal. The effect of these "other things" against this concept will depend on the weight that is attached to the ease of plant disposal in order to move assets to new markets, new products, or entirely new enterprises.

Summary:

The problem of obsolescence is normally prompted by the constant process of change. While flexibility may be built into the plant to thwart obsolescence and economic loss in many instances, there are still some situations that inevitably lead to complete product or plant obsolescence.

The importance that is attached to a company's ability to quickly and profitably dispose of its plant facilities in case of obsolescence will determine the extent to which the principle of plant fragmentation will be applicable at the design stage.

The problem of the disposal of industrial assets in case of business failures, or some drastic changes in products, materials or the geographical location of markets, is not as grave as the problem of security of industrial assets from fire destruction. This problem will be the subject matter of the next chapter.

CHAPTER 5

SECURITY OF INDUSTRIAL ASSETS FROM FIRE HAZARD

Apart from the considerations of change and obsolescence, another potential economic problem to which a fundamental solution should be provided is the security risk of fire hazard. Each day, great havoc is being wrought by the outbreak of fire in industrial premises.¹

The largest fire loss in the history of American industry occurred on August 12, 1953, when the General Motors Hydramatic Transmissions plant at Livonia, Michigan, burned to the ground. In a matter of fourteen hours, three lives were lost and property estimated to be worth \$40 million was damaged.² General Motors has one of the best safety records in the United States and this plant had been provided with modern fire-fighting equipment.

The Livonia fire was just one of over one hundred fires which occur in North American manufacturing plants each day. While not individually so spectacular, these fires account for \$150 million property damage annually as well as the loss of hundreds of lives, thousands of jobs, and the closing of many businesses.³

²ibid. ³ibid., p.170.

¹Russell de Reamer, <u>Modern Safety Practices</u>, (John Wiley & Sons Inc. New York, 1958), p.169.

In the United Kingdom, the picture is very much the same. The direct loss from fire has been estimated to amount each year to about **£25** million, arising from about 45,000 building fires. Of these, about 6,000 occur in industrial establishments, including some 150 that each cause a direct loss of £10,000 or more.⁴ These direct losses do not take into account consequential loss of production and wage-earning time, or effects upon other dependent industries. Indirect losses are difficult to assess, but it is obvious that they can be very serious.

Fire hazard is therefore a great economic problem in industry since it is a potential security risk to industrial assets both material and human. Great fires, like the one at Livonia clearly indicate that although a great fire may not occur within a period of ten years in a plants' lifetime, yet it is a potential source of anxiety, for when it does occur, mechanical fire-fighting devices, fire-resisting construction and other technical measures will not prevent extensive havoc.

From the range of common fire causes, abnormal materials and processes, and abnormal occupancies which exists in industry (see Appendix 1 for greater details), it is obvious that almost no type of industrial enterprise can claim to be free from the risk of fire hazard.

Before an appropriate architectural solution to the problem of fire is considered, present available building design and construction measures will be examined.

⁴ G. J. Langdon - Thomas: <u>Fire Protection in Factory Buildings</u>, (No.9 in Factory Building Studies, H.M.S.O., London, 1960,) p.1.

Present Building Design and Construction Measures

The design and structural aspects of fire protection, including restriction of spread of fire, means of escape, and access for firefighting, involve the whole field of building - site planning, internal planning and the form and materials of construction.

Site Planning

In the siting of industrial buildings in relation to fire protection, three factors are normally taken into consideration:

- Access roads for fire-fighting appliances.
- Distance between adjacent properties to reduce spread between buildings.
- Access from roads and open spaces into the buildings.⁵

Existing practice requires that adequate access roads should be provided around the building for the efficient operation of fire appliances. No fixed road width is given but the architect must ensure that the access to his buildings will be adequate for the fire-fighting appliances in the locality.

The siting of buildings in relation to one another also play an important part in reducing fire spread. By-laws specify minimum distances in relation to adjoining property (usually only for single-storey buildings),⁶ but they do not provide for spacing of buildings belonging to one company. However, the same considerations would obviously apply, and actual by-law requirements should be regarded as a guide only.

⁵ibid. p.6. ⁶ibid.

Apart from road access for fire-fighting appliances, there should be adequate access into the building or building complex for fire-fighting operations. Unless hydrants are provided within the building, an important criterion in relation to access and siting will be the fire cover provided by a fire appliance. With the pressure likely to be available, the maximum effective throw from a fire-fighting nozzle may be about 75 ft. This therefore imposes a limitation on the size and plan shape of the building, (figure 16).



Figure 16: cover available from fire hose limits size of building (G. J. Langdon-Thomas, p.6)

Another important consideration for the fire protection of industrial plants is the fire resistance of building materials and structural elements.

Fire Resistance of Structural Elements:

Existing practice also requires that the fire resistance of the various structural elements of a building should, ideally, be sufficient to resist the effects of the fire load without collapse under the structural load. The periods of fire resistance appropriate to various fire loads are

as follows:⁷

Fire load	(B.t.u/sq. ft.)	Fire	Resistance	(Hours)
Less than	100,000 (low)		1	
100,000 -	200,000 (moderate)		2	
200,000 -	400,000 (high)		4	

These standards allow for a complete burn-out of the combustible contents of the building. For small buildings lower standards of fire resistance are considered adequate because fire fighting can be expected to control the fire more easily.

In a single-storey building, no specific standard of fire resistance is required by by-law, except in relation to the risk of spread of fire to adjacent premises. Nevertheless, the industrial management may consider, in its own interest, whether fire protection is economically justified in its particular case.

In steel-framed single-storey structures the columns can usually be protected without much difficulty. The large-span steel trusses are more difficult to deal with; sprayed coatings of asbestos or some other fire resistant materials provide one of the more convenient methods of protection. The initial cost of protecting steel work by means of concrete or a sprayed coating may be largely offset by saving the maintenance cost of painting.

The decision whether to protect all structural steel work will also be influenced by the other forms of fire protection available, and the economic justification.

7_{ibid., p.7.}

Since the fire resistance of building materials and structural elements does not ensure the security of the contents within the building structure, but merely prevents the collapse of the structure, an additional measure, in the form of internal planning devices to confine the spread of fire, should be considered.

Internal Planning

It is obvious that the smaller the region within which an outbreak of fire is initially confined, the less will be the chance of it developing into a major fire. It is usually claimed that in many types of industry, there are sound reasons for large undivided areas, but this is not always so, and often, undue importance is attached to open planning. Division should be the first consideration in relation to fire protection, even to the extent of providing a separate building for the storage of combustible materials and for high-hazard processes.

The normal practice, usually demanded by insurance companies, is the use of walls of adequate fire resistance which extend from ground to roof to divide a building into parts or divisions. The effectiveness of this practice largely depends on the fire-tightness of the joint with the underside of the roof, and around ducts and service pipes, doorways and conveyors. In most cases, what is usually regarded as adequate fire separation by compartmenting a building in this way, is a fire wall that has little ability to resist fire or contain it.

Figures 17 and 18 indicate that even though fire damage may not seriously affect the structure of the building, it creates great economic damage to the contents of the buildings. Obviously, the greater the space



FIGURES 17 & 18 - FIRE DESTRUCTION OF INDUSTRIAL ASSETS

(Langdon-Thomas: Fire Protection in Factory Buildings, H.M.S.O, London, 1960, p.11, p.8). involved and the more combustible the contents, the greater will be the loss.

Existing design and construction measures against loss by fire appear to be inadequate, for although a plant structure may not collapse entirely, its contents invariably get destroyed. As this has proved to be agreat economic loss, it is desirable that a fundamental architectural solution be devised to limit the extent of loss.

An Architectural Concept

The notion of designing for security against extensive damage or destruction by fire, flood, bombing, explosions, and similar hazards, suggests a form of fragmentation of a system into main components in such a way that an accident in any one of them would not so easily affect other components.

In figure 19(a), an accident in the system, even though it may not bring total damage or destruction, still causes a partial damage of various components together, and may result in the collapse of a proper functioning of the entire system.

If, however, there is a separation in space of the main components, as in the figure at (b), damage to one component will not easily spread to another or affect the proper functioning of other components in the system. As it appears that the extent of damage and its proliferation is

FIGURE 19

a function of space, ideally, the greatest security would result where the components are widely dispersed.

Application of Concept

The concept of separating the main component elements of a plant system to provide intrinsic physical fire separation can be applied practically in different ways. Figures 20 and 21 indicate two of the various possibilities where the main parts are separated in space. In this way, the extent of damage and loss will likely be minimized. The greatest security will result where, in addition to physical separation, the connecting parts which are obvious weaknesses in these system, are treated with fire restricting elements or structures.

Conversely, the close concentration of activities or main components in figures 22 and 23 is more likely to produce less resistance to the spread of fire, and a greater extent of internal damage and economic loss.

It would appear then that where fire hazard is a great threat, as in synthetics, dry goods, rubber goods, or oil and colour industries, the main processing components within the system should be separated in space one from another. The extent of separation will depend on many factors, some of which are the extent of fire risk permissible, the degree of production integration essential, and the nature of other fire prevention measures.

Summary

The great economic loss that results each year from the hazard of fire in industrial premises demands a closer look into the nature of industrial fires and the measures available to combat the occurence of



Johnson & Johnson Surgical-dressing Factory in North Brunswick, U.S.A.

Architects: Walter Kidde Constructors Inc. North Brunswick, N.J. U.S.A. (W. Henn, II,p.282.)

FIGURE 20



International Business Machines Corp. in Rochester, Minn., U.S.A.

Architects: Eero Saarinen Assoc., Hamden, Conn. (W. Henn, II, p.164).

FIGURE 21

FIRE HAZARD

The extent of damage and loss is likely to minimized by the separation of building units in these examples.



Volkswagenwerk AG Factory in Hanover, Germany.

Design and contract work by the Volkswagen AG Building Department, Wolfsburg.

(W. Henn, II, p.132).

FIGURE 22



Chrysler Corporation Assembly Plant in Fenton Missouri, U.S.A.

Architects: Albert Kahn Inc., Detroit. (W. Henn, II, p.136).

FIGURE 23

FIRE HAZARD

The extent of damage and loss is likely to be great in these examples, because of the proximity of component units within the mass. fires. The range of abnormal materials, processes and occupancies in industries further indicate the universality and persistence of the problem of industrial fires.

Existing site planning regulations, fire resistance of structural elements and internal planning devices prove a substantial measure of safe-guard; but they are not adequate. When great fires occur, although the structures may not collapse, contents within them are destroyed.

A possible solution may well be the fragmentation of the plant system into main component parts which can be separated in space without lowering the operational efficiency of the system as a functioning entity. The extent of this fragmentation and separation will greatly depend on the extent of security risk involved in particular industrial cases.

Conclusion of Part One

In the first part of this section, we examined the economic problems associated with the constant process of change. To forestall the economic disadvantages of changing conditions, demands, and production processes, industrial physical plant facilities, as a production system, must contain an intrinsic capacity to adapt to changing requirements. It must be flexible and easily expandable to allow for changes to be made easily, cheaply and conveniently. Thus, thwarting obsolescence is an economic advantage.

But obsolescence is not necessarily always a result of complete business failures. It may be prompted by complete change in product, raw materials or geographical location of market. When it does happen, it should be possible for a company to dispose of its physical facilities easily, and at little sacrifice.

Although change and obsolescence may paralyse a company, the destruction of a company's assets by fire as has been observed may completely liquidate it. The hazard of fire is a threat to the majority of industrial enterprises and as such, an intrinsic physical design measure needs to be taken to minimize it.

Therefore, it appears from the examination of economic problems that when a plant system is fragmented and separated in space, economic advantages over and above those of the centralized concentration of functions, result.

In the next part of this section - Part Two - the discussion will shift materially from economic to technical considerations. The aspects to be examined will now be: first, the criteria for the selection of production processes and the shortcomings of this approach from an

architectural point of view; and second, the physical layout of plant facilities and services. The objective would be to determine the degree of appropriateness and efficiency of existing methods.

SECTION TWO Part Two

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CHAPTER 6

INTRODUCTION TO TECHNICAL CONSIDERATIONS

Certain prevailing attitudes and concepts about process flow and technological progress make it difficult to provide a good architectural design solution to some of the technical problems encountered in industrial establishments. One of these points of view - namely, that low current operating costs are the primary objective¹ - has led some industrial managers and engineers to overemphasize the benefits of moulding the plant around the present process flow.

The materials flow pattern, then, becomes the basis for the entire plant design as well as for the success of the enterprise. All too frequently, insufficient emphasis is placed on determining the most efficient plan for the flow of materials through the production facilities.

It should be our conclusion, then, that plant layout comes first. No industrial building should be erected without having first completed a plant layout study. This will determine the desired flow of materials, the most economical arrangement of physical facilities, and will serve as the basis for the building design. Of course, the architect should be consulted in the early stages for advice on general building construction information, but his actual design work should follow that of the plant layout engineer.²

¹Elwood S. Buffa, <u>Modern Production Management</u>, (John Wiley & Sons, New York, 1965), p.17.

²James M. Apple, <u>Plant Layout and Materials Handling</u>. (The Ronald Press Company, New York, 1963), pp.4-5. As an important digression, this author has underlined a part to emphasize the prevailing attitude of some industrial engineers towards the scope of industrial architecture. Another misconception is that technological progress is a revolutionary change, whereas it is cummulative.

Many people erroneously consider technological progress as something gigantic or revolutionary in its impact - something that affects our whole economy. This point of view fails to recognize that technological progress is, in most instances, the accumulation of rather insignificant, day-by-day changes.³

Because of these points of view, many industrial engineers and management executives start plant designing by determining the one best process flow for the operation; the building is then constructed around this pedetermined flow.

This concept is, of course, essential to low operating costs, but it is only a part of the plant facilities planning problem. Because it stresses the details of process flow, it naturally stresses also the characteristics and the processing methods of the product as it is to-day. This absorption in the present product and its process may, and sometimes does, preclude considerations of change and the product's future, and of human relations problems. As a result the solution does not incorporate the elements of flexibility needed to stay abreast of future technological change, and of work group cohesiveness and independence needed to meet the social and egoistic needs of the employees.

Since Part Three will be devoted to the examination of human considerations in industrial architecture, only the technical aspects of the production function will be considered in this part. These aspects are the nature of production processes and the criteria for selection, and the physical layout of plant facilities and services.

³Henry C. Thole and Charles C. Gibbons (Ed), <u>Business Action in A Changing</u> <u>World</u>, (Public Administration Service, Chicago, Illinois, 1956), p.207.

CHAPTER 7

THE PRODUCTION PROCESS

Production is the process by which goods and services are created. We find production processes in factories, offices, supermarkets. It consists of a sequence of operations that transforms materials from a given to a desired form. The transformation may be done in one or in a combination of the following ways:¹

1. Transformation by disintegration, in which one ingredient input produces several outputs with possible change in the physical shape or geometrical form; for example, producing lumber in a sawmill, rolling steel bars from cast ingots, making components from standardized materials on machine tools, oil-cracking which yields several products, and so forth.

2. Transformation by integration or assembly in which several components as inputs become essentially a one-product output; for example, producing machines, furniture, household appliances, automobiles, radio and television sets, electronic and electrical equipment, pharmaceutical and food products.

3. Transformation by service, where virtually no change in the object under consideration is perceptible, but where certain operations

¹Adapted from Samuel Eilon: <u>Elements of Production Planning and Control</u>, (Macmillan Company, New York, 1962), p.1.

are performed to change the parameters which define the object. This may include operations for improving the tensile strength, density, wear, or other mechnical properties of the object; operations that change its locality or state by transportation or handling means; maintenance operations. Examples are: sizing and coining in press work; servicing and light repair works of automobiles; loading and unloading of trucks.

As this thesis concerns only the production function of transformation by disintegration, by integration, or by assembly, or the three combined in one process, it deals only with the examination of manufacturing processes.

This chapter will discuss the types of manufacturing processes commonly in use in industry, the criteria for the selection of a process from technical and economic aspects, and the noticeable shortcomings of this approach from an architectural point of view.

Manufacturing Processes

Technically, the purpose of a manufacturing process is to attain one of the following objectives:

(a) To shape the material inputs as nearly as possible to the final desired form and dimensions, in order to save materials, machine time, and labour.

(b) To join components into assemblies that possess the required functional qualities, or

(c) To improve the properties of the materials inputs, for instance, by heat treatment, or by addition of other materials to form alloys or coatings.²

Depending on which of these objectives is desired, and the nature of the material inputs utilized, a manufacturing process can be a continuousprocess, repetitive-process, or intermittent-process type of production operation.³ (See Figure 24)

Continuous-Process Industry

A continuous-process industry is usually made up of operations that involve chemical reactions. The nature of the operations is such that a rigid control of flow systems must be adopted since a sequence of operations must be performed before another can commence. Usually the process can be a disintegration into components as in distilling and oil refinery; an integration as in cement, heavy chemicals and sugar; or a combination of disintegration and integration as in basic iron and steel, and aluminium refining. Production is normally continuous for twenty-four hours per day.

One of the main architectural design problems in this type of industry is that of successfully integrating building with the gigantic equipment and machines that often cannot be housed because of their size and complexity, but which must be expressed as clean, functional external elements. Naturally, the aesthetic and functional solution of this problem cannot be specified, since technology and systems are constantly changing, but must be left to the sense of order of the architect and the engineers concerned.

³The following process discriptions are adapted from James M. Moore, <u>Plant Layout and Design</u>, 1962, pp.4-7.



FIGURE 24 - TYPES OF MANUFACTURING PROCESS

(Figure is taken from: James M. Moore, <u>Plant Layout and Design</u>, (The Macmillan Company, New York, 1962), p.7.)

Repetitive-Process Industry

A repetitive process industry is usually one in which the product is processed in lots. A variety of operations may be involved, but the nature of the operation is such that flow cannot be rigidly controlled as in the continuous-process industry.

The product moves through the process in specified quantities called lots. Each item in the lot follows successfully through the same operations as the previous items. If lots of the same or similar items follow one another with regularity through the process, the situation becomes similar to the continuous-process type of industry, except that the production is seldom carried on twenty-four hours per day.

An illustration is a mass-production plant producing automobile engines with standardized parts. Today, this type of industrial process is used to manufacture numerous products such as telephones, television sets and tubes, refrigerators and electronic equipment.

This type of production process creates two distinct problems human and aesthetic. On the human side, because jobs have been broken down "scientifically" into their most elementary components, there is over-specialization and consequently over-simplification of jobs which in most cases become very elementary routine functions. This situation undoubtedly has certain advantages, such as requiring less skilled people and shorter training time. In many cases, however, the process has been carried to such extremes that jobs have little inherent interest or challenge; operations are reduced to the simplest possible repetitive level and the worker makes nothing he can identify as a product of his own

skill.4

In a recent study on those attributes of work which have important effects on workers' satisfaction, productivity, and absenteeism, it was discovered that where the number of different kinds of objects, tools, or controls an employee works on is small in variety (object variety), where there is little or no change in work pace, change in physical location, or change in required physical operations, (motor variety), or where method choice, sequence choice, pace choice, quality of inputs choice and importation of outside services choice are predetermined (minimal autonomy), workers' response will be low and unfavourable.⁵ And this is the situation in many repetitive - process industries to-day.⁶

Although it is not the purpose of this study to engage in technological polemics, it is important to bring out the fact that often, the strict adherence of industrial engineering to "machine" logic, per se, with little or no compromise with many other important considerations, is a disadvantage to efficiency.

The traditional assembly line is simply a piece of poor engineering judged by the standards of human relations, as well as those of productive efficiency and output.⁷

⁴James C. Worthy, "Organizational Structure and Employee Morale," <u>American Sociological Review</u>, vol.15, April, 1950, pp.175-177.

⁵Arthur N. Turner and Paul R. Lawrence, <u>Industrial Jobs and the Worker</u>, (Harvard University, Division of Research, Graduate School of Business Administration, Boston, 1965, (Appendix B)), pp. 152-153.

⁶ibid.

⁷Peter F. Druker, "The Way to Industrial Peace," <u>Harper's Magazine</u> November, 1946.

In the face of this, one may well ask, is it adequate that the architect should be consulted in the early stages for advice on general building construction information only, and that his actual design work should <u>follow</u> that of the plant layout engineer ? What then is the true meaning and scope of industrial architecture ? The art of building construction, of providing only shelter for the manufacturing process ?

Besides, when one considers the second problem - that of visual chaos - which most production processes, especially the repretitive-process type produce, one feels more convinced that the architect should be involved at the problem-analysis and production process selection level of the planning stage so that he might know how best human, functional, technical, and aesthetic requirements could be reconciled, and a more humane order restored to the conveyor-tangle and mechanistic chaos.

Intermittent-Process Industry

An intermittent-process industry is one that processes items of products when and as ordered. It is sometimes called a job-lot industry. Here a small lot of items may be ordered by a customer to be made to his specifications. Once the lot is completed, it is likely that the item will never be manufactured again, since it is normally concerned with special projects, models, prototypes, special machinery or equipment to perform specialized and specific tasks, or components to provide replacement for parts in existing machines. Examples are large turbo-generators, large boilers, processing equipment, special electronic equipment, shipbuilding, printing and publishing.

In this type of industry, flexibility of operations is of the utmost importance. The process layout principle⁸ applies very well to this type of industry.

Combination-Process Industry

A combination-process industry is one that combines various degrees of disintegration, integration, fabrication and assembly. Examples are: basic iron and steel, phamaceutical, and aluminium refining industries. In practice, for a given industry, some form of combination process is normally required to solve its particular manufacturing problems.

However, the use of combination processes is frequently adopted from a purely quantitative analysis. For instance, to obtain a compromise solution on the type and degree of combination to be used in a specific instance, the distances travelled in feet by each type of process flow are compared, and adjustments made for a combination solution.⁹

This approach appears to be a good weapon that can be utilized to further reconcile or integrate qualitative merits with quantitative demands, even if the result may seem initially more expensive. The important fact to realize in this respect is that the total efficiency of plant production system - men and machines - is what matters.

With the possibilities inherent in a combination process, the concept of fragmentation, once accepted as advantageous, should not be difficult to effect for varieties of manufacturing situations.

⁸Apple, op.cit., p.97. ⁹Eilon, op.cit., pp. 154-158.

Selection of a Process

Various economic and technical considerations go into the decision to select a manufacturing process. It is outside the scope of this study to go into details about these considerations, but it is significant to note that more often than not, the basis of selection demonstrates a first preference for technical appropriateness. "As in the case of materials, the selection of production process should be primarily determined by technological considerations."¹⁰

Although there would be available various alternative methods for manufacturing a product, the usual evaluation of such alternatives are strictly based on technical and economic factors. For example, typical evaluation questions are of the following nature.

(a) What additional functional qualities result from the processes in question, apart from the minimum requirements set out in the specifications, and how much do they cost ?

(b) How do the processes compare in cost at various production ranges, and what is their rating ?

(c) Under what conditions is it advisable to increase the capacity of a given production centre by acquisition of additional equipment, while machines operating on an "inferior" process (as determined by the above rating) remain idle or have to be scrapped ?¹¹

Other factors which go into considerations for decision-making on the type of process to be adopted are the "availability of machine time,

10Eilon, op.cit., p.182.

¹¹op.cit., pp. 183-184.

shop loading and fluctuations in the production schedule, expansion possibilities, subcontractors' offers and competence, subcontracting policy, quantity to be produced, effect of the experience and learning of operators on the efficiency of the process.^{#12}

There is no denying that the criteria of technical efficiency and economic soundness in the selection of production process are essential to low operating costs but this is only a part of the planning problems that must be resolved before a final selection is made.

Short-comings in Process Selection Criteria

Some of the equally important factors which the technical and economic criteria do not appear to take into consideration are:

(a) The problem of nuisance charactristics of some machines in terms of effluent disposal; fumes, smoke and air pollution; noise and vibration; and intrusion into the landscape (where this is an important consideration);

(b) The quality of a process or its flexibility to facilitate physical design against fire hazard or plant disposal in case of obsolescence (as discussed in Part One).

(c) The relation of production process to human considerations (as will be discussed in Part Three) and the consequent minimization of labour relations problems.

These are some of the qualitative aspects of a manufacturing facility which are best resolved at the process-planning and selection stage, but are usually not given adequate attention.

¹²Eilon, op.cit.

The Architect's Duty

It is not the duty of the architect to take over the technical responsibilities of the industrial engineer in the selection of a manufacturing process. But it should be his duty to carefully understand and appreciate the economic, technical, and operational objectives of the industrial managers and engineers. With this understanding, the architect should be in a position to make valuable suggestions as to how technical, functional, economic, human, and aesthetic conflicts might be compromised. For example, by studying carefully the engineers' graphic tools (schematic process outlines, process charts, activity charts) which are employed at the production process planning stage (see figure 25), the architect should be able to advise on modifications which might well involve little or no extra expense/rectify some of the short-comings mentioned above.

It is the contention of this author that the architect can be helpful in resolving some of the problems which result from purely mechanical production process planning and selection, but until industrial engineers have a better appreciation of the need for a broader consideration of these problems the full contributions of architects will remain unrealized.

Summary

Manufacturing production process consists of a sequence of operations that transform materials from a given to a desired form. This transformation may be by assembly, by integration, by disintegration or by a combination of these three together. The transformation process may be carried out by a continuous-process, a repetitive-process, an intermittent-process,



Two Examples of Schematic Process Outlines.

Schematic Diagram of An Ice-cream Process.



FIGURE 25

SCHEMATIC PROCESS OUTLINES

(From S. Eilon, <u>Elements of</u> <u>Production Planning and</u> <u>Control</u>, Macmillan, New York, pp.204-205). or a combination process, depending on the type of transformation desired.

The quantitative criteria for selection of a production process have been mainly technological and economic. It appears that qualitative considerations - human, environmental and visual - do not receive adequate attention .

It is maintained that a balanced, efficient and satisfactory production process should aim at meeting the requirements of both quantitative and qualitative considerations.

In the next chapter, the effect of technological change on the physical layout of plant facilities and services will be examined.

CHAPTER 8

PHYSICAL LAYOUT OF PLANT FACILITIES

It was noted in the last chapter that the selection of a production process is primarily based on quantitative operational efficiency criteria, the ultimate objective being that of low current operating cost. Important as this approach is, however, it does not take into consideration many important qualitative factors which also contribute in some measure to the prosperity of an enterprise - matters like the nuisance characeristics of some equipment and machines (noise, vibration, atmospheric pollution, and effluent disposal) which are directly attributable to the type of production process adopted; regard for process flexibility to facilitate design against fire, explosive and other hazards or plant disposal in case of obsolescence; and possible better integration of workers into the production process to minimize labour conflicts (a matter that will be the subject of Part Three).

Much in the same way, the criterion for the physical layout of plant facilities has been that of immediate operational convenience and efficiency, and although there is an explicit intention to provide for flexibility, the final arrangement often appears to be a contradiction

¹James M. Apple, <u>Plant Layout and Materials Handling</u>, (1963), p.7.

of this intention. As this chapter will indicate, adequate attention is not generally given to the problem of technological change on the proper functioning of the plants' elements, both individually and collectively.

Technological progress implies change; but change is not a spontaneous phenomenon. It is cummulative.² "Change is not an abstract state or succession of states, but the concrete growing process of organization."³

The conception of change as a dynamic phenomenon cannot be satisfied by the static conception of functional relationships. The design implication is a state of intrinsic adaptability where maximum flexibility of internal structure, and expandability of constituent elements are both attainable without jeopardy to the efficient operation of the elements in the organization, individually or collectively.

How this situation can be satisfied by the physical layout of plant facilities is the subject matter of this chapter. First the pattern of functional relationships which normally exists among a plant's physical elements will be examined. Then, an appropriate architectural arrangement which satisfies operational and circulational efficiency will be suggested. Emphasis will then be shifted to the production and services aspects of the physical layout pattern. In essence, the main objective will be the arrangement of industrial physical facilities to promote economic and technical efficiency as well as to fulfil other considerations

²M.W. Calkins, <u>The Persistent Problems of Philosophy</u>. The Macmillan Co. New York, 1939, (The Revolt against Metaphysical Absolutism), pp.437-438.

³D. M. Datta. <u>The Chief Currents of Contemporary Philosophy</u>, The University of Calcutta Press, 1950. (Chapter V - The Philosophy of Henry Bergson), p.242.

The Main Elements of a Manufacturing Plant

Every manufacturing plant, small or large, must require some office space for carrying out the administrative functions of the enterprise. There must be some space allocated to the transformation process which is the production function. For the workers employed in the plant, there must be provided some space allocated to those services that are essential for their comfort and well-being. The utilities and ancillary facilities to be used in the transformation process and service functions will have to be housed.

In effect, the four distinct elements to be found in any manufacturing plant are:⁴

- Administration those functions that serve the entire plant, consisting mostly of "general" office areas and related activities. Depending on the size and complexity of an organization, the administrative element could be composed of up to about five sub-elements - executive, general administration and reception, accounting, marketing and research, and engineering and research functions.
- 2. Production those functions that primarily serve the production system or organization. This consists, essentially of four subelements: pre-process (receiving and storage), actual process (transformation process), post-process (warehousing and shipping), and ancillary functions (engineering control, supervision, tool

⁴Adapted from Apple, op.cit., pp. 126-127.

crib and tool room, materials handling equipment room).

- 3. Welfare those services and facilities that are provided and operated primarily for serving or handling the needs of employees. This consists of about four sub-elements: First-aid or medical facilities, recreational and eating facilities, sanitary and other ancillary facilities.
- 4. Utilities those physical services that are primarily concerned with production needs. This includes mechanical and electrical service equipment, fire protection systems, ancillary facilities (water tower or reservoir, vehicle storage, maintenance shops, plant protection systems.)

The content, size and complexity of each of these major elements provided in any given manufacturing enterprise will naturally depend on the nature, size and complexity of that enterprise. A fairly complete list of the provisions that are normally required is given in Appendix II.

While it is appropriately the responsibility of the management, as the architect's clients, to prepare a comprehensive list of their functional requirements, it is possible that some little items like drinking fountains, adequate lighting and temperature which do not directly contribute to the production operation, but which are vitally necessary to the production efficiency of workers, may be omitted.

It is the duty of the architect to assist industrial managers to prepare a comprehensive list of the various items desirable for any particular enterprise under consideration. A practising industrial architect needs to compile a list, of all the items found desirable in industrial buildings of all types and categorized for easy reference. Each client

could then be given the list relevant to his case for guidance, to be deleted or supplemented as necessary during the brief preparation stages. After a comprehensive list has been prepared, the important problem will be the complete organization of items into an efficient circulation pattern to give a preliminary understanding of desirable relationship of main elements.

Relationship of Main Elements

Theoretically, the circulation pattern that occurs among the main elements of Administration (A), Production (P), Welfare (W) and Utilities (U) is a simple one. Because of the nature of their functions and compositions, a two-way circulation relationships between $A \rightleftharpoons P$, $A \rightleftharpoons W$, $P \rightleftharpoons W$, $P \rightleftharpoons U$. is expected. One-way relationships between $U \rightharpoonup A$, $U \rightharpoonup W$ for purely servicing functions are also needed (figure 26).



In many small and simple industrial organizations, a very simple space relationship evolves from this pattern. Some of the different types of patterns are shown in figure 27. But not all industrial plants have such a simple nature. Consequently, the complex nature of large organizations has brought about analytic design systems to portray true functional relationship pattern. The more common methods devised by industrial engineers are flow chart, "from-to" chart, and activity relationship chart.⁵ All of these are used for preliminary space relationship

⁵Apple, op.cit., pp.165-176.


FIGURE 27: Common Forms of Main Elements Relationship.





FIGURE 28: Activity Relationship diagram as developed by Richard Muther. planning, but by far the most convenient is the activity relationship diagram as developed by Richard Muther.⁶ In this, the pattern of activity relationships is portrayed in a graphic form by the use of connecting lines or bands of varying widths or thicknesses between different activities (figure 28).

The resultant type of preliminary relationship pattern (figures 29 and 30) are logical arrangements of activities purely from an initial operational point of view. These work, and pose no immediate operational problems. It is when the cummulative effect of change demands flexibility and expansion that they become complex.

Figures 31 and 32 are diagrams of existing examples that show the logical relationship pattern when the activity relationship diagram or some other method that adopts the same approach, is used with little discretion. In both cases, flexibility of internal arrangement of the production element is impossible in the true sense of the word, because of the fixed locations of major elements. For, flexibility does not consist only in large spaces, but essentially in the independence of each element to adjust without obstructing or being obstructed by other elements, and without diminishing the efficiency of the whole complex.

Moreover, expansion of any of the main elements is practically impossible without creating some tension in the fixed internal structure, and also, without greatly detracting from the visual form of the complex. Any expansion of a section naturally creates a disfigurement of the plant form.

^oRichard Muther, <u>Systematic Layout Planning</u>, (Industrial Education Institute, Boston, Mass. 1961), p.6-6.



FIGURE 29

THEORETICAL BLOCK DIAGRAM OF ACTIVITY RELATIONSHIPS.

(From E. S. Buffa, <u>Modern Pro-</u> <u>duction Management</u>, John Wiley & Sons, Inc. N. Y. 1965, p.415.



FIGURE 30 - THEORETICAL BLOCK DIAGRAM OF ACTIVITY RELATIONS

(From J. M. Apple, Plant Layout and Materials Handling, 1963, p.202.)

FIGURES 29 & 30 - LOGICAL SPACE RELATIONSHIPS AS EVOLVED THROUGH ANALYTHIC METHODS.



FIGURE 31: Eta Food Factory in Melbourne, Australia Architects: Grounds, Romberg & Boyd, Melbourne (W. Henn, II, p.8).

- A ADMINISTRATION
- **P** PRODUCTION
- W WELFARE
- U UTILITIES



FIGURE 32: Adams Brands Ltd. Confectionery Works in Scarborough, Ontario, Canada.

Architects: John B. Parkin Assoc. Toronto (W. Henn, II, p.36)



FOOD FACTORY OF ETA FOODS PTY. IN MELBOURNE, AUSTRALIA.. Architects: Grounds, Romberg & Boyd, Melbourne.

(W. Henn, II, p. 8.)



South-west aspect, showing main entrance canopy

Adams Brands Ltd. confectionery works in Scarborough, Ontario, Canada Architect: John B. Parkin Assoc., Toronto

The factory produces sweets of all kinds, especially chewing gum and allied products, which enjoy great popularity in the USA and Canada.

Major considerations in the planning were workers' comfort and the greatest possible cleanliness throughout the plant. Consequently all internal wall surfaces of the production rooms were covered with glazed tiles. The entire building was fully air-conditioned. All the production departments, with the requisite ancillary rooms and storage areas, together with offices and welfare rooms, were accommodated in the two-storey structure. The plant is connected to the main traffic network by siding and road. Delivery of raw materials takes place both by train and lorry; on the other hand, despatch is made only by lorry.



(W. Henn, II, p.36).

On the other hand, figures 33, 34, and 35 illustrate the improvements to the aspects of flexibility, expandability and visual form that are possible when the logical relationship pattern is sensistively adjusted without imparing the operational efficiency of the system. The most obvious aspect of this pattern of arrangement is the decentralization and articulation of the major activity areas, as opposed to the centralization concept of the previous ones. With decentralization, each area can be reorganized internally or expanded externally, (usually in more than two directions), without jeopardizing or imparing the efficiency of the other areas, or of the total complex as an entity. Moreover, this pattern satisfies, to an appreciable extent, the recommendations made in Part One of this study in respect to the economical problems of change and obsolescence and security against fire and other hazards.

Because of the inherent qualities possible in the decentralized and articulated disposition of major activity areas, an assumption shall now be put forward that where major activity areas such as administration, production, research and development (where this is relevant), welfare, and utilities all as already described, are differentiated and articulated in an orderly manner, a better architectural design solution will result which fosters operational efficiency in terms of flexibility and expandability.

This assumption however needs to be qualified. It has to be indicated that none of the component elements is of such a size or complexity that it loses the capacity to respond to change, and thereby becomes an obstruction to the operational efficiency of the entire plant-complex.

Obvious in the examples shown here, and in many existing industrial plants, is the disproportionate size of, and over-concentration of many



- A ADMINISTRATION
- **P** PRODUCTION
- W WELFARE
- U UTILITIES
- R RESEARCH
- FIGURE 33: Ball-bearing Factory of the Nice Ball Bearing Company in Kulpsville, Penn.U.S.A.

Architects: Carroll, Grisdale, and Van Allen, Philadelphia (W. Henn, II, p.115.)

- FIGURE 34: Kores S. A. Carbon-Paper and Typewriter-Ribbon Factory in Meaux France.
- Architect : Pierre O. Bauer, Paris. (W. Henn, II, p.210)





- FIGURE 35: Electrical Appliances Factory Plaisir, Seineet-Oise, Paris.
- Architect :Gerard Grandval, Paris (Bauen & Wohnen, Aug.'65, p.300).



Ball-bearing factoryTof the Nice Ball Bearing Comp. in Kulpsville, Penn., USA

Panoramic view of the whole plant from the eas





(Walter Henn, II, p,115).

Kores SA carbon-paper and type-writer-ribbon factory in Meaux, France Architect: Pierre O. Bauer, Paris

Layout: Scale 1 : 2,500

- A Production building

- A Production bund B Administration C Canteen D Surgery E Gatekeeper F Bicycle sheds
- G Lorry workshop H Warehouse J Car park for works personnel
- K Water tower
- L Proposed extension

Production building

- 1 Raw materials store 2 Ink manufacture

- 3 Ribbon store 4 Typewriter-ribbon manufacture 5 Carbon-paper manufacture

- 6 Die manufacture 7 Packing section 8 Finished goods store and despatch
- 9 Cloakrooms 10 Workshop
- 11 Transformer sub-station 12 Heat-generating plant



Access road with bicycle sheds and water tower



(W. Henn, II, p.210).



ELECTRICAL APPLIANCES FACTORY AT PLAISIR, SEINE-et-OISE, PARIS. Architect: Gerard Grandval, Paris.

(Bauen & Wohen, August, 1965, p.300).

components within the production element. If, as we have observed earlier, technological efficiency implies change, and change is not merely an abstract state or succession of states, but the concrete growing process of organization or development, then the static concentration of component activities within the production element will not satisfy the situation continuously.

This notion of physical change is a dynamic one and relationship of the main components within the production element must be expressed in a dynamic way so that they may acquire an adaptive disposition. This situation can be sustained only by the separation in space of the major component activities within the production system (figure 36).



Here we have a suggestion not unlike the one made in Chapter Two. Philosophically, both suggestions derive from the same metaphysical concept of change. Materially, however, this one differs in that its essence is to facilitate the operational absorption of technological development or organization, whereas the former one aims at realizing the economic advantages of an adaptive system.

Application of Concept to Production Element

Figures 37 and 38 illustrate two of the possible variations of the application of this concept to production element. In each example, the production system is differentiated and fragmented into main component activities. These components are set free in space in order that they may be able to respond individually or collectively to technological change. This separation affords the possibility for each component to expand horizontally or vertically without hinderance to other components, and also, without detracting from the quality of the visual form.

In figures 39 and 40 we see the obvious hinderance each component would constitute to others in adapting to meet technological developments. Furthermore, vertical development of each element, although possible is technically cumbersome, expensive and disturbing to the functioning of adjacent components.

Application to Servicing Function

A further application of this concept can be made to provide technical flexibility to the servicing function. Traditionally, mechanical and electrical power and services for the operation of the production function are provided on suspension devices on the plant roof or ceiling. Common examples are the electrical busbar, steam pipes, gas cables, and other service systems. The development of modern machines and equipment and consequently the great variety of service lines required for their proper operation have increased the complexity of the technical environment in the production system.

Just as the main component activities are decentralized, to provide flexibility, the service function too should be separated from other

Johnson & Johnson Surgical-dressing Factory in North Brunswick, U.S.A.

Architects: Walter Kidde Constructors Inc. North Brunswick, N.J. U.S.A. (W. Henn, II,p.282.)

FIGURE 37



International Business Machines Corp. in Rochester, Minn., U.S.A.

Architects: Eero Saarinen Assoc., Hamden, Conn. (W. Henn, II, p.164).

TECHNOLOGICAL CHANGE

Fragmentation of the production element to allow each component activity the capacity to absorb technological change without affecting adversely one another's operation.





Volkswagenwerk AG Factory in Hanover, Germany.

Design and contract work by the Volkswagen AG Building Department, Wolfsburg.

(W. Henn, II, p.132).

FIGURE 39



TECHNOLOGICAL CHANGE

Concentration of component activities hinder considerably the adaptive capacity of any one of the components within the system. Technological developments in any one component necessarily produces conflicts with adjacent components.

Chrysler Corporation Assembly Plant in Fenton Missouri, U.S.A.

Architects: Albert Kahn Inc., Detroit. (W. Henn, II, p.136).

FIGURE 40



FIGURE 41 - SERVICE BASEMENT

Plan of the Molecular Electronics Factory for Westinghouse, Elkridge, U.S.A.

Architects: Vincent G. Kling, Philadelphia, U.S.A.

(FACTORY MAGAZINE, MAY, 1964).

activities and located in separate zones like basements, basement corridors or floor channels, with convenient connection outlets. With this arrangement, maximum adaptability of the service function is likely to result. Figure 41 illustrates a practical example of this concept.

Summary

The physical layout of industrial plant facilities has often been based on strict mechanical logic of fixed activity relationship with the consequent result that the explicit objective of technical efficiency from the point of view of flexibility has not been obtained.

Technological progress implies change. This change is not an abstract notion, but a dynamic one . To satisfy it, the static concentration of major activities must be fragmented and each main component activity set free in space so that the property of adaptability may be obtained.

This principle applies also to the separation of service functions from the production functions, and appears to be the only state in which all component functions can adapt individually and collectively.

Conclusion to Part Two

The importance of the architect's consultation in the production process design and selection stages is emphasized by the fact that only the effective reconciliation of quantitative criteria of technical operational objectives with the qualitative criteria of variable human, environmental and aesthetic objectives can produce a truly efficient production system.

Furthermore, the provision of a static production system to cope with technological progress which is a constant process of change is incompatible. A dynamic process requires a dynamic system. This dynamic system is best obtained where a separation in space among the component elements occurs to provide each component with an adaptive capacity.

In the next part - Part Three - the discussion will shift materially to examine the factors which motivate industrial workers, and lead to human satisfaction and higher productivity in industry.



1

Part Three

CHAPTER 9

INTRODUCTION TO HUMAN CONSIDERATIONS

The prosperity of a manufacturing enterprise depends not only on the economic soundness, physical fitness and technical efficiency of its plant facilities, but also on the proper welfare of its workers. In point of fact, the attainment of the primary economic objective of profit through increased productivity greatly depends on how technical and human resources are utilized.¹ Human contribution to productivity is a factor that will ever be present, even with the advent of automation. For, even if a plant has only one employee who controls an automated system, his satisfactory performance is vital to the proper functioning of the system; a little carelessness or mistake on his part may result in great rejects and loss. In a company with many employees and little automation, productivity is likely to be determined largely by what the people rather than the machines do.² Sometimes, an improvement in technology is more

¹Robert A. Sutermeister: <u>People and Productivity</u>, McGraw-Hill Book Co.N.Y.1963. p.1.

²This is the case with many manufacturing companies in countries at the early stages of industrialization, especially those of Africa, Asia and Latin America where capital is scarce, mechanization and automation relatively under-developed, and labour abundant, Here, the choice of labour intensive principle as a factor of production in preference to capital intensive as is the case in North America, is made expedient by social, economic and political considerations.

For various arguments in favour of labour intensive and capital intensive methods of production, see <u>Industrialization and Productivity</u> Bulletin Series (U.N.O., N.Y), I (1958), pp.5-23; VII (1964), pp.25-33. than offset by changes for the worse on the human side of productivity so that productivity which should go up actually goes down.³

To improve human contribution to productivity, it is important that the factors which motivate and consequently lead to satisfaction and improved morale of workers should be carefully examined to bring into focus those aspects to which an architectural solution must be provided.

Figure 42 indicates that employees' job performance toward productivity is influenced by their ability and motivation. Thus, if a person had no motivation, he could be the most capable individual in the world, but there would be no connection between his ability and his performance. Or conversely if he had not ability, yet terrific motivation, again there would be no connection between motivation and performance. Both ability and motivation are essential ingredients to good employee performance.⁴

Ability is deemed to result from knowledge and skill. Knowledge, in turn, is affected by education, experience, training, and interest. Skill is affected by aptitude and personality as well as by education, experience, training and interest. While architectural design has no direct concern for these considerations, some aspects of motivation which may here be considered to result from the interacting forces in physical working conditions, individuals' needs and social conditions of the job environment, do require some form of architectural solutions to the problems they raise.

³E. L. Trist and K. W. Bamforth: "Some Social and Psychological Consequences of the Longwall Method of Coal-Getting", <u>Human Relations</u>, Vol.4, No.1. (1951), pp.3-38.

⁴Sutermeister, op.cit., p.8.



In this part those aspects of human motivation that have the potential, if satisfied, of improving workers' performance and morale, and consequently their productive capacity will be examined. These aspects are the effects on human satisfaction and productivity of physical working conditions, individuals' needs, informal organization of work groups, and the formal organization of leadership and supervision.

CHAPTER 10

PHYSICAL WORKING CONDITIONS AND MOTIVATION

The physical environment in which a man works plays a critical part in determining his work behaviour and his efficiency in the production system.¹ It may be too cold or too hot for him to operate his equipment; too dark to see objects and details clearly; too noisy for vocal communication or to hear signals; or too dull, dirty and drab to excite his interest, thereby depressing him. The task of the architect and the human engineering consultant therefore, includes defining and creating the best possible environment for the industrial worker.

For a long time, the entire scope of worker satisfaction in industrial plants has been assumed to be adequately satisfied by the provision of appropriate physical working conditions. It is usually thought that if the atmospheric condition is right, lighting and ventilation adequate, colour well used, noise adequately muffled or prevented, and washrooms, lockers, cafeteria, and so forth, are provided, industrial wokers will not have much to grumble about except financial incentives. Today, the architect and his consultants know a great deal about, and have adequate

¹H. C. Smith: <u>Psychology of Industrial Behavior</u>, McGraw-Hill Book Co., New York, 1964, p.204.

information concerning, the definition and creation of appropriate physical working conditions.²

Detailed studies known as the Hawthorne plant studies³ originally focussed on these aspects to determine their effects on employees' morale, satisfaction and productivity, but were unable to demonstrate any relation between physical conditions and output; later, the studies were redirected toward the areas of social conditions and group attitudes. Similarly, Homans, in his "Western Electric Researches",⁴ reported the continuous increase in productivity irrespective of changing conditions of the physical working environment, and the switch in direction by the researchers from physical working conditions to attitudes of individuals and groups. It was noted that the subjective feeling of the workers and the way they view the physical changes, rather than the changes themselves, seemed to influence motivation.

Working conditions can, of course, affect the employees' comfort at work, but there are many examples of employees working under bad

²For reports of studies on fatigue, monotony, rest pauses, shift work, noise reduction, illumination, music and their effects on human functioning and proficiency, see E. Fleishman, <u>Studies in Personnel and Industrial</u> <u>Psychology</u>, The Dorsey Press Inc. Homewood, III, 1961. Section 7: "Fatigue, Monotony, and Working Conditions", and Section 9: "Engineering Psychology."

³These research studies have been described in details in:

- Elton Mayo: <u>Human Problems of an Industrial Civilization</u>. The Macmillan Co. N.Y., 1933; and <u>Social Problems of an Industrial Civilization</u>, Graduate School of Business Administration, Harvard University, Cambridge Mass. 1945.
 - 2.T. N. Whitehead: <u>The Industrial Worker</u>, Harvard University Press, Cambridge, Mass, 1938 (2 Vols.)
 - 3.F. J. Roethlisberger and W.J. Dickson: <u>Management and the Worker</u>, Harvard University Press, Cambridge Mass, 1939.

⁴George C. Homans, <u>Fatigue of Workers</u>: Reinhold Publishing Co. New York, 1941, pp. 56-65. physical conditions who have a high level of morale and likewise, of employees working under the best physical conditions who have low morale.⁵ The importance of the provision of adequate and appropriate physical working conditions is not being diminished nor is it being suggested here that industrial engineers, managers, and architects should ignore the importance of comfortable working conditions. The implication is that if employees recognize that a job is unavoidably dirty, hot, or noisy, and that management has done all it can to improve conditions the poor situation will not necessarily cause low morale and low productivity of the employees.⁶

In most industrial working places today, the physical working conditions are good: desirable temperature, humidity, and ventilation are adequately provided; lighting and colour are good; noise is being greatly abated; rest periods and coffee breaks are allowed. Thus the presence of good working conditions in most plants and offices today is taken for granted and has therefore little, if any motivating force.

Since our architectural objective is to assist industry to fight some of its problems and provide suitable conditions for increasing its productivity, it now becomes absolutely important that we should extend our understanding of human needs and how they can be satisfied more completely. Let us examine the nature of human needs.

⁵See, for example, J. A. C. Brown, <u>The Social Psychology of Industry</u>, Penguin Books, Inc., Baltimore 1954. pp. 192-194.

6_{ibid}.

Human Need-hierachy and Motivation

Although workers themselves may not be aware of different kinds and levels of needs, their needs may be considered organized in a series of five levels or a hierachy of importance: physiological, safety, love, esteem and self-fulfilment.⁷ Really, these levels are not separate steps, but are interdependent and overlapping, each higher-need level emerging before the lower needs have been satisfied completely.⁸ For the purposes of this study, physiological and safety needs shall be considered under physiological; love as a social need; and esteem and self-fulfilment as egoistic needs.

Physiological Needs:

These involve basic essentials such as air, food, water, shelter, protection against danger, injury, threat, and deprivation. These necessities must be at least partially fulfilled before a person gives much thought to other needs. They are usually met mainly through money, security on the job, and appropriate physical working conditions. As these needs are satisfied, a man is inclined to place increasing emphasis on social and egoistic needs.

In any society, for people who have jobs, physiological needs are greatly satisfied but, "A satisfied need is not a motivator of behavior."⁹

⁷A.H. Maslow, "A Theory of Human Motivation," <u>Psychological Review</u> Vol.50, 1943, pp.370-396.

⁸A. H. Maslow, ibid.

⁹Douglas McGregor: <u>The Human Side of Enterprise</u>, (McGraw-Hill Book Co. Inc. New York, 1960). p.36.

Therefore, it can be assumed that more pay or more security on the job will not automatically lead to workers' improved job performance. The traditional rewards of industrial management provide little motivation because the struggle to satisfy subsistence needs has been won,¹⁰ (except in nations at the early periods of industrialization).

Although it cannot be assumed that more pay, more security and adequate physical working conditions may or may not lead to improved workers' performance, the point is, where pay and security are adequate and physical working conditions are sufficient to satisfy physiological needs, industrial managers, engineers, architects and social scientists must give adequate attention to the social and egoistic needs of industrial workers if they are to be motivated to better performance.

Summary

The physical environment in which industrial employees perform their tasks has a great effect on their physiological well-being and comfort. It is therefore a very important design consideration in industrial architecture. No brief for the design of industrial buildings can be regarded as adequate and comprehensive which does not take a good account of factors like temperature and humidity, lighting, colour, ventilation, noise, safety measures, washrooms, lockers and cafeteria. They are all very important, and because they are regarded as such and normally provided, they are taken for granted in any industrial plant. It will be inconcievable to think of a contemporary plant which does not provide adequate and appropriate physical working conditions. Because they are provided, they satisfy

¹⁰A. Zaleznik, Cristenson, and Roeth lisberger: <u>Motivation, Productivity</u> and Satisfaction of Workers, (Harvard Business School, Division of Research, Boston, 1958), p.354.

some physiological needs: but they therefore cease to be strong motivators of employees' performance. The attention of plant designers must therefore be extended to other levels of human motivation - social and egoistic which, if activated may lead to workers' satisfaction and better performance.

The nature of such needs will be examined in the next two chapters.

CHAPTER 11

SOCIAL NEEDS

When man's physiological needs are satisfied and he is no longer fearful about his physical welfare, his social needs become important motivators of his behaviour - needs for belonging, for association, for acceptance by his fellows, for giving and receiving friendship and love. Social needs of a worker can only be satisfied by contact with other employees.¹ Industrial management knows today of the existence of these needs, but it often assumes quite wrongly that they represent a threat to the organization. Many studies have demonstrated that the tightly knit, cohesive work group may, under proper conditions, be far more effective than an equal number of separate individuals in achieving organizational goals.²

Yet management, fearing group hostility to its own objectives, often goes to considerable lengths to control and direct human efforts in ways that are inimical to the natural gregariousness of human beings.

¹George Strauss and Leonard Sayles, Personnel: <u>The Human Problems of</u> <u>Management</u>, (Prentice-Hall, Inc. Englewood Cliffs, N.J. 1960), p.8.

²Stanley Seashore, <u>Group Cohesiveness in the Industrial Work Group</u>, (Institute for Social Research, Ann Arbor, Mich. 1954). p.98.

When man's social needs are thwarted, he behaves in ways which tend to defeat organizational objectives. He becomes resistant, antagonistic, uncooperative. But this behaviour is a consequence, not a cause.³

Work is a social experience, and most workers can fulfil their social need through membership in small work group. An individual employee can belong to several informal groups⁴ - task or functional group; friendship clique, composed of employees who have a liking for each other;⁵ and interest group of employees who "share a common economic goal and seek to gain some objective relating to the larger organization."

Clustering of workers-on-the-job all have these characteristics. They stem from the uniqueness of individual personality which refuses to combine into larger "wholes" without changing those entities. The sum of a group of individuals is something more than the total of the constituents; it is a new organization, because most of the members obtain satisfaction in gaining acceptance as a part of the group, and the group itself wields an influence on its members.⁶

The informal working group is therefore the main source of social control in an industrial organization.⁷

³ibid.

⁴Leonard Sayles, Behavior of Industrial Work Groups, (John Wiley & Sons, Inc., New York, 1958), p.144.

⁵This type of group cohesiveness can be promoted by the use of sociometry, finding out workers' likes and dislikes toward other workers, and placing them in congenial work groups. Another effective way is by status congruence or the compatibility of individuals within a group in many aspects. See Zaleznik, Christenson and Roethlisberger (1958).

⁶Leonard R. Sayles, "Work Group Behavior and the Larger Organization" in Arensberg et al., <u>Research in Industrial Human Relations</u>, (Harper & Row, Publishers Inc. New York. 1957). pp. 144-145.

⁷J. A. C. Brown: <u>The Social Psychology of Industry</u>, (Penguin Book Inc. Baltimore 1954), pp.124-156.

But the effectiveness of a group in playing this social control role depends on its size, cohesiveness and goals.

Size of the Work Group

It is an ancient sociological generalization ... that size of immediate work group is negatively correlated with productivity, or job satisfaction, or regular attendance, or industrial peace other factors being equal. This is due in part to the greater likelihood that primary relations (relations that are intimate, personal, inclusive and experienced as spontaneous) are more likely to develop in small groups than in large groups. It is due in part also to the fact that the worker in the smaller group is likely to have more knowledge of the relations between effort and earnings, and this seems to increase his incentive to work.⁸

Although small work groups may have greater potential for employee performance and increased productivity, whether or not the potential is realized depends in large measure on the cohesiveness and the goals of the group.

Cohesiveness of the Work Group

A cohesive work group is one whose members will stick closely to group norms, whatever they are.⁹ A cohesive group is likely to exhibit greater team work, gain greater social satisfaction from working together, have higher morale, and less absenteeism than a group which lacks cohesion.¹⁰ A cohesive work group has greater potential for motivating employees to better performance, or to poorer performance depending on the group's goals.

10_{ibid}. p.177.

⁸Harold L. Wilensky, "Human Relations in the workplace," in Arensberg et al., eds. <u>Research in Industrial Relations</u>, (Harper and Row, Publishers Inc. New York, 1957), p.28.

⁹George Strauss and Leonard Sayles, <u>The Human Problems of Management</u> (Prentice Hall, Inc. Englewood Cliffs, N.J. 1960), p.177.

However, research¹¹ has indicated that group membership or reward by the group was a major determinant of worker productivity and satisfaction, while reward by management had no noticeable motivational effect.

In this respect, it has been found that a cohesive work group tends to motivate its members to better performance, especially if they had been socio-metrically selected.¹² Of course, it is obvious that even if a group is highly cohesive, there may be some member who does not accept the group goal because he has a different reference group or aspiration level, or a different cultural background, or some other personal reason.

Goals of the Work Group

The potential in a small, cohesive work group can be used to support managements' goals or to sabotage them.

A work group may be cohesive in maintaining low production standards, resistance to change, and hostility toward supervision and/or other groups; or in denying membership to new comers, and demanding strict conformity of its membership. On the other hand, a cohesive work group may have high work standards, accept technological change, be friendly to other groups, co-operate with supervision, and have minimum unwritten codes on conformity for membership.¹³

"Where there exist informal organizations or groups with effective control over their members, if management wishes to change certain behavior, its attack must be made through the group and not the individual."¹⁴ To assure a positive benefit to the organization from group cohesivess, therefore, it appears that management must take necessary steps to provide

¹¹Zaleznik, et al., op.cit., p.383.

¹²Van Zelst, "Socio-metrically selected Work Teams Increase Production", Personnel Psychology, vol.5., No.3. 1952. pp.175-185.

¹³Stanley E. Seashore: <u>Group Cohesiveness in the Industrial Work Group</u>. (The University of Michigan Press, Ann Arbor, Mich., 1954), p.99.

14Brown op.cit., p.126.

the basic conditions of equity and supportiveness.¹⁵ In other words, management should provide a favourable environment for the development of cohesive groups.

Determinants of Group Cohesiveness

The internal cohesiveness of a group depends largely on the degree of interaction opportunity required by the work situation, and the status congruence of the workers.¹⁶ In respect of the former, it is obvious that the closer the functional proximity of individuals or subgroups, the more frequent will be the interactions between them. In other words, the more frequently individuals or subgroups interact with one another, the stronger will be their sentiments of friendship. In respect of social congruency, it is equally obvious that if an individual is congruent in his social status, he knows where he stands with respect to the group and is willing to abide by its norms. The group is readily able to identify him as a social entity and to bring him in as a member. Where an individual, on the other hand, is non-congruent, he is in a condition of ambiguity with respect to the group. He does not know where he stands, nor is the group readily able to relate to him because along certain dimensions this individual is a high status person, but along others, a low status person. Therefore the more socially congruent the individual is (the higher his status congruence), the more likely he will become a good member of the group.

Although there are some other factors like ethnicity, and individual predispositions, research has indicated that these are dependent to a

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<sup>15</sup>Seashore, op.cit., p.101.
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¹⁶Zalezink et al., op.cit., pp.169-217.

large extent on the two independent variables mentioned above: inter-action opportunity and status congruency. 17

Practical Implications of Cohesiveness Determinants

Once the case for work group effectiveness as the main social control force in industry is accepted, and the adoption and support of the informal work group is believed to be in the best interest of industrial management and the workers, it becomes necessary to investigate the effective introduction and incorporation of distinct work groups into the work situation.

Under the determinants of group cohesivess we observed that two factors must be satisfied in order to foster group cohesiveness: interaction opportunities and status congruence. The latter can only be satisfied by sociometry.¹⁸ In respect of the former, research has indicated the extent to which technology (the plant layout, or work flow pattern), has improved or mitigated interaction among workers. Researchers at the Tavistock Institute found that frictions and discontents at the work place are reduced when the work team incorporates all individuals whose work is highly interdependent.¹⁹ They studied cases in coal mining and textile weaving in which workers whose activities were directly interrelated were separated from one another by management's formal organization of production. Under these circumstances, the intimate communications and self-control mechanisms of the work group do not function efficiently:

^{17&}lt;sub>op.cit.</sub>

¹⁸Van Zelst, op.cit., pp. 175-185.

¹⁹A. K. Rice: "Productivity and Social Organization," "<u>Human Relations</u> Vol. VI, 1953, pp.297-329; also Trist and Bamforth, op.cit. pp. 3-37.

one individual tends to blame another (whom he does not know) for failure to complete the work quota and for other short-comings of coordination. Recriminations build onto one another and grievances follow. However, when those who are interdependent work closely together, and the informal group has the required interaction opportunity, it itself produces the needed adjustments and interpersonal coordinations required by the work process.

Architectural Implication of Social Needs

The significant implication of this consideration is that when the logical technological disposition of work process is being considered, the social effects should be borne in mind and necessary alternatives, compromise, or adjustments devised to allow the formation of coherent and cohesive work group units.
Summary

Human social needs can only be satisfied by contact with other people. In industry, the social needs of the workers should be fostered by the development of work groups. Since the attitude and goals of work groups may support or sabotage industrial management objectives, it is desirable that the goals should be directed to support rather than hinder.

This requires that the development of cohesive work groups should be initiated, supported and fostered by management. Architectural design can assist to attain a coherent development of work units by the design and arrangement of work areas to define zones for interactions required by the task, and those that are purely optional among groups and individuals. (Figure 43)



Before the design concept that will facilitate the realization and expression of the two types of distinct zones - required and optional interactions - is suggested, the conditions under which egoistic needs can be satisfied will have to be examined. This will be done in the next chapter.

CHAPTER 12

EGOISTIC NEEDS

When social needs are satisfied, egoistic needs become activated. Under egoistic needs will be discussed those needs that relate to one's self-esteem - need for self-confidence, independence, achievement, competence, knowledge; to one's reputation - need for status, recognition, appreciation, the deserved respect of one's fellows; and to one's selffulfilment - need for realizing one's own potentialities, continued selfdevelopment, being creative in the broadest sense of that term.¹

Unlike the lower needs, these are rarely satisfied; man seeks indefinitely for more satisfaction of these needs once they have become important to him. But they do not appear in any significant way until physiological, safety, and social needs are all reasonably satisfied.

The typical industrial organization offers few opportunities for the satisfaction of these egoistic needs to people at lower levels in the hierachy. The conventional methods of organizing work, particularly in mass-production industries, give little heed to these aspects of human motivation. If industry is to have the full advantage of the contribution

¹Maslow, op.cit., p.392.

to productivity that is possible from the workers, it will do well to discover the conditions under which these needs can be satisfied.

According to a study on motivation in work groups,² it was found that various conditions in a work group's environment will produce different need-activation patterns as shown in figure 44. However, it is significant to observe that where there is group-centred leadership, high-perceived contribution opportunity and high-perceived company supportiveness, the egotistic needs, as defined above, are activated and relatively satisfied. It would appear that these conditions are purely matters for industrial management alone to face. However, in order to bring into focus the possible architectural contribution to this problem, it is important that we should understand the basic structure and philosophy of management and the pattern of formal organization that results.

Organization Structure

Some recent writings on formal organization raise a question concerning the classical organization assumption about span of control, that a supervisor should have relatively few subordinates.³ Organizations which follow this practice tend to have a "tall" or "pyramid" organization structure, or many layers between president and employees, which allows for rather close supervision, (see figure 45). The question raised is whether a flat, decentralized organization structure with few layers between president and employees might not be preferable because it would give the subordinate more freedom to do the job in his own way, allow

²James V. Clark, "Motivation in Work Groups," <u>Human Organization</u>, (Vol.19, No.4, Winter 1960-61), pp.199-208.

³James C. Worthy, "Organizational Structure and Employee Morale", <u>American</u> <u>Sociological Review</u>, Vol.15, April, 1950, pp.169-179.

	1	2	3	4	5	6	7
							Company Per- ceived as supportive
CONDITIONS IN					Low-Perce- ived Contri bution_Opp.	High Con- tribution Opportunity	High Contri- bution Opp- ortunity
THE GROUP'S ENVIRONMENT				Production Centred Leadership	Accommoda- tive Leader ship	Accommoda- - tive Lea- dership	Group-Centred Leadership
			Low Status Congruence	High Status Congruenc e	High Status Congruence	High Status Congruence	High Status Cong r uence
		Low Inter- action Opp- ortunity	High Inter- action Opp- ortunity	High Inter- action Opp- ortunity	High Inter- action Opp- ortunity	High Inter- action Opp- ortunity	High Inter- action Opp- ortunity
	Low Employ- ment Secu- rity	High Employ, ment Secu- rity	High Employ- ment Secu- rity	High Employ- ment Secu- rity	High Employ- ment Secu- rity	High Employ- ment Secu- rity	High Employ- ment Secu- rity
EGOISTIC NEEDS				(NEED ACTIV	ATION)		
SELF-FULFULLMENT							
STATUS-PRESTIGE							
SELF-ESTEEM							
MEMBERSHIP							
SAFETY							
		NEED NOT ACTIVATED		NEED ACTIV BUT RELATI FRUSTRATED	ATED VELY	NEED ACTIV	ATED BUT SATISFIED
PRODUCTIVITY	(E)	FFECTS ON LOW	LOW	AND TURNO	VER-ABSENTEE MINIMUM	ISM) HIGH	нтсн
TURNOVER-ABS.	LOW	HIGH	HIGH	?	AVERAGE	LOW	LOW

FIGURE 44: Some Relations Between Conditions in the Work Group's Environment, Motivation, Satisfaction and Turnover-Absenteeism.

> (Taken from: James V. Clark: "Motivation in Work Groups," Human Organization, (Vol.19 No.4, 1960-61).



FIGURE 45: Pyramid and Flat Organization Structures. In the pyramid, each leader has few subordinates so that he can keep close control over their activities. In the Flat, each leader has many subordinates so that it is impossible for him to maintain tight control over his subordinates.

> Moving from a pyramid to a flat organization inevitably enlarges the responsibilities of workers and subordinate work groups. In a sense, leadership becomes group-centred.

(Figure is taken from: H. C. Smith, <u>Psychology of Industrial</u> <u>Behavior</u>, (McGraw-Hill, New York, 1964), p.164). him to use more of his own initiative, permit him to become more selfreliant, and in general allow him to satisfy his egoistic needs.

At this point the author wishes to quote at length some research findings of James Worthy on this point:

Our studies have shown that employee morale and operating efficiency are closely related to the degree the organization is integrated. Integration is not necessarily achieved, however, when the organization meets the requirements of machine-logic. As a matter of fact, what may appear to be logical from a purely technical standpoint may run directly counter to the personal and social demands of employees. We have seen a number of organizations which have a logical technology, a division of labour, and a hierachy of control but which are badly disorganized from the standpoint of the actual working relationships of the people involved. Such organizations are well-integrated only on paper. In actual fact, they are irritating and frustrating from the standpoint of employees, and inefficient, troublesome, and costly from the standpoint of management.

Our research indicates that two trends in particular are making effective integration difficult and contributing to the progressive deterioration of management-employee relations. One is the trend toward increasing size of administrative unit; the other, the trend toward increasing complexity of organizational structure. Both trends appear logical in terms of widely held theories of business organization, but in both cases improvements in mechanical efficiency are at some point over-balanced by losses in the willingness and ability of employees to cooperate in the system. Moreover, the larger, more complex organizations are likely to become unadaptive and rigid, and to find it difficult to meet the requirements of economic and social change.

Intelligent planning on the part of management in setting up formal structure of organization can do much to improve the quality of human relations in industry. Flatter, less complex structures, with a maximum of administrative decentralization, tend to create a potential for improved attitudes, more effective supervision, and greater individual responsibility and initiative among employees. Moreover, arrangements of this type encourages the development of individual self-expression and creativity which are so necessary to the personal satisfaction of employees and which are an essential ingredient of the democratic way of life.⁴

⁴ibid., pp. 178-179.

If we assume, then, that the concept of decentralization of formal organizational structure is a better management philosophy, and that any reasonable management will want to adopt it, what will be the architectural implications?

Possible Architectural Implications

Now, we know that decentralizing the organization tends to increase the responsibilities of the groups within it. However, the greatest potential of this principle can be realized only when, in addition to decentralization, the functions are less specialized; it is only then that the size and variety of tasks which the group has to perform increase. For it is possible to have a decentralized organization with specialized functions. For examples: Let us suppose an organization performs three essential functions, A, B, and C. Let us suppose further that the volume of output requires three units of each function. Under these circumstances, the organization could be set up in either of two ways:

 It could be set up in large divisions, each function (A, B, and
 C) being represented in each division, and each division, therefore, being a relatively independent administrative entity. (See Figure 46a).

2. On the other hand, the organization could be set up in three functional divisions, one division having all three A units, another all three B units, and the third all three C units. In this case, none of the three divisions has any independence; each can operate only in closest coordination with the other two. (See Figure 46b) (Worthy, 1950).

In this illustration, the unspecialized method provides for three small and independent units; the specialized only one unit. In general, the non-specialized organization makes it easier to decentralize authority



UNSPECIALIZED ORGANIZATION





SPECIALIZED ORGANIZATION

(b)

FIGURE 46: Specialized and Unspecialized Ways of organizing the same Functions. In the specialized way, none of the three divisions is independent; in the unspecialized way, all three are relatively independent.

> (Figure is taken from H. C. Smith, <u>Psychology of Industrial</u> <u>Behavior</u>, p. 163)



FIGURE 47: Unspecialized Decentralization and Specialized Decentralization. The unspecialized system activates and satifies "social" and "egoistic" needs.

and to increase the responsibility of individuals and groups within the organization.

In essence, the illustrations seem to define the nature of architectural solution that is required - technically, the formation of work units that can function as independent entities. Assuming that this is economically and technologically feasible, it will still be desirable to provide opportunity for optional interaction off-the-job to the group units and the individuals within them (see figure 47a).

Application of the Principle

The principle of decentralized and unspecialized formal organizational structure provides the creation of functionally independent entities. This is well illustrated by the concept of fragmentation exhibited by figures 48 and 49. In each example, functionally independent work units are set free in space in such a way that the size, nature, and characteristics of work group entities within the system are articulated.

This affords the creation of coherently cohesive units each of which is now able to visually perceive its relative position in the company's structure, and relate its contribution to the company's prosperity. It is within this group identity that an individual is able to conceptualize his personal contributions.

Furthermore, by this process of fragmentation and separation in space, the situation necessary for the provision of optional interaction opportunities among unit groups on the one hand and individuals on the other, may be created.



Johnson & Johnson Surgical-dressing Factory in North Brunswick, U.S.A.

Architects: Walter Kidde Constructors Inc. North Brunswick, N.J. U.S.A. (W. Henn, II,p.282.)

FIGURE 48



International Business Machines Corp. in Rochester, Minn., U.S.A.

Architects: Eero Saarinen Assoc., Hamden, Conn. (W. Henn, II, p.164). FIGURE 49

HUMAN WELFARE

Functionally independent work units are set free in space in such a way that the size, nature and characteristics of work group entities within the system are articulated.

Summary

Egoistic needs are those related to one's self-esteem, reputation, and self-fulfillment. Unlike the lower needs, they are more difficult to satisfy. The typical industrial organization offers little opportunities for these needs to be activated, even less satisfied. But if the potential higher productivity contribution that an employee is capable of producing is to be realized, suitable conditions in the work group's and organization's environment must be provided to satisfy his egoistic needs.

These conditions are high perceived contribution opportunity, group-centred leadership, company supportiveness and work group cohesiveness. They are best fostered when the formal organizational structure is flat and the organization of work is unspecialized.

The architectural implication of this is the provision of independent work units.

Conclusion to Part Three

Industrial efficiency and prosperity depend not only on economic and technical matters, but also on human welfare. Certain human considerations - physical, social, and egoistic needs - if satisfied, may prove to be the gateway to industrial peace and prosperity. These considerations will be met only when we take pains to understand the full nature of human motivation and make efforts to satisfy their requirements.

According to John Paton, "Direct incentives will increase production 20-50% but the ingredient I find in the excellent companies has a potential that overshadows the productivity increase achievable through industrial engineering techniques. When we learn to manage people, the increased productivity will be likened to the relationship of the water wheel to nuclear energy."⁵

Architecture holds a promise to help industry to manage people. It will achieve this by providing a pleasant physical environment which stimulates, and provides opportunity for the satisfying of social and individual's needs.

⁵Quoted in Alfred G. Larke, "Human Relations Research: Academic Wool-Gathering or Guide to Increased Productivity ?" <u>Dun's Review and Modern</u> <u>Industry</u>, Vol.68, No.1., July, 1956, pp.42-44. Mr. John Paton is the President of John Paton Management Engineering Firm.

S E C T I O N T H R E E C o n c 1 u s i o n s

CHAPTER 13

FUNCTIONAL DETERMINANTS AND THEIR SYNTHESIS

In Section Two, we examined design considerations of economic, technical and human significance. In this chapter, we shall review these considerations to bring out the main functional determinants of a satisfactory design solution.

1. Economic Considerations:

We observe that there are many economic factors which, properly considered, can influence the nature of an architectural design solution, the choice of building materials and method of construction. However, since our scope is limited to the design aspect or a general concept of industrial buildings, we limited our exploration to only the factors of change, obsolescence, and fire hazard.

It seems evident that the phenomenon of change which plagues manufacturing enterprises, especially the electronic and pharmaceutical industries, tends to create situations in which great economic losses result from the inflexible disposition of plant facilities. To cope with the constant problems of new products, new methods, conservation of employees' working time and the smooth running of plant facilities during modification programmes, the design of an adaptive system is necessary. The main

design consideration here is the phenomenon of "change".

The problem of complete plant obsolescence resulting from either business failures or changing market and locational requirements indicates that the prevalent method of providing one huge mass of building for industrial operations is not adequate. When it becomes necessary to dispose of existing plant facilities for new ventures, or new locations, great economic sacrifice is sustained. But when smaller units of buildings are provided the financial loss is not usually great. Because the problem of obsolescence is largely prompted by the phenomenon of change, the design problem here is also "change."

While flexibility and plant disposal may be unnecessary in some industries, judging from the range of potential sources of hazard confronting an industrial establishment, the problem of security relates to every industrial enterprise. Of course, the extent of risk and consequently the degree of security measures necessary will depend on many factors. However, it is advisable that an enterprise does not underestimate the havoc which may result from all varieties of hazards. In this connection, it appears that the extent of damage and loss greatly depends on the shape and size of the building. This defines the extent of the design consideration of "security" of assets.

2. Technical Considerations:

We observe that an industrial enterprise cannot operate at top efficiency without adequate technical measures. But technical appropriateness, per se, cannot attain the objective. The efficiency and appropriateness of technical measures may have to be decided upon by strictly quantitative criteria, but it is essential that these be reconciled with

those other qualitative factors which are equally essential to the attainment of operational efficiency. There is little doubt that the architect is fitted to help in this matter.

While the type of production process and method adopted for any particular enterprise will affect the physical layout of plant facilities it is most important that the strangulation effect of the prevalent system be avoided. The existing system, although it explicitly sets out to attain flexibility, is not adaptive. It is static and as such incapable of satisfying the dynamic process of technological progress. A dynamic process requires a dynamic system. It appears that from an architectural point of view, such a system will best be obtained by the design of dynamic smaller units of buildings instead of a concentrated, static single mass. The design consideration here is the factor of "change" in technological progress.

3. Human Considerations:

We observe that industrial efficiency and prosperity depend not only on economic and technical matters, but also on human welfare. The consideration of welfare has many aspects. It includes the provision and maintenance of adequate physical working conditions, and formal and informal organizations.

Industrial managers and plant designers have taken great strides in the recognition of, and the ability to provide, appropriate physical working conditions. These are no longer elusive problems and no industrial enterprise can overlook their provision. But because they are widely recognized and provided for, satisfactory physical working conditions no longer "motivate" employees because they are now commonly taken for granted.

The creation and support of cohesive work groups as the main social control force in industry have evoked different feelings, attitudes and organizational concepts. As indicated in chapter 11, a cohesive work group can support or sabotage management production objectives, depending on its goals and organization; but when management actively supports and fosters its creation, it becomes an instrument for obtaining higher productivity goals.

The two pre-requisites for maintaining peaceful cohesive work units are the provision of adequate interaction opportunities and status congruence. Assuming that social congruency can be obtained by sociometry, the task of designing appropriate plant layout, job methods and working arrangements to facilitate interaction opportunities is the problem for plant designers.

Even when social needs have been provided for by design, the difficulty of satisfying the needs of individuals within work group units becomes another problem. Here, a design solution can only be reached by co-operation between management and plant designers. Unless formal organizational structure is decentralized and unspecialized, plant designers may not be able to achieve much by design. But if this is done, plant designers need to explore the provision of building units which encourage the formation of independent work units.

Although this principle has the great potential of increasing industrial productivity and peace, it is essentially a human "welfare" consideration for it provides for the realization of the "human-self - the individual - in industry.

It now appears obvious that the main functional determinants which we must regard as having the potential of influencing architectural design solution are the phenomena of change, security and welfare. Change relates to the ability of a system to be adaptive; security, to the capacity to limit the extent of damage from hazards; and welfare, to the satisfaction and productivity of industrial workers. These three determinants demand different requirements in architectural design, but in essence, they all lead to the satisfying of functional demands.

Synthesis of Determinants

Throughout the stages of analysis it is observed that functional requirements of various considerations demanded in each case, the differentiation of activities in an industrial organization into the major constituent components, and releasing them free in space so that each component thus released may satisfy the requirements of change, security, and welfare. Thus in figure 50, the requirements for economic and technological change in terms of internal flexibility and external expandability



are easily satisfied. Similarly, dispersion of the main constituent components safeguards them from all varieties of hazards. And in terms of

welfare, differentiation or creation of independent work units, set free in space, solves the requirements for social and individuals' needs.

Theoretically, therefore, complete separation in space of major constituent components within the system will satisfy the functional requirements of change, security and welfare. In reality, however, it is important to know what effect this principle has on the integrity of the system as a functioning entity.

Let us imagine two extreme conditions, one in which there is complete close separation, and another, in which there are close interconnections. In the first case, the integrity of the system suffers because of the total lack, or the existence of a poor system of communication among the components. Since effective communication is not just a secondary or derived aspect of organization - a "helper" of the other and presumably more basic functions but in reality, the essence of organized activity and as such the basic process out of which all other functions derive,¹ therefore, the existence of constituent components in isolation is unreal. In the second case, if the pattern of interconnection is too close, a situation arises where great dependences result and independence of main components is lost; we obtain something not unlike that resulting from concentrated activity relationships, and we are back to the initial problems (see chapter 6).

However, if we imagine a situation where there will occur a pattern of communication or linkages, just enough to sustain adequately the integrity of the system without losing the independence of the main components, we shall obtain a situation where various degrees of dependences and

¹Alex Bavelas and Dermot Barrett, "An Experimental Approach to Organizational Communication," <u>Personnel</u>, Vol.27, No.5, March, 1951, pp.366-371.

independences occur together because the desire for effective communication would take varying importances.

To sustain the greatest amount of separation and effective communication, the greatest problem is in finding the least number of links among components that will guarantee the integrity of the system.

To restore the integrity of the system, all components which must communicate directly in closer proximity should be linked together but in such a way that the adaptive requirements and capacities of the components within the subsystem are congruent.²

This results in the creation of virtually independent subsystems consisting of congruent components (figure 51 a). Any further requirement for the consolidation of system-integrity would be provided by further linkages among the main subsystems, again, in such a way that the qualities of adaptiveness, separation and independence are not seriously jeopardized (figure 51 b).

We would therefore end up with a series of subsystems, all interlinked, yet sufficiently free from one another. This system will work because with respect to change, "the cycles of correction





FIGURE 51

²W. Ross Ashby, Design for A Brain, John Wiley & Sons, Inc. New York, 1962, p.204.

and recorrection which occur during adaptation are restricted to one subsystem at a time";³ with respect to security, the required separation which limits the extent and proliferation of damage and loss is obtained; and with respect to welfare, the required formation, articulation and independence of cohesive work group units which satisfy improved morale, and leads to higher productivity are also obtained.

Modification to Main Hypothesis

The initial hypothesis that where fragmentation of the huge mass of an industrial plant by articulation of the component activity areas is used as a framework of approach to the design of industrial plant facilities, certain economic, technical and human advantages will be obtained now appears inadequate. "Fragmentation" here is a wrong word since we are not dealing with the modification of existing plant facilities but with a design approach to new situations. In the design of new plant facilities, sets of requirements are prepared in the form of a brief. The design approach will normally start with the analysis and differentiation of requirements into major components. These major components will be integrated in space to form the required system. In essence, it is a decomposition of requirements into major congruent activities, and a recomposition by linkages to form an integral unit.

It will be more appropriate, therefore to think of this approach as a process of differentiation and integration in space.

³Christopher Alexander, <u>Notes on the Synthesis of Form</u>, (Harvard University Cambridge, Mass. 1964). p.43.

Examples to Support this Thesis

Many eminent industrial architects have not found the time to write about the thought processes and important functional considerations which have greatly influenced their designs. It is therefore difficult to infer particular design considerations from existing industrial buildings since such considerations may not, in fact, have been recognized by the designers.

However, it is possible to find existing examples which exhibit the spirit of this thesis. In addition to the two examples (figures 3 & 4, page 6) which have been used for illustration in the text, two other examples (figures 52 & 53), have been chosen for illustration here because they portray in different forms the properties suggested by this thesis.

A design requirement of figure 52 was the need for maximum flexibility and expansion. Demand for expansion ten times the initial capacity of 67,500 square feet resulted in the development of a support-free space module 90' x 90' with cantilevered perimeter which makes a total 137' x 137' basic module. This approach permits the addition of modules as required without interfering with existing operations. Figure 53 shows an extremely dispersed plant that lies in the midst of large plantations of fruit trees. It provides a variety of buildings for different functions, any of which can adjust independently. All the building units are one-storey high except the administration which will be five storeys high. Each building is given adequate park-like surroundings.

Both examples indicate widely dispersed functional units which are orderly interlinked to form a coherent entity. Both systems verify the truth that "diversity is only attainable through unity, unity only attainable through diversity."⁴ Application of design concept will now be discussed.

⁴Aldo van Eyck, quoted in Norbert Schoenauer; "Changing Architecture and Cummulative Form," <u>The Canadian Architect</u>, Vol.II, No.3, March, 1966, p.54.



FIGURE 52 - Molecular Electronics Plant for Westinghouse at Elkridge, USA. Architects: Vincent G. Kling, Philadolphia, USA.

> ("Factory" Management and Maintenance, McGraw-Hill, N.Y. May, 1964, pp.100-103).





Layout: Scale 1 : 5,000

1 Production building

- Production building
 Production building (in planning stage)
 Manufacture of components
 Heat-generating plant
 Canteen building
 Development laboratory
 Laboratory (in planning stage)
 Administration building
 Training contra

- 9 Training centre
- 10 Research laboratory
- 11 Car parks

IBM ELECTRONIC - COMPUTER FACTORY San Jose, California, U.S.A. Architect: John S. Bolles, San Francisco (W. Henn II, p.162).

FIGURE 53

Application of Concept

Substantially, the process for the interpretation and expression of this concept is defined by the modified hypothesis. The order, or essence of the problem of design in industrial architecture, as we have now realized, is the creation of a realm of spaces that satisfy the different requirements of economic and technical change, security of assets and welfare of workers. Since the demands of these determinants are different in context, the brief must be decomposed to satisfy the three aspects, first, independently, and second, collectively.

For the aspect of change, the set of requirements or brief must be decomposed and reorganized to bring into focus the functional structure of the problem. This decomposition is achieved by the hierarchical arrangement of congruent items - that is, the structured order of items which exhibit interactions or have common physical implications.⁵

For security, the extent of risk permissible, the nature of the operation, and other mechanical security measures to be taken, will determine the degree to which this consideration should be examined, and the extent of functional structuring.

For welfare, the optimum size for various activities, from the point of view of the formation of cohesive groups, relatively independent work units and the maintenance of normal human comfort, should be determined by research work. Normally, the type of activity, the type of production organization and the structure of the formal organization will influence the various categories of work units to be adopted, and the ultimate

⁵Alexander, op.cit., p.81.

structure of work group densities.

When the brief has been fully analyzed to form functional entities for the three aspects, constructive diagrams must be used to indicate schematically the patterns of the structural entities obtained in each case. A synthesis of these diagrams should result in various degrees of adjustments to satisfy the various needs. The development of the diagrams and the adoption of suitable constructional methods are matters of details.

Although it is most obvious that in almost all cases, the need to emphasize the importance of one consideration over another will arise, great care should be taken to see that no aspects are optimized to the disadvantage of others. A design problem is not an optimization problem, but the satisfying of various requirements in such a way that the total solution meets the purpose and function of the entire problem.⁶ This is perhaps the greatest role the architect must play: the ensurance of the satisfying of various sets of needs, physical and human.

By proper articulation of the series of subsystems and linkages called into being by the functional determinants, the solution will derive its organic form from the purpose and function for which it is created. The quality of the solution and the nature of the organic form that is obtained will both depend on the quality of the architect's realization of the nature of the problem, the clarity of his analytical approach to design, the quality of professional collaboration among the specialist consultants, and most important of all, the vision of management in accepting new ideas.

⁶op.cit., p.99.

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APPENDIXES

APPENDIX I - FIRE IN INDUSTRY

The following list of fire sources in Industry is compiled from G. J. Langdon-Thomas, <u>Fire Protection in Factory Buildings</u>, (Factory Building Studies, No.9, H. M. S. O., London, 1960).

Common Causes of Fires in Industry

- Smoking materials and matches
- Defective and improperly operated heating equipment.
- Careless disposal of ash and waste products.
- Defective or improperly designed and installed chimneys and flues.
- Inadequate clearance of heating equipment and heating ducts from combustible materials.
- Defective or improperly installed and operated electrical equipment and services.
- Friction and static sparks.
- Careless handling of flammable liquids and vapours.
- Use of open flame appliances.
- Spontaneous ignition of oily rags or waste materials, and excessive bulk storage of damp materials.
- Welding and pipe thawing.
- Explosion hazards from dust and chemicals.
- Defective incinerators.
- Exposure from other buildings on fire.

Materials and Processes Presenting "Abnormal" Fire Risks

Following is a list of some industrial materials and processes which present abnormal fire risk.

Materials:

-Compressed, liquefied and dissolved gases.

- Substances that become dangerous by interaction with water or air.
- All substances with a flash point below $150^{\circ}F_{\bullet}$
- Corrosive substances.
- Poisonous substances
- Radioactive substances
- Substances likely to spread fire by flowing from one part of a building to another.
- Substances in such a form as to be readily ignitable.
- Miscellaneous oxidizing agents and substances liable to spontaneous combustion.

Processess: The following processes are some of those that produce fire
risks:

- The application of heat, especially to combustible materials.

- Spray painting with flammable or explosive liquids.
- Processess producing flammable waste or dust, particular from disintegrators, grinders, and "reducing" machines generally.
- Use of flammable solvents.

Abnormal Occupancies

The following is a list of some industries that would usually be regarded as falling into the abnormal class.

- Artificial flower manufacturers.
- Artificial leather manufacturers.
- Artificial silk manufacturers.
- Basket makers.
- Bedding manufacturers.
- Book binders.
- Boot and shoe manufacturers.
- Brush makers.
- Cabinet makers.
- Calenders.
- Cardboard box manufacturers
- Cotton mills
- Distrillers
- Drug manufacturers.
- Dry Cleaners.
- Drysalters.
- Envelope makers.
- Film dealers.
- Fire works dealers.
- Fire lighter manufacturers.
- Flannel manufacturers.
- Floor polish manufacturers.
- Hat makers.
- Hay and Straw dealers.

- Linoleum manufacturers
- Match manufacturers
- Methylated spirit manufacturers.
- Oil and colour dealers.
- Oil refiners.
- Paint and varnish
- Paper bag makers.
- Paper manufacturers.
- Printers.
- Rag and waste dealers.
- Rice millers.
- Rope makers.
- Rubber goods manufacturers.
- Saw Millers.
- Straw good manufacturers.
- Tanners.
- Tar Distrillers.
- Tarpaulin makers.
- Upholstery manufacturers.
- Wall-papers manufacturers.
- Woollen manufacturers.
- Woodworking.

The above list is by no means exhaustive, but it indicates the extent of fire risk in industries.
ADMINISTRATION

A. Executives Functions

President Vice Presidents General Manager

B. General Section & Reception

- a.Personnel General Employment Training Credit Union Safety
- b. General File Room & Records Conference Room Vault Reception Room Switchboard

C. Engineering & Research

- a. Product Engineering Research Development Design Drafting Testing & Experimental
- b. Industrial Engineering Plant Layout Materials Handling Methods Standards Packaging Process Engineering Tool Design

- c. Production Control Planning Routing Scheduling Despatching Traffic Followup
- d. Quality Control
 Receiving
 In-Process (floor)
- e. Plant Engineering General Maintenance
- D. <u>Marketing & Research</u> Sales Advertising Marketing Promotion Research Purchasing
- E. Accounting
 - General Cost Payroll Credit

PRODUCTION

A. <u>Pre-process</u> - Receiving Storage or Stock Room B. <u>Process</u> - Production Process

- C. Post-Process Warehouse - Shipping
- D. Aucillary Functions
 - Tool Room
 - _ Tool Crib
 - Materials Handling Equipment Room

E. Administrative Functions - Engineering - Supervision

WELFARE

A. <u>Health and Medical Facilities</u>

- B. Recreational Facilities Food Services
 - Kitchen
 - Dinning
 - Vending Machines
 - Smoking & Games Rooms
 - Lounge Area
 - Outside Recreational Facilities
- C. Sanitary Facilities Showers
 - Locker Room
 - Toilets
- D. Aucillary Facilities Fire Escapes
 - Drinking Fountains
 - Time Clock
 - Bulletin Boards
 - Telephone Booths
 - Parking Spaces

UTILITIES

A. Mechanical Services

Heating Facilities Ventilating Equipment Air-Conditioning Equipment Power Generating Equipment Telephone Equipment Room Air Compressors

B. Electrical Services Electrical Substation Electrical Distribution Telephone Equipment Room

C. Fire Protection

Extinguishers Hoses Equipment Sprinkler Valves

D. Aucillary Services

Maintenance Shops Scrap Collection Area Vehicle Storage Plant Protection Systems Elevators & Stairways