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# Establishing and utilizing the concept of socio-technical-spatial systems in the 21st century work environment

Asmita Gami
*New Jersey Institute of Technology*

# ESTABLISHING AND UTILIZING THE CONCEPT OF SOCIO-TECHNICAL-SPATIAL SYSTEMS IN THE 21st CENTURY WORK ENVIRONMENT

by
Asmita Gami

Thesis submitted to the Faculty of the Graduate School of the New Jersey Institute of Technology in partial fulfillment of the requirements for the degree of
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# APPROVAL SHEET

Title of thesis: Establishing and utilizing the concept of socio-technical-spatial systems in the 21st century work environment

Name of candidate: Asmita Gami
Master of Architecture, 1987

Thesis and Abstract Approved: ______________________ __________

Dr. David L Hawk
Professor
School of Architecture

Signatures of other members of the thesis commitee

______________________ __________
Associate Professor of Industrial Eng.

______________________ __________
Research Professor of Architectuture and Mechanical Engineering

# VITA

| | |
|---|---|
| Name: | Asmita Gami |
| Permanent address: | |
| Degree and date to be conferred: | M. Arch., October 1987 |
| Date of birth: | |
| Place of birth: | |
| Secondary education: | Shreyas Vidyalaya, India. May 1974 |

| Collegiate institutions attended | Date | Degree | Date of Degree |
|---|---|---|---|
| Maharaja Sayajirao University of Baroda, India | 1974-80 | B.Arch. | June 1980 |
| New Jersey Institute of Technology | 1985-87 | M.Arch. | Oct 1987 |

Major: Architecture

| Positions held: | | |
|---|---|---|
| | Intern Architect<br>William Bodouva & Associates<br>New York | Present |
| | Co-ordinator<br>Architectural Information Center | 1986-87 |
| | Graduate Assistant, NJIT | 1985-86 |
| | Architect, Patel and Grover,<br>Baroda, India | 1980-85 |

ABSTRACT

Title of Thesis: Establishing and utilizing the concept of socio-technical-spatial systems in the 21st century work environment

Asmita Gami, Master of Architecture, 1987

Thesis directed by: Dr. David L Hawk
Professor of Architecture

Productivity is an important aspect of work environment in a market economy. It depends on the integration of the efficiency of the technical system, the social structure of the organization as well as the spatial environment. The relationship of productivity to the spatial environment within the changing work environment is the primary concern of this research. The research attempts to identify where we are now in terms of our understanding of productivity and its relationship to the work environment as well as the historic evolution that has brought us to this stage. In addition, this project attempts to explain the method of uitilizing the socio-technical-spatial systems in the design of a manufacturing facility for the General Motors Corporation. This 3.3 million square feet manufacturing facility is designed as a part of an international interdisciplinary research and design competition organized by the ACSA and the GM Corporation.

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IT IS DIFFICULT FOR CHANGE TO OCCUR
WITHIN THE EXISTING FRAMEWORK
THAT PRODUCES THE WORK ENVIRONMENT.

THERE IS A NEED TO FORMULATE AND EXPERIMENT WITH
A "NEW" PARADIGM,
RELEVANT TO THE EXISTING ENVIRONMENT.

"NEW" PARADIGMS
WITH NEW USES OF INNOVATIVE TECHNOLOGIES
NEED NEW WORK ENVIRONMENTS FOR PEOPLE WITH:

> NEW KINDS OF STRATEGIES,
> NEW APPROACHES TO DECISION MAKING
> AND NEW CONCERN FOR QUALITY.
>
> THE PEOPLE AND THEIR ENVIRONMENTS NEED TO BE:
> FAST RESPONDING
> SELF REGULATING
> AND SELF ORGANIZING

The central objective of the thesis is development of an understanding and demonstration of the potential of socio-technical-spatial systems for improving design of the work environment. As we approach the 21st century we find work change everywhere. Jobs are changing. The work ethic can no longer be counted on to keep people doing what they may not want to do. Technological sophistication and complexity are changing. Management requirements and strategies are changing. Basic social institutions are changing. All of this requires a fundamental re-evaluation of what we do, how we do it, and the settings in which both take place.

Present concepts for designing the work environment are insufficient to the increased complexities and continual updating that characterize the modern work environment needs. New concepts are required. They must be based on an appreciation of new realities which require fast-responding, self-regulating and self-organizing systems.

The general evaluators for achieving this agenda are:

I "Economic Analysis" as life cycle / production cost operators.

II "Flexibility" as potential for responding to change in product and process requirements, and rapid movement of materials and people.

III "Environmental Quality" as work environments that are productive, safe, stimulating places.

The key design feature is how to organize the process so that I and II are complimentary, not contradictory, and operating in support of III, so that III in turn supports I and II.

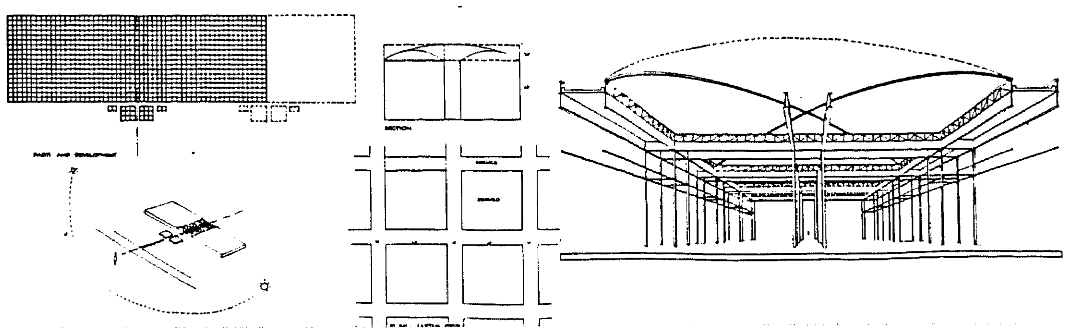
This thesis advances the construct of socio-technical-spatial systems as an approach to integrative design of work environments. The work builds on the long-standing and widely accepted source concept of socio-technical systems analysis. Initiated by work in English coal mines by Eric Trist and Fred Emery of Tavistock Institute of London, the construct illustrated how work settings could be improved by not considering them as social or technical sytems in isolation. This meant that the design of the work setting was not in terms of a technological imperative, i.e., a set of engineering variables, or a social imperative, i.e., a set of management variables, but in terms of the interactions of the two. Machines were designed for people and management systems were design for people using machines.

Herein, the architectural concept of space is added to the socio-technical approach, which results in socio-technical-spatial analysis. In short this means that the qualities of the spatial setting are as important as the social and technical aspects. This does not mean that it should thereby become the new imperative of facility design.

Instead, the analysis of space and its qualities should be added to the analysis of the technological and managerial systems. Thermal comfort, air and lighting quality, textures, color, sense of enclosure, sequence of experience, path, entry, etc. are included in the analysis with issues of line speed, labor input, automation, hierarchical control, work teams, etc. While it seems to make the job of facility design more difficult, it may actually give the designer better tools to actually solve the long-standing dilemmas in facility design.

The socio-technical-spatial construct was applied to an actual facility design problem. A team of students representing expertise in all three areas worked to integrate the best available knowledge of each into a proposal for a factory of the future for General Motors. Some aspects of the following thesis were generated by the team, but I assume full responsibility for any errors in judgement presented here. They represented the disciplines of Mechanical and Industrial engineering. I represented the discipline of architecture. It is hoped that the work presented here will help others faced with the problem of facility design that must meet contemporary needs, yet be capable of changing to meet tomorrow's needs with ease.

On the following page there is an overview drawing of the composite G.M. facility proposal. The first section of the text offers an overview of the history of the ideas that support the socio-technical-spatial construct. The architectural conclusion of the thesis can be seen in the drawings presented in last section.



3 primary design concepts for overall plant layout

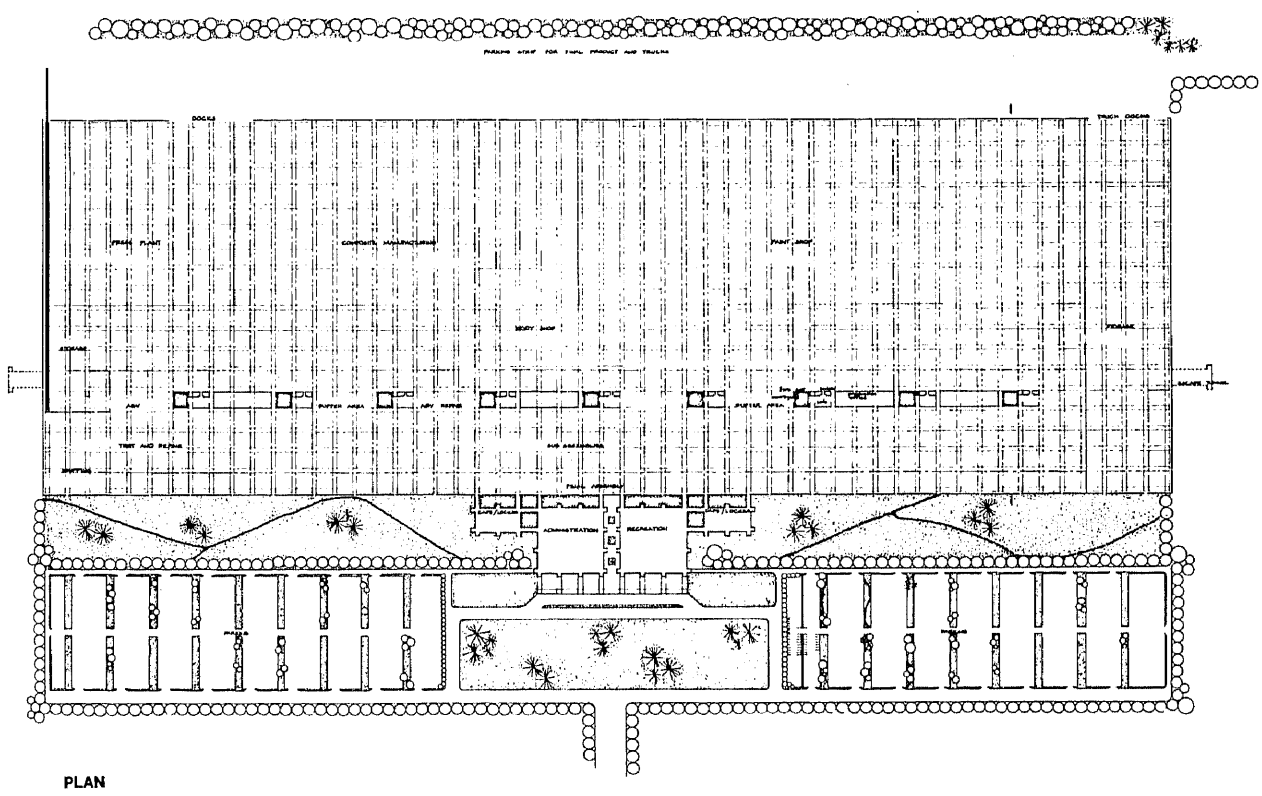



Figure i : Overall General Motors facility plan

# CHAPTER I

## WORK ENVIRONMENT : THE SETTING

### 1.1 THE PREINDUSTRIALIZED WORLD:

Before the advent of industrialization, work was organized around small groups or individuals. With the advent of industrialization, a new and more centralized structure for work entered into industrialized society. Decisions about the creation, organization and allocation of work are no longer made at the small group or individual level, but moved into specialized managerial functions centered in organizations. Supporting this development was evidence that large scale operations meant lower costs and higher productivity. All of this drastically changed the environment within which humans lived and worked.

### 1.2 INDUSTRIALIZED POST-INDUSTRIALIZED WORLDS:

As we approach the end of the 20th century, new patterns of ways and values of looking at the world have emerged. A central question regards the desires and rights of the individual to be given responsibility for more of his or her environment, and given the possibility to create new products and production characteristics through enterprise and initiative. Having more control of a work environment and improved qualities of the environment are becoming important manifestations of these needs.

The emerging technologies of microelectronics, computer processing, robotics, and telecommunications permit work to be done in new ways, or they can simply be applied to doing traditional jobs in faster ways, with even greater centralization. The alternatives in new forms and patterns of work, with new machines, ought to be more fully investigated. Microelectronics can allow work can be decentralized and enriched through widened responsibility. The important book by Cal Pava, Managing the Office of the Future, describes the choices and their consequences in some detail. He presents evidence of the greater opportunities in accepting new management philosophies, such as those associated with centralization, so that new and exciting technical capabilities can be fully utilized. He draws evidence from several service industry companies as to how more skill intensive work can be more interesting and can be organized to make greater use of human capabilities. To date there has been less study of these potentials in the manufacturing industry.

## 1.3 MANAGEMENT OF TECHNOLOGY:

Mainstream U.S. economic thought continues to assume that the greater the wage, the more people will be driven to work. "Hard work can be bought. Other cultures have gone deeper into human motivation in the workplace and tried to understand what drives the human "will to work". This can be seen in countries like Japan and Sweden. Japan has managed to marry novel applications of technology to social motivations about why quality work is important.

At each point in history, it seems that the older generation had to work harder than the younger one. This may or may not be true. It does illustrate a central dilemma in linking pay to performance in a cause-effect manner. Another dilemma in this belief is seen in the quite poor performance of many middle managers in major corporations that have been very highly paid. Recent history in the automobile companies illustrates this. Perhaps the most we can say is that some people, perhaps even all people, have an inner need to do a good job, at least some of the time, regardless of the pay. Their upbringing, culture and education have imbued them with a need to work, and perhaps even a need to accomplish tangible things. This route seems to provide a much truer access to understanding human motivation and willingness to work. It may be important to do research on more of these issues, and how they relate general environmental quality factors.

Technology is increasing at an accelerating pace in all fields. Technical progress and modernity tempted management to invest in computers and other equipment in an unplanned and haphazard manner. This can have disastrous results. To avoid this, new technology needs to be introduced via careful analysis, always keeping in mind the central role of the individuals who will be working with the machines. Humans must be able to choose and influence the application of technology in the systems involved. Many examples have illustrated how this is more important than the sophistication of the technology itself. The socio-technical-spatial approach is one means to this end.

# CHAPTER II

# PRODUCTIVITY : THE GOALS

## 2.1 PRODUCTIVITY AND ORGANIZATIONS:

Productivity is generally defined as output divided by input, where output is the desired product and the major input of concern is labor. Of course, this is a very simplistic approach which excludes unwanted outputs (eg.pollution) and unplanned for inputs (eg. high interest rates). Within this study, productivity is conceived in the more comprehensive long-term approach, consistent with Leontieff's input/output analysis. In this more general sense, it is argued that productivity refers to the effectiveness with which organizations employs all its needed resources: social, technical, material, energy, and capital. Herein it is argued that the facility and especially the space element needs to be added to the analysis.

Organizations, cannot be instantly made but can only be generated over time with many factors essential to their success. They are directly and indirectly dependent on many somewhat intangible issues and activities: human behavior and interaction of the people in the work setting are quite important in any such list. It is important to note that a flower cannot be made only from a seed, but needs many other variables to operate in concert, i.e., to be organized with regard for each other.

While much is known of the effects of individual environmental components, little is known of how these might interrelate in a stable and complex system which facilitates or thwarts human activities. Work settings must vary with the people and the activities for which they are being used. It is also difficult to translate existing evidence into effective designs and to maintain a high level of effectiveness in an organization. Workers must develop new capabilities to meet new demands. This requires a change in physical oraganization and a much greater flexibility in their essential facilities. Designing and fitting the facility to its purpose becomes a continual process. Productivity is not just minimizing labor input but also considers the quality of the environment within which work takes place.

## 2.2 PRODUCTIVITY AND FLEXIBILITY:

Flexibility and Production volume provide constraints to manufacturing decisions but decisions concerning them rest on technologies that are:

- Independent of the design of the product. Technologies can be used for many different products and designs eg. simple manual tools, stand alone NC tools, job shops, etc.
- Programmable so that it can also accomodate a range of

various configurations, each of which reflects a different product design.
- Flexible enough to accomodate a range of product designs within a single configuration.

A major barrier to the effective use of this automation is lack of understanding of its impact on strategy. Managers will have to learn to accomodate a whole new set of strategic possibilities, such as:

- Custom-tailored and individualized products for both consumer and industrial markets with more finely tuned market segmentation and product positioning strategies.
- Broadly proliferated families of product design as well as increased variety.
- Production rates more closely tied to short-term demand fluctuations and, as a result, rapid response to customer orders for both products and replacement parts. This means enhanced distribution capacity with reduced stocks and less warehousing. In some cases, local production or repair centers to respond to geographic differences in customer needs.
- More direct sales, applications engineering and other simplified distribution channels, especially in industrial markets.
- Advertising and promotion emphasing production process capabilities - quality, reliability and responsiveness to customer needs - rather than product design

characteristics.

- More "skim" pricing coupled with rapid changes in product designs - hence, fewer "mature" products and a speedup in the product life-cycle.
- Quicker incorporation of new and state-of-the-art technology into product designs.
- Greater variety of market segments for a given company as well as an increasing substitutability of products, processes and suppliers.

Integrating these new capabilities - economies of scope - into its strategy will offer a company huge advantages in the worldwide market-place. A holistic approach into the strategy eg. organizational linkages of marketing with production and design and administrative support systems will increase the company's competence.

Without flexibility, or the ability of the system to modify its informational base, a system's information - no matter how fit it may have once been - ultimately becomes inappropriate for the external environment, which is necessarily in a state of continual change and eventually the system faces inevitable extinction.

## 2.3 THE HAWTHORNE EXPERIMENT:

The human aspects of productivity were uncovered in the Hawthorne Experiments. The objective of these experiments was to identify the causes of fatigue in the Hawthorne Works' employees. In these experiments, a control and an experimental group of workers were told of the objectives of the experiment and consulted on various alternatives that would be tested. The experimental group was exposed to variances of environmental factors which included social elements like pay, work hours, benefits, etc. and physical factors such as lighting, temperature and humidity.

To most people's surprise productivity improved in both the experimental and control group. Conditions were returned to the initial state and productivity still improved. These unexpected results were explained as the Hawthorne Effect - it was the experiments themselves that contributed to improved productivity through an improvement in the psychological attitude of the workers which developed through consultation with those conducting the experiments.

It may be possible to use this experimental process directly to improve productivity through environmental design and management. i.e. - instead of attempting only to generalize findings, the process of generating, testing and modifying hypotheses of how environmental alterations facilitate productivity could be diffused as a basic method of improvement itself.

The present way of approaching the complex system of human environmental actions is to decompose reality into a variety of parametric constructs - illumination, stability, acoustic performance, comfort, privacy, etc. These parameters are examined in pairs and at times with mediating variables wherever required. Each is considered separately. They are almost never seen as complex interactions. The result frequently is a good laboratory experiment, but sloppy science in that it is of no relation to reality. The parametric problem does not lie with decomposition or degree of control but in difficulties of synthesis once analysis has been done.

Interactions between humans and their surroundings are an important example of this. They are by their nature systemic; of the system; there being more potential in the connections than the parts being connected. Parameters interact and are dependent upon each other. eg. the amount of light in a room affects the amount of heat, which in turn, affects the air quality. Disconnected analyses are extremely difficult to reconnect into viable systems.

If the environment were to fit like a glove to an organizations purposes, which it doesn't, there would still be the difficulty in trying to cope with change. This is partially due to changing technology and partially due to changing human values. These changes characterize both work and the environment. Dislocation is not the only serious problem caused by technology. Some workers complain about being deskilled and others say their employers are using the computer as a control device. It makes little sense to have a new technology and yet operate it via the old social system. Bureaucracies must physically reoraganize to implement new programs and policies, even if this requires a change in the organizational form.

Managers can adopt new technology to improve performance, but this is increasingly requiring environmental changes as well. Often the new machines require air temperatures and cleanliness that humans have long wanted. Recognizing this gives a facility designer a powerful tool for construction improvement.

One key to successful space design is the provision of undifferentiated space with a flexibility of fittings and equipment. Production and maintenance work, traditionally separated under the scientific management organization of work, needs to merge into one fluid work system. Today, we need work environments that both allow and produce continuous innovations.

# CHAPTER III

# SOCIAL SYSTEMS : THE PARTICIPANTS

## 3.1 THE HUMANIZATION PROBLEM:

Our social order is coming to be determined by technological ideas which are changing in a pre-determined and unquestioned way which is often not in the interest of humans. As automation progresses, the technical content of many jobs increase and thus more skilled workers are required. The more specialized a worker's skill becomes, the harder it is for his superior to tell him how to do his work. Managers have difficulty telling computer programmers or CAD operators how to do their work; they can only tell them what results they want, which offers some freedom of choice in the increasing technology of work. Also, the more skilled a worker is, the less inclined he is to give blind loyalty to an organization.

Attitudes towards organizations have also began to change due to increased education and economic security. This results in a growing demand for organizational objectives to be open to adjustment by the individuals that work to carry them out. The objective of humanization is not to turn all organizations into instruments, whose sole purpose is to satisfy its members. This responsibility gives rise to environmentalization problems. Since humanization and environmentalization problems are interactive, they require a joint solution - i.e. not to be treated as separate entities but as a whole. In short, the problems are to be treated holistically rather than in fragments. This is the same approach historically required to acheive high quality architecture.

3.2 PARTICIPATION IN DECISION MAKING:

Studies of teamwork approaches, or workers working in groups, headed by a "representative", results in more responsibility than a normal assembly line worker over the final product, which in turn leads to improved efficiency. Projects could grow out of the desire to find different ways of working that would be personally satisfying for the individuals involved with the specific task, while also boosting productivity. It is therefore necessary to find out where the interests of the people lie and how many of them are interested in what they do. Many different theories have been shifted through, ranging from quality circles and participative management to motivational models.

The aim is not to influence moral or ideological values, but rather to create a work environment that provides social reward. Each work team is destined to have a defined responsibility for quality and productivity. This innovative system could be reflected in a new wage structure, in addition to the basic salary of each worker.

The principal elements could be a bonus scheme for developing individual skills eg. the mechanical technicians in the composite or press shop and also a "team" bonus. This bonus could be paid to the work team in accordance to the amount of responsibilities taken up by the team eg. responsibilities such as quality and quantity control, maintenance, personal administration, etc.

All these incorporate socio-technical-spatial innovations with a work organization seeking to give the individual greater responsibility and to provide more comprehensive work. This work organization comprises of job rotation, job enlargement and group work principles. The job rotation principle allows workers to rotate jobs at certain intervals. Following the principle of job enlargement a number of direct production tasks, and some indirect tasks such as maintenance are combined to increase the job cycle time. The fundamental goal of these principles is to make work more physically and psychologically satisfying. The group work organization creates potential for increasing participation in decision-making and at the same time increasing productivity.

## 3.3 DIGNITY AT WORK:

Job rotation, job enlargement and group work organization, along with the adoption of new technology and architectural improvements are all intended to improve the quality of working life. Yet, what is lacking is greater participation in decision-making and control over one's own work and activities. Work organization is a socio-technical innovation. Like the technical innovations of robots and computers, it is a tool in the hands of people. Its effectiveness to improve quality of working life and stimulate organizational development is ambiguous; it all depends on how effectively the tool is used - the quest being to better align the interests of the individual with the interest of the organization.

The unattractive nature of most jobs - which are not only monotonous and repetitive but are rigidly controlled by the fixed speed of the line - is one cause of high personnel turnover and absenteeism. To be sure, there are many people who can adjust to such jobs, but for others adjustment is not possible. To work in such manufacturing processes over a period of time becomes not only boring but a source of emotional stress. Hence, jobs have to be enlarged and the work organization changed to give more variety to the work and alleviate the stress. All these issues had to be taken into account at the GM facility used as the example in this thesis.

# CHAPTER IV

## TECHNICAL SYSTEMS : THE MEANS

### 4.1 REFINED CAPABILITIES:

New technology demands new ways of thinking and needs to have new or refined capabilities such as:

Product Flexibility: in product design and product mix, which allows for an almost unlimited variety of specific designs within a reasonable family of options, including alternative materials. To achieve model flexibility, quick die-change technology will be the norm.

Rapid Response: to changes in market demand, product design and mix, output rates and equipment scheduling.

Greater Control: accuracy and repeatability of processes, all of which lead to better quality products and more reliable manufacturing operations.

Reduced Waste: lower training and changeover costs and more predictable maintenance costs.

Greater Predictability: in all phases of manufacturing operations and more information, both of which make possible more intensive management and control of the system.

Faster Throughput: due to better use of all machines, less - in process inventory, fewer stoppages for missing parts or materials or machine breakdowns. (Higher speeds are now made possible and economically feasible by the sensory and control capabilities of the "smart" machines and the information management abilities of the new CAM software)

Distributed Processing Capability: made possible and economical by the encoding of process information in easily replicable software.

These emerging capabilities directly challenge most current assumptions about manufacturing that stem from the notion of economies of scale - in particular, the notion that greater production volumes display lower unit costs than do lesser volumes. Greater volumes allow for the use of expensive special-purpose equipment, which in turn, is justified only by large scale operations. By contrast, the new technical capabilities rest on economies of scope - that is, efficiencies wrought by variety, not volume. Putting it simply - computer controls, programmed production sequencies and electronic memory make feasible the application of leading - edge processing techniques to small production runs.

## 4.2 AUTOMATION:

Manufacturing automation, a dream just a generation ago, is now becoming a reality. Initially, manufacturing automation took the form of automated control of single processes such as machines, conveyors or product test stands. The next stage was to expand the control to include an entire function such as materials handling or assembly. Presently, automation is approaching a third stage - the integration of these automated processes into a whole - i.e. viewing automation as a holistic process. This latest development can be viewed as a shift from manufacturing automation to total factory automation.

Total factory automation, often referred to as "the factory of the future", is being made possible by parallel advances in both computer and communications technology. Efficient information transfer is one of the keys to implementing automation. Breakthroughs in computer technology and communications technology - local area networks - have been made.

A local area network, or LAN, is a system of hardware and software that allows members of logically related groups to communicate over distances of a few feet to about twenty miles or more. In a factory, typical group members may include robots, programmable controllers, data collection devices, video monitoring systems and badge readers. By facilitating machine to machine communication, LANs can weld the different phases of a manufacturing operation into a single, unified process. This will make way for the ultimate factory technology: computer integrated manufacturing, now known as CIM.

The basic concept behind CIM is that by totally automating and linking all the functions of the factory and the corporate headquaters a manufacturer would be able to turn out an essentially perfect, one-of-a-kind product - at the lowest possible cost. With a computerized factory, having expert systems and other forms of artificial intelligence, a company could:

Conceive of new products on a computer-aided design (CAD) system that would allow designers to optimize their ideas.

Pass the CAD data electronically to a computer-aided engineering (CAE) system to verify that the design will do the job intented and can be made economically.

Extract from the CAE the information needed to make the product. The information would be sent to a CAM system, which in turn, would send electronic instructions for making the product to computer controlled machine tools, robotic assembly stations, and other automated equipment on the shop floor.

Coordinate with computerized management systems, such as manufacturing resource planning, which keeps a running tab on the consumption of parts and materials, and manufacturing process planning, which helps schedule production for optimum efficiency. In addition, the mainframe computer in the factory would continously update the corporate data banks used by marketing, finance, purchasing and other headquaters functions.

This facile factory will have a profound impact on how manufacturers do business and will be so flexible that it will be able to make the first copy of a product for a great deal less investment. With a CIM factory that can be reprogrammed to switch from making one product to another in a very short time, companies would have the ability to respond to instantly changing market conditions, tailor products for each buyer, cultivate a wider mix for customers and introduce new products at will.

Moreover, the new technology could make cheap foreign labor less attractive. Because labor costs would be virtually zero and other offshore savings - cheaper materials and lower overheads - would be overwhelmed by the benefits of quick turn-arounds and low inventories, the computerized factory could potentially produce things here in U.S. for less than they would cost to import from China or Korea. So the ideal location of the factory of the future would be in the market where its products are consumed. Amongst the American companies, the hang-up is partly cost, because CIM does not come cheap. Partly, it is technological since the pieces are not yet in place. Partly, it is a shortage of high quality engineers. Implementing CIM demands a long-range commitment and entails wrenching changes in organization and culture.

## 4.3 HUMAN SIDE OF AUTOMATION:

Trying to achieve productivity gains in various offices and industries are part of a powerful synergism taking root in the U.S. - i.e. the pairing of people with automation. Americans are now turning to the human side of technology, partly by borrowing from Japanese techniques, and also by using other methods. eg. Japanese companies do emphasize a fundamental redesign of jobs to make them more appealing to workers. Also, when the Japanese use production teams, they usually keep them under the control of first-line foremen. Leading companies are now integrating workers in socio-technical systems that revolutionize the way work is organized and managed. Traditionally, jobs were designed with no capacity for people to initiate anything. If something went wrong, it would turn out to be an inflexible response. Jobs, today in the 21st century should be so designed that people can be more than a pair of hands behaving in a mechanical way. The great wave of automation that has swept through factories and offices since 1980 is losing momentum, largely because not enough companies, are adopting the innovative work practices that get the most out of automation. With or without work reforms, computer based technology is having an enormous impact on people. In one way or the other, it has changed the jobs of almost half of the U.S. work force. It has made jobs challenging for some and on the other hand "deskilled" others.

To give people a greater variety of duties, a socio-technical-spatial manufacturing facility design would call for teams to assemble entire subunits of a car from parts moved throughout the floor on automated guided vehicles. Team members could be free to move around, rotate jobs, pace themselves within a longer work cycle and have more control over product quality. Studies by researchers at the Wharton School (eg. Volvo, Ahmedabad textiles, General Foods, Sun-oil, etc.) have shown that group assembly, not only make workers feel better, but also produce higher quality and increase productivity.

# CHAPTER V

# SOCIO-TECHNICAL-SPATIAL SYSTEMS : THE CONCEPT

## 5.1 THE CHANGING APPROACH TO ORGANIZING WORK:

It is evident that advanced computer technology calls for a radical change in traditional work practices. Traditional management methods of dividing work into discrete tasks that require little skill or training, is not helpful in a computerized workplace where many functions like materials handling, assembly, inventory control, testing, etc. are integrated by a computer and a group of people performing as a socio-technical team. It is difficult to clearly measure performance or to clearly differentiate jobs in modern manufacturing.

For these reasons, many companies are emphasizing broader-minded jobs, teamwork, multiskilled workers, etc. The innovations also include other policies like job enhancement, training programs, reward for group performance, etc. for developing "committed" workers.

What management assumes about workers

OLD WAY Worker wants nothing from the job except pay, avoids responsibility, and must be controlled and coerced.

NEW WAY worker desires challenging job and will seek responsibility and autonomy if management permits.

How the job is designed

OLD WAY Work is fragmented and deskilled. Worker is confined to narrow job. Doing and thinking are separate.

NEW WAY work is multi skilled and performed by teamwork where possible. Worker can upgrade whole system. Doing and thinking are combined.

Management's organization and style

OLD WAY Top down military command with worker at bottom of many supervisory layers; worker is expected to obey orders and has no power.

NEW WAY Relatively flat structure with few layers; Worker makes suggestions and has power to implement changes

Job training and security

OLD WAY Worker is regarded as a replaceable part and is given initial training or retraining for new jobs. Layoffs are routine when business declines.

NEW WAY Worker is considered a valuable resource and is constantly retrained in new skills. Layoffs are avoided if possible in a downturn.

How wages are determined

OLD WAY Pay is geared to the job, not the person, and is determined by evaluation and job classification systems.

NEW WAY Pay is linked to skills acquired. Group incentive and profit-sharing plans are used to enhance commitment.

Labor Relations

OLD WAY Labor and management interests are considered incompatible. Conflict arises on the shop floor and in bargaining.

NEW WAY Mutual interests are emphasized. Management shares information about the business Labor shares responsibility for making it succeed.

Data: Richard E Walton, Harvard University, BW

It makes no sense to have a new technology and yet operate the old social system. The old "control" paradigm has to be replaced by the new model of "commitment".

The goal in the General Motors factory is to create a manufacturing facility which without any sacrifice of efficiency or profitability will give employees the opportunity to work in groups, to communicate freely with each other, to shift between jobs, to feel a genuine identification with the product and a responsibility for quality and to influence their working environment.

5.2 A "NEW" PARADIGM:

Traditional industrial society, due to the assembly line production, exploited people. It was this industrialization that created a conflict between the pursuit of productivity and the right to dignity at work.

Monotonous methods of production and fragmentation of work created physical and mental problems, which resulted in a negative effect on production and product quality. People who are socially isolated in their workplace doing jobs that consist of simple repetitive operations make little use of their intellectual, emotional and mental potential. To improve work it is necessary to bring out the best in people. Their interests and motivations need to be aroused so their talents and abilities can be put to good use.

To reform peoples' working life, and, in turn their workplace, a wide range of issues should be considered and interwoven, the most important being the social, technical and the spatial elements. What really counts is the sustained long term improvements in productivity which is far more than financial resources. Such improvements could be a product or a service that fulfills an important function - something useful than can be produced profitably. The process for producing this good or service needs to also enhance the well-being of the workers involved. These results are acheived by people who know what and why they are doing and who feel well in body and soul and who can express their feelings, intuitions and rational in and through their work. This makes people and eventually the society flourish. The working place must be so organized that it releases the powers that lie hidden in people's ambitions, dreams and physical and psychological needs, in people's wish for growth, a sense of community and control over what they do. Individuals need to be able to see things in their full potential to acheive results.

## 5.3 A HOLISTIC APPROACH:

The "workplace" - be it in a small or large organization, will become an increasingly complex interaction between people, technology and organization. The ability to compete in the future will not come from the building of large production plants but from the ability to lead and motivate people in this complex interaction in organizations and production systems.

All this implies that in the future fewer people will produce more and the value added per employee will increase. The strategy of the future does not rest on the new emerging technology but on the necessary transformation of the workplace and this requires a deeper understanding of the holistic approach that deals with the socio-technical-spatial factors, as well as humanistic values. Production technology and organization now drive values in society and the ability for societies to adopt. People will be the driving force for this strategic action, an improvement of the human condition.

Facility designers, including architects, will always have some difficulties in understanding the management of the organization, but these need to be overcome. Designers need to be aware of management philosophies and how they are supported by facility design. Recent evidence points to increased reliance on more holistic management perspectives, which even includes facility design. In many respects this is becoming similar to traditional architectural design concepts. Each part of the system has to be efficient and have its own integrity, but at the same time, the parts must fit together. It is the role of management to have a holistic overview and the ability to maneuver the organization in the varying conditions of the overall environment. This is particularly critical in a complex organization. This philosophy states that people are the key resource in an organization and they must be treated fairly and in an environment of trust to perform their best.

# CHAPTER VI

# THE GM MANUFACTURING FACILITY PROJECT : THE APPLICATION

## 6.1 PROPOSAL STATEMENT:

This proposal results from a multidisiplinary team effort. The team included two undergraduate students from Industrial Engineering, a graduate student from Mechanical Engineering, specialized in the field of robotics and a graduate student from Architecture. The industrial engineers were primarily responsible for the plant process and layout, the mechanical engineer for the manufacturing details and use of AUTOCAD computer graphics and the architect for integrating all components into a factory of the future.

Two field trips to automobile factories proved to be very helpful and initiated interest to work on the competition. The field trips were made in the local area- one to a Ford plant and a General Motors plant. Both facilities gave sense of plant organization and movement in large spaces that make up manufacturing facilities. Both facilities gave a clear sense of the many problems that beset design and management of modern manufacturing.

The study included extensive library research which extended into areas of behavioural science, automation, high technology, productivity, etc.

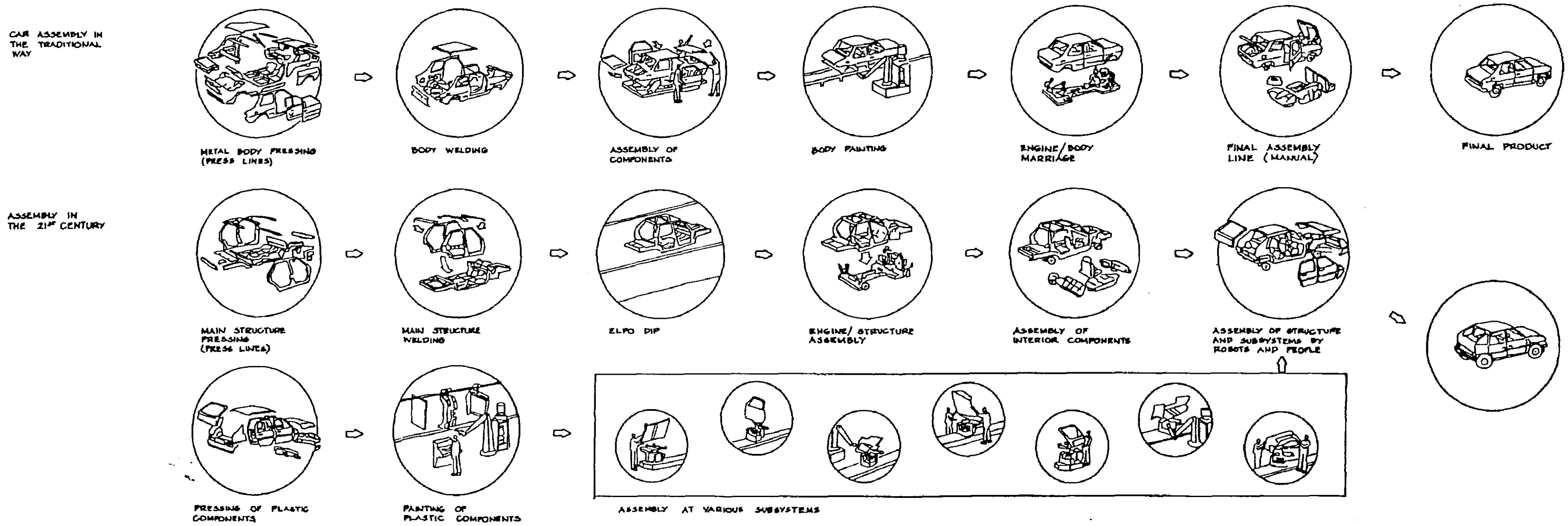



Figure ii : Car Assembly

## 6.2 IDENTIFICATION OF ISSUES:

The following major issues were examined during the design process for the factory of the future: productivity and environment, technical systems, socio-technical systems, socio-technical-spatial systems, flexibility, and a ten year life cycle.

Productivity and Environment: Much time was invested in tryint to create a humanly desirable physical environment. This work was based on an understanding that the provision of humanly supportive facilities to satisfy the worker's psychological needs can result in improved productivity. One goal of the design is to improve working conditions in areas where the physical environment is anticipated to be stressful and/or the production processes are to be monotonous.

Studies (eg.Scott paper) suggest that most of the workers prefer teamwork. It can facilitate exposure to a greater variety of tasks, compared with repetitive jobs on a conventional assembly line, and richer social interaction and support in accomplishing difficult tasks. The teamwork approach to production processes requires a drastic change in management style and methods. This new approach replaces the old idea that a manager's main function is to control workers, with the concept that a manager should encourage employees to collaborate in a joint pursuit for excellence.

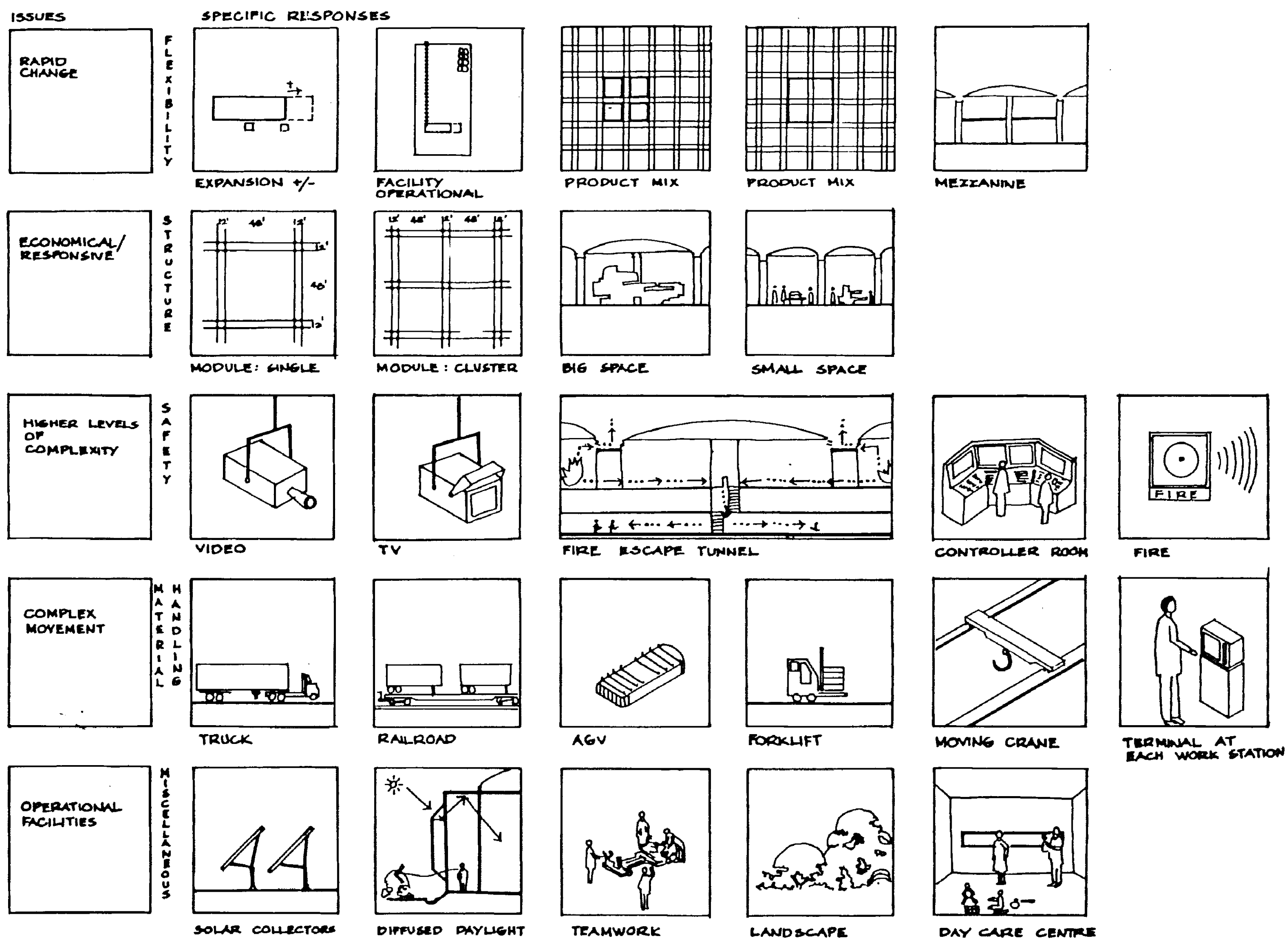



Figure iii : Basic components of the 21st century factory

Socio Technical Systems: Leading companies have been experimenting with integrating workers and technology in "socio-technical" systems that revolutionize the way work is organized and managed. The concept of a socio-technical system arises from the consideration that any productive system requires both a technological organization - equipment and layout of work settings - and a work organization. Socio-technical work systems calls for involving workers whenever possible in planning a new or redesigning a plant. Traditionally the technical design comes first, then the work flow and finally follows the placement of work stations.

Socio-Technical-Spatial Systems: To fully realize the potentials of automation, one needs to analyze the "spatial" aspect - which is the architectural dimension. The spatial scope of an analysis represents places, processes and events occuring within a broad rather than a narrow region of the individual's (or group's) geographical environment. The measurement of health might be limited to reports of discomfort - while at work or could be expanded to include assessments of non-work experiences (complaints of impaired vision or muscular discomfort while at home) Socio-technical-spatial studies should be done as a comprehensive service but are seldom dealt with in an integrated fashion.

Flexibility: Flexibility is a key issue in the design of this facility. The mix of storage and production in the plant is expected to change during the plant's lifetime.

Product Flexibility: Requirements for active stock at each work group is complicated by the changing component designs and demand mix (Refer figure 1). To accomodate the demands for change, the required flexibility of operations calls for a systems approach to structure. The framing structure is designed so that crane runway beams, mezzannines and catwalks could be put wherever needed in the modules. The elements used are standard and simple. The system is designed for dead, live and dynamic loads. This flexibility allows change without affecting or disrupting the adjacent areas.

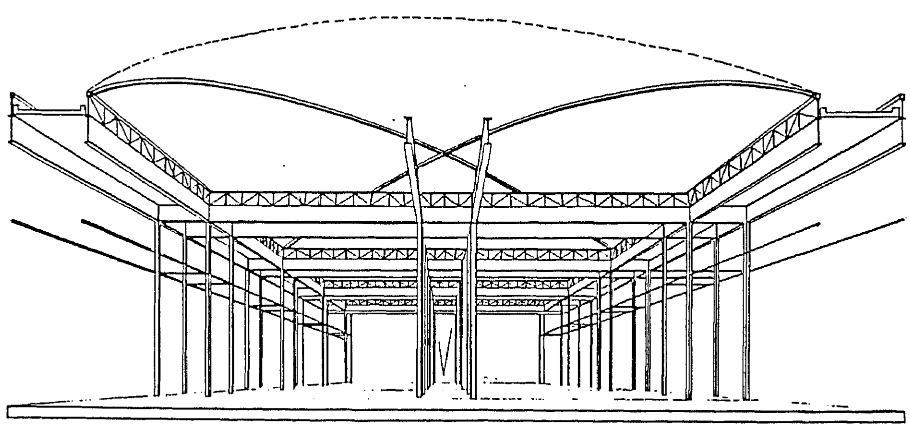


Figure 1: Fabric roof over large module

Mix Flexibility: The flexibility allows a carrier to bypass some work groups or to extend the workcycle in other groups (Refer figure 2). This permits great mix, process and volume flexibility not available in assembly lines with synchronous conveyors. In some instances, kits of parts may be assembled at off-line storage areas on miniretrievers or carousel storage systems and sent to a work group on a designated carrier.

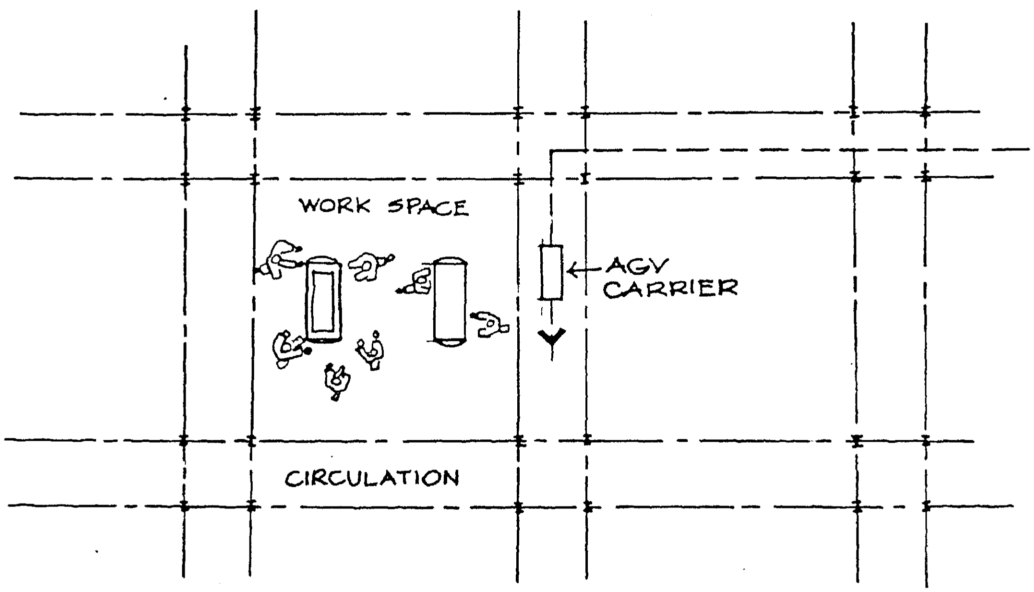



Figure 2: Typical module

Expansion Flexibility: Expansion of the factory is facilitated by the structure (Refer figure 3). New modules could be added with little internal disturbance. An impressive aspect of the design is the consistency of the structure, service lines, production lines and supportive offices. All are part of a single coherent conception and operation.

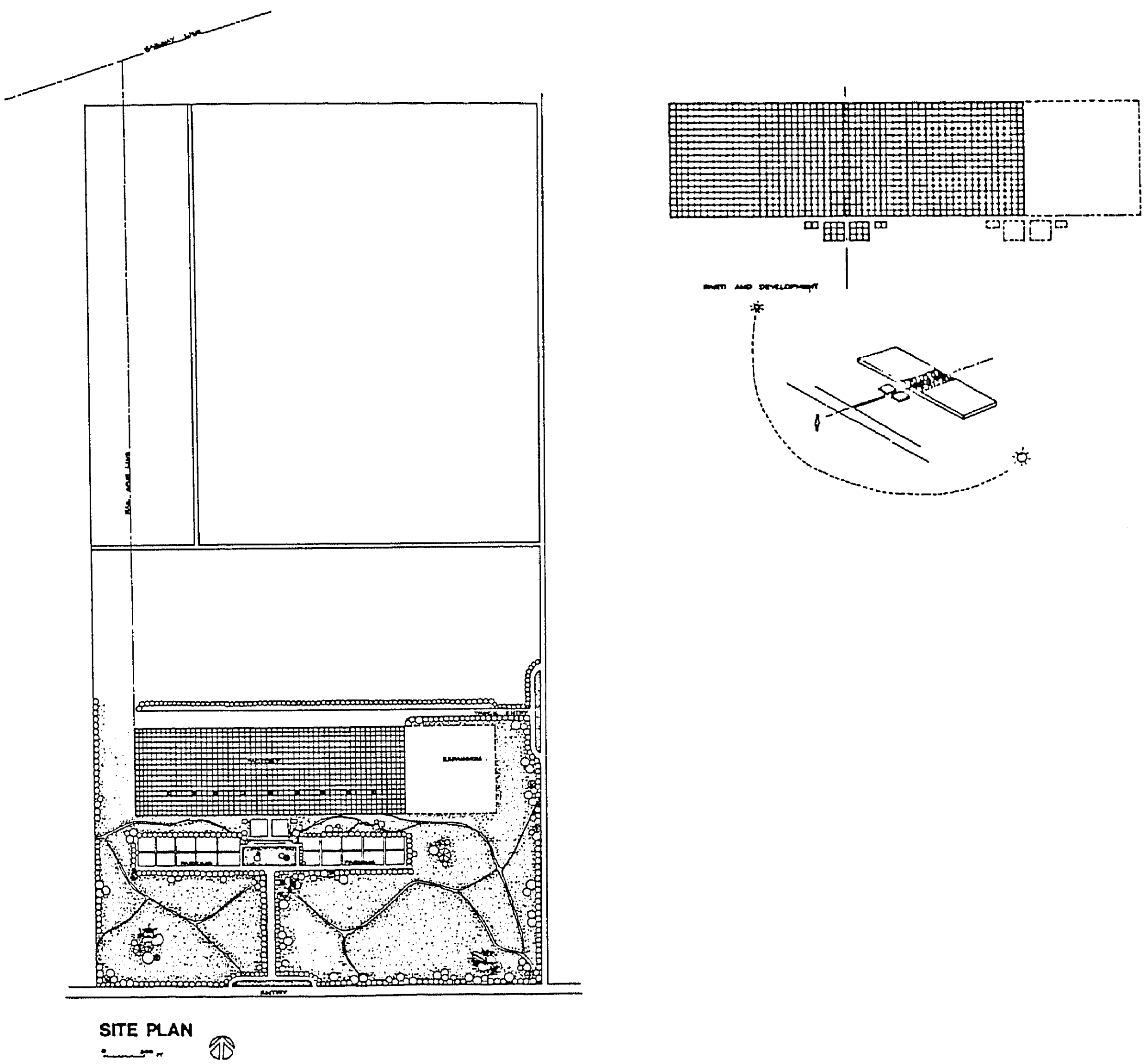



Figure 3: Plans showing future expansion of facility

Operational Flexibility: Alternative sources permit a diversified energy base (Refer figure 4). Use of solar collectors and/or photovoltaic cells permits flexibility as an alternative energy resource. Solar collectors are designed so that they open up with the rays of the sun and close as the sun goes down. The sun's energy can be collected and stored and then used in a more concentrated form wherever and whenever needed.

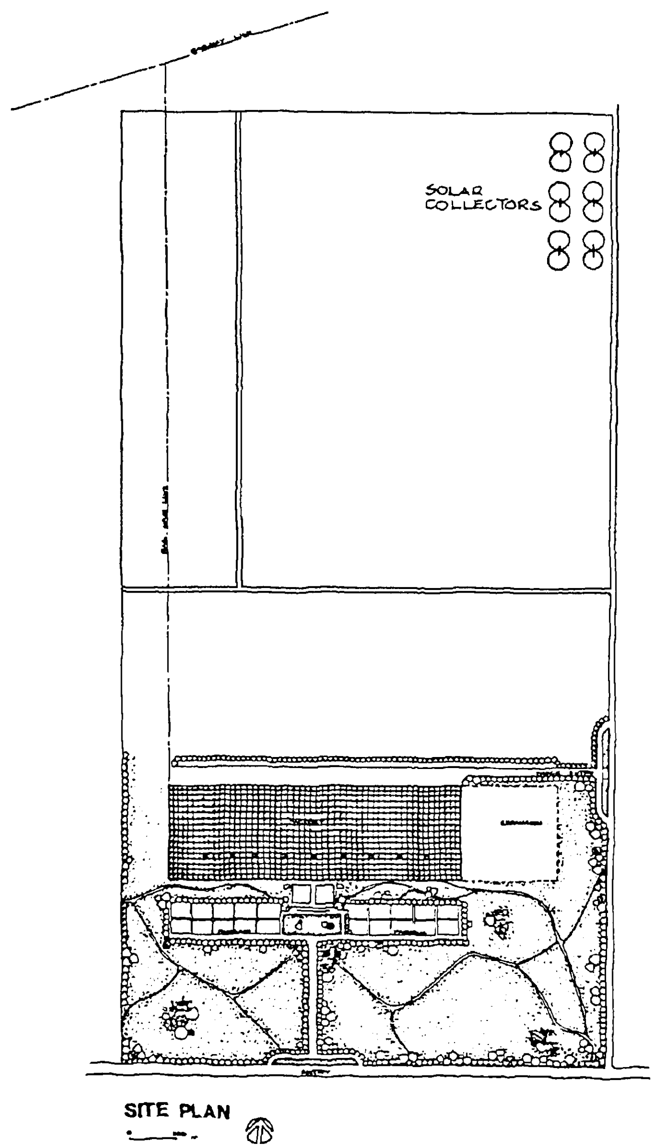



Figure 4: Plan showing solar collectors

10 Year Life Cycle: The finish materials for the factory's envelope are selected with reference to a ten year life cycle (Refer figure 5). The assemblies for the building's exterior, metal panels and metal supports can be dismantled and used elsewhere if needed. The fabric roofs have a life span of ten to twelve years, are easy to fabricate and install.

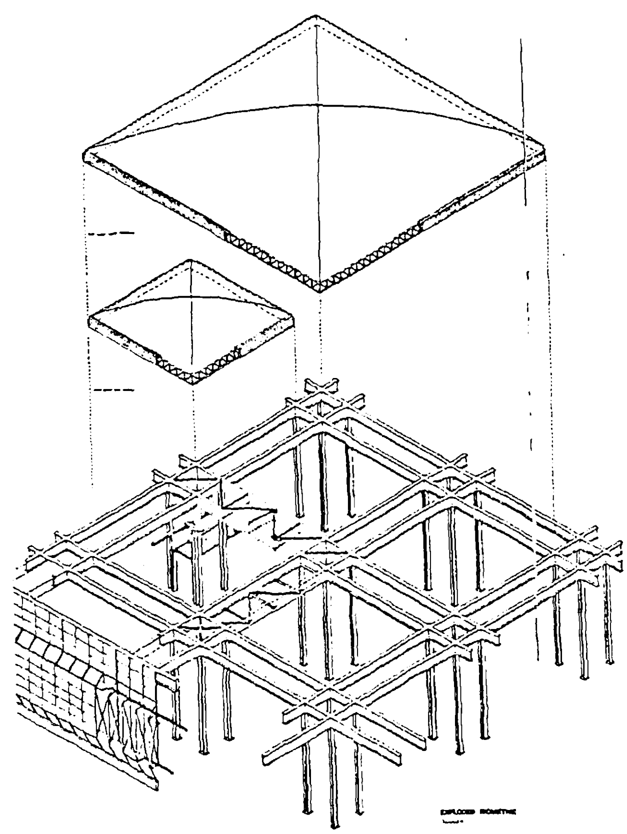


Figure 5: Exploded Axonometric

Clarity of the Building's Organization: The tartan grid provides a clear distinction between service and served spaces and also provides a clear picture of the circulation pattern and the work spaces (Refer figure 6). The 12 feet bays are used for circulation and movement of goods, services and people and the 48 feet bays are used as work spaces. Social trends will continue to place emphasis on a need for pleasant and emotionally satisfying work places. These trends include better employee and worker amenities, better parking, day care centres, health club and cafeterias. Different from the traditional factory, it should be a paragon of efficiency, while giving greater recognition to the needs of people.

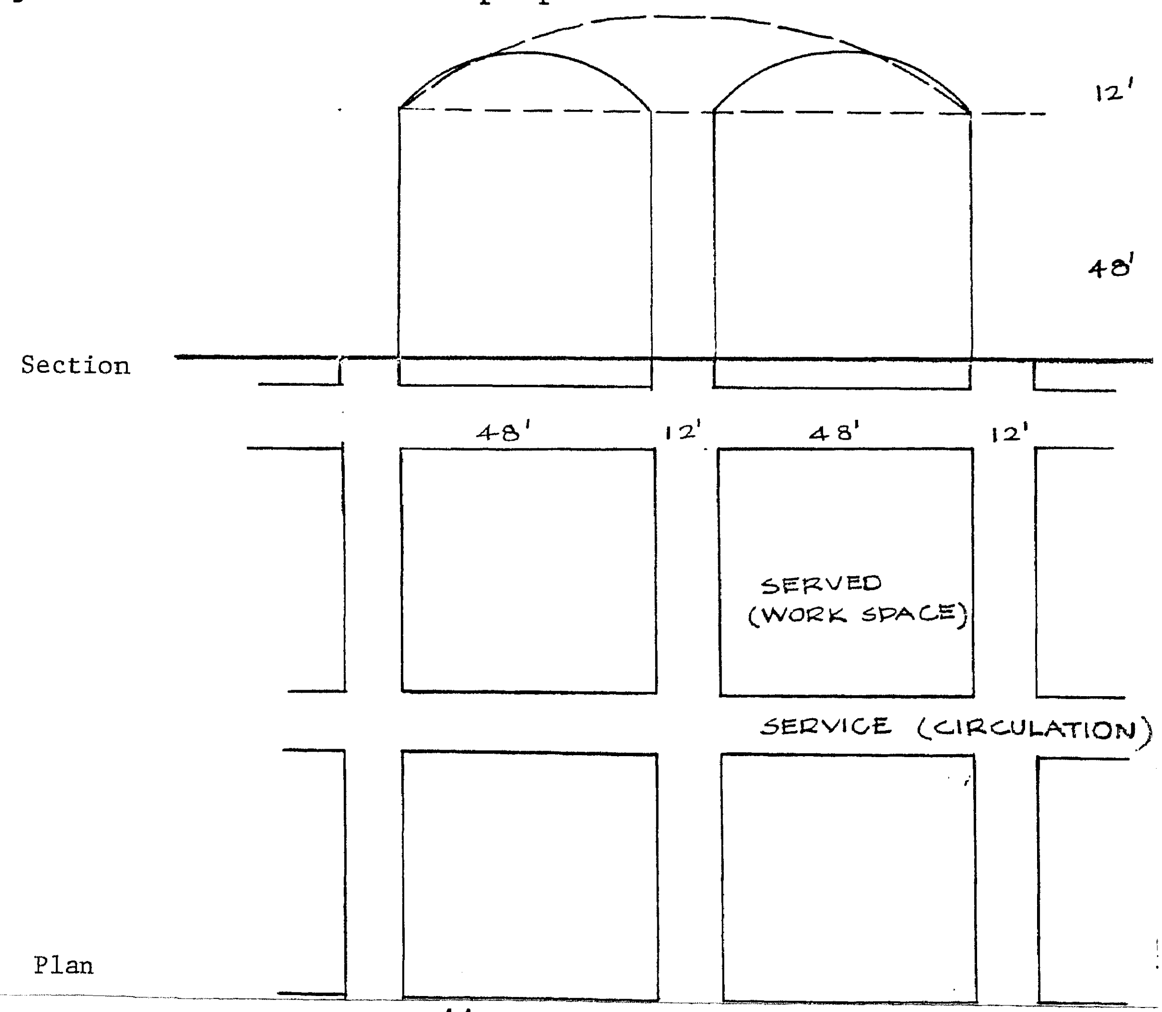





Figure 6: The tartan grid

## 6.3 TRADITIONAL CAR FACTORIES:

In automobile production, conveyor are used, with the help of which the auto is constructed one part at a time. This transportation device is known as a "mechanically powered line" or an " assembly line". The assembly of the car is done by workers stationed alongside the line. This same system is used for many other products. Production based on a moving line has been an efficient way to "control the flow of materials at an established speed, and thus it facilitates production planning". But the use of such a system has also meant that it is the "line" that controls the work, the work pace and the entire activity of the people on it. The mechanized line does not meet the requirement that machines should serve people. It also does not meet the requirements of flexibility. The assembly line is not the prime example of monotony in industry, but it is more stressing than many other systems. Its negative qualities are of two kinds. First, a safety margin must be allowed for determining how much work must be done at each station. Secondly, the worker feels forced to work harder than is actually necessary in order to generate a little further margin. The fixed speed, the constant fear of not being able to keep up with the pace of the line and consequent continuous efforts to widen the safety margin - all this has been found to be the major cause of the stress arising from assembly line work. This calls for job redesign. It is important that tasks be expanded to make the jobs more varied and interesting. To do this, other assembly formats are needed.

## 6.4 FLEXIBLE MANUFACTURING:

Basic structure of a flexible manufacturing system:

| | | |
|---|---|---|
| Software | Control system | System level control<br>Cell level control<br>Individual machine programs<br>Sensors and actuators |
| Production Process | Storage transport | Transformation<br>Machining/fabrication<br>Assembly/finishing<br>Automatic vehicles/<br>Conveyors/robots. |
| Hardware | | Automated storage |

The development of automated production techniques were stimulated by Japanese labor shortages in the early 70's, in much the same way that shortages of labor in USA stimulated mass production.

Automation is fuelled by three aims:

- To reduce direct labor and lead times and to rationalize design in its broadest sense, including the scheduling and organization of product development.
- The interaction between manufacturing and market place.
- Control over product variety and quality.

The success of automation in achieving these goals are revealed in a detailed study, entitled "The FMS Report" and cited the following achievements:

- Lead time cut by 40%
- Machine utilization improved by 30%
- Unit cost reduced by 12%
- Labor costs reduced by 30%
- Improved product quality
- Reduced scrap levels

It is not necessary for companies to introduce flexible manufacturing at one sweep in order to realise its benefits. Sensibly, these could be achieved incrementally first with machining centres, then with robotic finishers, assemblers and then automated transport.

A fully developed flexible manufacturing system includes all the following processes - machining and fabrication, assembly, finishing, storage handling and transport at the core of which are numerically controlled machines.

Computer controlled machining centres are able to function as individual steps in a continuous manufacturing process ( capable of milling, drilling, boring, attaching screws, etc.) Changes in the artifact or changes in the work sequence do not always require re-arrangement of the line-up of machines. The outcome is large savings of time as well as floor space. It is in the assembly where the largest savings are made as it has been estimated that 50% of production costs in the car industry are incurred at the materials handling stage.

Automated machines can not only undertake the whole range of manufacturing processes, in step-by-step tasks, but they can also be used to inspect, reject or correct the results. Moreover, all the machines involved in these processes can be controlled and directed centrally by computer. They can share the same memory, database and language. The influence of flexible manufacturing on design practices can be operated at three levels - the detail, embodiment and the concept. The central implication of this on the facility design is a large and growing need for communication linkages.

## 6.5 AUTOMATED GUIDED VEHICLES:

Automated Guided Vehicles (AGVs) are winning the endorsement of leading U.S. manufacturers, as flexibility and adaptability needs become critical on the factory floor. Due to demands from users for ever increasing sophistication, a whole new class of vehicles is being developed that finds its way without any guidance. AGVs fit into two broad manufacturing categories: 1. Materials handling and 2. Assembly systems. (Refer figures 7 and 8). In materials handling, AGVs deliver inventory from holding to production areas, or between work stations; they replace manually operated equipment like forklifts or rigid automation like transfer lines. In assembly systems, AGVs are themselves the production platforms, supporting products like automobiles, engines and tractors while work is being performed. Thus they do away with conventional industrial conveyor lines. And unlike a conveyor line, an AGV can be sent to any station in the system's route, in any sequence, at any time. In order to meet the specialized needs of different industries, AGV carriers may be outfitted with a wide variety of fixtures for holding or transfering work pieces. The guidepaths consist of wires embedded in the factory floor. Each carrier has an antenna that detects the magnetic fields surrounding the guide wires when the wires are energized at low voltages. In all but the simplest AGV systems,a central control computer dispatches carriers, tracks them and governs their movements of the various guidepath loops. Automobile factories are the greatest users of the AGVs.

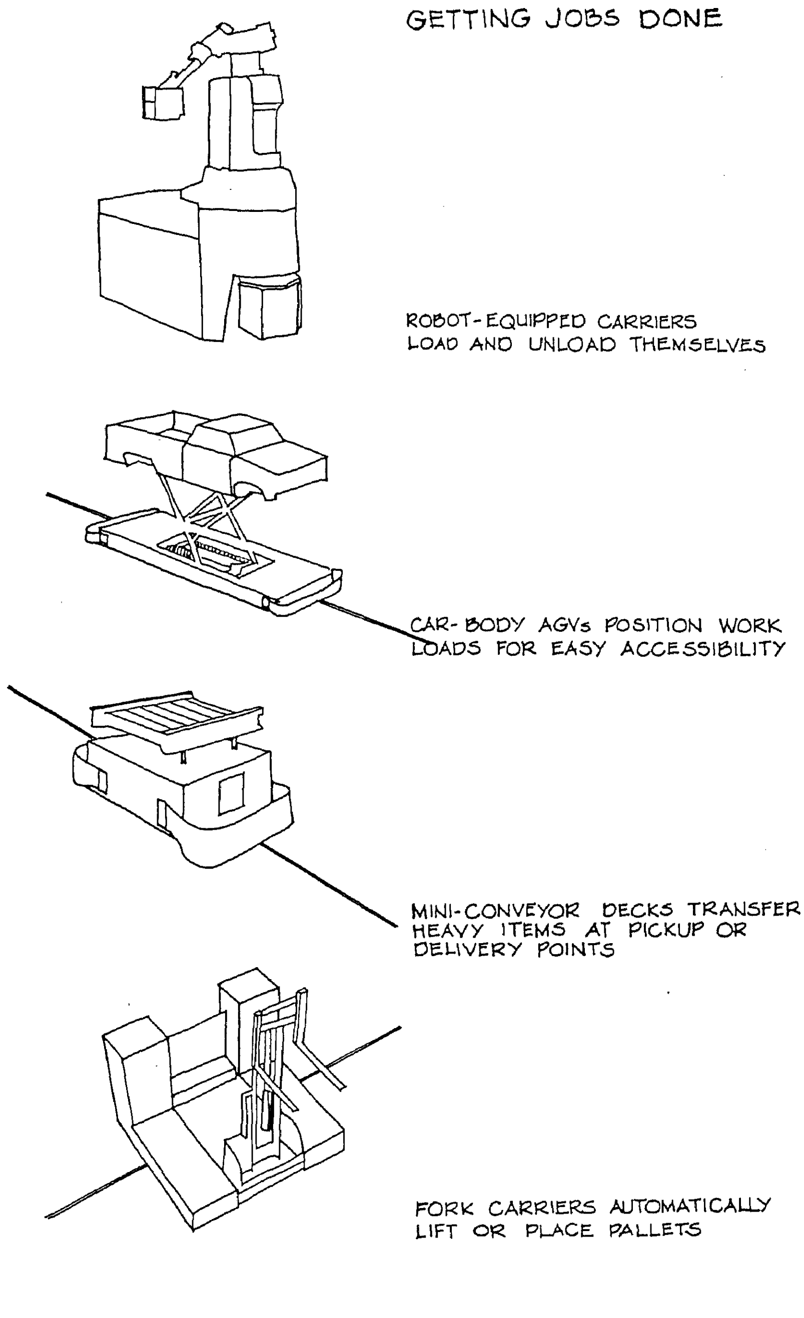



Figure 7: AGVs - Staying on course

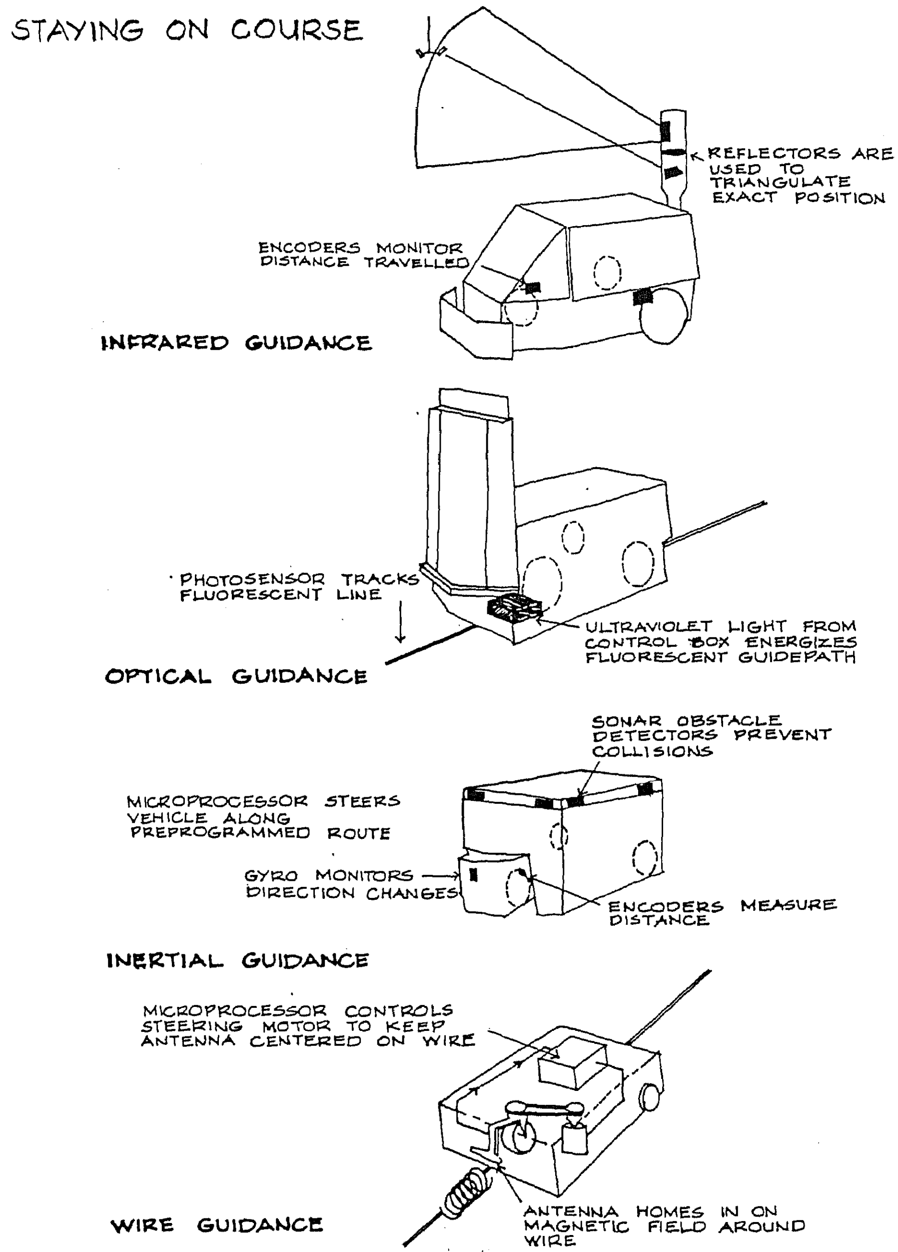



Figure 8: AGVs - Getting jobs done

6.6 GENERIC ALTERNATIVES:

Various alternatives were developed while designing the GM manufacturing facility. One was to have all the activities under a single roof, which resulted into a grid at regular intervals. But this approach provided no innovations and carried the same flat roofed norm for a typical industrial building. Also, people working in a huge space always feel lost and bear no identification of own workspace. The grid provided no clear distinction between the service and the served and this resulted in a chaotic flow of materials.

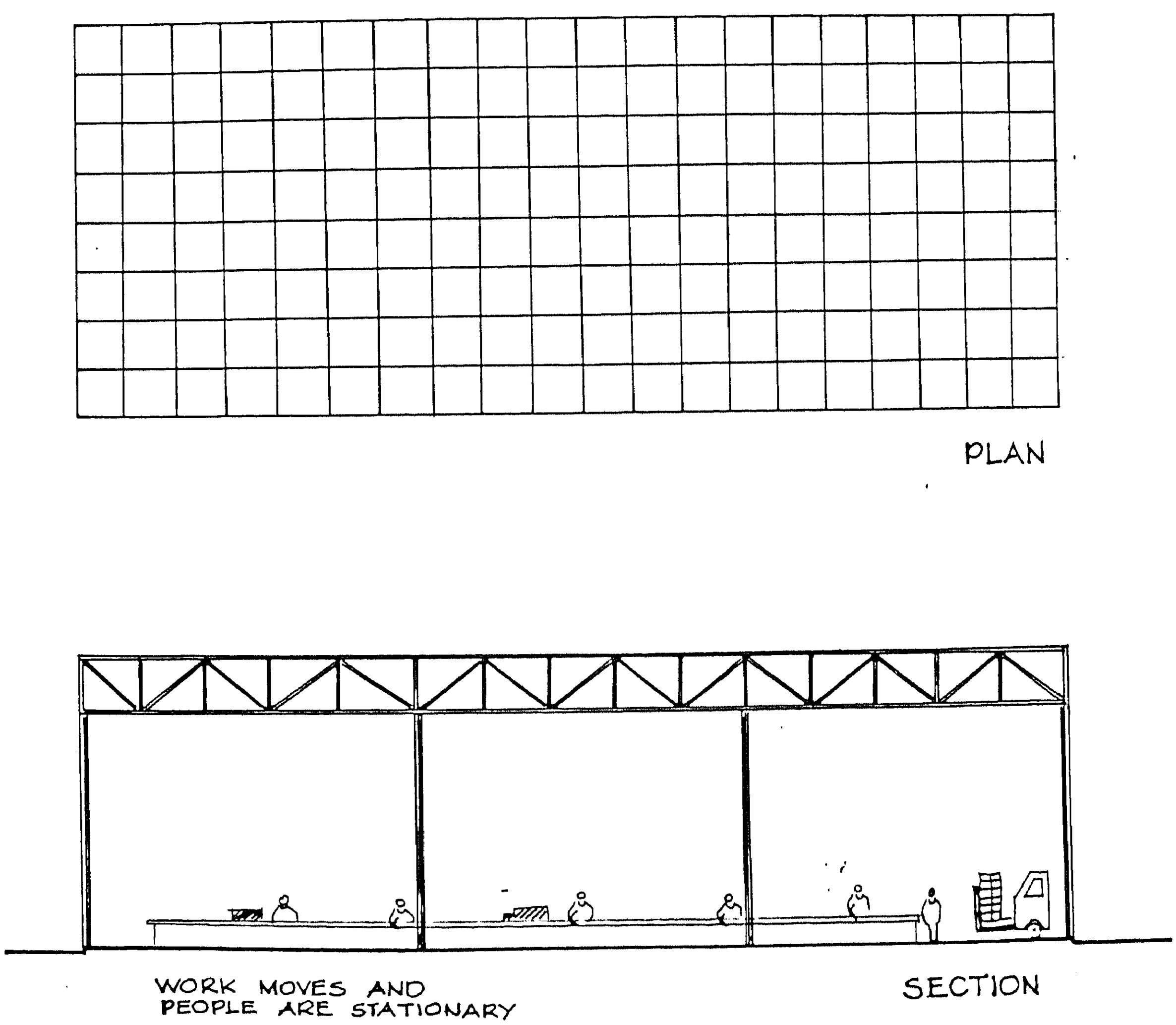



Figure 9: Alternative I

The second alternative was to have different areas for the different activities and yet all under one roof in the shape of an "E". This resulted in creating smaller factories within a huge factory and offered a comfortable and pleasant working environment than the typical huge factory. The different areas were not only separated by walls but also by huge green areas. But by breaking up a huge factory into smaller ones, the socio-technical aspect of the design was lost. Each of the smaller factories was made into a kind of a product cell with all the resources needed to manufacture independently of its product line. This would result in the workers being unfamiliar with the final product. Also, flow of materials from one small factory to another resulted in several bends and corners.

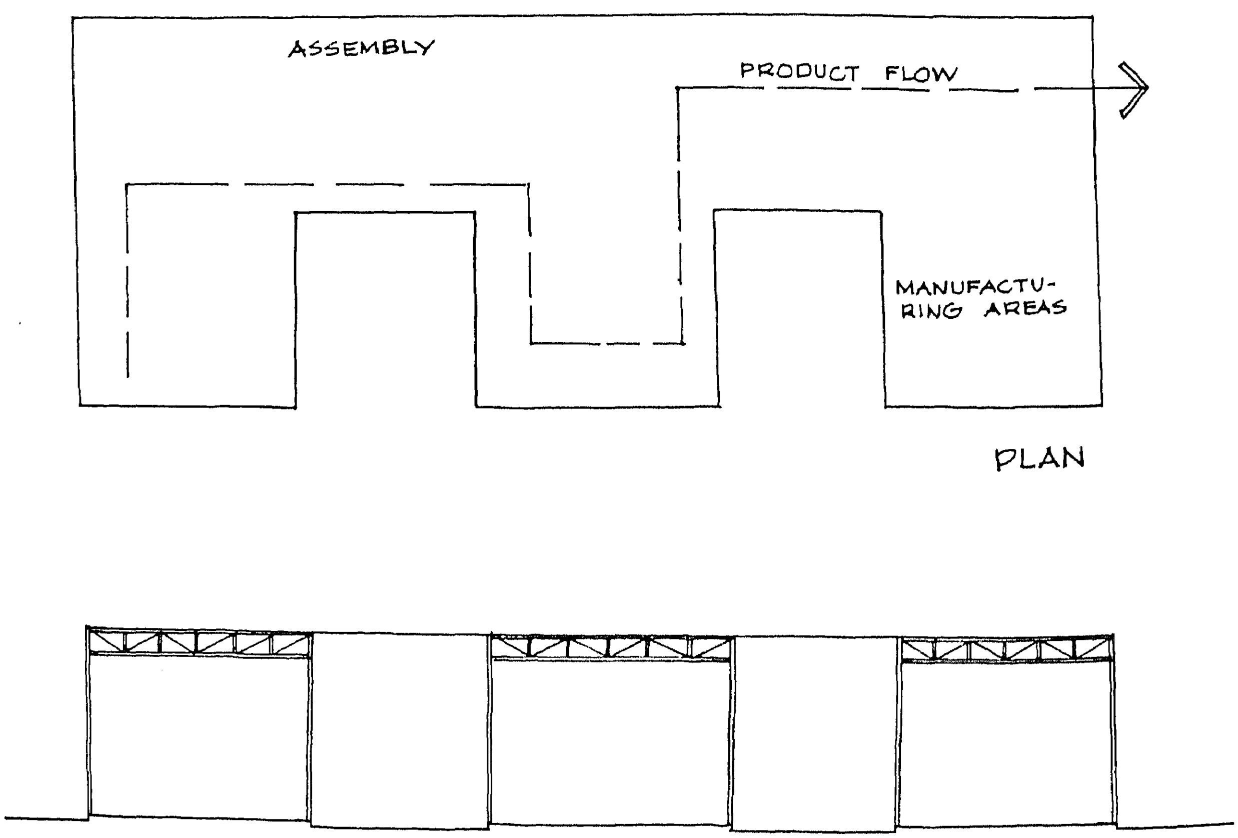



Figure 10: Alternative II

## 6.7 THE "PARTI":

Various alternatives were developed with the final scheme emerging as a flexible module which defines a clear pattern between the circulation and work spaces. The result was a tartan grid, alternating on 48 feet and 12 feet centres. The 48 feet bays served as work spaces while the 12 feet bays served for movement and circulation of materials and people. The overall plan consists of three squares, each of which has 18 modules by 18 modules. This forms a rectangle of 18 x 54 modules. These dimensions basically rose from the size of the equipment and the width of the automated guided vehicles to allow easy flow of both materials and people. This results in 73% for work space and 27% for circulation space. The same propotions are carried over in the section of the module - the height to the top of the structure being 48 feet and then 12 feet to the top of the cross arched roof (Refer figure 6).

The tartan grid is also carried over for the supporting services- like the administration, recreation, cafetaria and workers' lockers - to emphasize continuity and coherence with the factory building.

There are two different modules for the roof. The two sizes relieve the monotony of a homogeneous roof line, thereby articulating the roof area to a human scale. These roofs further emphasize the notion of identification of the different work spaces, rather than having the feeling of being lost in a vast space. The central axis of the complex is emphasized. Begining with the main entry into the site, the factory's roof profile is seen as having smaller roofs in the line of the axis, flanked by larger roofs on either side.

The factory has the potential for expansion on the east end. Another square of 18 modules running lengthwise and 18 modules running widthwise can be easily added.

6.8 STATEMENTS OF CONCEPT:

Flexible production, innovative assembly systems, high product quality and teamwork assembly are some of the main concepts in the plant.

Flexibility and Human Productivity: The main idea was to create a facility which, without any sacrifice of efficiency or profitability, will give employees the opportunity to work in groups, to communicate freely with each other, to shift between jobs, to feel a genuine identification with the product and a responsibility for quality, and to influence their working environment. The principle of group work organization strives to do this by creating potential for increasing participation in decision-making while at the same time increasing productivity, all the while taking place in spaces which support both objectives.

Each work group is responsible for its operations area. Strategically sited buffer zones between work stations make it easier for the assembly teams to influence their own work situation and production rates. Each work team has a defined responsibility for quality. This innovative system can be reflected in a new wage structure - the principal elements being a bonus scheme for developing individual skills and a "team" bonus, which could be paid to the team according to the amount of responsibilities such as quality and quantity control, maintenance and personnel administration. A major effort has been made to adapt technology to human beings, rather than subordinating people to the dictates of the assembly line and machines.

Human determinants and the desire to come up with an innovative and flexible module so as to minimize the building's impact on the landscape, largely fixed the design.

The Module: The proposed General Motors plant is a very large industrial structure, with a total floor area of about three million square feet, all on one main level. The factory floor is rectangle in shape - 18 modules by 54 modules - laid out on a tartan grid alternating at 48 feet and 12 feet centres. (Each module is 48 feet by 48 feet with 12 feet circulation space on all four sides) Despite the size, one would not have the impression of being in a large building because of the unusual roof line and form. One aim was to incorporate a small workshop atmosphere in all work areas. For that reason and economy, the building was given roofs in two sizes - 1. a single fabric cross arched roof spanning over a single module and 2. a single fabric cross arched roof spanning over four such modules.

Movement and communication pulsates along and within the 12 feet bays, making the work spaces accessible from all four sides. These bays could be viewed as circulation paths or interior streets looking on and participating in the flow of people, services and goods from one work space to another. These interior streets are flat roofed with a built-up roof deck on which are supported the mechanical units.

The most important aspect of the GM plant is the variety within the consistency of the entire design - structure, service, production and offices are all part of a single coherent structure. To support whatever layout the plant may need, the structure must need to provide regular and consistent supports for considerable loads, with minimal or no interruptions. The building also needs to offer a spacious feeling with a lot of natural light for people will be spending an extensive amount of time indoors.

All in steel, the structure is tightly and clearly tailored to various functions. Flat-roofed structures that are so often the norm, aren't. The columns are laid out on a tartan grid alternating at 48 feet and 12 feet centres, with bracing provided where needed to resist lateral forces. Beams run in both directions over which span steel cross arches. They are covered by silicoe coated fibreglass fabric, and which are highly translucent, resistant against tear and easy to fabricate and install. To bring down the whole building to a human scale, the smaller roofs are largely concentrated in the area where most of the people work and the larger roofs over spaces that have huge machines and need to have a larger scale.

Expansion: Expansion of the factory is also facilitated by the structure: New modules can be added without any internal disturbance; cladding on the facade could be dismantled and removed following completion of the new bay.

Lighting: Along the external walls, two strips of continuous glazing flood light into the building. The top level glazing have fixed prismatic panels arranged vertically with deflectors arranged horizontally. The lower level glazing consists of openable windows and allows the worker to view outside into the landscape.

Receiving and Materials Flow: At the north end is the receiving area, where materials and parts are unloaded and inspected. These materials are either dispatched to their significant work spaces or into the storage area.

Work Areas: The areas are arranged so as to separate but yet combine the crude from the refined spaces - the crude spaces being the press plant, composite manufacturing, paint shop, etc. i.e. spaces that need more machines to people and that produce toxic wastes. The refined spaces being the sub systems asssembly where there tend to be more people and hence more social interaction. The final assembly that is the value add line is an edge condition which takes place at the south edge of the factory. This result emphasizes that all workers can see where the final decisions are made - an important part of the corporate philosophy. The final product comes out on the west end and is either shipped by rail or truck or parked in a linear parking lot at the north end, protected by dense landscapping.

Amenities: Courtyards, cafeterias and supporting offices are located where it is central to all workers from where they can look at the assembly process which would provide some identity with the company and the product. Also, this identity is enhanced by workers working in small teams to make the product almost complete. This also establishes assembly as the "heart of the factory."

The Site: In order to approach the site, one drives through a huge landscapped park arriving into parking lots on either side and the administration building, recreation center (facilities like health club, day care,etc.), cafeterias and locker rooms along the central axis of the factory. This central axis is further emphasized in the factory and this could be read/seen in the roof line - the smaller roofs on the central axis flanked by bigger roofs on either side. These supporting services to the factory are treated to have the same structure and roof so that on one hand it separates the activities and on the other combines them into a single coherent relationship. In summary, on the floor, it is difficult to disentangle architecture from the machinery that stands or dangles everywhere, arranged according to its own logic and distractingly insistent in both color and noise. Above this, the building almost seems to levitate, an illusion acheived by structural form, roofline and daylight flooding in from the sides and above.

6.9 TECHNICAL SYSTEMS:

LIGHTING: The lighting is extremely efficient, although somewhat unusual. Instead of the usual rather weak overall illunination supplemented by separate strong lighting at the work places, at this plant the overall illumination is strengthened by high intensity discharge lights and also by task lights so that it serves the individual workplaces. This gives the entire working environment a warmer and lighter tone.

In addition to this artificial lighting, there is also a great flood of natural light from the fabric roofs above which are highly translucent. These fabric roofs consist of double membranes and permit about 20% of solar transmission with a shading co-efficient of .42 to .35.

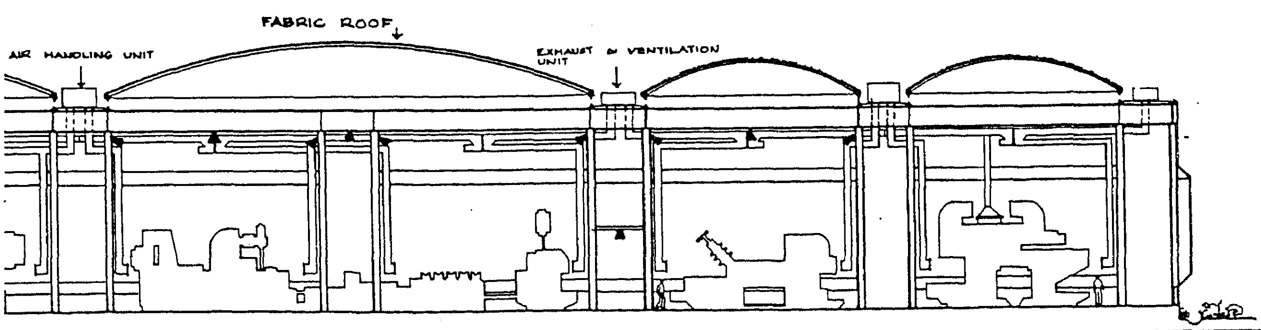



Figure 12 : Lighting at work spaces

Along the external walls are two strips of glazing - the lower level glazing have openable windows and provide light on the factory floor and the top level glasing consists of fixed prismatic panels and optimun control prisms arranged vertically. Compared with conventional systems, these prismatic panels carry natural light farthest into an area, cuts on energy costs of artificial lighting and also provides diffused lighting.

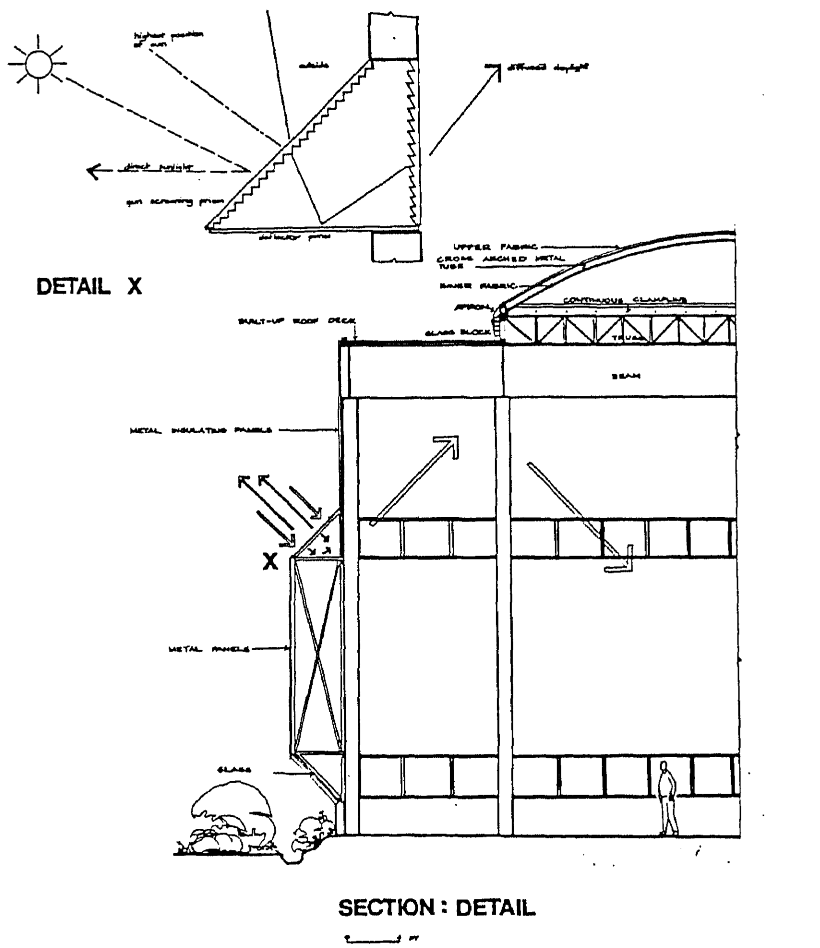



Figure 12 : Lighting at external walls

VENTILATION: The ventilation system is of a large capacity. In the few places where there are engines operating, there are exhaust hoods over them to remove oil, mist and other contaminants from the air, a job ordinarily accomplished less efficiently by a higher rate of plant ventilation. The ventilation system also consists of heat recovery type ventilation units placed above the 12' bays at regular intervals.

HVAC: This system consists of air handling units and exhaust and ventilation units, with heat exchangers, placed on the flat roof tops of the 12 feet circulation paths. Conditioned air is released at a low level of 10 feet above the factory floor and this increases the layering of the the plant tenperature. Heat released from the equipment normally caused warmed air to go up and mix vertically. The rising air displaces the hot air near the ceiling and forces it down, increasing the temperature on the working level. This releasing of conditioned air at a lower level in the factory can sharpen and stabilize the temperature profile holding vertical circulation to a minimum.

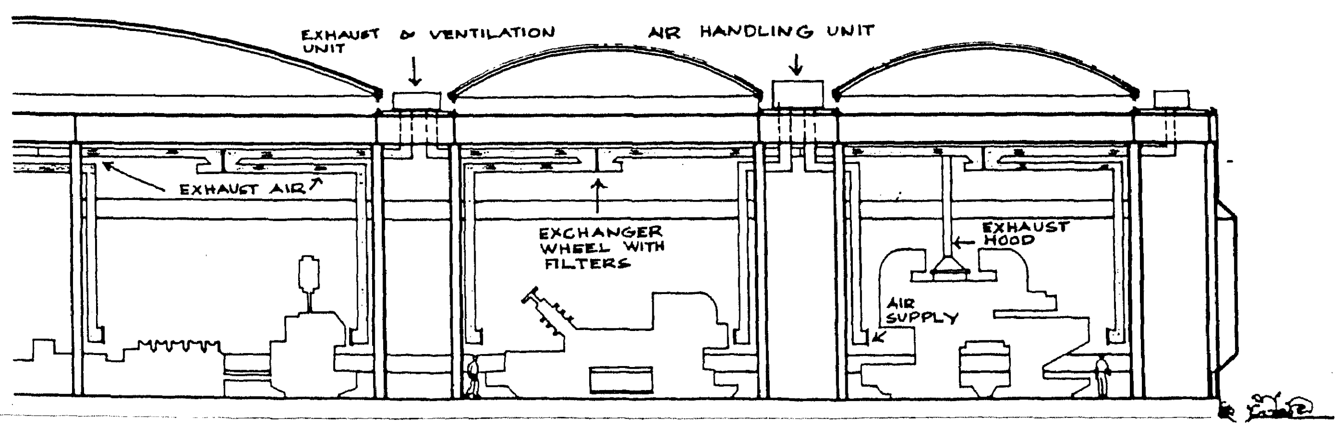



Figure 13 : HVAC

FIRE PROTECTION: In case of a fire, there are fire exits placed on the north and south exterior walls at regular intervals as well as there is a basement level protected horizontal tunnel through the middle of the building along the east-west axis which ultimately opens up outside at the east and west ends of the building, so that travel distances to an exit are limited to 400 feet. Also, smoke detectors and automatic sprinklers are provided at the ceiling level.

RECEIVING OF MATERIALS: The raw materials arrive either by truck or rail. The long north facade of the factory provides the necessary flexibility for the innumerable truck docks needed for just-in-time delivery of the materials. The materials are thus delivered to the appropriate work station by AGV's or stored in the storage area and then delivered whenever necessary either by AGV's or by conveyor systems running along the 12 feet circulation paths.

## 6.10 OUTLINE SPECIFICATIONS:

DIVISION 1 General Conditions:

A.I.A. form of Agreement between owner and General Contractor

DIVISION 2 Site Work:

1. Sediment Control structures and devices during

construction.

2. All building excavation, utility trenching and baclfilling.
3. Grading.
4. Paving as shown on site plan.
5. Landscaping, seeding and sod.
6. Sidewalks, curb and gutters.
7. Storm-water pipe and structures.
8. On-site utilities.

DIVISION 3 Concrete:

1. Footing, foundation and concrete shall be reinforced 2,500 psi mix. Interior slab to be 4,000 psi mix.
2. Exterior concrete finish for sidewalks to be broom finished.
3. Interior concrete slabs to be steel trowel finish and sealed with industrial surface hardeners. Maximum pour 600 s.f. forced 22 with 6 x 6 10/10 w.w.m.

DIVISION 4 Masonry:

1. All CMU shall be hollow load bearing type with duro wire joint reinforcement Type S and N mortar as required.
2. Face brick shall be thru body color, wire cut face type, oversize, with colored mortar, both selected by the Architect.

DIVISION 5 Metals:

1. Structural steel to be hot rolled A-36 steel with wide flange beams, columns, truss joists, and structural arches to support the fabric roof.
2. Provide miscellaneous lintels, angles, plate, and joists as required.
3. All steel to be shop primed.
4. Steel deck to be 1 1/2" 22 ga. wide ribbed, metal deck, primed.

DIVISION 6 Wood and Plastic:

1. Countertops shall be thru color plastic laminate over particle board with back splash.

DIVISION 7 Thermal and Moisture Protection:

1. Sealant shall be appropriate for the intended use.
2. Roof insulation shall be double membrane with 4" batt insulation and 4" air space inside.
3. Roof shall be Vestar architect-fabric or approved equal in the manufacturing facility as well as the administration building.
4. Insulation:
   a) Exterior Walls: 1' styrofoam R 14
   b) Slab: 1" styrofoam rigid board, R=5 at perimeter under the slab.

DIVISION 8 Doors and Windows:

1. Entrance doors:

   Entrance doors shall be basic single door frame units with one or two sidelights either to the left or the right side as shown in the architectural drawings.

2. Windows:

   Windows shall be aluminium casement windows, with operable shutters and double insulated glass.

3. Steel door frames shall be 1 3/4" hollow metal type prefitted for mortice type hardware. Exterior doors to be fully insulated and weatherstripped.

4. Flush door frames shall be hollow metal type prefitted for 1 1/2" pair butt hinges. ( Interior and exterior primed ).

   Exterior doors shall have full perimeter weatherseal.

5. Wood doors shall be 1 3/4" hollow core stain grade oak, 7' 0" high.

6. Hardware shall all be medium duty commercial type. Finish US-10, and include mortice sets, lock sets, latch sets, hinges, closers, door stops, kick plates, and all associated accessories.

DIVISION 9 Finishes:

1. Interior partitions shall be metal stud and drywall.

2. Paint: All other interior offices shall have one coat primer, and finish coat. Stain and varnish all wood doors. Paint all exterior doors and frames.

3. Carpet: Floor shall be carpeted with 28 oz. face weight Antron III Nylon carpet, direct glue down application.

4. Tile: a) VAT shall be 12" X 1/8" standard colors.

   b) Ceramic Tile: Bathroom floors shall be 1/8" thick 2" X 2" glazed material thin set. Walls shall be 1/8" thick 4" X 4" glazed material thin set.

5. Base: All office area spaces to have 4" vinyl cove base, continuous strip with molded corners. Color by architect.

DIVISION 10 Specialties:

1. Toilet room accessories shall be stainless steel or brushed chrome type, recessed where possible.
2. Provide full width mirrors over each lavatory.

DIVISION 11 Furnishings:

1. Provide vertical fabric blinds for all office windows, color by architect.

DIVISION 12 Special Construction: NOT USED

DIVISION 13 Conveying Systems: NOT USED

DIVISION 14 Mechanical Systems:

1. HVAC: All major spaces shall be ventilated and conditioned. Ventilation is provided by heat-exchanger ventilating units. Air-conditioning is provided by air handling units located on the roof. Distribution shall be by insulated metal duct work, concealed above the ceiling. The building will be zoned.
2. Plumbing: All bathrooms will be equipped with tank type toilets ( floor mounted ) and urinals ( wall mounted). Lavatories shall have water conserving faucets. Water heater shall be fully insulated high efficiency electric type.
3. Water service shall be connected at the public right-of-way.
4. Sanitary sewer service shall be connected at the public right-of-way.

DIVISION 15 Electric:

1. Lighting shall be high intensity discharge fixtures and task lights.
2. Exterior site lighting shall be high efficiency mercury vapor type on timers or photo cells on pole mounted decorative units. Wall mounted exterior light fixtures near each entrance door.

## 6.11 SPECIAL FEATURES AND INNOVATIONS:

The GM plant bears several innovations and state-of-the art technologies, most of which have been discussed in the earlier sections as well as have been shown in the drawings:

1. Teamwork concept rather than a rigid assembly line.
2. Using daylight systems to cut out direct sunlight and utilize only zenith (vertical) light.
3. Using Vestar Architectural Fabrics to introduce natural light into the work environment.
4. Material handling by utilizing several different types of automated guided vehicles.
5. Dealing with just-in-time delivery.
6. Utilizing CAD, CAM, CIM and flexible manufacturing.

# CHAPTER VII

# CONCLUSIONS

The traditional environment within which the car industry operates is in a major crisis. But while governments and industry's top management may change, the basic infrastructure endures. Some of the car industry's inertia is rested in tangible areas like factories, plants and equipment, but much of it is in employee loyalty, working practices, management style and ethics. The contribution of this latter group is embodied in the design of the products themselves - a company is what it produces - and the key people who realize that embodiment are the production planning specialists and the workforce on the floor. The use of computer technology is bringing increased flexibility and is facilitating closer links within the factory, with the customer as well as between other related companies. All of these changes are highly visible in the practices of the car producers.

Socio-technical-spatial systems could be an immensely important trend, one that is producing a new model of job design and work relations that will shape the workplace well into the 21st century. In the traditional work practice, work was fragmented. Doing and thinking were separated as the worker was expected to obey orders and had no power whatsoever which ultimately resulted with the worker wanting nothing from the job, except his salary and avoided responsibility. In the changing or present approach to the work organization; the work is multiskilled and performed by teamwork wherever possible; doing and thinking are integrated. The worker today has the power to implement changes and to make suggestions resulting in an urge for challenge and responsibility in his work. This new "paradigm" will gradually replace the traditional system characterized by authoritarian management. This new approach requires socio-technical-spatial planning i.e. integrating the psychological and social needs of workers with technological requirements in designing a new or "better" system or redeveloping an old one.

Reductions of the GM facility drawings are presented on the following pages. They are the clearest description of the results of the intentions in this thesis.

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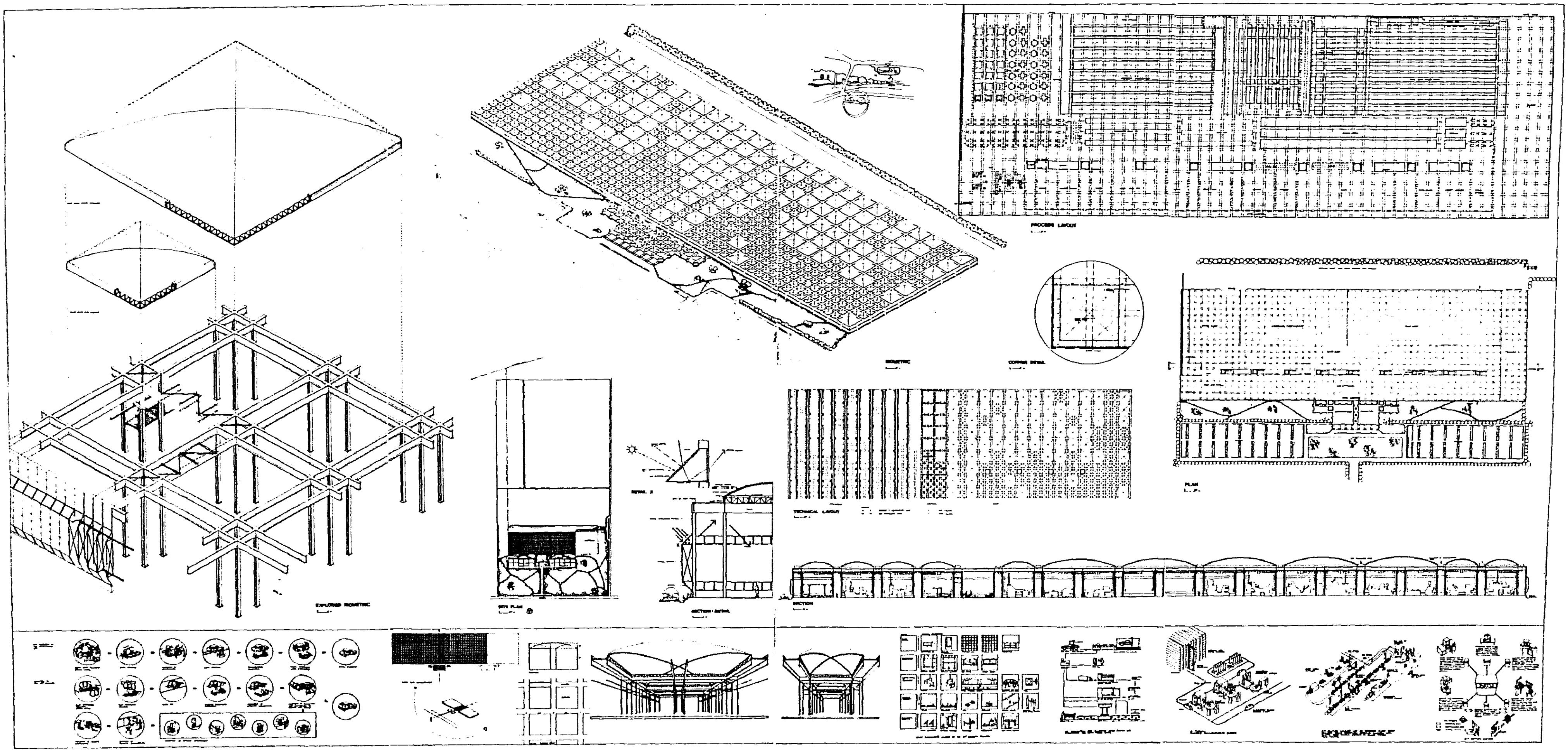
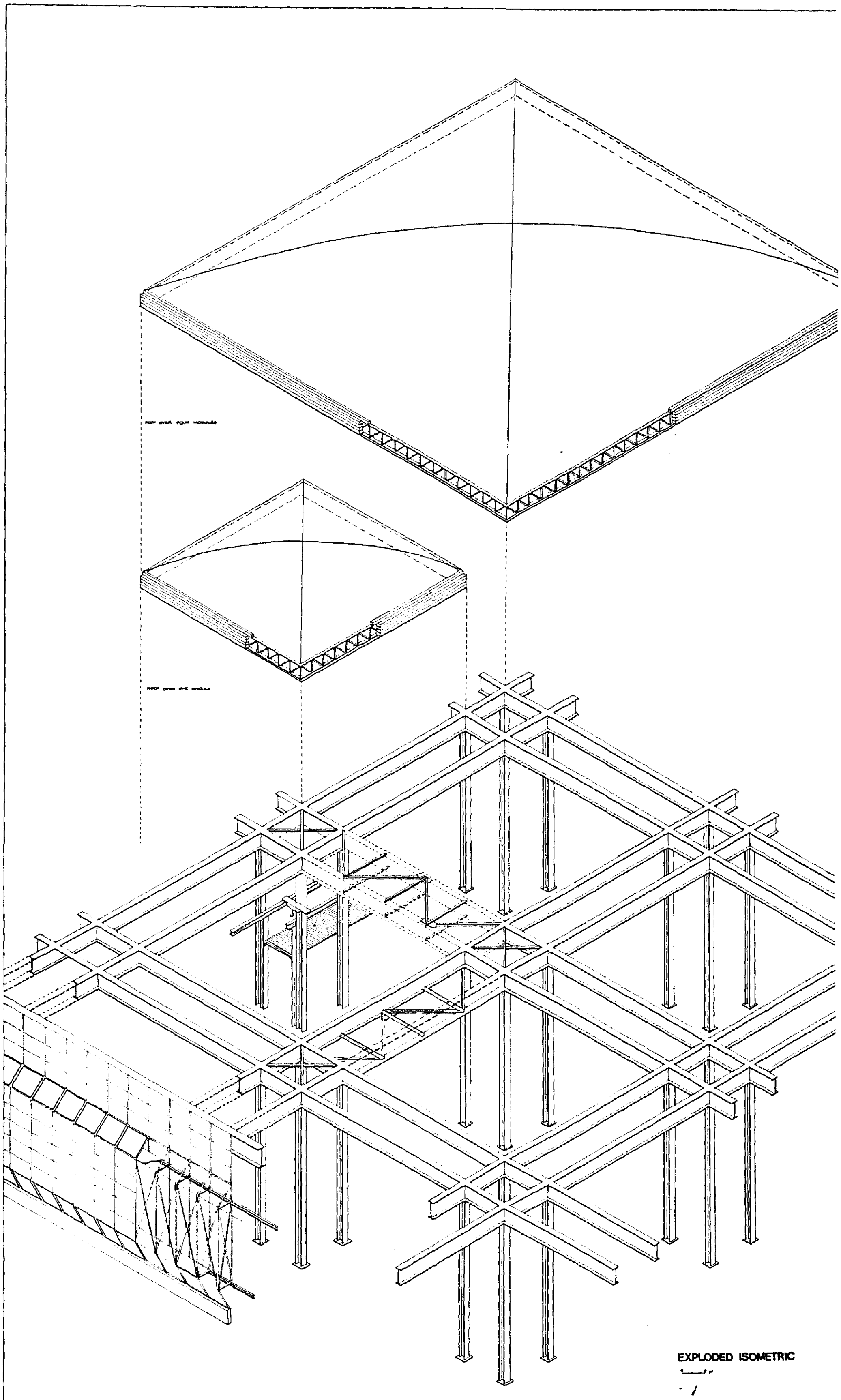


General Motors facility overview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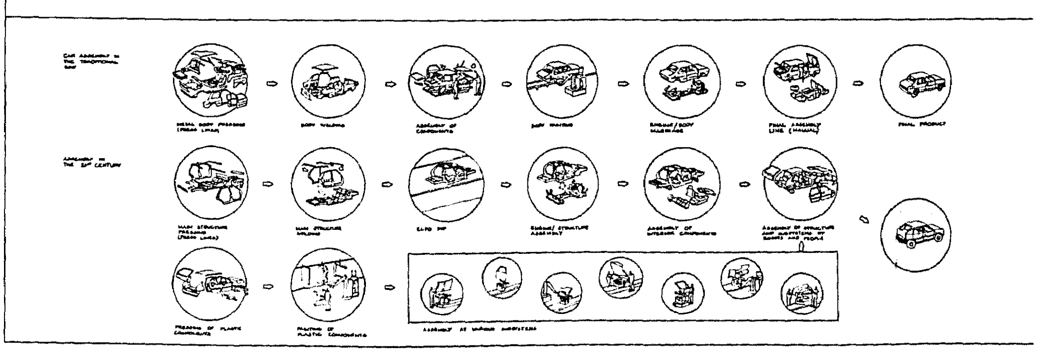

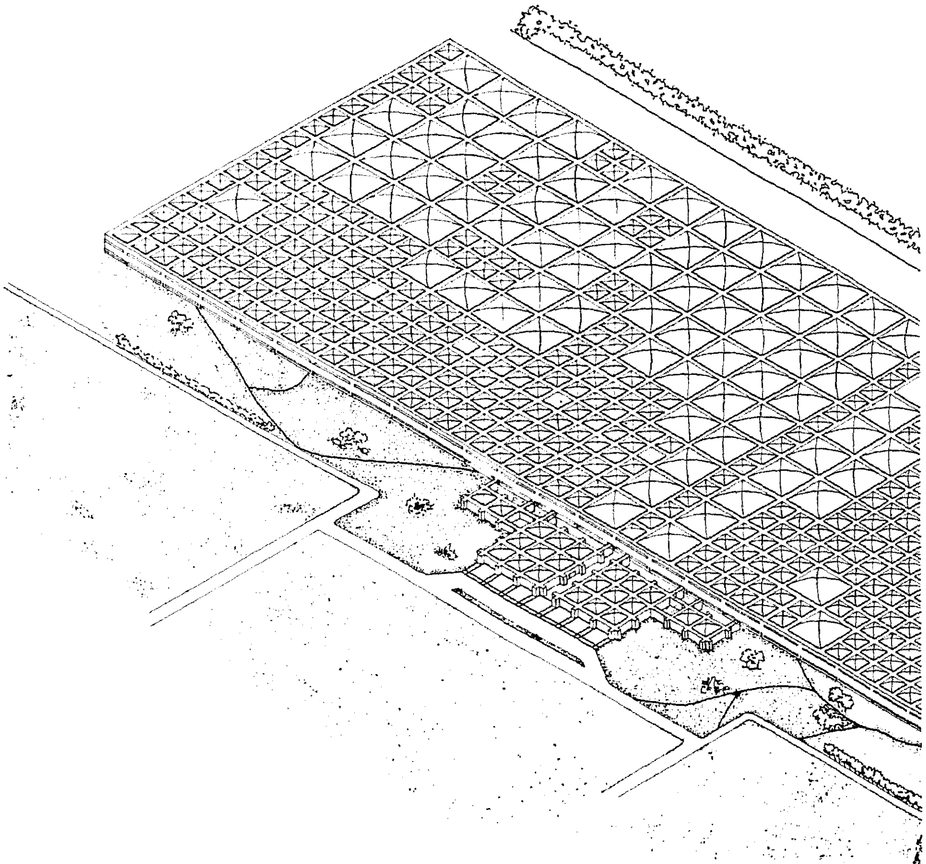

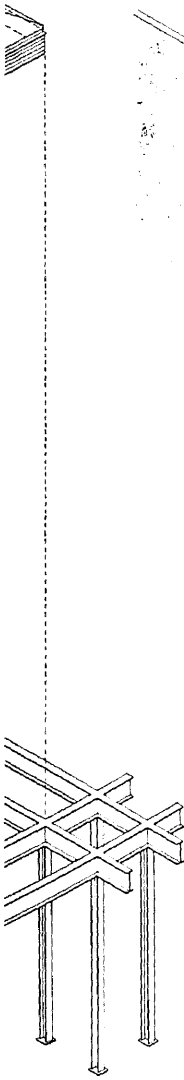

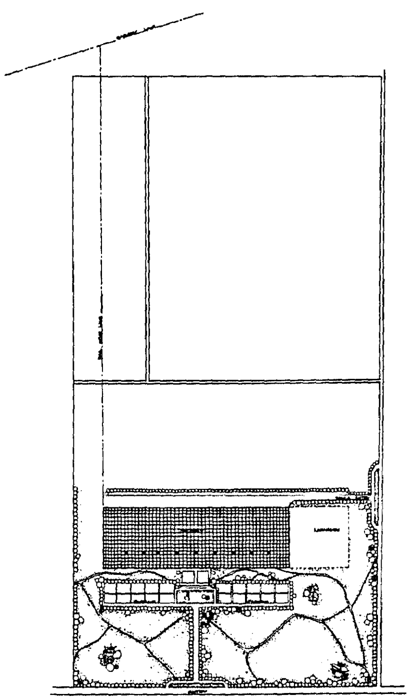

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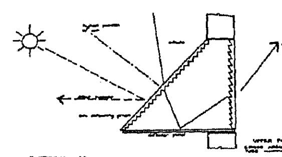

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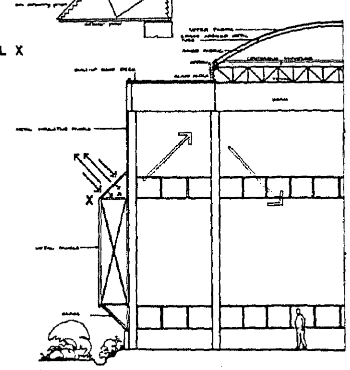

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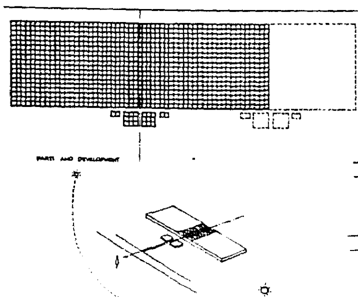

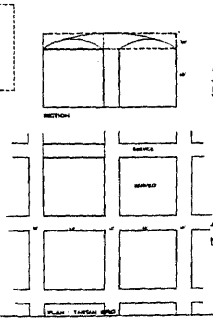

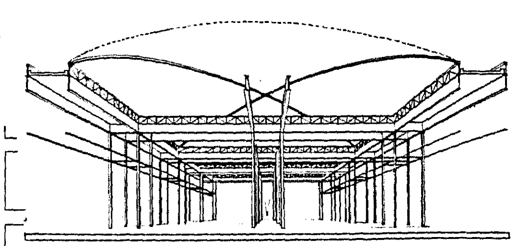

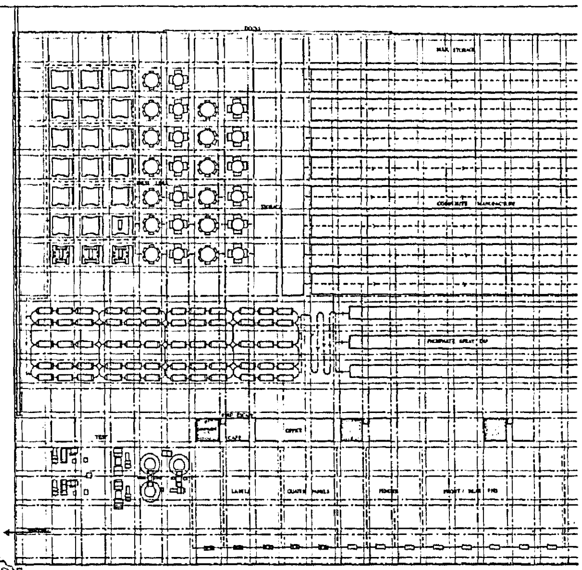

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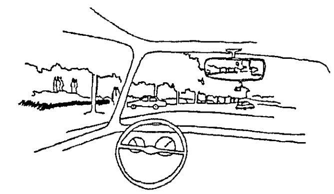

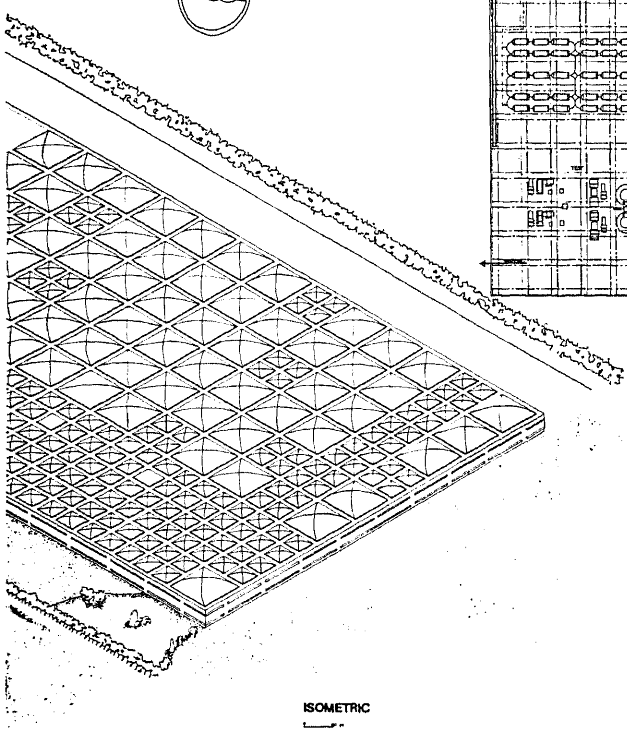

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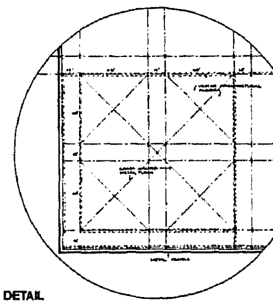

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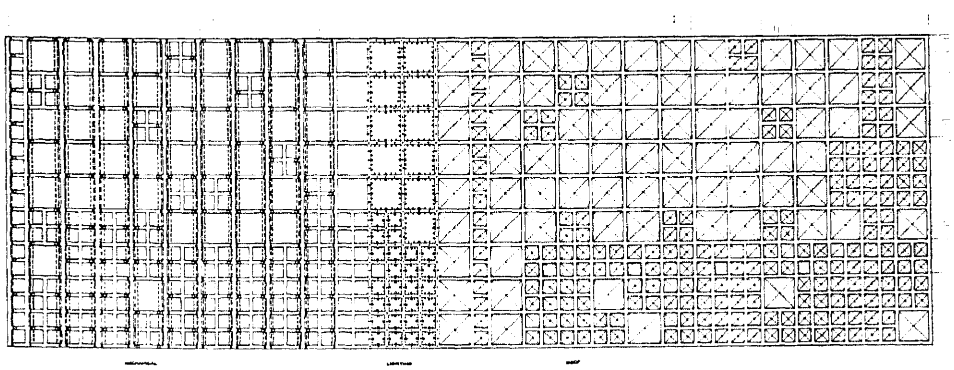

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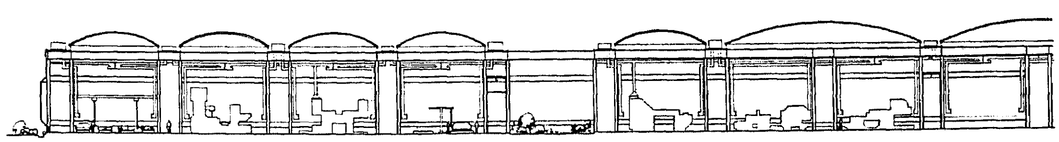

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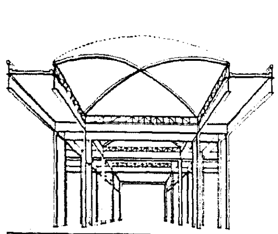
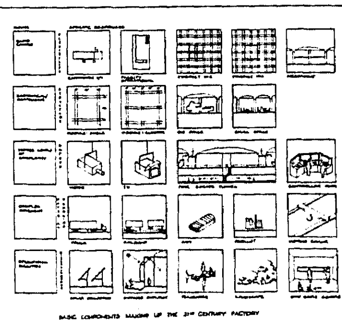
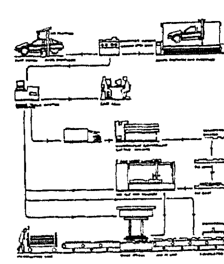
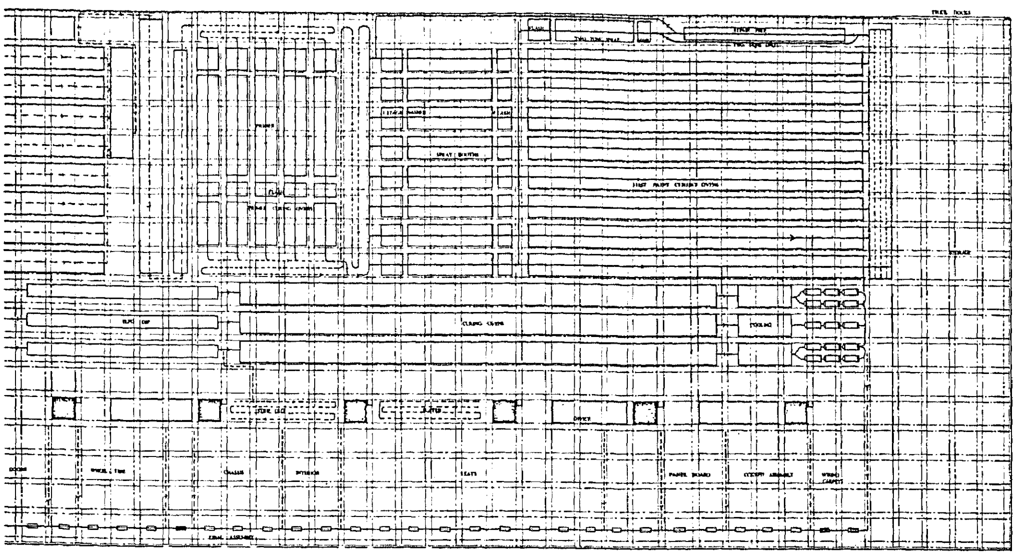


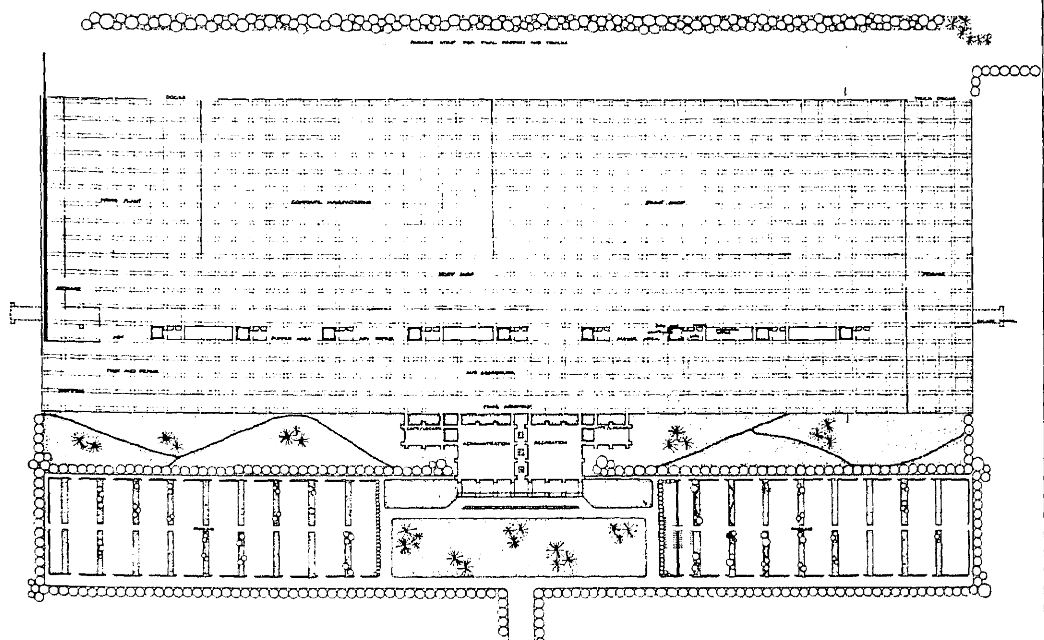


BASIC COMPONENTS MAKING UP THE 21ST CENTURY FACTORY



AN APPLICATION FOR COMPUTER AIDED DESIGN AND ENGINEERING FOR BODY PRESS WORK





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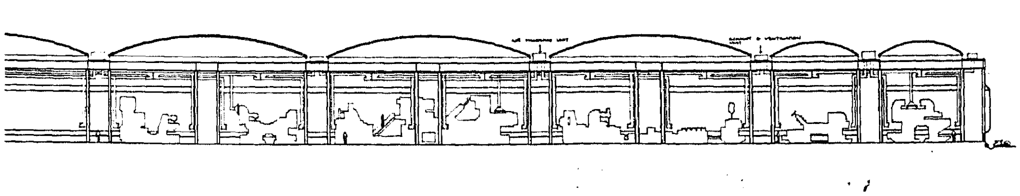
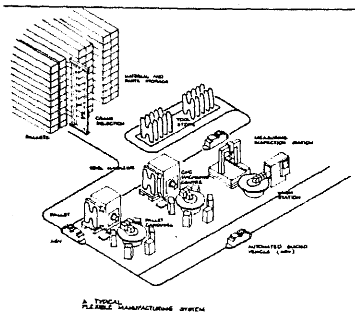
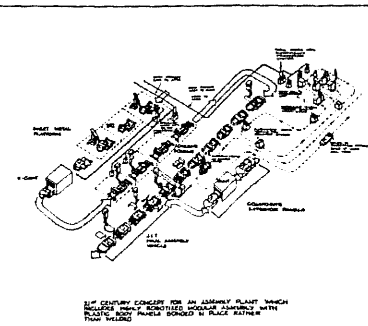
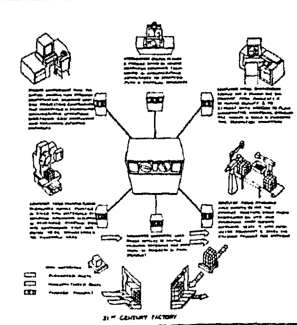




A TYPICAL FLEXIBLE MANUFACTURING SYSTEM



21ST CENTURY CONCEPT FOR AN ASSEMBLY PLANT WHICH INCLUDES HIGHLY ROBOTIZED MODULAR ASSEMBLY WITH PLASTIC BODY PANELS BONDED IN PLACE RATHER THAN WELDED



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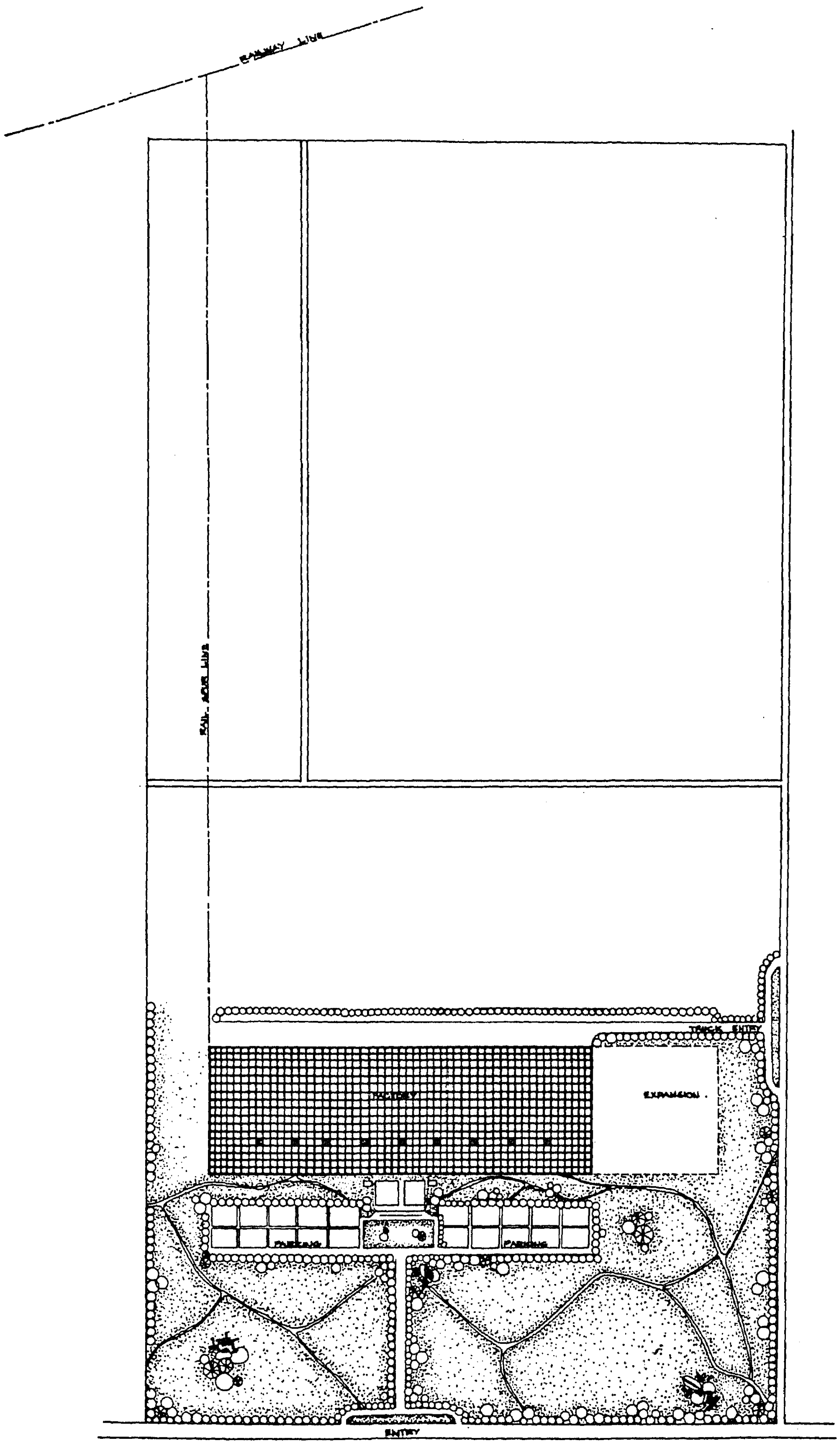


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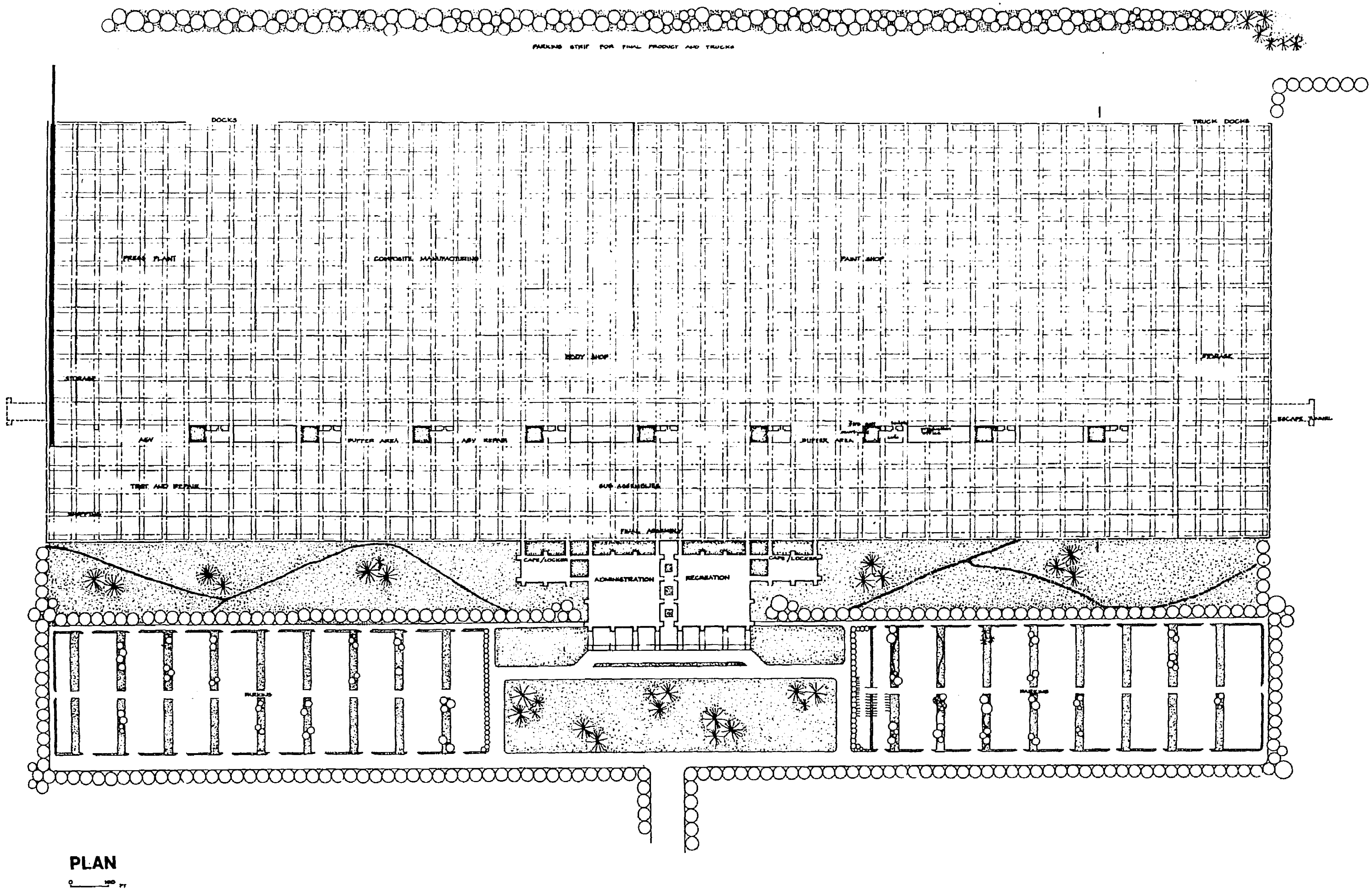
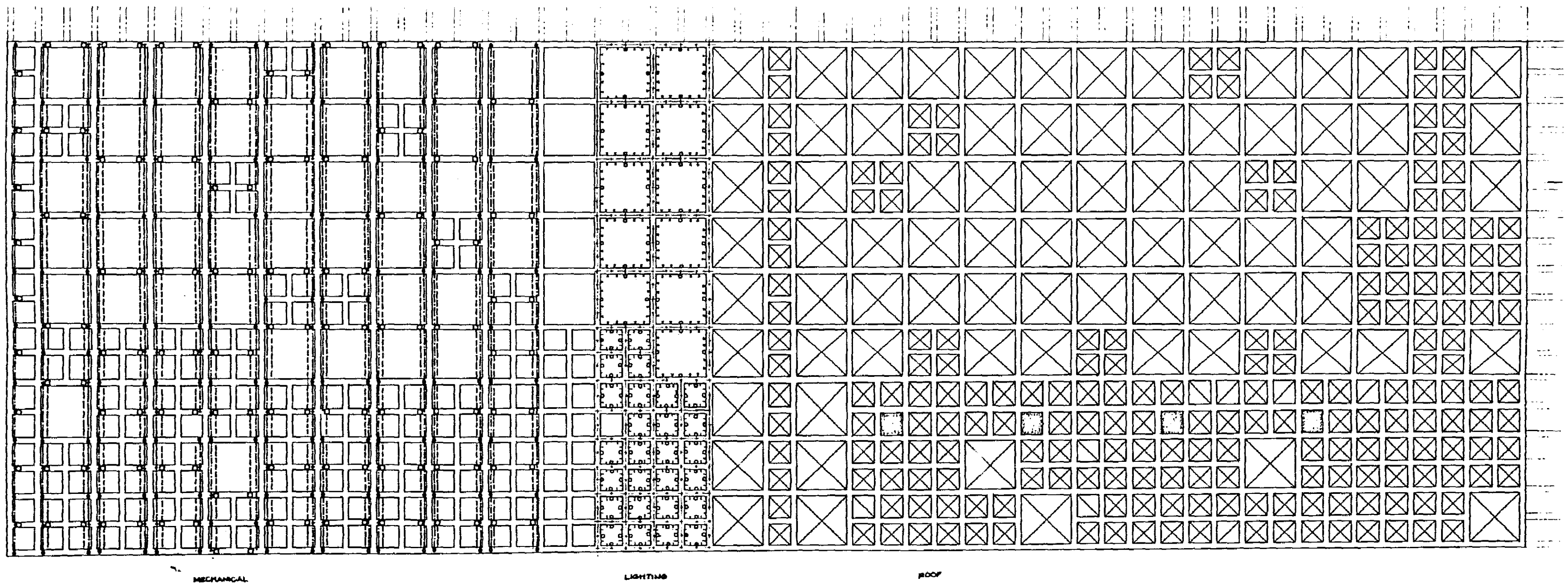

PARKING STRIP FOR FINAL PRODUCT AND TRUCKS
DOCKS
TRUCK DOCKS
PRESS PLANT
COMPOSITE MANUFACTURING
PAINT SHOP
BODY SHOP
STORAGE
AGV
BUFFER AREA
AGV REPAIR
ESCAPE TUNNEL
TEST AND REPAIR
SUB ASSEMBLIES
FINAL ASSEMBLY
CAFE/LOCKER
ADMINISTRATION
RECREATION
PARKING

PLAN




LEGEND

- EXHAUST & VENTILATION UNIT
- AIR HANDLING UNIT

o - HID LIGHTS

▼ ⅰ - TASK LIGHTS

**TECHNICAL LAYOUT**

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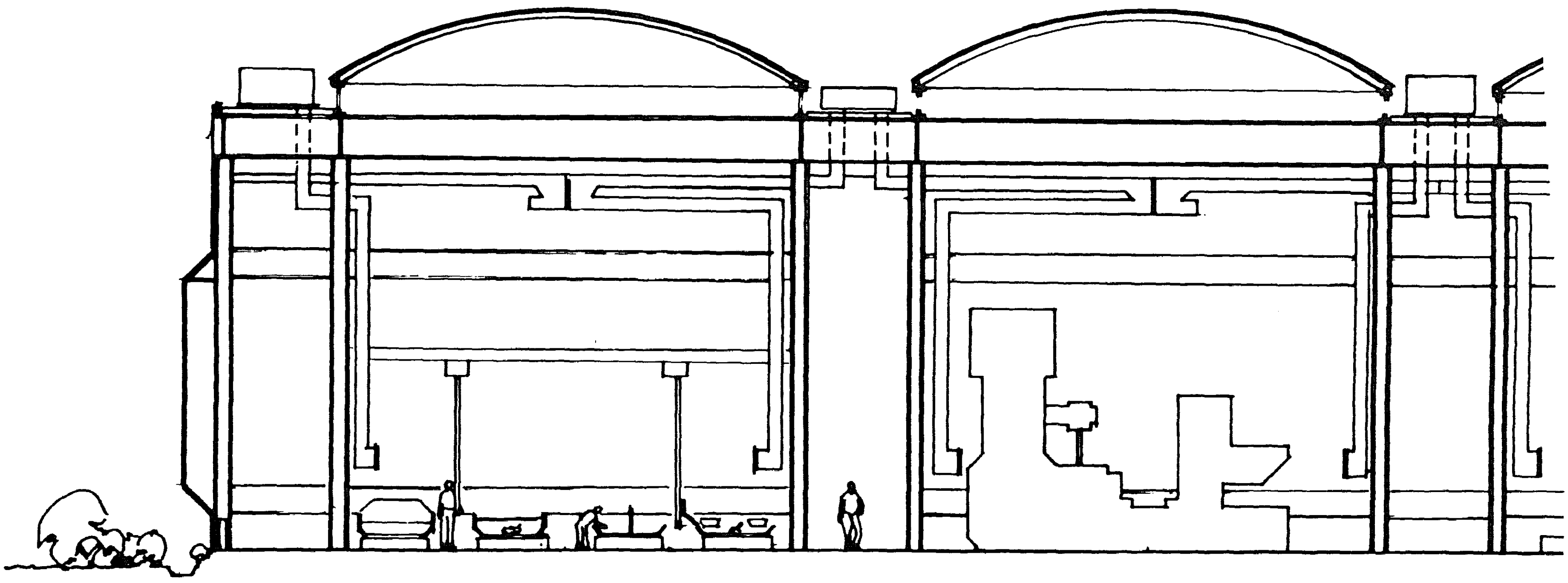

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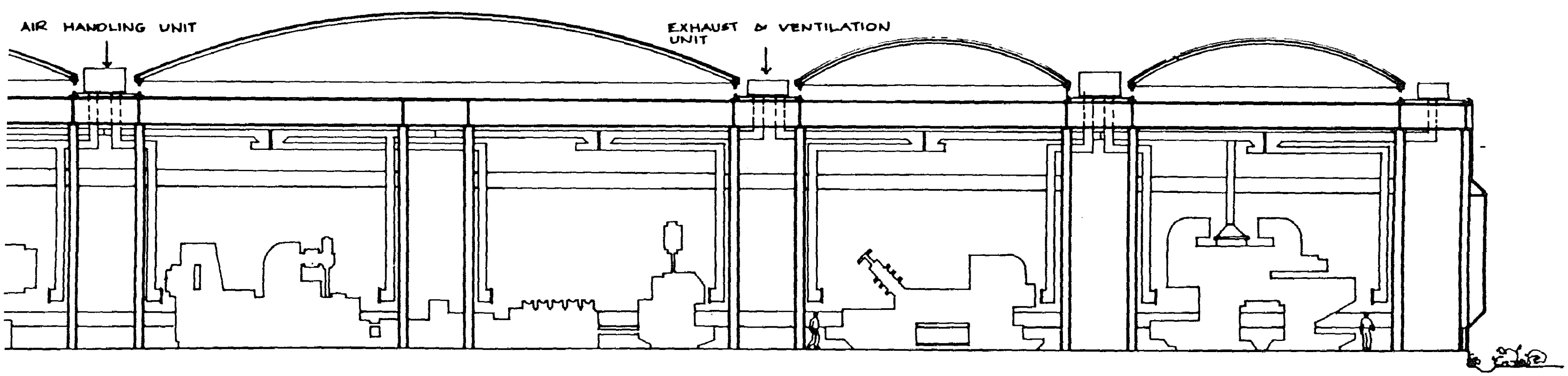
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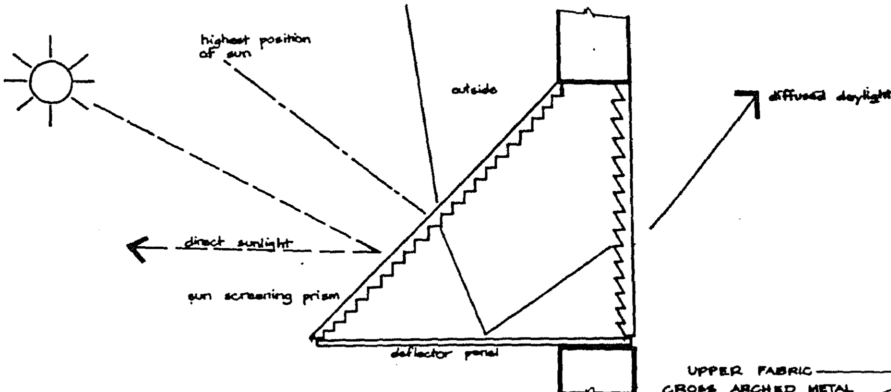


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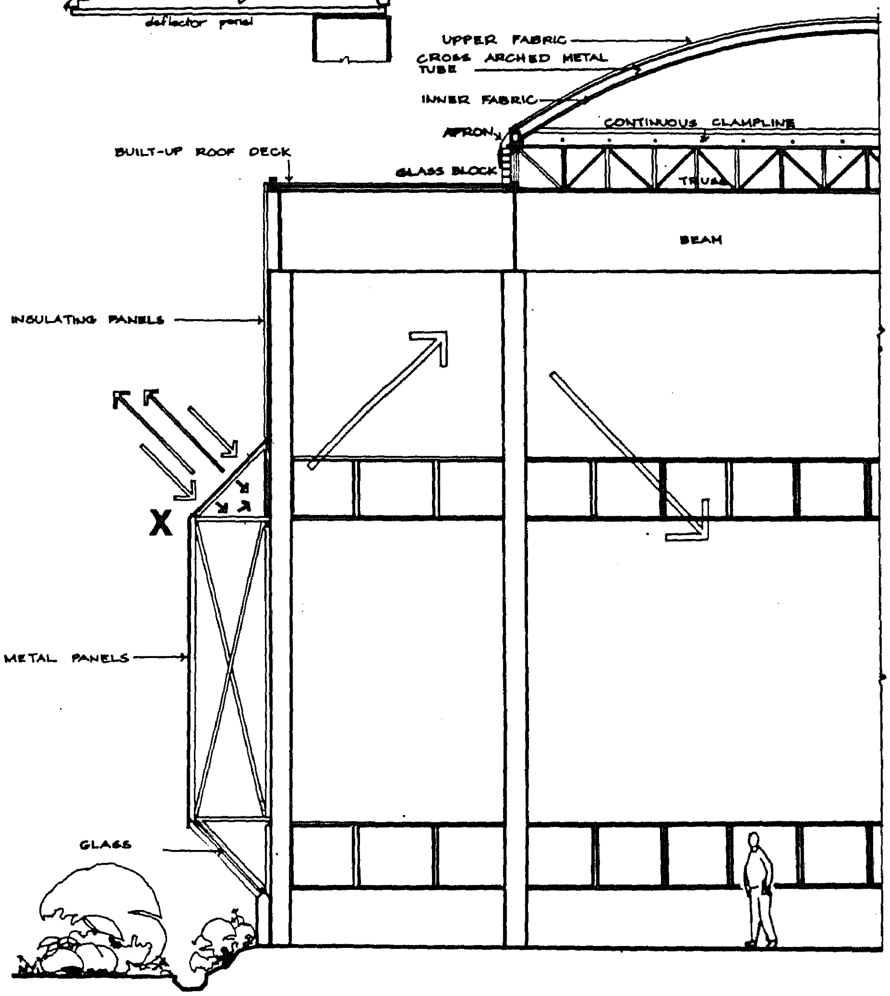


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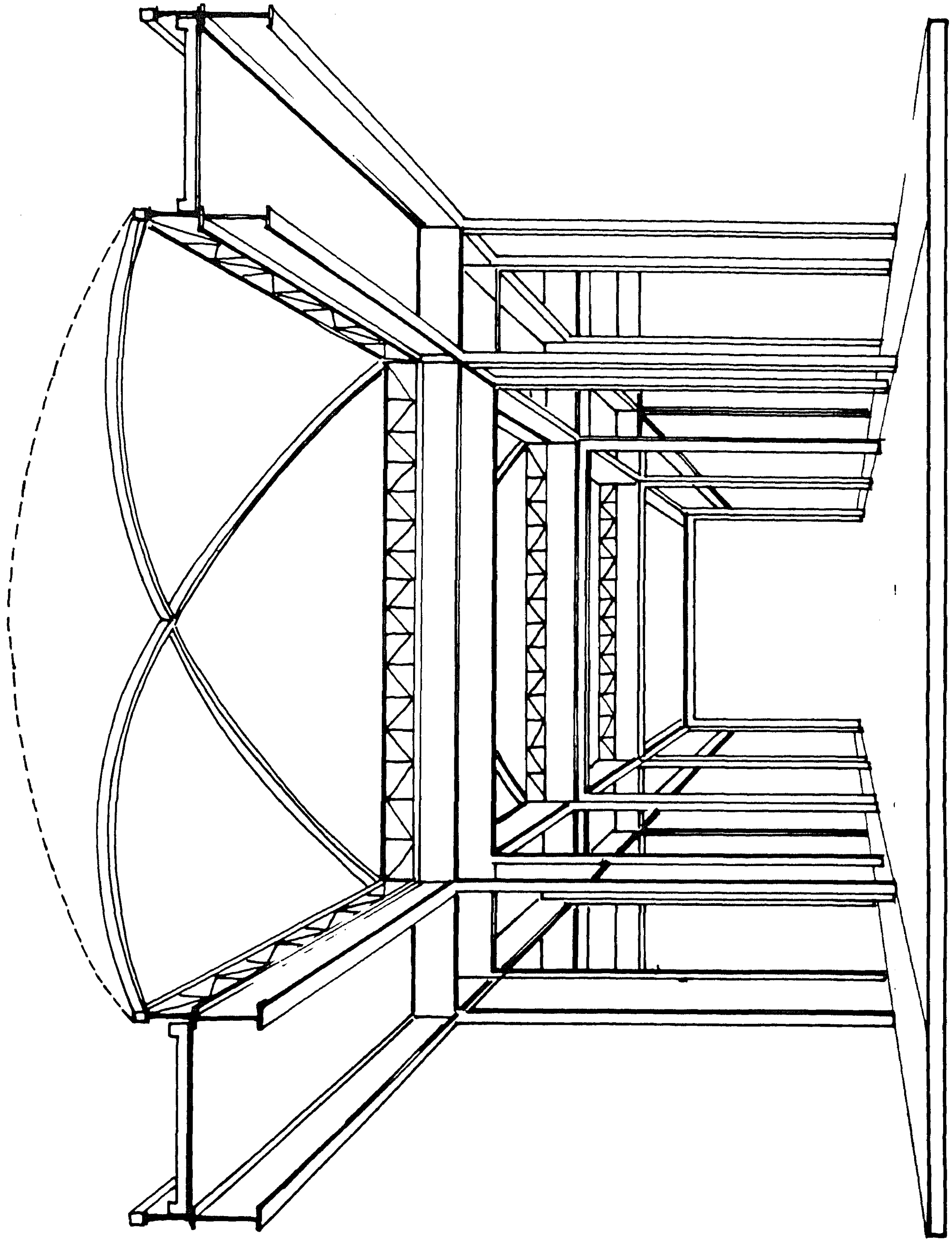

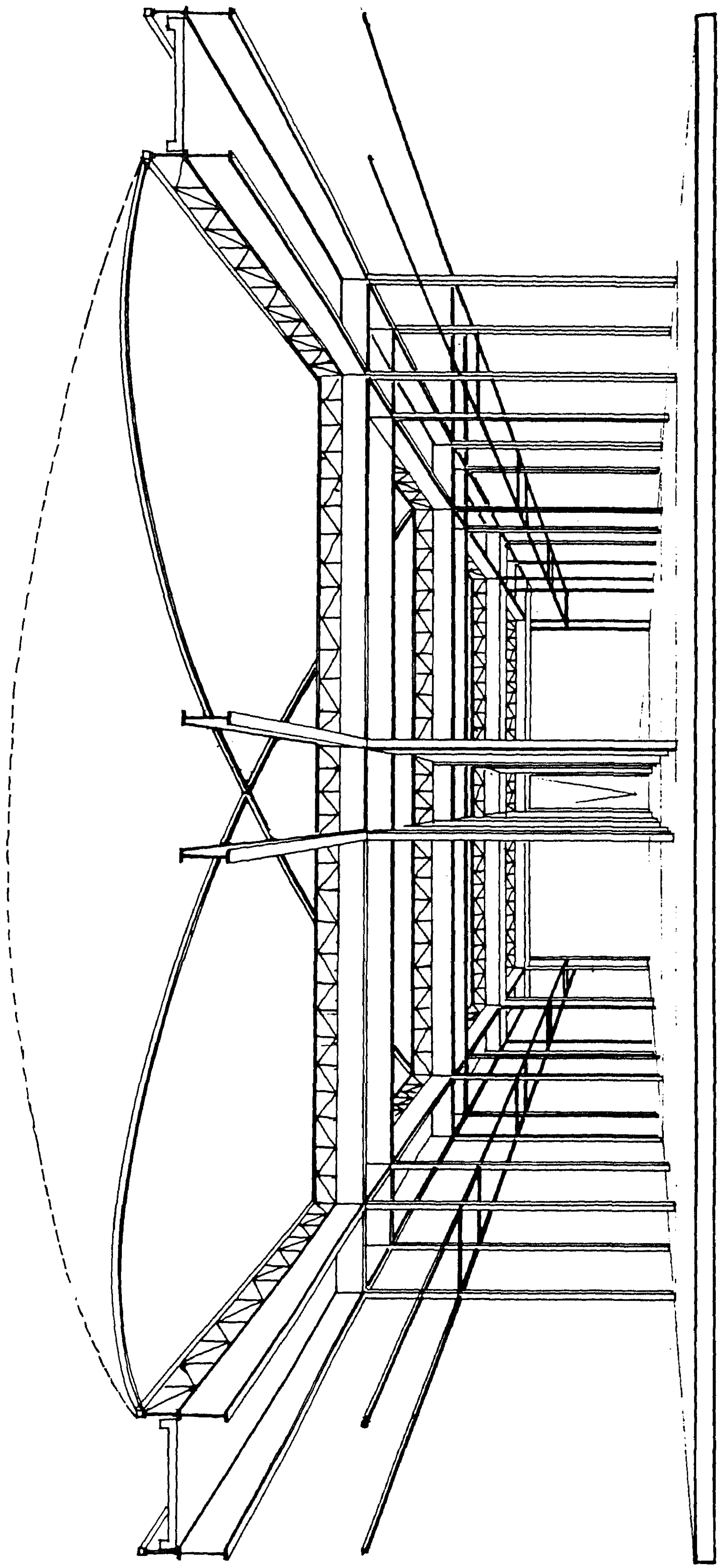

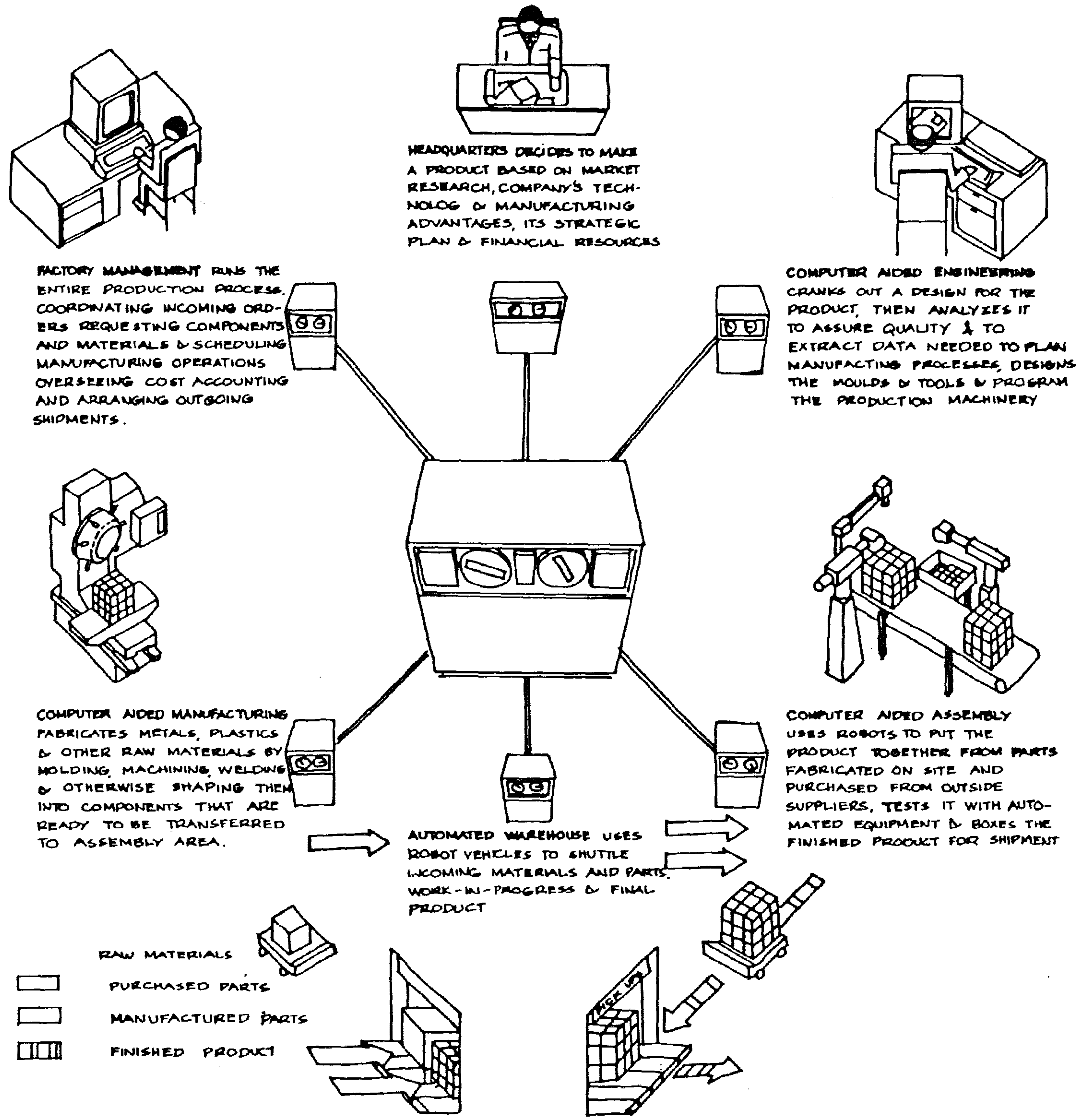


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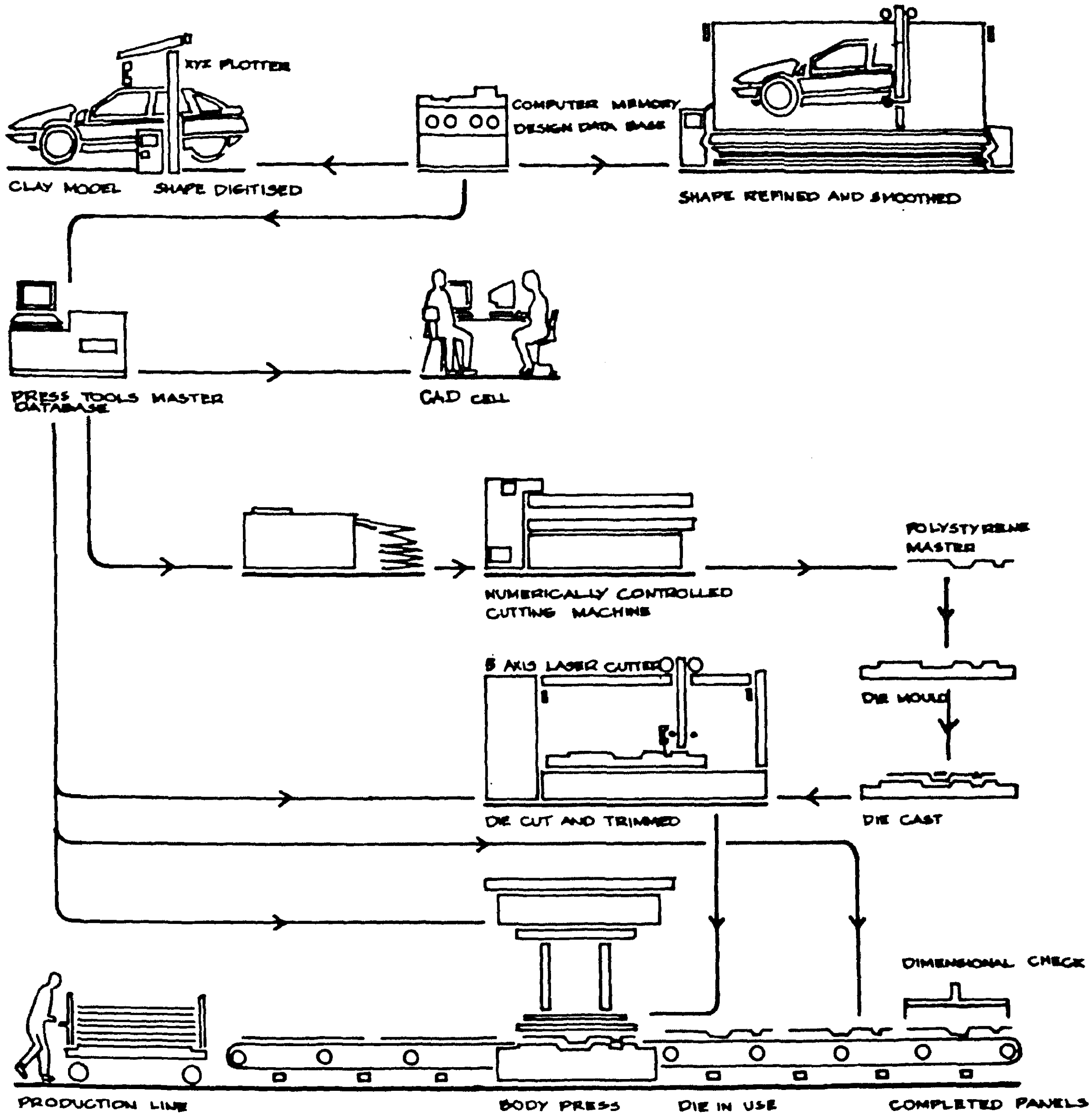


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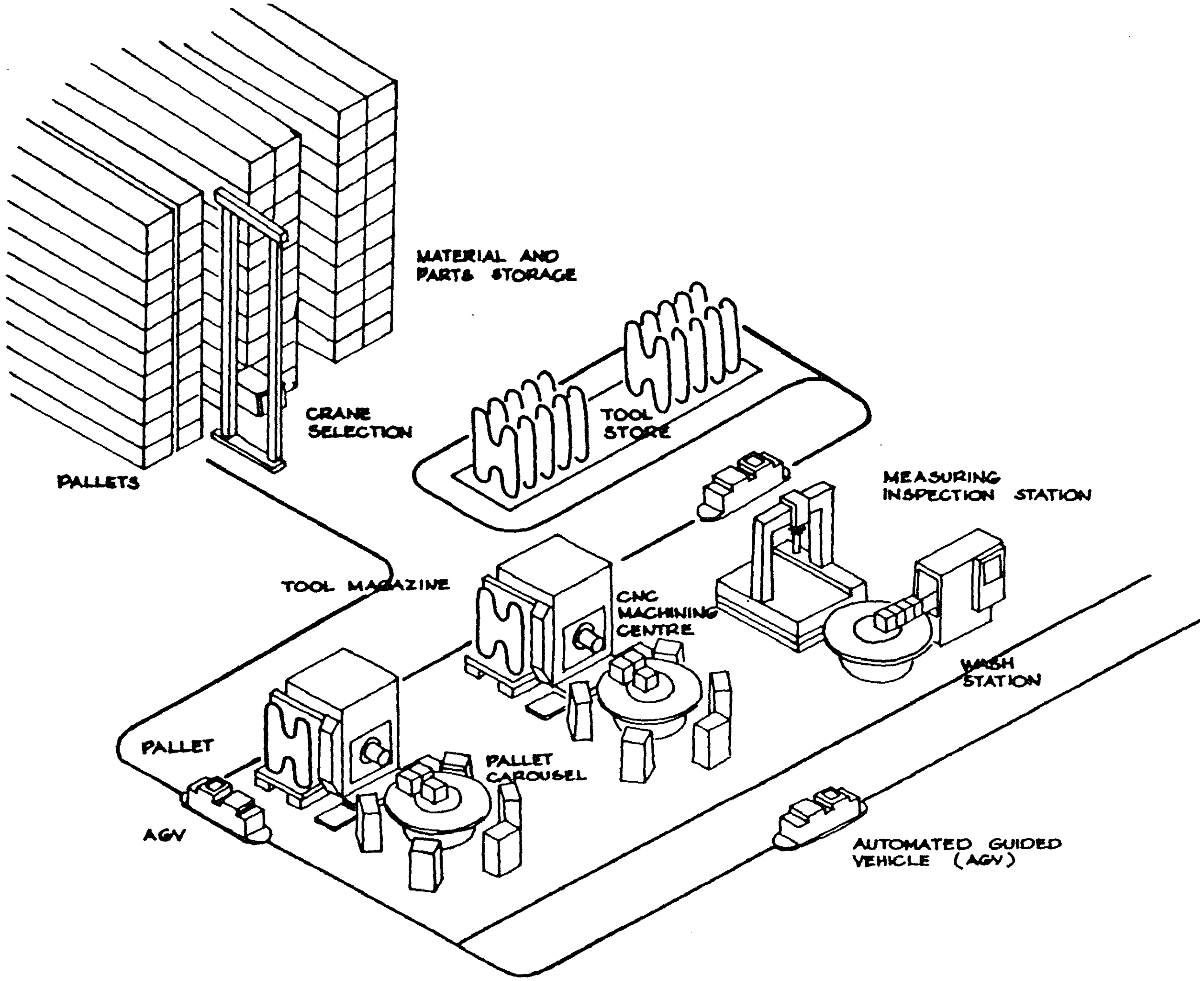


A TYPICAL
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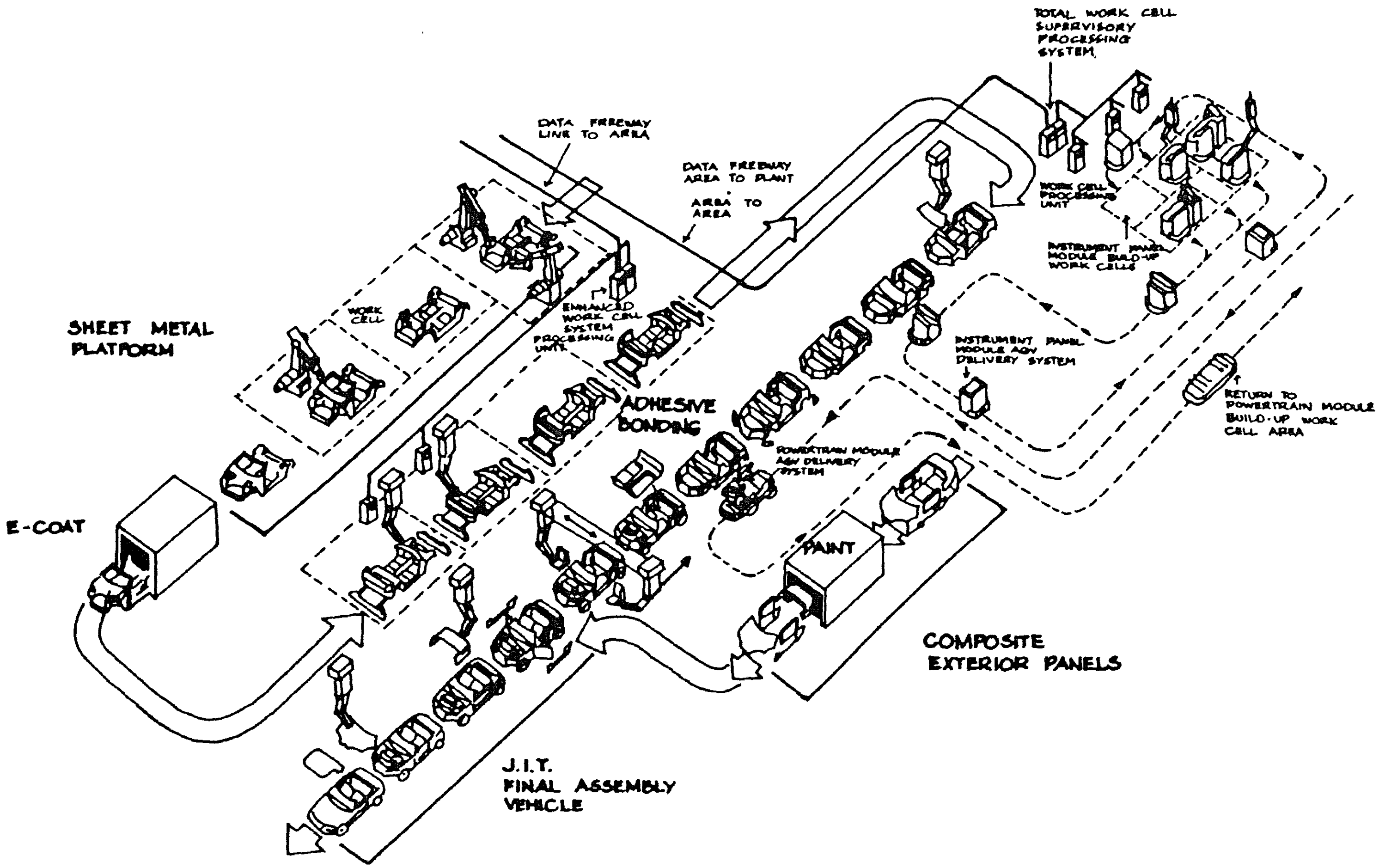


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