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URBAN STUDIES

by

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This year, the Executive Group for the Greater São Paulo (GEGRAN) of the Secretary of Economics and Planning for the State of São Paulo joined INPE in a project to study the applications of systems approach and remote sensing with aircraft and spacecraft (NASA ERTS-1) to urban studies, including demography, traffic, pollution, etc.

INPE internally has established a group for such studies which includes also rural areas and migration problems.

This report is part of the above effort. Its publication has been authorized by
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ABSTRACT

In this paper Systems Methods are applied to urban problems. It is shown that by utilizing this method one can synthetize new urban developments. Also the analysis of established cities like Greater São Paulo can be more readily done by the systems approach.

Special emphasis is placed on introducing modern management principles to the field of urban design.

Also, ways are shown how to utilize recently developed data collecting computer and image processing techniques.
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1.0 INTRODUCTION

A successful Urban Studies Project involves the intricate interaction of three basic elements:

- Strong technical leadership by persons versed in modern methods of systems engineering and management.
- Qualified technical personnel drawn from diversified disciplines.
- Adaptation of modern techniques of analysis and synthesis.

This note deals with the above aspects within the framework of the following constraints:

- Existing technical capabilities of INPE are taken into account.
- New hardware and software is suggested only when applicable to other projects at INPE.

No endeavor was made in discussing the topics in detail. From the number of existing systems and approaches the writer selected those which she thinks is worth exploring. Some of the ideas presented are old proven methods in urban studies, others are new and still in the process of evolution. A creative Urban Studies Group utilizes both.
2.0 - WHAT IS URBAN STUDIES?

Maybe the easiest way to define Urban Studies is to say what it is not:

   it is **not** traffic engineering, it is **not** pollution control, it is **not** land use or irrigation; it does not even come under the category of the familiar phrase of city planning.

   If all this it is **not**, than what is it?

   It is the study of the complex **interaction** of technology, social conditions, environment, politics, business and personal interests, etc. This various interests sometimes enhance each other, sometimes they work against each other. Their activity changes in **space** and **time**. And to complicate matters, the actions are often **random** (stochastic) in nature.

   Pictorially one can visualize the interaction between an Urban System and influencing elements as on Figure 1.
FIGURE 1

GRAPH OF INTERACTIONS FOR AN URBAN SYSTEM
On Figure 1, one can consider the inputs \( i_k^2(t); k = 1, 2, 3, \ldots, n \) as random signals which produce a random output \( u(t + \Delta t) \) at a later time. \( \Delta t \) is a finite quantity. This output \( u(t + \Delta t) \) is the quality of life in the Urban Systems.

Note the marked difference between this model and a conventional approach. In designing a traffic network, for example, a traffic engineer used to view the system in terms of the maximum flow of vehicles in the system. Such a model is of course important and will be discussed later in this paper, but it is not a model in urban design. An urban design model for this specific problem would include the effect of pollution from the exhaust fume, noise generated by traffic, alteration of life pattern in the area due to the new road system, safety, etc. In one word, the urban system model would have the quality of life, as an output.

It is evident that the quality of life exerts influence on the social system, politics, business interests, etc. This can be represented with a feedback loop as shown on Figure 2. For clarity, on Figure 2 only one signal \( i_1(t) \) is shown. Similarly there is a feedback loop to the other signals \( i_k(t); k = 2, 3, \ldots, n \).
FIGURE 2 - AN URBAN FEEDBACK SYSTEM
If the urban system would be linear, one could consider the effect of one signal at a time. The output then would be the sum of the individual output signals (Figure 3).

\[ u(t + \Delta t) = \sum_{k=1}^{n} u_k(t + \Delta t) \]

**FIGURE 3**

**LINEAR SUPERPOSITION PRINCIPLE**

On Figure 3 the feedback loops are not shown, but their effect has to be taken into account.
A linear system model would permit to consider individually the effect of technology, environment, etc. One could further sub-divide to areas of traffic control, pollution control, irrigation, etc., consider the effects individually and then superimpose the result.

Unfortunately, an urban system is non-linear and hence the superposition principle fails. In addition, there is a time shift between the output due to different inputs. That is, the effect of \( i_1 \) applied at time \( t \) could show at time \( t + \Delta t \); the effect of \( i_2 \) applied at time \( t \) could show at time \( t + 4\Delta t \), etc. Of course, linear approximations are useful for the simple reason that one knows more about linear systems. The systems engineer responsibility to determine when are such approximations valid.

Models have been made where the urban system is considered to have fixed boundaries. One cannot accept these models without strong reservations. The development of cities in the past indicated that suburbs grow around the city limits. Later the city expands finally incorporating these areas within its boundaries.

A clear indication of expanding boundaries can be seen in the Greater São Paulo area. Also, it is forecasted that there will be a continuous line of developing cities between São Paulo and Rio de Janeiro. After a while they will merge into larger units and one has to consider expanded boundaries.
3.0 - OPTIMAL CONTROL OF AN URBAN SYSTEM

One would like to control the urban system in such a way as to obtain an optimal output $u(t)$. Recall that the output $u(t)$ was the quality of life in the urban system.

First one has to discuss what the word "optimum" means. The word has been misused many times by substituting for it its colloquial synonym "best". In a systems design one cannot attain the "best". One can only design to get the best possible performance with respect to a decision criterion. When the decision criterion changes, the optimum output of the system changes. Hence it is of primary importance for the urban system designer to choose very carefully the decision criterion he is going to employ in his design.

For example in the design of a transportation system one has to decide what the main objectives of the system are: should it be the

1. fastest
2. safest
3. least pollutant
4. most comfortable
5. most attractive
6. least expensive
7. quietest
8. take the shortest route
9. take the scenic route
10. interconnect the least number of points
11. interconnect the most number of points, etc.

If no 3 is chosen as a main objective, then the decision criterion \( D \) will be the function of

\[
D_3 = D(\alpha \% \text{ carbon monoxide}, \beta \% \text{ sulphur emission}, \gamma \% \text{ other pollutants}).
\]

\( \alpha, \beta, \gamma \) are prescribed quantities.

In this case, one designs the system to optimum performance with respect to \( D_3 \). Clearly the system will not be the fastest, the safest, etc. It will be optimum only with respect to the prescribed level of pollution.

On the other hand, should one choose to combine no 3 and no 7 in the decision criterion

\[
D_{3,7} = D(\alpha \% \text{ carbon monoxide}, \beta \% \text{ sulphur}, \gamma \% \text{ other pollutant, } x \text{ decibel noise level})
\]

\( x \) prescribed

the system would be controlled to optimum performance with respect to \( D_{3,7} \).
Ideally, since one wishes that \( u(t) \), the quality of life, should be optimum, one ought to employ a decision criterion \( D_1, 2, 3, \ldots n \), incorporating all the variables. Of course, in practice one has to compromise.
4.0 - **SYNTHESIS OF AN URBAN SYSTEM**

The word "synthesis" means to "put together". What will be attempted here is to put together an ideal urban system from basic units.

The four basic units considered are:

- Urban unit
- Suburban unit
- Industrial unit
- Activities unit

4.1 - **The Urban Wheel:**

An urban system is synthetized in the form of an "urban wheel" as on figure 4. The hub of the wheel is occupied by the activities unit and the other units are positioned along the spokes.

The urban wheel is designed with the principle in mind to intersperse industry and dwelling units.

This type of arrangement is contrary to the conventional one where there are large areas of separate industrial and dwelling concentrations.
FIGURE 4 - THE URBAN WHEEL
In the urban wheel arrangement smaller industrial and dwelling units are interspersed. These units are separated with large green belts and forests.

The new arrangement reduces concentrated pollution, reduces commuting time, relieves traffic congestion and eliminates the plague of urban eyesore.

Each unit within the urban wheel is designed to be self-sufficient to a certain degree.

The activities unit and the urban unit is designed on the principle to separate pedestrian and vehicular traffic. The suburban unit and industrial unit applies this idea only partly.

The activities unit where large department stores, police, hospital, cultural centers etc., are concentrated, is easily accessible from each unit without the necessity of crossing through other units. By this, traffic congestions are eliminated.

The main arteries of transportation within the urban system are along the rim and the spokes of the wheel. Note that the interurban transport routes (routes between separate urban systems) connect directly
to the activities center, thus avoiding interference with the traffic of individual units.

Garages are located at the end of each radial road. The circular traffic around the activities unit is one way and is of low density. For example, a worker coming from the industrial unit would park his car in the nearest garage. He would enter the circular flow only a couple of hours later after finishing his business in the activities unit. Since this entrance is staggered in time, no rush hour traffic is expected around the inner ring. On the other hand, rush hour traffic is expected on the outer ring, therefore the capacity has to be designed accordingly.

Figure 5 shows the interconnections of several urban wheels along the interurban transport routes.
FIGURE 5 - INTERCONNECTION OF SEVERAL URBAN SYSTEMS
4.2 - The Urban Unit

This is the ideal housing unit of the future. It is designed for "optimum" quality of life, for optimum efficiency, with minimal cost. It also incorporates optimal land use policies, conserving the most land for recreational and agricultural purposes.

Figure 6 shows the schematic representation of an urban unit. The inner core of the unit consists of a complex of high rise apartment buildings. The inner core is encircled by a traffic belt, a recreation belt, and an agricultural belt. Of course, the circular shape is idealized, but the position of the inner and outer belts is essential.
The urban unit is designed with the following basic principles in mind:

1.- The urban unit is completely self-supporting as far as services are concerned. It must contain schools, churches, small shops, within the central core of the unit. It should provide professional services such as medical, dental, nursery, baby-sitting, senior citizen care, gardener, caterer, handyman, etc. service on a collective cooperative basis. It should employ a management service for the coordination.

Service personnel and their families should live within the urban unit. All energy distribution sewer and waste disposal system should be centralized to offer maximum efficiency for minimum cost.

Small handicraft and non-polluting industry of small size employing no more than 10 persons can be encouraged within the unit to contribute toward operating cost. Small research type organizations are encouraged.

2.- Pedestrian and vehicular traffic should be completely separated: the routing of vehicles is around the inner core of the unit. It does not enter the inner core of the unit.
3. All shops and services should be located within walking distance.

4. An urban unit should not be too large in size. Approximately a complex of 20 high-rise apartment buildings (20-30 stories high) would be a good rule of thumb.

5. The forest and recreation belt around the innercore of the city should be large enough to preserve its natural state. A rule of thumb would be 1/4 acre per inhabitant. There is no automobile traffic permitted within the belt. Pedestrian, carriage, horse and bicycle path is provided. It contains swimming-pools, tennis courts, football fields, etc.

6. The agricultural belt at the outer core of the urban unit should provide mainly for fresh vegetables and fruit for the unit if the climate is favorable. If not, it could produce other crops or cattle farming. Secondary roads for vehicular traffic are permitted. Family houses for farmers are permitted.

The inner core of the urban unit can have different forms of arrangement. The main importance is that vehicular traffic should not be permitted. No bicycle or horseback riding permitted. One form of arrangement is shown on Figure 7. An artist's conception is given on Figure 8.
FIGURE 7 - Schematic representation of the inner core of an urban unit.
FIGURE 9 - ARTIST'S CONCEPTION OF THE INNER CORE OF AN URBAN UNIT
The buildings are centered around a central praça with trees and landscaping. The houses are mixed income buildings to provide for everybody employed in the urban unit. Landscaping and small children's parks are interspersed with the buildings. Vehicular traffic enters at the back of the buildings with ample parking space for tenant, guest and service vehicles in the basement of each building. Note that street parking is not permitted. Shops are serviced also from entrances within the buildings.

The main floor of the buildings is occupied by small shops, restaurants, etc., along arcades. No obtrusive neon signs etc. is permitted. Advertisement has to be approved by a committee.

4.3 - Suburban Unit

This is a conventional unit with one family housing and intersecting streets. The recreation facilities are interspersed within the unit and community operated. The downtown shopping and service area should be designed on the principle of separating pedestrian and vehicular traffic. Since the suburban unit is less densely populated than the urban area, open parking lots and on street parking are permitted.

The suburban type of arrangement is less attractive as far as economy, land use, distribution of energy, etc., is concerned. It should be discouraged with:
i. Strict zoning laws.

One or two acres of land should be the minimum for each house.

ii. Availability of credit.

The credit conditions should be more stringent than for urban housing.

iii. Building codes.

Each suburban unit should adopt an individual building code enforcing design and quality of housing.

It is stipulated that the urban unit will be more attractive to families of every income bracket due to the advanced level of services and recreation facilities.

4.4 - Industrial Unit

The industrial unit consists of an "industrial park". There are a number of industries, (interrelated or not) situated in the park. Large acreage of forest and virgin land surrounds the industrial buildings, thus reducing pollution and eyesore.

The industrial unit is also self-sufficient, providing for medical care, restaurants, recreation, security force, etc.
There is no open space for parking. Garages are located within the buildings.

The industrial park idea has been successfully used in the recent years by a number of industrialized countries. It is more economic in energy distribution, services, etc., than the individual factory concept. It is especially ideal for small factories which cannot individually afford a similar arrangement.

Strict coding should enforce design, open space, acreage etc., required for industrial parks.
4.5 Activities Unit

The topographical and structural construction of the activities unit is very similar to that of an urban unit. Only the buildings are now occupied by activity centers such as department stores, banks, police, medical center, chamber of commerce, cultural centers, etc. Here too, the pedestrian and vehicular traffic is completely separated. The only modification is that the garages are not located within the buildings. A garage belt is built around the activity unit (Figure 9). The garages are located next to the main connecting roads. Incoming traffic enters these garages directly. The traffic circle is used only when leaving the activities unit. There are pedestrian overpasses from the garages to the activities unit. Activities units are designed to serve communities of the size of 200,000 people.
FIGURE 9 - TRAFFIC FLOW AROUND THE ACTIVITIES UNIT
5.0 Synthesis of a Metropolis

A city with more than two million inhabitants can be considered already a metropolis. Here, besides the usual activity centers, one has to provide for a center core. This center core acts like a gravity center. It concentrates the main banking, shipping and commercial activities of the area. It can also provide for larger scale cultural, social and sport activities. Theaters, opera, convention halls, stadiums, zoo, botanical garden, etc. are located in the main gravity center. There is no industry around the gravity center, but residential areas are permitted. Only public transportation is permitted within the gravity core. Here too, pedestrian and vehicular traffic is separated as shown on Figure 10. The activities are centered around pedestrian malls. Figure 11 shows the structure of the metropolis. It consists of the interconnection of the gravity center with urban wheels.
FIGURE 10 - TOPOGRAPHY OF THE GRAVITY CENTER
FIGURE 11 - METROPOLIS
6.0 - STABILITY OF AN URBAN SYSTEM

A built in property of the fixed boundary model is that the urban system based on this model is stable. By this is meant that no matter where how and when one disturbs its state, after a while it will go back to its original stable state. An example would be the case when a road is under construction and blocked from traffic. After the initial congestion around the block, the cars disperse in the neighboring streets and the flow of traffic is undisturbed again.

Since this stable property is the consequence of the supposition of fixed boundaries, one has to conclude that it is not the inherent property of the urban systems but the built in property of the model.

On the contrary, one has to suspect that there are unstable states which can be local or which can propagate.

One example for a local instability could be the state of an airport area where the noise level passes the threshold of human endurance and makes the area inadequate for living (figure 12).
FIGURE 12 - LOCAL SINGULARITY

In case a new airport cannot be built (due to financial or other reasons) then $x=0$ is a local singularity.

In addition, it is an essential singularity since there is no way to remove it.
On the other hand, if ways are found to build an additional airport, the number of airplanes would decrease and the noise level in terms of distance would be as on Figure 13. In this case, $X=0$ is a removable singularity.

**Figure 13** - $X=0$ is a removable singularity
An example for a propagating singularity in an urban system is the classical case of a gold mining town. The close down of the mine would create a singularity in the miner unemployment chart at time $t_0$. At a later time $t_1$, the building of new houses will stop, at time $t_2$ the automobile industry will be affected, etc. Clearly at a certain critical time $t=t_c$ the town is deserted and becomes a ghost town. (Figure 14).

Every industrial or agricultural urban area based on a single product economy is very susceptible to propagating singularities.

Clearly, natural (e.g. earthquake) or man made (e.g. breakage of a dam, riot in a ghetto, etc.) catastrophe can induce both local and propagating singularities.

It is the responsibility of the urban designer to locate and avoid such singularities.
7.0 - ANALYSIS OF AN URBAN SYSTEM

7.1 - METHOD OF ANALYSIS

In an established urban area like Greater São Paulo one is confronted with an already established pattern of houses, factories, traffic, pollution, etc. The best one can hope for is to apply a small change (input) to the system and observe the output due to this change. Here too one can use feedback to control the system to optimal performance, but the decision criteria are strongly influenced by the existing conditions.

With the method of analysis one breaks down the whole urban system into smaller parts and observes the behavior of these sub-systems. The flow of information in the analysis process is shown on Figure 15. For each sub-system similar flow diagrams apply.

Note that figure 15 consists of three major loops:

Loop I - represents the planning and design stage of the project. In this stage the urban problem is identified. Extensive data collection efforts aid in this task. Methods of improvements are formulated.

Loop II - is the loop of experimenting. In this phase one can simulate the urban problem on a computer and obtain an "optimum" design. This theoretical study can be applied in practice to a field.
FIGURE 15.
Information flow diagram showing relationships between formulating, structuring, and other aspects of the urban problem.
experiment. That is, the method is implemented in a small urban area. Depending on the outcome of the field experiments, the computer simulation is modified and again a new field experiment is done, etc. Note that loop II can be executed a couple of times before one obtains the desired outcome.

Loop III - is a feedback loop incorporating the outcome of computer simulations and field experiments. Based on these results the whole urban design is modified. Most likely, loop II is executed again with the modifications, before one gets the final output from the system.

The final analysis yields not only one, but two basic information about the system. One is "the results from the system" which tells how the system performance changed due to the modifications. The other output gives information about the urban system itself. It reveals its inherent merits and inadequacies. To give an example: traffic simulation studies show that where vehicular and pedestrian traffic is interspersed, the maximum improvement one can make in the traffic flow is about 18%. This shows the inherent inadequacies of the present system and points in the direction of separating vehicular traffic and pedestrian traffic (see sections 4.2 and 4.5).

The closed loop method of analysis as outlined here has
great advantages over the conventional open loop method. It has the built-in capabilities of constantly improving the urban design during the course of analysis. In an open loop method (where feedback loops I, II and III are not employed) this is not possible.
7.2 PROJECT PHASE DIAGRAM

The analysis of an urban system is a complex task. It can be approached in two ways. One way is to establish an urban group which deals exclusively with urban problems. However, in most institutions this approach is unfeasible due to inadequate human and financial resources. The other (and more sound) approach is to draw on the institute's already existing resources. In this case it is necessary to closely coordinate the efforts of various groups during all phases of the urban analysis. This coordination can be done by the systems analysis group.

Figure 16 indicates the plan of cooperation between various groups. The diagram is in a matrix form, where the nonzero elements of the matrix are marked with a circle. Each circle indicates the participation of a specific group in a given phase of the project.
Phase I
Overall System Design

Phase II
Data Collection

Phase III
Data Organization and Retrieval

Phase IV
Simulation of the Pilot Project

Phase V
Pilot Tests

Phase VI
Validation of the Pilot Project

Phase VII
Validation of the overall System Design

Phase VIII
Conclusions and Recommendations

FIGURE 16 - PROJECT PHASE DIAGRAM
Phase I - Overall Systems Design:

During this phase the whole urban system has to be viewed in its entity. Consideration has to be given to all interacting elements as outlined in section 2.0. The final decision on the method of analysis has to rest on the consideration of the cost involved. First, the cost of the analysis has to be considered; second, the cost of implementation of the recommended results has to be estimated. Usually the cost of analysis is not a restricting factor. On the other hand, the cost of implementation has to be seriously considered at the outset of the project. Consultation of authorities to estimate available funds is imperative.

Phase II - Data Collection:

The data collection phase of the urban analysis is usually the most time consuming process. However its importance cannot be underestimated. No meaningful urban analysis can be done without adequate statistical and dynamical data. Data collection can be done by utilizing conventional statistical techniques (e.g. census) and remote sensing (section 8.1.1)

Phase III - Data Organization and Retrieval:

In this phase image processing techniques have to be applied to subtract meaningful data from the aerial photographs (see e.g.
section 8.2.2).

Also, classification of urban areas according to usage and utility has to be made (section 8.1.1).

The establishment of a unified computerized data base is essential to a urban analysis. Moreover, this data base has to be such that the retrieval of all data pertinent to a given area should be the most efficient. The geocoding concept discussed in section 8.2.1 combines data obtained by statistical methods and data obtained from aerial photographs. The geocoding method provides for the most modern urban data base.

Phase IV - Simulation of the Pilot Projects:

Simulation of the pilot projects involves a number of tests running simultaneously. Mathematical models are applied to representative sub-areas of the urban system. These models are simulated on the computer and their behavior to various inputs are observed. An optimum model is selected for each sub-system.

Phase V - Field Tests:

The optimum models are applied to field tests in selected urban areas. This phase is the most involved in that respect that it
requires the cooperation of various agencies. For example, it requires the cooperation of various traffic departments if it is a traffic test, the cooperation of traffic departments and industry if it is a pollution test, etc. It needs financing by the state or federal government. Private financing is also conceivable if individual or community benefits can be shown.

This phase also involves the hiring of special technicians. The experiment might involve actual hardware applications. To give an example, one might have to install special traffic counting devices, traffic lights, pollution control devices, etc. More likely political and social cooperation is required from people having interests in the test area.

Phase VI - Modification of the Pilot Projects:

Based on the outcome of the field tests the computer simulation models are modified. Some new data must be collected if additional variables influencing the urban system are discovered. Also some modified field tests can be conducted. However, this is not essential because at this stage the simulation models are quite reliable.

Phase VII - Modification of the Overall System Design:

Based on the findings for the sub-systems, the overall
urban system is modified. A computer simulation of the overall system is most likely out of proportions due to the complexity of the problem. However, simulation of integrated sub-systems is feasible.

Phase VIII - Conclusions and Recommendations:

The evaluation of results is the most important phase of the whole urban analysis project. Based on the evaluations recommendations are made to local, state or federal governments for necessary legislatures, regulations, investments, etc.
7.3 - An Example - Greater São Paulo

Analysis of a large metropolis like greater São Paulo proceeds on two levels:

i, macro analysis

ii, micro analysis

The macro analysis is hindered by the fact that mostly only large scale projects can alter the existing urban pattern. These large scale projects are usually very costly and therefore they are unfeasible. However some ideas could be implemented which are moderate in cost, but still are expected to produce substantial improvement.

Activities satellites

Observation of routes converging on the center portion of São Paulo indicate that all major activities converge in the center area. This results in a tremendous traffic problem, pollution, in general in very unpleasant living conditions.

Plans to improve the traffic problems have been made by introducing circular major routes around the inner core of the city. A chart of the existing and planned major arteries by 1990 are shown on Figure 17.
FIGURE 17 - 1990 NETWORK OF GREATER SÃO PAULO
It is stipulated by this writer that the proposed new routing will provide only temporary relief from the traffic point of view. This relief might dissipate early due to increased population and additional concentration of activities. Certainly, it does not do anything to improve the final objective of urban planning: the quality of life.

It was shown in section 4.0 that activities units dispersed to serve communities of 200,000 population are highly desirable.

It is proposed here to establish similar activities units around the periphery of the densely populated areas in Greater São Paulo. These activities units would greatly relieve the burden placed on the inner core of the city. Also it would be more community centered, thus serving the existing needs far better. The structure of the activities satellites is similar to that outlined in Section 4.5.

The location of the proposed satellites is indicated on figure 18. The location was strategically planned to coincide with routes on figure 17, and to take into account the most densely populated areas by 1990.

Additional activities satellites can be positioned on a greater radius around the inner city as more areas become densely populated in the future time.
Urban unit blocks:

Since place is limited in an established urban area, one cannot hope to establish an urban unit as described in section 4.2. However, the idea can be approximated by establishing urban unit blocks.

The sketch of such a block unit was given on figure 8. Note that pedestrian and vehicular traffic is completely separated. Since a recreation belt is unfeasible, the recreation facilities are located within the urban unit.

Urban unit blocks could be easily established by the government of Greater São Paulo. Areas designated for redevelopment could be bought by the government. Private industry could be encouraged by attractive terms to build in the area.

It is stipulated that such a building project is not more costly than the present practice of constructing individual highrise buildings. It only needs coordination and advance planning.

Staggered development

In presenting the concept of the urban wheel in section 4.1 it was shown that it is highly desirable to intersperse industry with dwelling and activities units. Such a development in Greater São Paulo could be
approximated by a good planning on future locations.

Imperative to such a planning is a thorough data collection effort to indicate the existing conditions (see section 8.1). By using the techniques of information processing and retrieval as outlined in section 8.0 one can plan ahead in locating the industrial and urban units of the future.

Gravity Center

The gravity center of Greater São Paulo is located in the inner core of the city. To rehabilitate this area according to the concepts outlined in section one has to take the following approach:

i, Designate blocks (not just streets) where vehicular traffic is not permitted. In these areas former streets serve as pedestrian malls.

ii, Reroute traffic around these "malls".

iii, Permit only public transportation and emergency vehicles in the inner core.

iv, Establish garages around the gravity center.
v, Subsidize public transportation and discourage private vehicles on routes converging on the gravity center.

**Micro analysis**

Micro analysis consists of locating problem areas as for example shown on figure 19. Clearly the results on traffic could be eased by planning not two 4 lane highways but by four 2 lane highways. Three of these 2 lane highways can be allocated to rush hour traffic, thus changing direction in the two middle lanes when required. (figure 20).

The aerial photographs are just as well important in the micro analysis as they were in the macro analysis. For example, the dynamic traffic picture can be established as on figure 21. Based on these photographs one can observe the traffic bottle necks and eliminate the problem by planning traffic signals, etc.

Pollution can be measured and mapped by the techniques of section 8.4.
FIGURE 19 - RUSH HOUR CONGESTION IN A FOUR LANE HIGHWAY.
Figure 20 Lane Reversal in Rush Hour Traffic

Direction of Middle Lanes Reversed in Rush Hour Traffic
In general, mathematical models and computer simulation are very useful in micro analysis. The references contain some mathematical models, which can be directly applied to urban analysis.

The procedure of micro analysis for each problem separately follows as outlined in section 7.1 and 7.2.

It cannot be overemphasized that macro analysis has to precede micro analysis. In an ideal situation, macro analysis (that is good planning) would put micro analysis out of business.
8.0 Tools of Analysis

Every form of the arts and the crafts has its specific tools. Urban design is a special blend of arts and crafts therefore it must have its own specific tools too. Without them urban design either remains in the realms of utopia or reverts to the primitive age.

Since urban problems are highly complex, one can expect that urban "tools" will be likewise so. Indeed most of them were developed only in this decade and almost all utilize highly developed technology.

What will be attempted here is to give an outline of these technologies. The purpose is to call attention to their existence. Clearly a detailed presentation is out of the scope of this paper.

8.1 Data Collection

At the foundation of urban design is the tremendous effort of data collection. Before one attempts to analyze an urban system one has to have a clear picture of land use, population distribution, family income, irrigation facilities, etc.

Various forms of data collection have been done
in the past. Some of these were conducted by local, state or federal governments. Data can be found in criminal records, geographical survey, traffic counts etc. These data collecting efforts were done by conventional methods of questionnaires, counting devices etc. In addition to these statistical data, much data exist which were collected by industry. Examples are: electric bills; telephone bills, mail order addresses etc. All these data are useful and should be utilized by an urban designer.

A fairly new method of data collection is by aerial photography and by other remote sensing devices. This type of data collection has the advantage that it can be updated more readily. Also for some studies like traffic control and pollution control it can supply a dynamic data base.

The conventional methods of data collection will not be discussed here. However an urban designer should utilize every available data and combine them in a most suitable way for urban design (see Section 8.2.1, the "Geocoding Method").

8.1.1 Remote Sensing

The remote sensing capabilities of IMPE are well documented elsewhere. The "Bandeirante" aircraft mainly contains sensors which supply the following data:
1. Data from UV-VISIBLE-INFRARED SENSORS
2. Data from photographic sensors
3. Auxiliary Data

A chart of the data acquisition system is given on Figure 22.

The immediate categorization and sorting of the data can be done by the land use code given in Appendix I.

Land use determination by remote sensor analysis provides extremely useful data for urban analysis. Such data can be compared by data available from other statistical sources. A coded map of an urban area is given on Figure 23. This coded information can be computerized as outlined in the next section.
FIGURE 22 - CHART OF DATA ACQUISITION SYSTEM
FIGURE 23 - CODED LAND USE PATTERNS
8.2 - INFORMATION PROCESSING AND RETRIEVAL

8.2.1. Geocoding Method

The data base requirements for urban, regional and national planning share a common feature: the data has both value and spatial components.

A new development in structuring data base is the "geocoding" concept. In a geocoding system each data entity is given only a simple spatial identifier. The most convenient is to use a Cartesian coordinate system and use one point of the grid for the spatial coordinates.

The mesh size of the grid is determined by the map scale and the digitizing accuracy. The grid point uniquely determines the spatial location of the data entity. (See Figure 24).

The multitude of political and topographic areas require that the information could be retrieved from the area of an arbitrary polygon.
FIGURE 24 - GEOCODED INFORMATION RETRIEVAL
The data entity within an arbitrary polygon can be quite varied. It might consist of dwelling units, crop parcels, census data, police data, etc. The main feature of the grid block method is that not all data entities have to be entered by x-y digitizer. For example, algorithms can be developed which convert street address codes to grid blocks.

The proposed data base has great potentiality for combining data obtained from aerial photographs with other forms of data. It can combine photographic data with population statistics, law enforcement data, health statistics, planning and land use data, meteorological data, traffic density count, block and parcel data, etc. The "geocoding" method combines all this data into one unique spatial point. It integrates studies to avoid waste of resources.
The applications are limitless. The data base can provide common data for national cartography, agricultural planning, geographical studies, urban development, pollution control, crime control, traffic planning, etc.

System users can request data from the national central data file for a specific area. Using such a data base, planners can answer questions like:

- What is the school population within a given radius of the proposed school sites?
- What is the value of land proposed to be displaced by a new highway?
- What is the density of population within a given radius of proposed supermarket?
- What roads require surfacing in a given geographic area?
- What is the crime to population ratio in a given area?
- What are the possible sights of new urban developments?
8.2.2. Image Enhancement

There are new image enhancement techniques which can be applied to the aerial photographs used in urban analysis.

The purpose of the image enhancement techniques is to modify the image appearance in order to extract information more readily.

There are many image enhancement techniques, here only two of them will be mentioned, namely

- coherent optics
- digital computer methods.

Coherent optical systems are capable to perform linear operations on the amplitude transmission of film transparencies. Digital computers can perform linear operations on amplitude transmission, intensity transmission or on the density. Also, computers are able to perform nonlinear operations.

Linear operations

Consider two dimensional monochromatic images. Such an image can be characterized by the intensity of the image \( i(x, y) \), which is a real function of the spatial variables \( x \) and \( y \).
An image enhancement technique is an operation on the intensity. Suppose one has a set of instruments, say, a collection of lenses, pinholes, etc. as on Figure 25.

The question is, what kind of operations will the instruments perform on the intensity?

Schematically, one can represent the problem in the following way: the instruments are represented by a "black box", the intensity \( i(x,y) \) is the input to the black box, and \( u(x,y) \) the processed image is the output from the black box.

Now suppose that the instruments perform only linear operations on the image.

The property of the linear operations is:

- If the input is \( i_1(x,y) \) then the output is \( u_1(x,y) \)
- If the input is \( i_2(x,y) \) then the output is \( u_2(x,y) \)
- If the input is \( i_1(x,y) + i_2(x,y) \) then the output is \( u_1(x,y) + u_2(x,y) \)
- If the input is \( ai(x,y) \) where \( a \) is constant, then the output is \( au(x,y) \)
The above properties indicate that the superposition principle holds.

Consider the case when the photographic plate is exposed only at a single point, \((x, y)\). Let the intensity of the image be unity. One can think of a mathematical "function" \(\delta(x, y)\) which describes this property:

\[
\int \delta(x - \xi, y - \eta) \, d\xi \, d\eta = 1 \text{ at } x = \xi, y = \eta \\
\delta(x - \xi, y - \eta) = 0 \text{ at } x \neq \xi, y \neq \eta
\]

According to the above definition, the delta function \(\delta(x - \xi, y - \eta)\) behaves like a density function. It has an infinite intensity density at \(x = \xi\) and \(y = \eta\), otherwise it is zero. Hence \(\delta(x - \xi, y - \eta)\) behaves like an impulse at the point \(x = \xi\) and \(y = \eta\). This can be represented pictorially as on figure 26.

\[\text{FIGURE 25 - THE DELTA FUNCTION}\]

*The \(\delta\) function is not a function in the ordinary sense. It is the limit of a sequence of functions.*
One can measure the output of a system due to an impulse input function

\[ \delta(x-\xi, y-\eta) \rightarrow \text{IMAGE ENHANCEMENT SYSTEM} \rightarrow G(x,y; \xi, \eta) \]

\( G(x,y; \xi, \eta) \) is called the impulse response function of the system.

\( G(x,y; \xi, \eta) \) is sometimes called the Green's function. It was named after the English mathematician George Green who in 1823 first characterized a system's property with the impulse response function. His problem was quite different in nature. He was interested in the electromagnetic potential distribution within a circle, due to a radiating point source. However his method has been so powerful that in recent years it became an important method of solution in physics, mathematics, engineering. The same method can be applied to stochastic processes which are so important in economics management, urban, etc. problems.

A linear system is completely characterized by its impulsive response function.

To illustrate this property, suppose that one has a photographic plate which is exposed not just at one point, but a number of points which have the respective intensities \( a_1, a_2, \ldots, a_n \).
That is

\[ i_1 = \alpha_1 \int \delta(x - \xi_1, y - \eta_1) \, dx \, dy = \alpha_1 \]

\[ i_2 = \alpha_2 \int \delta(x - \xi_2, y - \eta_2) \, dx \, dy = \alpha_2 \]

\[ \vdots \]

\[ i_n = \alpha_n \int \delta(x - \xi_n, y - \eta_n) \, dx \, dy = \alpha_n \]

This is illustrated on Figure 27.
denote

\[ a_1 = a(\xi_1, \eta_1) \]
\[ a_2 = a(\xi_2, \eta_2) \]
\[ \vdots \]
\[ a_n = a(\xi_n, \eta_n) \]

So the input-output picture of the system is:

\[ i_1 = a(\xi_1, \eta_1) \quad \xrightarrow{G(x,y;\xi,\eta)} \quad u_1 = a(\xi_1, \eta_1) \ G(x,y;\xi_1,\eta_1) \]
\[ i_2 = a(\xi_2, \eta_2) \quad \xrightarrow{G(x,y;\xi,\eta)} \quad u_2 = a(\xi_2, \eta_2) \ G(x,y;\xi_2,\eta_2) \]
\[ \vdots \]
\[ i_n = a(\xi_n, \eta_n) \quad \xrightarrow{G(x,y;\xi,\eta)} \quad u_n = a(\xi_n, \eta_n) \ G(x,y;\xi_n,\eta_n) \]

Since the system is linear, the superposition principle holds. Hence for the total input: \( i(x,y) = \sum_{k=1}^{n} \sum_{\ell=1}^{\eta} \sum_{m=1}^{\eta_m} a(\xi_k, \eta_m) \)

the total response will be

\[ u(x,y) = \sum_{\ell=1}^{\eta} \sum_{m=1}^{\eta_m} a(\xi_{\ell}, \eta_m) \ G(x,y;\xi_{\ell},\eta_m) \]

This is shown on Figure 28.
Now suppose that $i(x,y)$ is not discrete but a continuous function. This is the case in a regular photograph where the intensity of image changes continuously. Then

$$u(x,y) = \int \int_{-\infty}^{\infty} G(x,y; \xi, \eta) i(\xi, \eta) \, d\xi \, d\eta \quad (1)$$

Where again, $G$ is the impulse response of the system.

If one knows $G$ for the given system then the output can be obtained by a simple integration as in the above equation.
The last equation can be written with a symbolic notation:

$$u(x,y) = E[i(x,y)]$$

where $E$ stands for the recipe: multiply the Green's function by the intensity and interpret.

Any image enhancement technique can be considered as an operator $E$ which operates on the image $i(x,y)$ and produces the enhanced image $u(x,y)$.

Image enhancement techniques vary from simple intensification and magnification to sophisticated filtering.

For example the intensification operator is:

$$E[i(x,y)] = K \cdot i(x,y)$$

where $K$ is a constant. In this case the "operation" is a simple multiplication with a constant.

The magnification operator can be written as:

$$E[i(x,y)] = i(mx, ny)$$  \hspace{1cm} (2)$$
where \( m \) is a constant. This means each point \((x,y)\) with a constant factor \( m \).

The Fourier Transform operator is:

\[
E \[ i(x,y) \] = \int \int i(\xi, \eta) e^{i(\xi x + \eta y)} d\xi \, d\eta
\]  

(3)

Note that equation (3) is a special form of (1) where the Green's function is an exponential.

The equipment shown on Figure 25 performs Fourier transformations. These operations are possible because of the Fourier-transforming property of a lens.

Imagine a film transparency with amplitude transmission \( h(x,y) \) placed in the front focal plane of the lens, where \( x \) and \( y \) are the spatial coordinates of the front focal plane, and illuminated with collimated monochromatic light. Then the amplitude of the light at the back focal plane of the lens will be

\[
H(\xi/\lambda f, \eta/\lambda f) = H(v, w)
\]  

(4)

the Fourier Transform of \( h(x,y) \).

where \( v \) and \( w \) are frequency variables, \( \xi \) and \( \eta \) the spatial coordinates of
the back focal plane, \( \lambda \) the wavelength of the light, and \( f \) the focal length of the lens.

Such linear filtering techniques are very useful in enhancing information from photographs.
8.3 Computer interactive graphics

Computer interactive graphics is a new tool in urban design. It is based on man-computer interaction. The urban designer describes a part of his design, for example by prescribing the urban polygon he is interested in. He can do so by drawing with a "light pen" on a cathode-ray display tube. He performs some analysis and then, based on the results of his analysis, changes the design.

A schematic diagram of an interactive display system is given on Figure 29. The light pen is a light sensitive device shaped like a pen. It permits the urban designer to select any information displayed on the screen. For example, the program might be a study in the effect of traffic signals in an urban area. The designer indicates on the display the area he is interested in by drawing a polygon enclosing the road network in question. He can indicate the positioning of traffic signals by working with the light pen. The geocoding activates all data pertinent to that point. This could be traffic density, road condition, road surfacing, period of rush hour, etc. A network program will give the flow of traffic for this special position of signals. Again, the designer may indicate new position of signals and analyze his network. He performs a kind of iterative method of operation using a conversational approach with the computer.

The importance of the computer graphics method is that even the nonspecialist can now interact directly with a large central data processing system. It is feasible that local governments will have excess to the central data file and programs. This will aid them in solving special urban problems.
FIGURE 29. INTERACTIVE DISPLAY SYSTEM
8.4. Computer Study of Systems Dynamics

Computer studies range from simulating a whole urban system to the program of synchronization of traffic lights. These computer programs are very important in the systematic study of urban systems. Of course, one has to keep in mind that some of these programs deal with a highly idealized model. This is expected since the urban problems are very complex non-linear problems. The best one can hope for is only a mathematical approximation to such problems. Some references in this paper present computer simulations and their critique too.

One computer program which has general value to many areas of urban design is a digital contouring program.

Contour charts were originally used as two dimensional pictorial representations of topographic land formations. The contour lines indicate equidistant elevation forms a given reference surface (figure 30). Points \( P_j \) and \( P_{j+n} \) serve as reference points. Points \( Y_j \) and \( Y_{j+n} \) are control points. With reference to these four points, the location of \( i \) (grid point) is found in a digital contouring program.
FIGURE 30 - SEGMENT OF A SURFACE PROFILE PASSING THROUGH A GRID POINT AND TWO CONTROL POINTS:

For example, an urban pollution chart would be as on figure 31:

FIGURE 31  CONTOUR CHART
The equidistant points (that is, the same level of pollution) is connected with a contour line.

Similar contour charts can be drawn indicating levels of population density, traffic congestion, etc.
9.0 CONCLUSIONS

The purpose of this study was to apply systems methods to the field of urban design.

It was shown that both the methods of system-synthesis and system-analysis are useful in urban design.

Procedures in establishing and coordinating urban studies were indicated. Also, modern techniques applied to urban studies were outlined.

The references given here are relevant to the ideas discussed in this paper. They also provide literature for further studies in urban design.

The material contained herein can form the basis of a one week systems seminar in urban studies. It also provides conceptual guidelines to an urban studies group.

Systematic application of the ideas to future and existing urban areas like Greater São Paulo seems promising.
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0 Residential

01 Single Family (including detached, semi-detached, triple-attached and row, plus individual mobile homes)

02 Multi-Family (two or more dwellings in a single building, including apartments and residential hotels)

03 Rooming and Boarding Houses

04 Membership Lodgings

05 Residence Halls and Dormitories

06 Retirement Homes, Orphanages and Religious Quarters

07 Seasonal Housing (including summer cottages and farm labor camps)

08 Mobile Home Parks or Courts

09 Hotels, Motels and Tourist Accommodations

00 Residential, (not classified)

1 Industrial/Storage

11 Manufacturing and Processing

12 Research and Testing

13 Wholesale, Warehousing and Solid Storage
14 Contract Construction

15 Vehicle Storage - Truck Parking

16 Vehicle Storage - Taxi Parking

17 Vehicle Storage - Bus Parking

18 Refuse Disposal

19 Industrial/Storage (not classified)

2 Educational

21 Nursery Schools

22 Elementary Schools (Grades 1 - 6)

23 Combination of Nursery and Elementary Schools (pre-school through 6)

24 Secondary Schools (Grades 7 - 12)

25 Colleges and Universities

26 Commercial Schools

20 Educational (not classified)

3 Transportation/Communication/Utilities

31 Railroad/Rail Rapid Transit Rights of Way (includes terminals)

32 Street and Highway Rights-of-Way
33 Airports

34 Auto Parking

35 Bus/Taxi Terminals

36 Radio/Television and Telephone/Telegraph Communications

37 Electric Utility

38 Gas Utility

39 Water/Sewer Utility

40 Transportation/Communication/Utilities (includes marinas, pipelines, etc.) (not classified)

4 Consumer Services

41 Stores

42 Shopping Centers

43 Gas Stations, Auto Repair, Automobile Dealers and Auto and Truck Rentals

44 Repair Services (not auto repair)

45 Personal Services

46 Eating and Drinking

47 Medical and Dental Clinics, Centers, and Laboratory Services

40 Consumer Services (not classified)
5 Offices

51 Commercial Offices
52 Professional and Trade Associations
53 Institutional Offices
54 Federal Government Offices
55 State and Local Government Offices
56 Foreign Governments and International Organizations including embassies, chanceries, etc.
50 Offices (not classified)

6 Institutional Services

61 Cemeteries
62 Hospitals
63 Nursing Homes
64 Other Health Facilities (except those coded under 47)
65 Police Stations
66 Fire and Rescue Stations
67 Correctional Institutions
68 Military Installations
69 Welfare and Charitable Services

60 Institutional Services (not classified)

7 Public Assembly

71 Churches, Synagogues, and other places of worship

72 Civic, social and fraternal associations

73 Libraries

74 Permanent exhibitions, including museums, art galleries, monuments, planetaria, aquariums, and urban historic sites

75 Sports and miscellaneous assembly including stadiums, auditoriums, recreation halls, etc.

76 Entertainment assembly including theaters

70 Public Assembly (not classified)

8 Parks and Recreation

81 Indoor recreation, including recreation centers, indoor swimming, gymnasiums, ice and roller skating rinks, bowling, and penny arcades

82 Outdoor Amusements, including fairgrounds, race tracks, go-cart tracks, miniature golf, golf driving ranges, and amusement parks

83 Private Outdoor Recreations, including tennis, swimming, country clubs, and yachting clubs, limited to members and guests
84 Commercial Outdoor Recreation, including resorts, riding academies, ski runs, organized camps, and marinas

85 Public Golf Courses

86 Play lots, playgrounds and playfields

87 Outdoor Courts and pools open to the public (tennis, basketball, swimming, etc.)

88 Parks - Leisure and ornamental

89 Parks - general recreation, including individual camping and picnicking as well as areas for the enjoyment of nature, including zoos, botanical gardens, arboretums and national parks

90 Parks and Recreation (not classified)

9 Undeveloped and Resource Uses

91 Agriculture and Related Activities

92 Forestry Activities and Related Services

93 Mining Activities and Related Services

94 Permanent Conservation Areas

95 Other Resource Production and Extraction

96 Undeveloped and Unused Land Area

97 Water Areas
98 Vacant Floor Areas

99 Under Construction

90 Undeveloped and Resource Uses (not classified)

* "Land use determination by remote sensor" NASA Report, N-72-12330