# REMOTE SENSING TECHNIQUES FOR CONDUCTING OFF-STREET AND TERMINAL PARKING STUDIES FROM HELICOPTOR AND LIGHT AIRCRAFT

by

David Andrew Kinnaird, B.A.A. (Urban Planning)

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## ABSTRACT

Although remote sensing has been used in certain aspects of transportation studies, it appears that little attention has been given to its application in parking assessment. For this reason, a study has been undertaken to demonstrate that oblique aerial photographs can be effectively used to investigate parking characteristices in shopping plazas, in particular to determine the rates of occupancy and turnover that occur in the available parking stalls.

From a light aircraft and a helicopter, panchromatic prints and colour slides of two shopping plazas in Dundas and Hamilton, Ontario, were taken with hand-held 35 mm cameras. Photographs were taken every 15 minutes over a period of 1 hour. A comparison of the films used indicates that the presence of colour in the slides permits easier differentiation between vehicles and hence easier identification of the changes that occur at each parking stall.

Procedures for extracting and recording data from the photographs and analysing the results were described. In addition to obtaining information on occupancy and turnover, it is demonstrated that the aerial view permits on excellent assessment of the effectiveness of the vehicular system. The ease of vehicle movement, the effectiveness of signing, parking stall preferences, the occurrence of illegal parking and the separation of delivery vehicles and passenger cars can all be deduced from the photography.

# CONTENTS

# FIGURES

Page

Figures

## 1. INTRODUCTION

Highway planning, traffic studies, parking assessment, and highway inspection are four broad categories of transportation to which remote sensing offers substantial and unique opportunities of data acquisition. Lindgren[1] asserts that over the past two decades aerial photography has made major contributions in the first category, that of highway planning, but that few studies, if any have been developed within the other three areas. Progress has been made, although slowly in the second interest area, traffic studies. Here, aerial photography taken from fixed wing aircraft and helicoptors at altitudes of less than 5000 feet, has produced information concerning traffic flows, measured in terms of vehicle concentrations, speeds, and delays.

Of primary interest to a municipality, is the maintenance of an efficient transportation network, and in the case of the roadway component, efficiency is rated according to the system's capability to minimize delays. Delay can be reduced providing that the network has the capacity to absorb the travel demand. Bearing this in mind, the municipality

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1. David T. Lindgren, "Urban Applications of Remote Sensing," in John E. Estes and Leslie W. Senger (eds.), 1973, Remote Sensing: Techniques for Environmental Analysis, Hamilton Publishing Company, Santa Barbara, California, pages 225-241.

must continuously monitor demand patterns and adjust the variables at its disposal (signal cycles, traffic control, i.e. regulatory, warning, and guiding devices, parking legislation, pavement marking etc.) in order to maintain an efficient network.

Travel occurs between various places of origin and destination, and where a vehicle comes to rest for any given period of time, the place of storage is referred to as a terminal. Examples of terminals are: airports; railway, bus, and rapid transit stations; retail centres; an urban area's central business district; a university; a place of residence; etc. The central issue here is the capability of the terminal to absorb vehicles, store them, and discharge them back into the circulation network. Of interest to the municipality's agencies involved with traffic phenomena, are facts such as the number of terminals within a district, terminal operational characteristics (rates of input and discharge) and the terminals' effect on the entire local area (their attractivity measured in terms of demand for service, occupancy and turnover).

To initiate an effective traffic program, the municipality must review continuously all elements associated with travel demand and included here would be a review of the major nodes of attraction in terms of location, capacity, and accessibility.

Remotely sensed data contain five characteristics which are strong persuaders for a municipality to resort to the use of aerial sensors ultimately, and in this regard, for use in traffic related studies. The characteristics are: compatibility, flexibility, reliability, timeliness,[2] and accessibility.

Compatibility refers to the remotely sensed data's capability to relate to other data sets including other remotely sensed data in a spatial context. Flexibility refers to its capability to be used by a variety of investigators using different formats. Reliability refers to the capability of remotely sensed data to reflect the existing target conditions. Timeliness refers to the imagery's ability to sense a target area in a short interval of time, to trap the phenomena's characteristics for interpretation by any user, and the rapidity at which the data is available to the user. Accessibility suggests that under certain conditions remote coverage of a phenomenon may provide data while ground coverage may not.

Assuming that an aerial study of a retail centre would be undertaken, measuring the demand for service for the

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2. Eric G. Moore and Barry S. Wellar, 1969, "Remote Sensor Imagery in Urban Research: Some Potentialities and Problems, Interagency Report, NASA-118, United States Department of the Interior, Geological Survey, Washington, D.C., page 39.

parking area, which of the characteristics of the remotely sensed data would illustrate advantage to their use? All five characteristics may be cited, and constitute the following advantages:

(i) Reliability: the imagery would reflect all phenomena related to the target; for instance, the supply of parking stalls, and their usage would be ascertained; the characteristics of the vehicles would be known; the street furniture, signing, and illegal actions could be determined, to mention a few.

(ii) Flexibility: the imagery could be used for transportation, traffic, and retail marketing studies; municipal code enforcement, and land use studies; etc. and each agency could define its own format for data manipulations.

(iii) Compatibility: the imagery would provide data for the above interested groups, and yet may be compared with or related to other data sets due to its open-ended format.

(iv) Timeliness: the characteristics of the phenomena under surveillance are frozen in time on the imaging medium, ready for interpretation by any interested agencies; the imagery's data would be available within an extremely short period of time of acquisition compared to data produced via ground surveys (i.e.) census data.

(v) Accessibility: the nature of the platform offers access to a variety of targets all within short time intervals and hence offers practically simultaneous sets of data (i.e.) within one or more districts, the number of parking lots, their supply of stalls, and demands for service may be ascertained.

In terms of parking assessment studies, little work has been documented involving colour photography, other than that undertaken in Stark County, Ohio, in 1967, by Syrakis and Platt.[3] Their study involved the assessment of both on-street and off-street parking supply and demand in the urban cores of three communities in Stark County. Their area of concentration involved the on-street faction, however.

Consequently, the area of interest in this study involves off-street parking, and in particular this study is designed to generate remote sensing techniques and methods of data extraction from imagery of terminals with surface parking. The two test sites were retailing consortia. The primary target was the University Plaza in Dundas, Ontario, a shopping plaza designed to service its surrounding neighbourhood. The secondary target was the Greater Hamilton Shopping Centre, a much larger and more complex establishment, designed to act as a regional attractor.

The objective of this research project was to determine the comparative utility of black and white panchromatic film and colour positive film in a parking phenomena assessment

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3. Thomas A. Syrakis and John R. Platt, 1969, "Aerial Photographic Parking Study Techniques," Highway Research Record, No. 267, Highway Research Board, Washington, D.C.

for each of the targets. The goal for each mission flown was to establish appropriate imagery in order that reliable interpretation and analyses methodologies might be developed for the assessment of parking phenomena at terminal facilities of different design and function.

## 2. DESCRIPTION OF TARGET SITES

The target for the first mission was the University Plaza in Dundas, Ontario while that in Mission 2 was the Greater Hamilton Shopping Centre.

### (a) University Plaza

The University Plaza in Dundas, Ontario actually consists of two distinct parcels of land.[4] The first parcel to be developed at 101 Osler Drive involved the outdoor mall and grocery store (Dominion Store) at the eastern end of the site, in the late 1950's. The site is owned by Third Lendorff (Canada) Limited and the trustee is Wentworth Shopping Centres Limited of Toronto. Originally the only access point to the plaza was the western one which joins onto Osler Drive at the gasoline station. The second parcel at 119 Osler Drive was developed in 1967 by Steinberg Reality Limited completing the present site with a combination grocery/general merchandise store. A second access point to and from the plaza was also built, and this intersection with Grant Boulevard is signalized. Twenty-five retailing outlets comprise this plaza. The parcels of

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4. Refer to Figure 1.

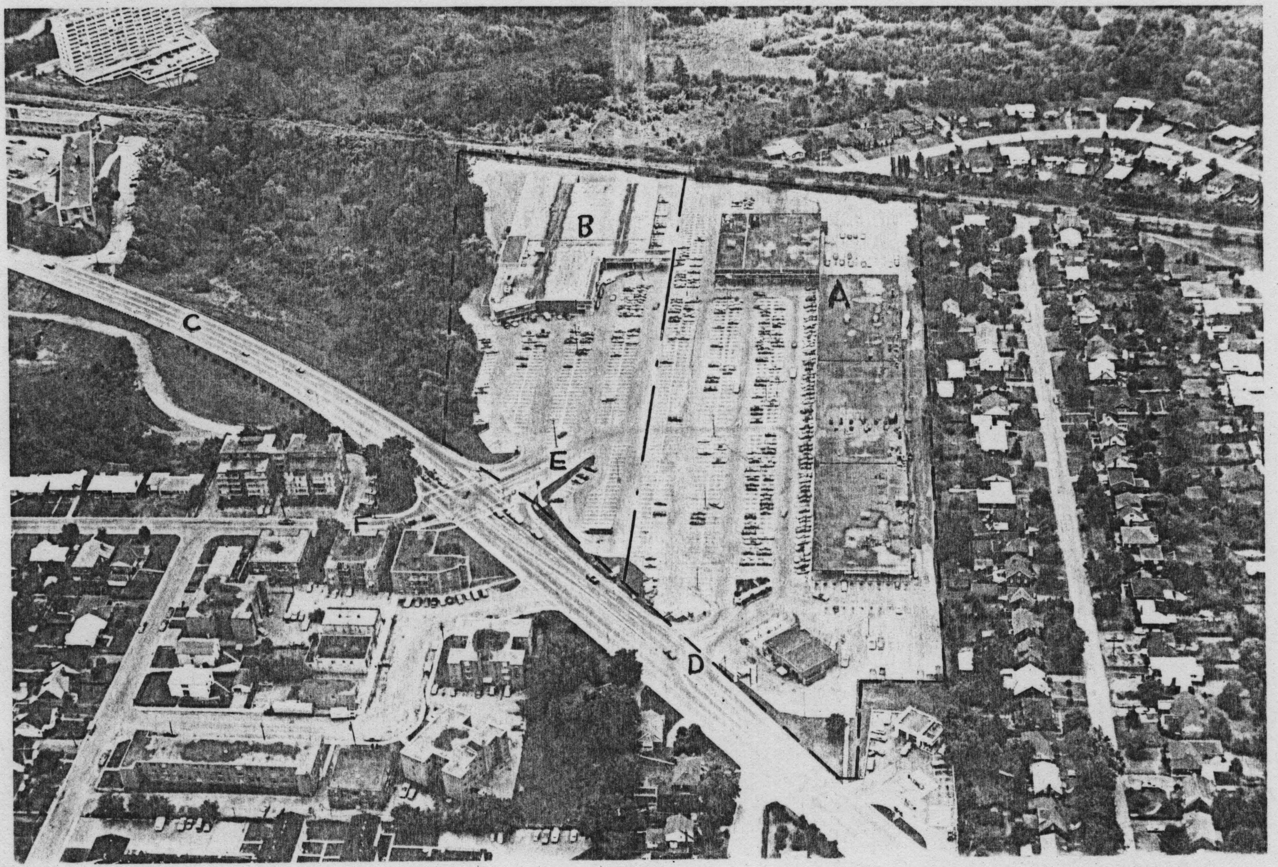


Figure 1. University Plaza, Dundas, Ontario. Photograph was taken facing west at 2000 feet, July 21, 1975. Scale is approximately 1:1800.

Legend: A The older mall and Dominion Store parcel and physical plant.

B The Steinberg Realty parcel and physical plant.

C Osler Drive

D The original entrance

E The newer access point with signalized intersection

F Grant Boulevard

land approximate a trapezoidal configuration and the site is approximately 7.7 x $10^5$ square feet or 17.5 acres, standing at a mean elevation of 330' A.S.L. Parking accommodates 1000 vehicles in surface stalls. The University Plaza is an outdoor neighbourhood retailing consortium which serves Dundas and the western end of Hamilton. The size of this plaza offered an excellent opportunity to develop an analytic methodology for the parking assessment division of this research report.

(b) Greater Hamilton Shopping Centre

The Greater Hamilton Shopping Centre (GHSC) occupies a site of 70 acres, and in 1954, construction offered the first unit of development. The Jockey Club tavern at the south-west corner of the site is the only surviving indication of a former land use, an east-end race-track. By 1965, the GHSC had reached a size of 75 retailing outlets and parking accommodation for 5000 vehicles, with an estimated daily turnover of 5 vehicles per stall. As a regional shopping centre, in 1965 the GHSC estimated as an attractor, its range from Brantford to Niagara Falls.

From north clockwise,[5] the site is bounded by the multiple track line of Canadian National Railways, Kenilworth Avenue North, Barton Street East, and Ottawa Street North. There are eight points of vehicle access and egress, and several informal pedestrian routes across the elevated rail lines.

Today, the GHSC consists of 89 retailing outlets in the form of stores and kiosks.[6] Outside of the climate controlled enclosed mall, the other land uses on the site include:

(i) residential (apartments);
(ii) a car dealership;
(iii) a tavern;
(iv) a Brewer's Retail;
(v) 2 grocery stores;
(vi) a Canadian Tire Store;
(vii) a tots' playground;
(viii) a gas and service station;
(ix) a twin cinema;
(x) a key kiosk;
(xi) a carwash; and,
(x) vacant undeveloped land

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5. Refer to Figure 2.

6. Refer to Figure 3.

Figure 2. The Greater Hamilton Shopping Centre, Site and Location. Photograph was taken facing north at 3900 feet, July 28, 1975. Scale is approximately 1:4400.

Legend: A CNR line (elevated)

B Kenilworth Avenue North

C Barton Street East

D Ottawa Street North


<u>Figure 3</u>. The Greater Hamilton Shopping Centre, Land Use and Retailing Configuration. Photograph was taken facing south at 3900 feet, July 28, 1975. Scale is approximately 1:4400.

Legend:

- A The Jockey Club Tavern
- B Brewers Retail
- C Dominion Store
- D Loblaws Store
- E Residential Apartments
- F Car Wash
- G Car dealership
- H Combination: Canadian Tire Store, Twin Cinemas.
- I,J Vacant Land
- K Tots' playground - Safety instruction
- L Robinson's Department Store
- M The Centre Mall
- N Sears
- O Key Kiosk
- P Sears gasoline and Service Centre
- Q Kenilworth Avenue North
- R Barton Street East
- S Ottawa Street North
- T CNR line (elevated)

The Greater Hamilton Shopping Centre, one of the Cadillac-Fairview Corporation assets, has been reviewed in many forms of studies. One study, a parking plan, was to provide a maximum of free parking with a minimum of walking distance to the stores, as the basic objective. This plaza, with its variety of land uses is one of the most complex retailing/residential arrangements presenting an interesting challenge as an air photo interpretation exercise, and is an extremely valuable research target in terms of developing a pre-parking assessment data extraction methodology.

## 3. THE MISSIONS

As in any situation, this investigation was subject to a set of limitations and constraints, and hence in planning the project, attempts to minimize disruptive influences were imperative. The limitations and constraints encountered included costs, availability and configurations of platforms, availability of sensors, weather conditions, seasonal variations in parking demand, and inconsistencies formed on an ad hoc basis, such as abnormal retailing conditions.

The original mission was planned for Saturday, July 19, 1975 and was to consist of consecutive passes over both targets. Following unexpectedly upon several days of exceptionally fine weather, inclement conditions forced the abortion of the mission at the last minute. The mission was reinstated on Monday, July 21, 1975 due to the logic of reasoning through the limitations and constraints set.

The nature of the first flown mission (denoted as Mission 1 henceforth) required consecutive passes over the target at discrete intervals of time in order to detect changed conditions in the target phenomena. During the period of time in the air, the weather suffered a relapse, and consequently the mission had to be modified. Mission 1 thus provided appropriate imagery for the smaller of the two targets, that being the University Plaza in Dundas, Ontario, rather than for both targets.

The innovation of flying Mission 1 on a Monday, rather than Saturday was in essence an unforeseen windfall, for two reasons. Firstly, unusual ad hoc retailing practices culminated on the Saturday, July 19, 1975 at the University Plaza. It was during this display of attraction for increased customers, that parking stalls of extreme turnover were utilized for the retailing function, and hence would have severely influenced research derivations. In the second sense, should the mission have been a normal one on that Saturday, the imagery would have resulted in a superfluous amount of data which would have distracted from the goal of the mission, and would not have allowed certain interpretive skills to be developed. Upon recognizing these from the processed imagery, Mission 2 was planned for the following Monday, July 28, 1975 and concentrated on the larger of the two targets, the GHSC. Mission 2 not only provided appropriate imagery of the second target, but also offered an opportunity to expand the research to the evaluation of different sensor platforms. The two different platforms consisted of (a) a helicoptor, and (b) a fixed wing light aircraft.

The following paragraphs represent a summary of the missions' log entries.

(i) Mission 1:

Mission 1 was flown on Monday, July 21, 1975 between 11:15 a.m. and 12:45 p.m. The flight originated from Hamilton's Mount Hope Airport, and the vehicle was a Bell 47·G2 helicoptor chartered from Glanford Helicoptors Limited. Photographic sensors consisted of two Asahi Pentax 35mm cameras equipped with through-the-lens metering systems, and 50mm lenses. The cameras were mounted one above the other in a hand-held bracket which resembled an open square frame. This arrangement allowed the investigator relative flexibility in aiming the sensors through the portal which normally accommodated the helicoptor's passenger door. A manual triggering arrangement provided nearly coincidental firing of both cameras. The platform was restricted to below-cloud ceiling altitudes provided by variable weather which developed during the mission. The altitudes were more than sufficient for providing good imagery scale of the smaller of the two targets,[7] but were too low to accommodate the planned mission tactics aimed at the larger target. Since vertical

7. Refer to Appendix A, "Imagery Scales."

photography was impossible to achieve, a method of high oblique photography was derived, and more than one frame per pass was taken as the platform circumnavigated the target. This produced desirable results in areas which accommodated parking stalls beneath structural overhang. Film and emulsion speeds for the first mission consisted of Kodak Ektachrome-X positive film (ASA 64) and Ilford Panchromatic negative film (ASA 125). Both cameras were set at infinite range and 1/250 second shutter speed. Consecutive fly-overs occurred every 15 minutes for 5 periods commencing at 11:30 a.m. As a sensor platform, the Bell 47·G2 helicoptor presented both advantages and disadvantages. The former consisted of the vehicle's capability to hover over a target, the capability to fly without the passenger door, and the protective bubble allowed ease of advance target sighting. Disadvantages consisted of the expense of chartering, the slow ground speed of 60-80 m.p.h. which limited its range and hence target selection if more than one target was to be studied in a consecutive manner, the compactness of the two-seat cockpit, and the vibration which presented a nuisance in recording details by writing. The vibration had no effect on the photography, due to the fast shutter speed and hand-held arrangement which damped the oscillations.

(ii) Mission 2:

Mission 2 was flown on Monday, July 28, 1975 between 11:30 a.m. and 1:00 p.m. The flight originated from Hamilton's Mount Hope Airport, and the vehicle was a Cessna '172' four-seat aircraft chartered from Hamilton Flying Club. The photographic sensors were identical to those used on Mission 1, but the camera mount was of a different design. In order to accommodate the small horizontally narrow window, the cameras were mounted on a horizontal bar bracket. A manual triggering mechanism provided nearly coincidental firing of both cameras. The weather during the second mission was sunny with few clouds and the platform ceiling was 10,000', more than ample to provide good imagery scale of the larger target.[8] Photographic tactics were identical to those used in the first mission. Film and emulsion speeds for the second mission consisted of Kodak Ektachrome-X positive film (ASA 64) and Kodak Panchromatic negative film (ASA 125). Both cameras were set at infinite range and 1/250 second shutter speed. Consecutive fly-overs occurred every 15 minutes for 5 periods commencing at 11:45 a.m. As a sensor platform, the Cessna '172' presented both advantages and disadvantages. The advantages consisted of the vehicle's

8. Refer to Appendix A, "Imagery Scales".

larger cockpit for baggage storage, greater speed, lighter vibration, reduced noise which allowed faster pilot-investigator conversations, and the capability to open the passenger window for a pass over the target. Disadvantages consisted of the greater speed of the vehicle which would present difficulty in investigating nearby targets, the wheel pods and wing struts which interfere with high oblique views and decreased flexibility in aiming the cameras. The platform configuration was not adequate for advance target sighting, and the window could not be locked open, presenting a safety of operation difficulty and rapid change in environmental conditions in the cockpit.

Imagery scales varied from 1:9,000 and 1:22,000 approximately for Mission 1 and Mission 2 respectively.

Prior to both missions, their planning reflected the following elements:

(i) the objective and goals of each mission;
(ii) the use of the imagery and target phenomena;
(iii) testing of cameras and films for operating capability and emulsion saturation; and,
(iv) the selection of date and time of day for each flight.

Immediately before each mission, the following preparations were undertaken:

(i) briefing of the pilot;
(ii) selection of the flight path; and,
(iii) preflight check of equipment and loading of the cameras.

Finally during the mission, three tasks other than the sensing which were undertaken were:

(i) in-flight calibration of the cameras;
(ii) selection of suitable altitude over the target; and,
(iii) recording of the sensing details.

Both missions flown were subject to a common assumption for reasons of cost, availability of qualified personnel, and documented recommendations. The assumption was that a time slice, or interval between successive frames would be 15 minutes, and not less. In general, such a study must not be confined to the duration of one hour, and should the mission last say 6 or more hours, with greater than 4 frames per hour taken, costs in terms of film, processing, and interpretation would increase significantly. The verification of the 15 minute interval study would entail placing observers at every point of access and egress, in order for them to undertake a license plate survey of inbound and outbound vehicles. This type of ground truthing would present considerable difficulty in acquiring data about employee parking and hence any attempt to develop them for this project was abandoned. The final reason for the assumption is based upon the Syrakis et al[9] report which recommends 15 minute time slices for any aerial parking study. Hence, the time interval between consecutive frames over one target was 15 minutes.

9. Ibid., page 27.

## 4. FILM CHARACTERISTICS

Before any mission may be undertaken, as implied in the previous section, certain details must be established. Of extreme importance is the resolution of the choice of recording media used in the mission which must be tested in terms of its capability to detect and record the target phenomena, as well as its capability to provide easily interpreted imagery. The choice must reflect the following considerations, beginning with the most basic elements.

Wenderoth, et al,[10] define colour as that aspect of visual perception by which an observer may distinguish between objects having the same size and shape. Colour has three characteristics: hue, saturation, and brightness. Hue is that characteristic which differentiates between different wavelengths of visible light. Saturation indicates the purity or amount of white contained in colour, white brightness is a measure of the amount of black in a colour.

The perception of colour is related to factors such as the radiant peak of the illuminating source (the solar disk),

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10. Sondra Wenderoth, et al, 1972, Multispectral Photography for Earth Resources, West Hills Printing Company, Huntington, New York, page 1-2.

environmental conditions which produce scattering and absorption of the sun's rays, and the angle of incidence of solar radiation brought about through latitude, time of day, and time of year. The above represent characteristics which affect the perception of colour prior to the incident rays striking the target. Once the radiation has struck the target, perceived colour is affected by the environmental conditions which exist between target and sensor, the target's reflectivity, and the material properties of the target. Perception is heightened by tonal contrasts between the target and its background. The registration of the target by the sensor onto the sensing medium is a function of lens characteristics (such as resolution: the number of line pairs/mm), filter characteristics (spectral region cut-offs), camera variables (such as shutter speed, f/stop, and correct calibrations) and film emulsion characteristics.

In general, commercial colour films, and definitely the one selected for these two missions are tripack in design. They consist of three emulsion layers sensitive to a different spectral region, and are blue, green, red respectively. Advantages associated with commercial colour films are that they give good to adequate rendition of colour, their short turn around time of processing, and their inexpense of use.

Disadvantages are the fixed exposure ratio of each layer of the emulsion to light, the fixed range sensitivity to colour in each layer, and the fact that once the film is exposed and processed, there is almost no way to alter the results.[11]

Commercial panchromatic films register red, green, blue, and ultraviolet radiation and have wide exposure latitude. Rather than producing a colour product, the targets captured on their emulsion may be deciphered by variations in gray tones brought about through different silver densities retained on the film following developing.

Films used during the first mission were: Kodak Ektachrome-X (64 ASA) and Ilford Panchromatic (ASA 125). The second mission utilized Kodak Ektachrome-X and Kodak Panchromatic (ASA 125). During the initial stages of mission planning, colour infrared film was considered and tested for use due to its widespread utility in the field of urban studies. The use of a Wratten No. 12 filter (yellow filter) coupled with this film permits film perception of green, red, and infrared radiation. The loss of the blue region of the spectrum in the resulting imagery prohibited its use in traffic studies

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11. Ibid., pages 1-1 to 2-4. (Wenderoth, et al have produced an informative manual on this topic.)

due to the consequent loss of the first discriminant of interpretation in this study (colour). Hence, the positive colour film and panchromatic films were used here.

Filters were not used in either mission due to the low altitudes and the clear conditions, despite the low ceiling in the first mission.

Film characteristics may be reviewed in the appropriate Technical Appendix.[12]

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12. Refer to Appendix B "Film Characteristics."

## 5. DATA EXTRACTION FROM THE IMAGERY

Following the film processing stage, the imagery assumed the following format: (a) colour 35MM slides from the Ektachrome-X positive films; and, (b) black-and-white prints (5" x 7") from the panchromatic films. Although cost is always a consideration in any venture, the total cost to acquire the prints exceeded that for the colour slides by a factor of six.

Instruments of precision such as the Richards MIM No. 1 light table with its travelling stereoscope offer 35mm colour slides as a viable alternative to black and white enlargements. The Richards light table is available for data extraction in a mono- and stereo-scopic mode and may be rigged to accommodate both positive film and prints of negative film. Its variable magnification capability makes it an extremely valuable instrument in this type of study. The Bausch & Lomb Zoom 240 transfer scope may also be used with both types of imagery, and should prints not be readily available, this instrument offers a mapping capability which is important at the outset of the data extraction stage in this analysis.

Data was acquired from the colour imagery in the following manner, using the ranked discriminants which were the vehicle's (1) colour; (2) type and size; and, (3) position in stall. From the black-and-white prints vehicle discrimination occurred via vehicle: (1) tone; (b) type and size; and, (3) position in stall. The colour film offered a greater range of first order disciminants compared to the black-and-white film and possessed a definite advantage in not exploiting physical weakness in the observer. Tonal contrasts in the panchromatic film prints were contained to three levels of gray; those being light, medium, and dark. The colour film did not offer satisfactory resolution between navy blue and violet hues. It was found in both cases that slight alteration in altitude and a change in photographic angle in relation to the sun affected the hues and tones slightly. Any questions concerning vehicle identification were solved via the second and third order discriminants.

The issue in the data extraction was the method by which vehicles could be identified in the parking stalls in each photograph. This necessitated a coding procedure by which the imagery elements were classified, and resulted in the following coded hierarchy:

(a) target/site designation;
(b) target partitioning designation;
(c) aisle designation;
(d) parking stall designation;
(e) stall vacant/occupied by vehicle designation: vehicel (colour/tone), type and size, position - in-stall designation;
(f) time of photograph.

(In the case of (e), vehicle type and size was used to establish that the vehicle was something other than a passenger car, while "position-in-stall" was used in interpreting whether a vehicle was actually parking, or driving through a stall.)

A change in target conditions detectable between consecutive frames would indicate the status of each stall, and in aggregation the occupancy and turnover of the parking demand over a time slice. Occupancy is the total number of vehicles demanding service during a time slice while turnover is the number of vehicles which have exited from the parking lot in a time slice, and have used a given service time. Time slice is the unit of time between consecutive frames and was a 15 minute interval in this study.

Other data to be extracted from the imagery included illegal parking, the effectiveness of the interval circulation system, the adequacy of the signing, the separation of delivery and consumer vehicles, and minimization of pedestrian-vehicle conflicts.

## 6. INTERPRETATION OF IMAGERY AND DATA ANALYSIS

### (a) Evaluation of the Imagery

The scales of the original imagery were 1:9,000 and 1:22,000 approximately in Mission 1 and Mission 2 respectively. The 1:9,000 scale by far presented a more easily interpretable format, so much so that the type and occasionally the make of vehicles could be deduced. The "5 in. x 7 in. prints" of the University Plaza increased the scale to approximately 1:1800.[13] Both the black and white prints and the colour slides as formats offered a variety of advantages and disadvantages in their use.

Although the scale had been changed to 1:1800 in the enlarged positive prints, there was no indication of graininess. The matte finish offered the opportunity to code the parking rows and stalls right on the print and hence eliminated the need to map the imagery prior to extracting the data. The gray tones reduced the capability of the first order discriminant and forced the frequent use of second and third order discriminants. This created a situation of visual

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13. Refer to Appendix A "Imagery Scales."

and hence physical fatigue in the investigator. The cost of the purchase and processing into the black-and-white prints exceeded that of the colour transparencies by 6 times, but was much less than that which would be incurred if colour prints were required.

The colour transparencies offered an inexpensive medium by which to record parking phenomena. The availability of colour allowed freely the use of the first order discriminant although the scale required that a mapping of the imagery take place prior to data extraction. This increased the time of interpretation somewhat but, the colour decreased the element of fatigue greatly and hence neutralized the loss of time in this regard. For display purposes, the transparencies must be printed which added slightly to the cost of using colour film. One complete set of exposures of each target during a pass is illustrated in Appendix C.

Hence, in general, if the appropriate viewing equipment is available, colour positive film is recommended as the recording medium for parking assessment and traffic studies, in terms of cost, the reduction of interpreter fatigue, the capability of using a first order discriminant, and user convenience.

(b) Analysis of the Imagery Extracted Data Concerning the University Plaza, Dundas, Ontario.

In general, the high oblique photographs taken from the circumnavigating platform offer a reasonable alternative to vertical stereophotos. They pose as a valuable and satisfactory source of data regarding the phenomena of parking. They do not, however, offer a reliable base from which to take accurate photogrammetric measurements, nor one from which accurate maps may easily be drawn.

The technique of data extraction has already been described in a general sense. In greater detail, the following methodology was developed for data extraction from the imagery of the first mission over the University Plaza:

(i) Using the Bausch & Lomb ZTS, rough oblique maps of magnification 3X (imagery scale) were drawn.

(ii) The target was then coded in terms of each row of stalls (A, B, C,...AA,...3A...) and every stall was assigned a number (1,2,...12). Example: If row "D" had only 5 stalls, then the coding was D1, D2, D3, D4, and D5, respectively.

(iii) For each flight over the target, the status of each stall was ascertained and noted.

A sample of a data sheet is illustrated in Figure 4.

| STALL | FRAME 1<br>11:30 am | FRAME 2<br>11:45 am | FRAME 3<br>12 noon | FRAME 4<br>12:15 pm | FRAME 5<br>12:30 pm |
|---|---|---|---|---|---|
| F 53 | B | Br | Br | Br | Br |
| 54 | W/Blk | W | M/W | | |
| 55 | T | G | R/W | Br | Br |
| 56 | | | Blk | B | B |
| 57 | B | R | G/Blk | G/Blk | R |
| 58 | G | T | T | S | S |
| 59 | R | | G/Blk | | B |
| 60 | G | G | Blk | Y | Y |
| 61 | S | T | B | | W |
| 62 | S/Blk | C/Blk | | B | B/Blk |
| 63 | Container | - | - | - | - |
| 64 | Container | - | - | - | - |
| 65 | B | T/Blk | | B | B |
| 66 | | B/Blk | | R/W | R/W |
| F 67 | G | G Trk | | R | Y/Blk |

<u>Figure 4</u>. Excerpt from Stall Occupancy Record, University Plaza, Mission 1, July 21, 1975. Each letter comprises a coded first order discriminant and vehicle type is considered to be a passenger car unless designated otherwise. A vacant frame vs. stall co-ordinate indicates an unoccupied stall.

From these procedures the following information was ascertained: (1) total supply of parking;
(2) demand for parking;
(3) duration of parking demand;
(4) parking accumulation;
(5) occupancy and turnover;
(6) incidents of illegal parking;
(7) effectiveness of internal circulation network;
(8) effectiveness of signing;
(9) effectiveness of modal separation of delivery vehicles and passenger cars;
(10) pedestrian-vehicle conflicts.

Pertinent calculations and deductions may be reviewed in the Technical Appendix section of this report. In order to maintain continuity, a summary of the findings is presented here.

In summary, the resulting analysis of the data extracted from imagery of the University Plaza contains the following facts and deductions.

The University Plaza is designed to accommodate 1000 vehicles.[14] Of the 605 vehicles observed in the five consecutive frames, only 444 vehicles were eligible for a

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14. Refer to Appendix D "Supply of Parking, University Plaza, Dundas, Ontario."

duration-of-parking measure.[15] Greater than 55% of the vehicles occupied their stalls for less than or equal to 30 minutes, which indicated that a rapid turnover of patrons occurred. Half of these vehicles occupied their stalls less than or equal to 15 minutes, and hence the parking design should accommodate these consumer habits. Only 19.7% of the vehicles occupied their stalls for a time between 45 and 60 minutes which suggested that few shoppers stayed for medium periods of time. The residual 25% of the vehicles which stayed greater than 60 minutes were attributed to staff parking. Illegal parking peaked at 3.1% of all vehicles per time slice and did not constitute any major threat to the efficiency of the internal circulation system.[16] The arrival of vehicles declined from the first, to the third time slice (12:00-12:15 p.m.) where it reached a minimum.[17] Departing vehicles peaked in the second and third time slices (11:45 a.m.-12:00 noon, and 12:00 noon-12:15 p.m. respectively.) In spite of the peaking in arrivals and departures in the third time slice, the occupancy remained relatively consistent, averaging 282 vehicles ± 2.5%. The pattern of parking design appears to have originated from the first parcel's development. With the two parcels now being developed, the internal circulation system

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15. Refer to Appendix E "Demand for Parking, University Plaza, July 2[illegible] 1975."
16. Refer to Appendix F "Incidents of Illegal Parking, University Plaza."
17. Refer to Appendix G "Parking Accumulation, University Plaza."

presents a confusing picture. Inadequate and contradictory pavement markings (directional signing) contribute little to the efficiency of internal circulation.[18] The central north-south corridor forms a major axis to the parking arrangement and yet forms a congested point of access and egress at the signalized intersection at Grant Boulevard. Its width has been reduced for the sake of providing a few extra parking stalls and hence acts as a bottleneck during all but the lowest input and output rates.[19] Modal separation of delivery vehicles and passenger cars is excellent, defined by restricting deliveries to the rear of all buildings and away from the bulk of marked parking areas.[20] Although there were no apparent pedestrian-vehicle conflicts in the aerial photographs, the parking design, and points of access and egress present pedestrian drivers and shoppers with a hazardous "no-man's land" situation.[21] With a large selection of apartment residences within one block of the plaza, pedestrian traffic would not appear unreasonable. Hence, the circulation system's design ought to reflect pedestrian safety.

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18. Refer to Appendix H. "Effectiveness of Internal Circulation Network, University Plaza."
19. Refer to Figure 5.
20. Refer to Figure 6.
21. Refer to Figure 7.


(a) Looking south from the intersection with Grant Blvd., the major axis with its lack of adequate signing and barriers creates a hazardous situation for motorists.

(b) Looking north along the major axis, the poor pavement markings offer a confusing route to drivers. The narrow passage opens possibilities for bottlenecks to occur at moment's notice.

Figure 5. The North-South Major Axis of the University Plaza, Dundas, Ontario: Area of Potential Congestion, and Extreme Hazard.

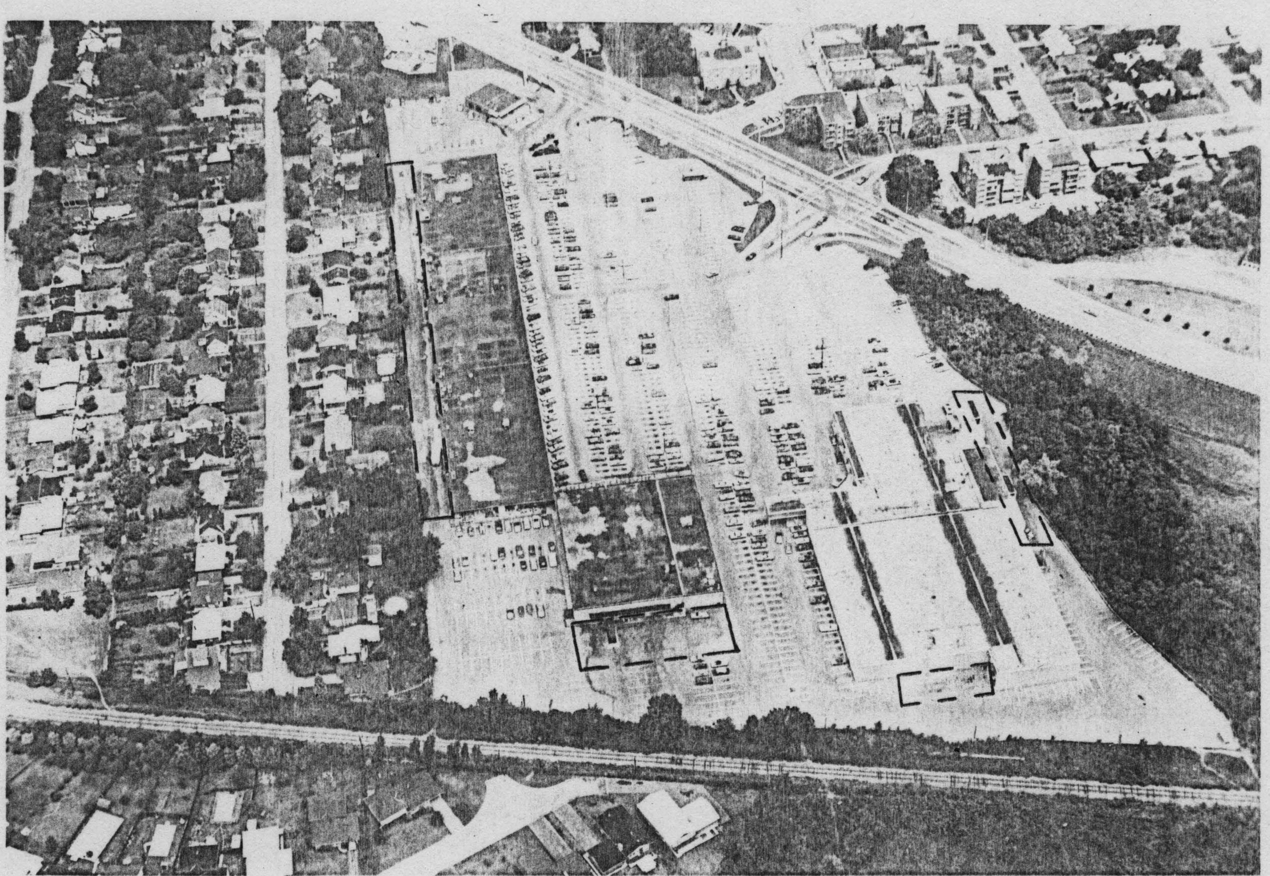

Figure 6. Modal Separation of Delivery Vehicles and Passenger Cars, University Plaza, Dundas, Ontario. Photograph is taken facing east at an altitude of about 1800'. With all deliveries to the rear and away from the bulk of the parking, modal separation is excellent. This is an example of good design in such facilities.

Figure 7. Pedestrian-vehicle conflict, University Plaza, Dundas, Ontario. The photograph was taken facing east along the corridor of rapid turnover.

The poor signing for vehicles, and the lack of some means by which to separate pedestrian and vehicular traffic offers a potentially dangerous "no-man's land" situation. Relinquished metal shopping carts present a nuisance and hazard to drivers.

In terms of interpretation of aerial photographs, the time and day of the mission over the University Plaza offered a unique opportunity by which to assess the intensity of use of the parking areas. The intensity of use may be assumed to be high/medium/low according to the degree of oil stains on the pavement.[22] The process is one of continuous deposition and evaporation via solar heat until the oil becomes a film of sludge. Asphalt, being oil based is not damaged by the residues, but if faulty will absorb them. Should the areas of sludge be utilized by traffic, eventually the residues will be carried off by the tires. Should the parking stalls contain such sludge in varying degrees, then their usage may be judged accordingly.

In general, Mission 1 has provided an excellent opportunity in which to establish a good technique by which to acquire remotely sensed imagery of parking, as well as a good format by which to extract parking assessment data from the imagery. This methodology may now be used to assess parking in any terminal of any size.

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22. Refer to Appendix I. "Deducing Stall Use by Pavement Stains."

## (c) Greater Hamilton Shopping Centre

Now that a methodology has been formulated, the repetition of the exercise is redundant. In the case of the Greater Hamilton Shopping Centre, the analysis will be treated in a different manner to that of the University Plaza. There is good reason for this change in analytical tactics. The reader is reminded that the two targets were quite different in form and function in spite of them both being retail consortia, and hence certain differences are likely to be present. For instance, the consumer's shopping time is quite likely to be larger at the GHSC by virtue of its size and contents. Should this be likely, the duration of the mission should be increased beyond the one hour for it to hold relevant meaning. In this case, the constraint of cost dictated the photographic time and hence restricted the data input concerning parking phenomena. Rather than repeat the original exercise, now an exercise of redundancy, the investigation should now explore tactics for the development of a methodology by which to analyse a target more complex than that of Mission 1, and, hence prepare for the mode of analysis used in Mission 1 for targets of greater size and complexity. The product of both analyses may then be used with confidence to assess parking in any terminal.

The following methodology reflects the procedures which should be undertaken in order to prepare for a parking assessment analysis of any terminal.

1. Define target boundaries.
2. Define all land uses within and external to the target boundaries.
3. Define the internal circulation system.
4. Define all points of access and egress to the target.
5. Define all parking areas associated with each land use and their supply of stalls.
6. Define all delivery areas.
7. Define all pedestrian access points to the site and to the structures on the site.
8. Determine where illegal parking occurs.
9. Determine the site's regulatory devices in terms of overhead, curb, and pavement signing.

The objective of the interpretive exercise is one of determining the organization of the target and its capability to accommodate effectively those traffic functions related to terminals: intake, storage, and discharge of vehicles in an efficient and safe manner.

By defining land uses within the site, the interpreter will be prepared for varying parking demand values. For areas of rapid turnover the local circulation network must be designed to offer maximum access and egress and this would be a key element for which to search. Regardless of target size, the internal circulation network should be logical in routing in order to assist vehicle operators to proceed to desired parking areas. The interface with the external roadway system defined by access and egress points is important in terms of delivering acceding vehicles to the internal network and offering sufficient storage areas when discharging from the site. The supply of stalls for each land use and in toto define whether the site conforms to existing bylaws and offers an explanation concerning future development potential. The definition of delivery areas and pedestrian routes offer indicators of circulation efficiency and safety. Illegal parking is an indication of misunderstood signing or driver (consumer) rejection of existing parking and signing devices. Finally, regulatory devices, although not legally binding on private property define efficiency in the circulation network.

The exercise undertaken in this paper for the secondary target reflects the derived methodology above.

The target was found to be bounded by three arterial streets and a slightly elevated multiple rail line to the north. The surrounding land uses are small lot single family residential dwellings with the exception of retailing along the southern side of the southern arterial and the large industrial plant (Dofasco) to the north-west.[23] Within the site, land uses appear to be residential, vacant, scattered unit retailing, automotive, a converted gasoline station, a car dealership, a mall with end department stores, an unusual storage or display area, a retailing store of extremely high turnover, and an undiscernable land use on the south-west corner which when ground truthed realized as the Jockey Club Tavern. In terms of parking assessment, the area of high turnover deserves careful consideration while the expected demand on the scattered unit retailing stalls ought to be medium in terms of duration of parking. Similarly the duration ought to be high in terms of the mall and end retailing stores.

The residential, and car dealership uses are removed from the bulk of the site's parking area. The internal circulation network[24] consists of two concentric rings which offer access to parking and delivery areas. The outer ring is better defined and does not interfere with delivery stalls. There appear to be six lanes of access and ten lanes of egress, with storage areas of approximately 3 vehicles in most intake and discharge points. Six formal and five informal (across the rail lines) pedestrian routes encounter the site. Despite the

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23. Refer to Figure 8.

24. Refer to Figure 9.


Figure 8. Defining the Land Uses External to the Target Site, GHSC. The photograph was taken facing north at about 3900'. Scale is approximately 1:1800.

Legend: C Commercial-Retail

I Industrial (Dofasco)

R Residential (predominantly small-lot single-family housing).

Figure 9. Circulation System Elements. GHSC.

Legend:
- A Outer ring road
- B Inner ring road
- C Arrows denote direction of vehicle movement at access/egress points
- D Pedestrian routes (informal)
- E Pedestrian routes (formal)
- F Delivery areas

well marked aisles and design to allow maximum parking and minimum walking distances, some illegal parking does occur. The total supply of parking stalls, excluding the car dealership and the undefined land use in the south-west corner (the Jockey Club), consists of 4360 places, some 13% fewer than advertised (5000 stalls).[25]

Ground surveys identified the respective land uses and from sampling the parking vehicles from the aerial photographs, the following parking duration information was obtained:

| Parking Duration (minutes) | | Land Uses |
|---|---|---|
| short term: | less than 15 | Brewers Retail |
| " " | 15 - 30 | Canadian Tire (and Cinemas) |
| medium term: | 30 - 45 | Dominion, Loblaws |
| " " | 45 - 60 | Central North parking lot (GHSC) |
| long term: | greater than 60 | All other uses and lots, including the vacant land (Dofasco employees.) |

The exception to these findings was the lot at the south-east periphery where parking was divided into short term and long term durations. The former parkers probably consisted shoppers at the arterial road stores, while the latter, like

25. Refer to Appendix J. "Supply of Parking, Greater Hamilton Shopping Centre."

most peripheral users were employees of the site. Occupancy during the time of the second mission increased from 1614 vehicles to 1947 vehicles, peaking at 12:30 p.m.[26]

In general, the Greater Hamilton Shopping Centre provides an orderly picture from the air of an effective parking and circulation system. From the ground, it presents a different conclusion. Advance signing at the access points is poor and the conglomeration of land uses on the site is confusing. The undeveloped land, following a heavy downpour becomes a quagmire. Separation of delivery vehicle and passenger cars is poor[27] and deliveries to the Centre Mall stores with the efficiency of the inner ring roadway.[28] Deliveries to the scattered unit retailing are more efficient in this context. Incidents of illegal parking were scarce, reaching a maximum of 22 vehicles (1.2% of the total parking demand, both legal and illegal).[29] Pedestrian safety is mixed in conclusion, because part of the site accommodates pedestrians in separated walkways while other areas force them to cross high turnover areas and poorly marked roadways without crosswalks or driver warning signed areas.

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26. Refer to Appendix K. "Occupancy Values for GHSC"
27. Refer to Figure 9.
28. Refer to Figure 10.
29. Refer to Appendix L. "Incidents of Illegal Parking, GHSC."

Figure 10. Congestion along south side of inner ring road, GHSC, created by lack of separation of passenger cars and vehicles making deliveries to the central mall.

Despite the above criticism, for a site with such a variety of land uses, the GHSC presents a reasonable circulation network whose efficiency must be rated as good. With a variety of cosmetic changes such as increased signing and pavement markings,[30] the network's efficiency would improve the little it needs to make it extremely high.

In general, Mission 2 has provided an excellent opportunity to define an interpretation methodology by which to divide a complex terminal into parsimonious elements prior to data extraction concerning parking assessment. This methodology may be universally used in a parking assessment study of any terminal.

30. Refer to Figure 11.

Figure 11. The Need for Changes in Pavement Markings and Signing, GHSC. Picture is taken facing north along the outer ring road, east side of the site. The lack of pavement markings and signing at the point of integration of the ring road and a three lane access point creates a nuisance and hazard to drivers.

## 7. STUDY RECOMMENDATIONS

The recommendations derived from this research are grouped into two categories and presented as: (a) remote sensing techniques, and (b) imagery interpretation techniques.

(a) Remote sensing techniques.

(i) Compared to panchromatic black and white film, colour positive film is recommended for use in parking assessment studies due to its cost, flexibility in interpreter use, reduction in interpreter fatigue, and time in data extraction.

(ii) The larger is the scale of the imagery, the easier it is to discriminate between vehicles, and hence platform altitudes should be kept small in parking assessment studies.

(iii) A constant platform altitude and consistent exposures in relation to the sun will produce consistent emulsion colours making vehicle discrimination less fatiguing.

(iv) If vertical stereo-photographs are unable to be obtained, then high oblique photographs from at least two sides of the terminal will produce imagery of sufficient detail in terms of parking assessment. Photogrammetric measurements cannot be made easily from oblique photographs.

(v) Either fixed wing or helicoptor platforms can be used in hand-held sensor studies. Each platform has its own relative merits and disadvantages in terms of cost, speed, range, internal space, vibration, noise, configuration, operating safety, and cockpit environmental conditions.

(vi) Through-the-lens light metering (TLM) systems on the Asahi Pentax cameras offer a definite advantage for obtaining good exposures under varying light conditions. To minimize wrong exposure conditions, cameras with TLM's coupled with automatic exposure controls should be used. Electric film drives would prove helpful.

(vii) A black and white panchromatic film should be used as an inexpensive back-up recording medium when a mission requires a colour positive film. The cost of the panchromatic film, without prints, is approximately 25% that of colour positive film, and provides an inexpensive safety margin.

(b) <u>Imagery interpretation techniques</u>

(i) Prior to extracting parking assessment data from the imagery, site and circumstance information must be obtained via air photo interpretation. These details will indicate parking demand variables, the effectiveness of the terminal's internal circulation network, its character in relation to interfacing with the external roadway system, delivery vehicle/passenger car conflicts, pedestrian/vehicle conflicts, and general site design merits and disadvantages. Ground surveys will provide accurate land use information.

(ii) Parking assessment data can be efficiently extracted by coding the site in terms of designating the target, target partitions, rows, and stalls, by photographic frame, and hence time. Each stall's status by time slice can be developed via coding vehicle occupation by vehicle colour, type and size, and disposition in the stall.

## 8. CONCLUSION

There are several conclusions which may be gleaned from this study. The most significant one is that remote sensing offers an extremely potent source of data when considered for parking assessment studies. Its advantages over conventional ground based studies are cited by the five characteristics which remotely sensed data possess: accessibility, compatibility, flexibility, reliability, and timeliness.[31]

The successful use of hand-held 35mm cameras for this research must not be overlooked. The cost of acquisition of full scale parking assessment imagery, although high for a university research project, must be considered as extremely low for a municipal agency or consulting firm involved with such a study, when compared to conventional ground based data acquisition methods. The cost of acquisition of the imagery would be determined by the study duration which would normally be about 8 hours, rather than the 1 hour utilized in this research, which was dictated by the constraint of cost.

31. Refer to Chapter 2 of this report.

Although remote sensing in urban studies has made enormous successes with the use of colour infrared film, such an emulsion is not suitable for parking assessment studies, nor in any traffic related studies in which vehicle colour acts as a prime discriminant. Colour positive film is recommended for use should the appropriate viewing equipment be available.

In relation to conventional ground surveys remotely sensed imagery presents two distinct advantages about which little is mentioned. The imagery records characteristics about the population of elements of the target, rather than that of a sampling. It also occupies small storage space, and from this, data may be reconstituted quickly should they be required. This represents an unprecedented user convenience, in situations where field checks would be impossible to carry out, especially in relation to dynamic targets (i.e.) traffic phenomena.

Although Black and White enlargements of matte finish have been used satisfactorily in this report, colour prints of matte finish would provide the same capability by which to illustrate parking assessment and internal circulation system deficiencies, but would have enhanced the report in terms of illustrating its flexibility in interpretation. Their cost prohibited such an addition to a university research report.

Finally, the methodology developed in this research report may universally be used in parking assessment studies of all terminal and off-street parking sites.

# TECHNICAL APPENDICES

## TECHNICAL APPENDICES

Appendix A. "Imagery Scales"

Imagery scale(s) is calculated from the following relation: $S = \frac{f}{H-h}$, where f = focal length of lens
H = platform altitude
h = ground elevation (A.S.L.)

(a) Mission 1

f = 50mm = 0.165'
H = 1800' - 2000'
h = 330'

$$\frac{0.165}{1800-330} \geqslant S \geqslant \frac{0.165}{2000-330}$$

$$\frac{1}{8900} \geqslant S \geqslant \frac{1}{9500} \quad \text{or} \quad S \approx 1:9{,}000$$

(b) Mission 2

f = 50mm = 0.165'
H = 3900'
h = 330'

$$S = \frac{0.165'}{3900-330} \approx \frac{1}{22{,}000}$$

(c) Scale of B/W, and Colour Prints

Enlargement scale = Film scale x enlargement factor

Enlargement factor = ratio of any dimension of enlargement to original (i.e.) $L_{enlargement} : L_{original}$

$= W_{enlargement} : W_{original}$

....Cont'd

where $^{L}$ enlargement = $6\frac{1}{2}$"

$^{L}$ original = 1 3/8"

and "original" is the 35mm slide or negative.

Thus Enlargement Factor = $6\frac{1}{2} \div 1\ 3/8 \approx 5x$

Thus Enlargement Scale = Film scale x 5

Thus Enlargement scale, University Plaza

= (1:9000) x 5 = 1:1800

and Enlargement Scale, GHSC

= (1:22000) x 5 = 1:4400

Where University Plaza Film Scale = 1:9000, and GHSC Film Scale = 1:22,000.

Appendix B. "Film Characteristics"

Mission 1, Monday July 21, 1975.

Ilford, FP4, Panchromatic Black and White, ASA 125.
Grain: very fine; resolving power: high

Kodak Ektachrome-X*, Colour Positive, ASA 64

Mission 2, Monday, July 28, 1975.

Kodak, Plus-X, Panchromatic Black and White, ASA 125
Grain: very fine; Resolving Power: high

Kodak Ektachrome-X*, Colour Positive, ASA 64.

* To give meaning to this appendix, a photocopy of published Kodak material is included. The source is: Kodak, 1971, "Sensitometric and Image Structure Data for Kodak Color films," Publication E-78, Eastman Kodak Company, Rochester.

# Sensitometric & Image Structure Data for KODAK Color Films

Most photographers do not need sensitometric and image structure data for the Kodak color films they use. For practical use in getting good color pictures, the information given in *KODAK Color Films* (Publication No. E-77) is reasonably complete. Further practical information useful in the handling, exposing, and processing of Kodak color films is available in the *KODAK Color DATAGUIDE* (Publication No. R-19).

There are some photographers, however, who require additional information about Kodak color films. Photographic technicians, scientists, and engineers often need to know how a particular color film will record certain tones and colors or at what percent response the film will record detail of what size.

This packet of data sheets has been prepared to provide the technical community with sensitometric and image structure information for the Kodak reversal and negative films used in still cameras and for the Kodak films used for making transparencies and slides from negatives and transparencies in photographic laboratories. As new products are introduced, the contents of the packet are changed, but it is not always possible to include data sheets for all the current products in these categories. If you do not find in this packet a data sheet for a film in which you are particularly interested, request a copy from Department 412-L, Eastman Kodak Company, Rochester, New York 14650. It will be sent to you without charge as soon as it is available. Please ask for *sensitometric and image structure data* and give the complete film name (and number if known).

There are slight variations in the manufacture of any product. The data given in the enclosed data sheets were obtained from measurements made from representative production films under the conditions of exposure and processing specified. They do not apply directly to a particular box or roll of photographic material, nor do they represent standards or specifications which must be met by Eastman Kodak Company. Further, the company reserves the right to change and improve product characteristics at any time.

The appearance and utility of a photographic record are closely associated with the sensitometric and image-structure characteristics of the film used to make the record. Sensitometry is concerned with the measurement of the response of photographic materials to electromagnetic radiation. Image-structure properties are important in determining the extent to which the film can faithfully record information.

The degree to which sensitometric capability is realized, as well as the structure of the image obtained, depends on the manner in which the film is exposed, processed, and viewed. There is no unique relationship between exposure and ultimate density, because the derived density is influenced by additional elements. The wavelength of the exposing light and the variables in processing, among other factors, affect the nature of the image in varying degrees. The structural details of the densitometer used to examine the image affects the magnitude of the density values. Similarly, an image-structure property, such as the resolution obtained, depends on the contrast of the subject, the manner in which the film is exposed and processed, the optical system, the spectral quality of the exposing radiation, and the technique of evaluation.

The values of the parameters used to express the various film properties, as determined under laboratory conditions, may be slightly different from the values as measured in a practical application. Nevertheless, the data from such laboratory tests permit valid comparisons between materials for use in selecting the film best suited to the intended application. If an application requires high overall performance, final tests of the film and other components must be made under conditions that match, as nearly as possible, those expected in practice.

Furthermore, film properties are likely to be affected by the age of a sample and the manner in which it has been stored. All of the data presented in this packet have been obtained with samples that were relatively fresh, and therefore represent materials as delivered by the manufacturer and stored for a few months under recommended conditions. The rate of change of various characteristics due to aging can be different for various photographic materials. In addition, some materials are affected by adverse storage conditions more than are others.

## CHARACTERISTIC CURVES

The sensitometric properties of films are best represented in a graphic form that illustrates the relationship between photographic densities and the exposures used to produce them. These curves are known by various names: characteristic curves, D-log E curves (density versus log exposure), and H & D curves (after Hurter and Driffield, who originated the method). Normally, the density values are plotted as ordinate values (vertical scale), while the exposure values are plotted as abscissa values (horizontal scale) in logarithms (to the base 10) of meter-candle-seconds (mcs).

The response of a film may vary with changes in the spectral distribution of the exposing light. In sensitometric tests, therefore, the light used to expose the film usually simulates to a very close degree that to which the film is normally exposed in practice. In laboratory sensitometric exposing equipment, appropriate combinations of filters and artificial light sources produce close approximations of the desired spectral distributions. For making sensitometric exposures, a specially constructed step tablet in contact with the photosensitive surface modulates the corrected exposing light. This step tablet consists of a strip of film or glass containing a series of densities which vary the illumination reaching the sample, according to the transmittance of the individual steps. Exposure time is constant for a given sample. Such practice simulates most picture-taking situations, in which an object modulates the light over a wide range of illuminance, causing a range of exposure values on the film.

In the laboratory, the processing of sensitometrically exposed strips of film takes place in a machine designed specifically for the purpose—one capable of extremely precise control. This sensitometric processor provides consistently reproducible agitation, maintains a constant temperature of the processing liquids, and controls the time of immersion in each solution to the second. Processing conditions that differ from those employed in the sensitometric processing machine may not necessarily duplicate the laboratory sensitometric results.

Densitometric measurements of the processed sensitometric strip provide the basis for the characteristic curves. Status densitometry refers to measurements made on a densitometer that conforms to a specified *unfiltered* spectral response (see *Response Functions for Color Densitometry,* by G. H. Dawson and W. F. Voglesong[1]). When a set of carefully matched filters, such as the KODAK Densitometer Filter Set AA (Certified), is incorporated in the densitometer, the term Status A densitometry is used. The densities of color positive materials (reversal, duplicating, print, and slide films) are measured by Status A densitometry. When a set of carefully matched filters such as the KODAK Densitometer Filter Set MM (Certified) is incorporated in the densitometer, the term Status M densitometry is used. The densities of color negative films (color negative, internegative, and copy films) are measured by Status M densitometry. (Certified KODAK Densitometer Filter Sets are purchased directly from the manufacturers of densitometers. For further information, contact the densitometer manufacturer.)

[1]*Photographic Science and Engineering,* Vol. 17, No. 5 (September-October 1973), 461-468.

## SPECTRAL SENSITIVITY CURVES

Spectral sensitivity refers to the response of a color film to radiation of various wavelengths. Three spectral sensitivity distributions are shown in the spectral sensitivity curves—one each for the red-sensitive (cyan-dye forming), the green-sensitive (magenta-dye forming), and the blue-sensitive (yellow-dye forming) emulsion layers. In the laboratory, the test film sample is exposed to bands of radiation 10 nanometers wide throughout the spectrum, and the sensitivity is expressed as the reciprocal of the exposure (in ergs/cm$^2$) that is required to produce a specified density.

The specified density is as follows:

For reversal films—an equivalent neutral density (END) of 1.0.

For direct duplicating, slide, and print films—END of 1.0 above D-min.

For negative films—a density of 1.0 above D-min.

The measurement of spectral sensitivity is discussed in *The Theory of the Photographic Process.*[2]

## SPECTRAL DYE DENSITY CURVES

Spectral (diffuse) dye density curves for reversal, duplicating, slide, and print films represent normalized dyes to form a visual neutral density of 1.0 for a specified viewing and measuring illuminant. Reversal sheet films, which are generally viewed on illuminators, are measured with an illuminant having a color temperature of 5000 K. Reversal roll films and slide films, which are generally viewed by projection, are measured with an illuminant having a color temperature of 3200 K.

Spectral dye density curves for negative films represent typical densities for a mid-scale neutral subject and for minimum density. The density measurement of color film images is discussed in *The Theory of the Photographic Process.*

## IMAGE QUALITY AND IMAGE STRUCTURE DATA

The detail quality of a photographic image cannot be measured completely by one type of test or expressed by one number. Resolving power test data give a reasonably good indication of image quality. However, because they are descriptive of the limit of the capacity of a photographic system or system component to record detail, they do not indicate how well the system (or component) will reproduce detail of sizes somewhat larger than the limit. For more complete analyses of detail imaging, other evaluating methods such as the modulation transfer function and film granularity are often used.

The resolving power figures given on the data sheets are to the nearest figure given in the ANSI sequence. Because of this, two films may have the same listing while one may actually resolve the test chart slightly better than the other. To compare the detail imaging characteristics of two films, look at both high- and low-contrast resolving power listings, the MTF curve, and the granularity value.

[2]C. E. Kenneth Mees and T. H. James (eds.), *The Theory of The Photographic Process* (3rd. ed.; New York: Macmillan, 1966).

**Resolving Power.** The resolving power of a film refers to the limit of the ability of the film to record fine detail distinguishably. Resolving power is also referred to as *resolution.* In measuring resolving power, a parallel-line test chart is photographed, usually at a great reduction in size. The lines on the test chart are separated by spaces of the same width as the lines. Test charts usually contain many target elements of various line sizes. Examination of the film image with a microscope determines the target element with the greatest number of lines per millimeter which are distinguishable, light from dark, in the test film. The higher the number of lines per millimeter that can be distinguished, the higher the resolving power.

Resolving power data, as published herein, is determined according to a method similar to the one described in ANSI Standard No. PH2.33-1969, *Method for Determining the Resolving Power of Photographic Materials.*

Resolving power values are given for two test-object contrasts (TOC), 1.6:1 and 1000:1. The 1000:1 TOC value can be classified by descriptive adjectives according to the following chart:

| 1000:1 TOC | Classification |
|---|---|
| 50 or below | Low |
| 63, 80 | Medium |
| 100, 125 | High |
| 160, 200 | Very High |
| 250, 320, 400, 500 | Extremely High |
| 630 or above | Ultra High |

**Modulation transfer function** is a measurement used to describe the ability of films, lenses, and other optical components to reproduce the detail contained in an object. Modulation transfer characteristics of a film indicate the effects on the microstructure of the image caused by diffusion of light within the emulsion.

To obtain these data, patterns having a sinusoidal variation in illuminance in one direction are exposed onto the film. The "modulation," $M_o$, of each pattern can be expressed by the formula

$$M_o = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$ , in which E represents exposure.

After development, the photographic image is scanned in a microdensitometer, the densities of the trace are interpreted in terms of exposure, and the effective modulation of the image $M_i$ is calculated. The modulation transfer factor is the ratio of the modulation of the developed image to the modulation of the exposing pattern, or $\frac{M_i}{M_o}$. The modulation transfer curves show a plot of this ratio (on a logarithmic scale) as a function of the spatial frequency of the patterns in cycles per millimeter.

By multiplication of ordinates of the individual curves, the modulation transfer data for a film can be combined with similar data for the optical system with which it will be used, to predict the final image-detail characteristics.

More detailed information on this subject can be found in *Methods for Analyzing the Photographic System, Including the Effects of Non-linearity and Spatial Frequency Response,* by G. C. Higgins;[1] *Methods of Appraising Photographic Systems,* by F. H. Perrin;[2] and *Measurements of Sine-Wave Response of a Photographic Emulsion,* by R. L. Lamberts.[3]

**Granularity and graininess** are terms that are often confused and used interchangeably in discussions of the uniformity of silver or dye deposits in photographic emulsions. The *granularity* of photographic materials is defined as a mathematical summary of the spatial variations of density that are measured when numerous readings are made with a densitometer having a sufficiently small aperture. Granularity is a purely objective or measured quantity. *Graininess* is subjective and is often defined as the sensation of nonuniformity in an image that is produced in the mind of the observer when the image is viewed. It is usually not "seen" in the film image directly, but in enlargements made from that image.

Granularity measurement data as published herein are expressed as Diffuse RMS Granularity Values. This value represents 1000 times the standard deviation of density produced by the granular structure when a uniformly exposed and developed sample is scanned with a densitometer calibrated to read American National Standard diffuse visual density (PH2.19-1959). The measurements, made with a 48-micrometer diameter aperture, will indicate the magnitude of the graininess sensation produced by viewing the diffusely illuminated sample with 12X monocular magnification. If the viewing magnification is changed, the rms values may no longer correlate with the relative graininess sensation. RMS (root-mean-square) is a mathematical term used to characterize deviations from a mean value.

Reversal and direct duplicating color films are measured at a gross diffuse density of 1.00. Negative, internegative, slide, and print color films are measured at a net diffuse density of 1.00.

The granularity values can also be given graininess classifications according to the following chart:

| Diffuse RMS Granularity Value | Graininess Classification |
|---|---|
| 45, 50, 55 | Very Coarse |
| 33, 36, 39, 42 | Coarse |
| 26, 28, 30 | Moderately Coarse |
| 21, 22, 24 | Medium |
| 16, 17, 18, 19, 20 | Fine |
| 11, 12, 13, 14, 15 | Very Fine |
| 6, 7, 8, 9, 10 | Extremely Fine |
| less than 5, 5 | Micro Fine |

For further information on graininess and granularity, see Kodak Publication No. F-20, *Understanding Graininess and Granularity.* A single copy can be obtained on request from Eastman Kodak Company, Department 412-L, Rochester, N. Y. 14650.

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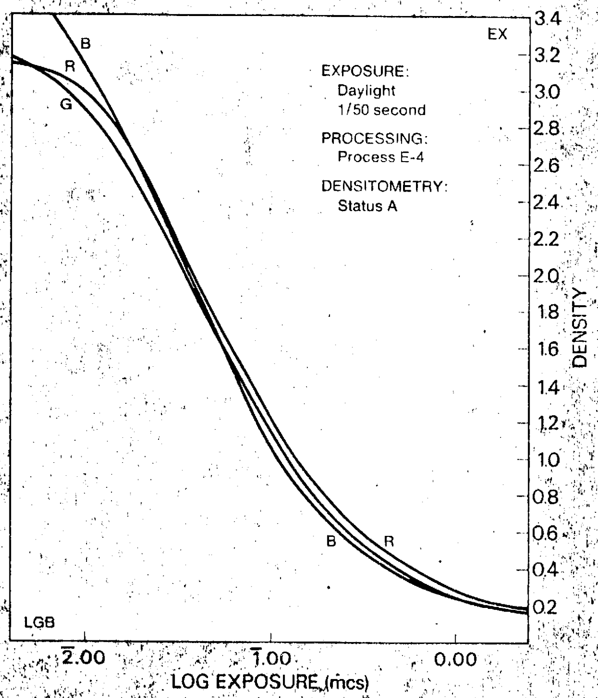
[1] *Photographic Science and Engineering,* Vol. 15, No. 2 (March-April 1971), 106-118.

[2] *Journal of the Society of Motion Picture and Television Engineers,* LXIX (March 1969), 151-156; (April 1960), 239-249.

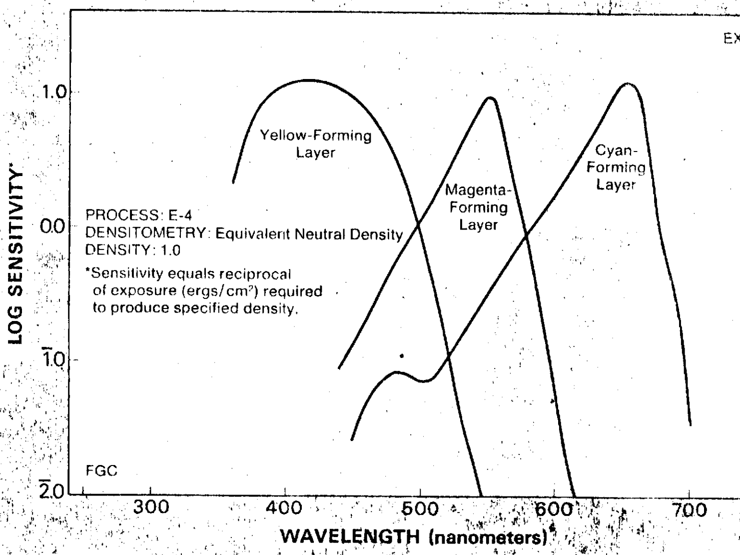
[3] *Journal of the Optical Society of America,* XLIX (May 1959), 425-428

# KODAK EKTACHROME-X Film

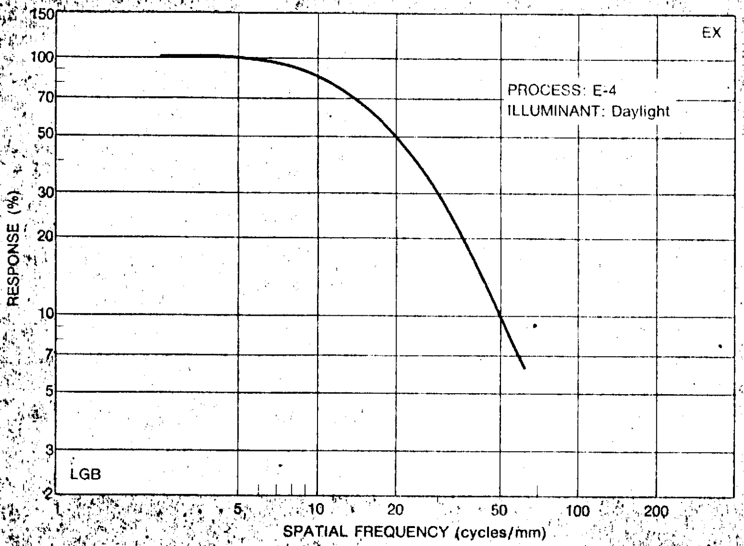
## CHARACTERISTIC CURVES




## SPECTRAL SENSITIVITY CURVES

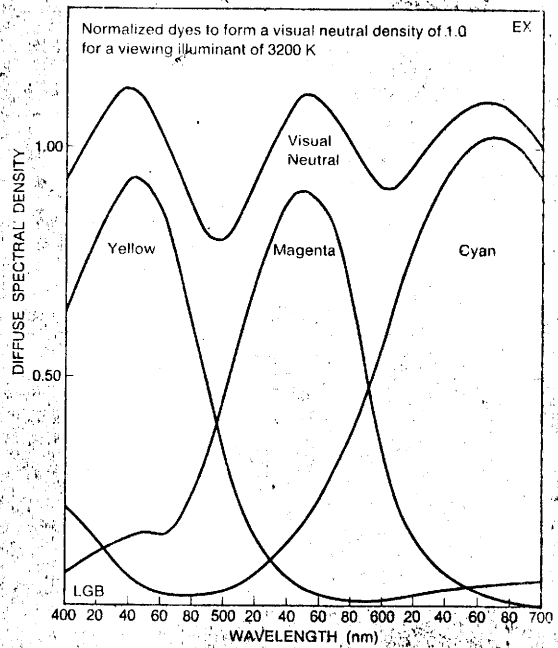



## MODULATION-TRANSFER CURVE




(Granularity and resolving power values on other side)

## SPECTRAL DYE DENSITY CURVES




**NOTICE:**
**The sensitometric curves and data in this publication represent product tested under the conditions of exposure and processing specified. They are representative of production coatings and, therefore, do not apply directly to a particular box or roll of photographic material. They do not represent standards or specifications which must be met by Eastman Kodak Company. The company reserves the right to change and improve product characteristics at any time.**

**DIFFUSE RMS GRANULARITY VALUE:** **12**

(Read at a gross diffuse density of 1.0, using a 48-micrometer aperture, 12X magnification.)

**RESOLVING POWER VALUES:**

| | |
|---|---|
| Test-Object Contrast 1.6:1 | 40 lines per mm |
| Test-Object Contrast 1000:1 | 80 lines per mm |

(Determined according to a method similar to the one described in ANSI Standard No. PH2.33-1969, *Methods for Determining the Resolving Power of Photographic Materials.*)

## BRIEF SUMMARY OF OTHER DATA

**Film Description:** For color slides in daylight, with blue flashbulbs, or with electronic flash. Can be processed by the user, Kodak, or other laboratories.

**Sizes:** EX120, EX126-20, EX127, EX135-20, EX135-36, EX620, EX828

**Speed and Exposure:**
ASA 64—Daylight—No filter
ASA 20—Photolamp (3400 K)—No. 80B Filter
ASA 16—Tungsten (3200 K)—No. 80A Filter

**Reciprocity Information:**

| Exposure Time (Seconds) | 1/50,000 to 1/10 | 1 | 10 |
|---|---|---|---|
| Exposure Increase | None | + 1 stop | + 2 stops |
| CC Filter | No Filter | No Filter | CC15Y |

**Storage:** Keep unexposed film in original sealed package at normal room temperatures. Place unopened packages in refrigerator if higher-than-normal room temperatures are likely to occur. Process exposed film as soon as is practical. Protect transparencies from dust and fingerprints, storing them at 21 C (70 F) or less at a relative humidity between 15 and 50 percent.

**Safelight:** Total darkness.

**Processing:** Process E-4 chemicals.

Professional and Finishing Markets Division
**EASTMAN KODAK COMPANY • ROCHESTER, N..Y. 14650**

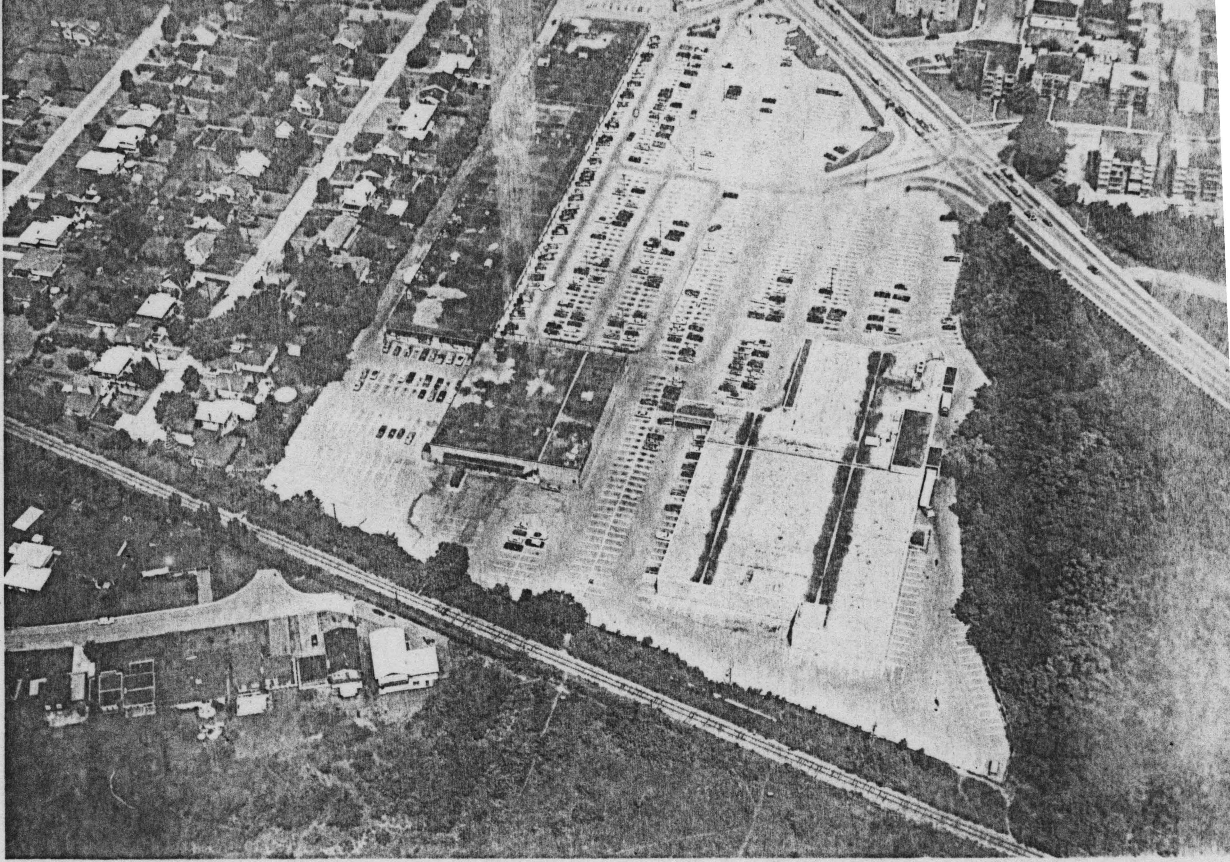
KODAK EKTACHROME-X Film
Kodak Publication No. E-78-3

New Publication 1-74AX

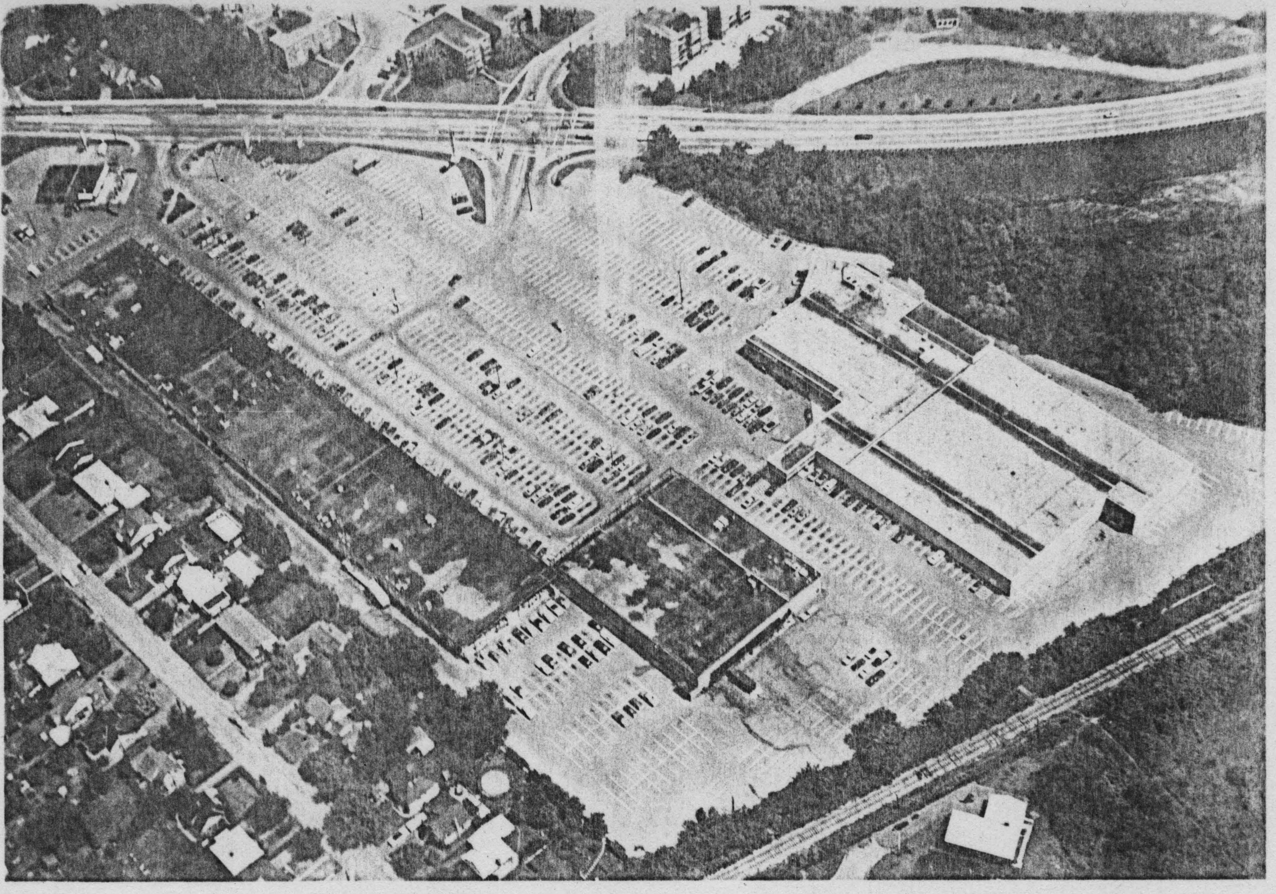
Appendix C. "Imagery Comparison for Each Target"

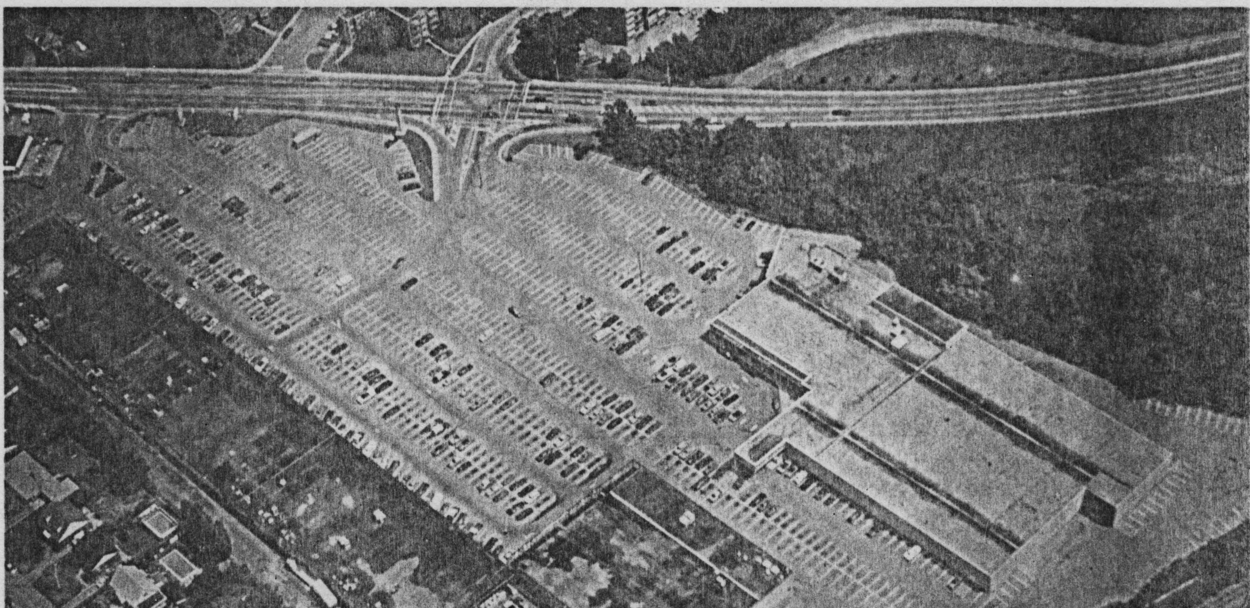
The first set of photographs represent the University Plaza imagery. Imagery scale is approximately 1:1800. The photographs were taken at an altitude of approximately 2000'. Note the nearly coincidental capture of target phenomena using the manual camera shutter mechanism.

The second set of photographs represent the Greater Hamilton Shopping Centre. Imagery Scale is about 1:4400. The photographs were taken at an altitude of approximately 3900 feet. The conversion of the colour slides into colour enlarged prints has reduced the clarity of the imagery.

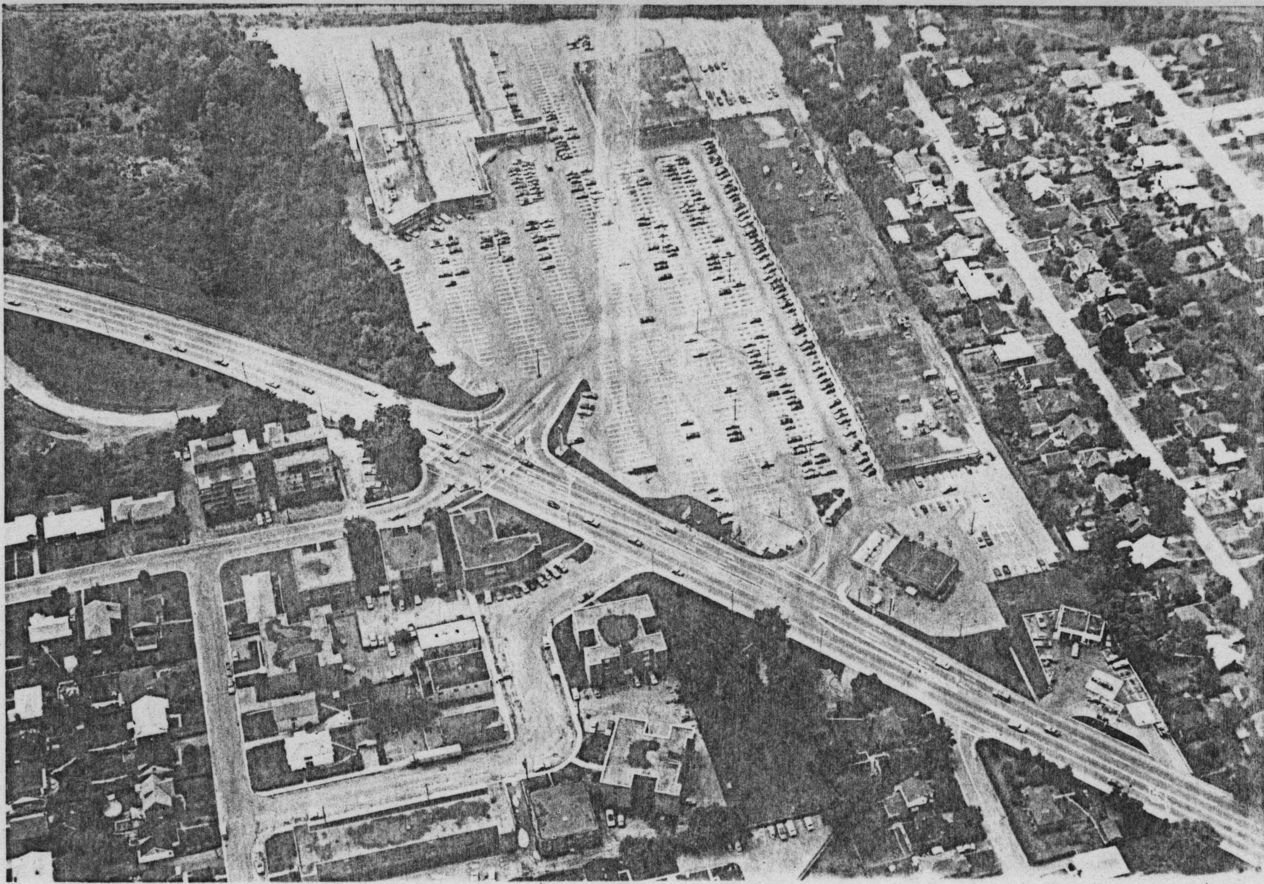


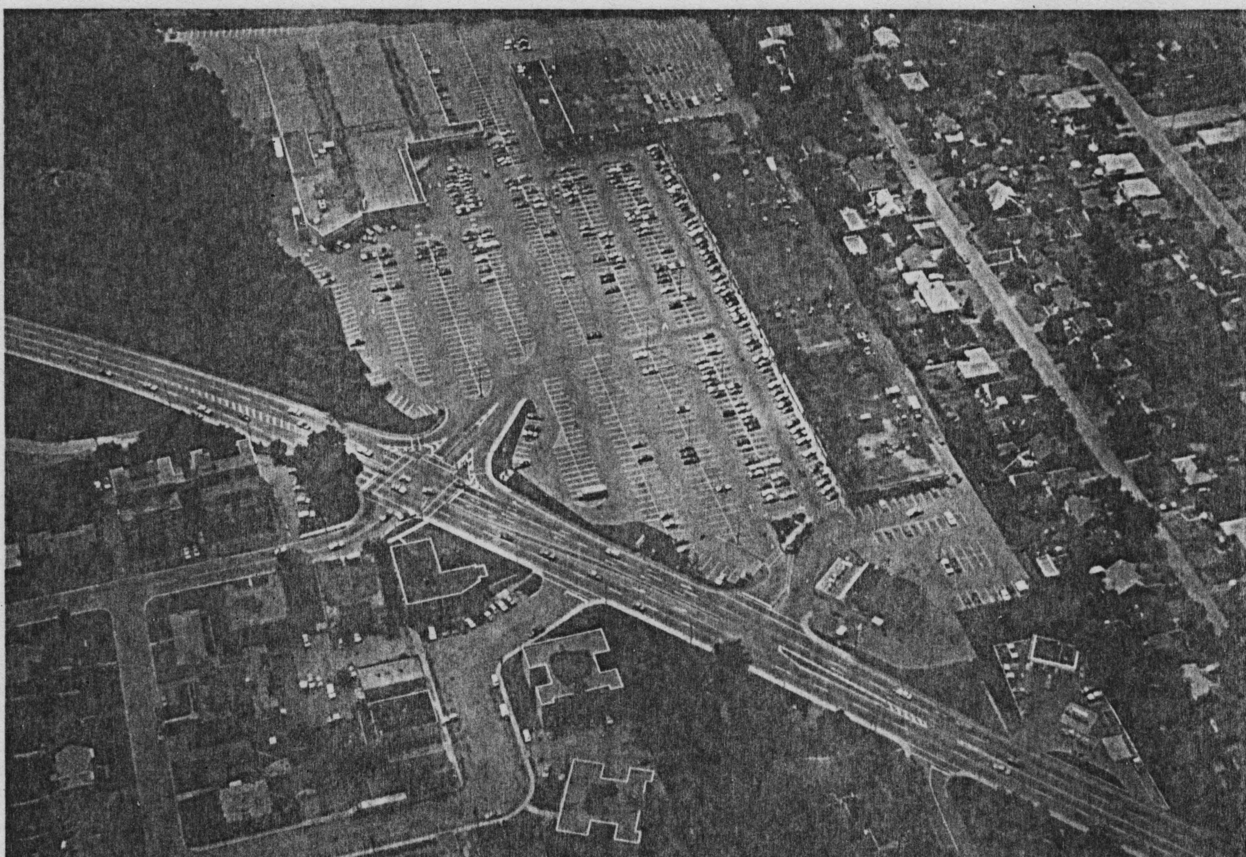
University Plaza, Dundas, Ontario: facing west, noon, 21/07/75.





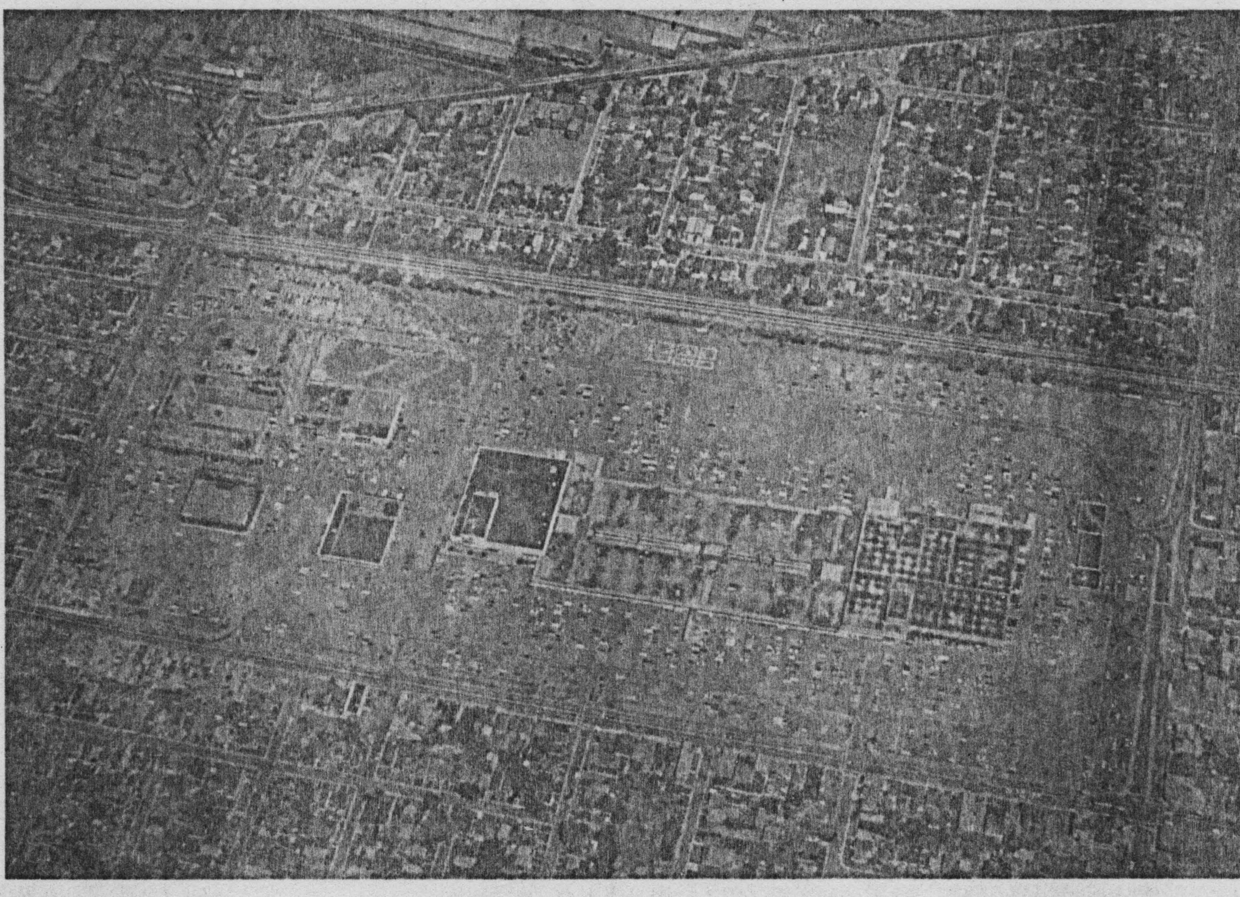
University Plaza, Dundas, Ontario, facing north, noon, 21/07/75.





University Plaza, Dundas, Ontario: facing east, noon, 21/07/75.

Greater Hamilton Shopping Centre: facing south, noon, 28/07/75.



Greater Hamilton Shopping Centre: facing north, noon, 28/07/75.

Appendix D. "Supply of Parking, University Plaza, Dundas, Ontario"

| Rows | No. of Stalls |
|---|---|
| A | 6 |
| B | 5 |
| C | 5 |
| D | 10 |
| E | 11 |
| F | 66 |
| G | 28 |
| H | 28 |
| I | 33 |
| J | 31 |
| K | 32 |
| L | 27 |
| M | 22 |
| N | 10 |
| O | 5 |
| P | 9 |
| Q | 32 |
| R | 32 |
| S | 32 |
| T | 32 |
| U | 32 |
| V | 36 |
| W | 10 |
| X | 9 |
| Y | 24 |
| Z | 26 |
| AA | 11 |
| BB | 28 |
| CC | 31 |
| DD | 26 |
| EE | 23 |
| FF | 7 |
| GG | 24 |
| HH | 15 |
| II | 14 |
| JJ | 17 |
| KK | 10 |
| LL | 3 |
| MM | 3 |
| NN | 22 |
| OO | 32 |
| PP | 33 |
| QQ | 9 |
| RR | 9 |
| SS | 6 |
| TT | 6 |
| UU | 5 |
| VV | 5 |
| WW | 4 |
| XX | 6 |
| YY | 9 |
| ZZ | 9 |
| 3A | 10 |
| 3B | 10 |
| 3C | 10 |
| 3D | 10 |
| 3E | 10 |
| TOTAL | 1000 stalls |

The total supply of parking, University Plaza, Dundas, Ontario is 1000 spaces.

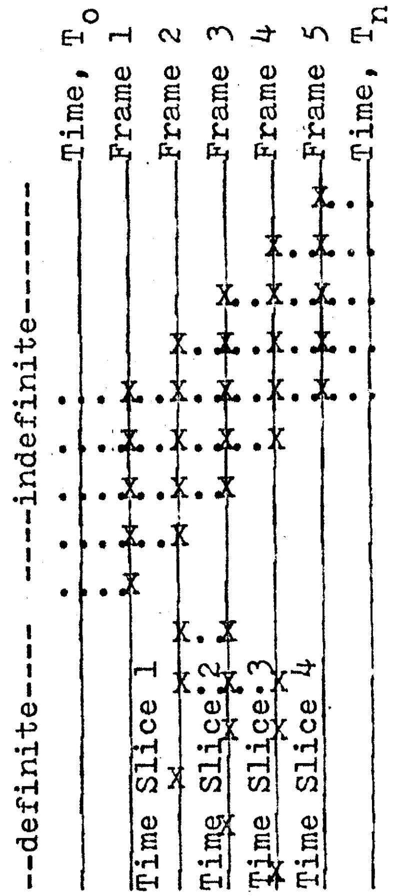
Appendix E. "Derivation of Duration of Parking, University Plaza, July 21, 1975.

From the stall occupancy data, for 5 consecutive frames 605 vehicles occupied 606 stalls (1 bus occupied 2 stalls back-to-back). In order to determine duration of parking figures, assumptions must be made concerning service times for vehicles which occupy parking stalls either before the first flyover, following the final flyover, or both.

For any occupancy of a stall which falls between the second and fourth frames of a mission, a definite time of parking duration may be obtained, and in essence is a range of times. Any other condition is uncertain and hence must be subject to assumption concerning duration. The potentially existing conditions and assumptions concerning durations of parking are illustrated in Figure E1.

The method utilized biases the data. In this regard the zero time is positively biased at the expense of the 15 minute intervals and hence deletes 161 vehicles from duration calculations.

The summary of durations is illustrated in Table E1, and a graphical representation is presented in Figure E2.




| | Time that Space is Occupied (minutes) | | Rate as "t" minutes |
|---|---|---|---|
| 1 | 0 | assume equivalent to | 0 |
| 2 | 15 | assume " " | 30 |
| 3 | 30 | assume " " | 45 |
| 4 | 45 | assume " " | 60 |
| 5 | 60 | assume " " | 60 + |
| 6 | 45 | assume " " | 60 |
| 7 | 30 | assume " " | 45 |
| 8 | 15 | assume " "8 | 30 |
| 9 | 0 | assume " " | 0 |
| 10 | $15 < t < 45$ | average to | 30 |
| 11 | $30 < t < 60$ | " " | 45 |
| 12 | $15 < t < 45$ | " " | 30 |
| 13 | $0 < t < 30$ | " " | 15 |
| 14 | $0 < t < 30$ | " " | 15 |
| 15 | $0 < t < 30$ | " " | 15 |

Figure E1, Determination of Duration of Parking of Vehicle

| Time Occupied (minutes) | 0 | 15 | 30 | 45 | 60 | 60+ | Totals |
|---|---|---|---|---|---|---|---|
| Number of Vehicles | 161* | 123 | 122 | 50 | 37 | 112 | 444** |
| % of Known Occupants | N/A* | 27.7 | 27.5 | 11.2 | 8.5 | 25.1 | 100% |
| Duration Interval | | Short | | Medium | | Long | |

* Not applicable.

** Number of vehicles of known occupancy: 605-161 = 444. These are eligible for duration calculations, and constitute 73.5% of the sample.

Table E1. Summary of Durations of Parking, University Plaza, July 21, 1975.

Deductions

(a) 55.2% of consumers shop in 30 minutes, suggesting a rapid turnover of patrons, with half of them (27.7%) shopping 15 minutes.

(b) 25.1% of vehicles occupy their stalls for 60+ minutes, suggesting that they may be staff vehicles. The imagery defines that they are not in high turnover areas which confirms this.

(c) 19.7% of vehicles occupy their stalls for time t: 45 t 60 min. suggesting that few shoppers stay for medium periods at this plaza.

(d) Parking design should accommodate the majority of short term parking.

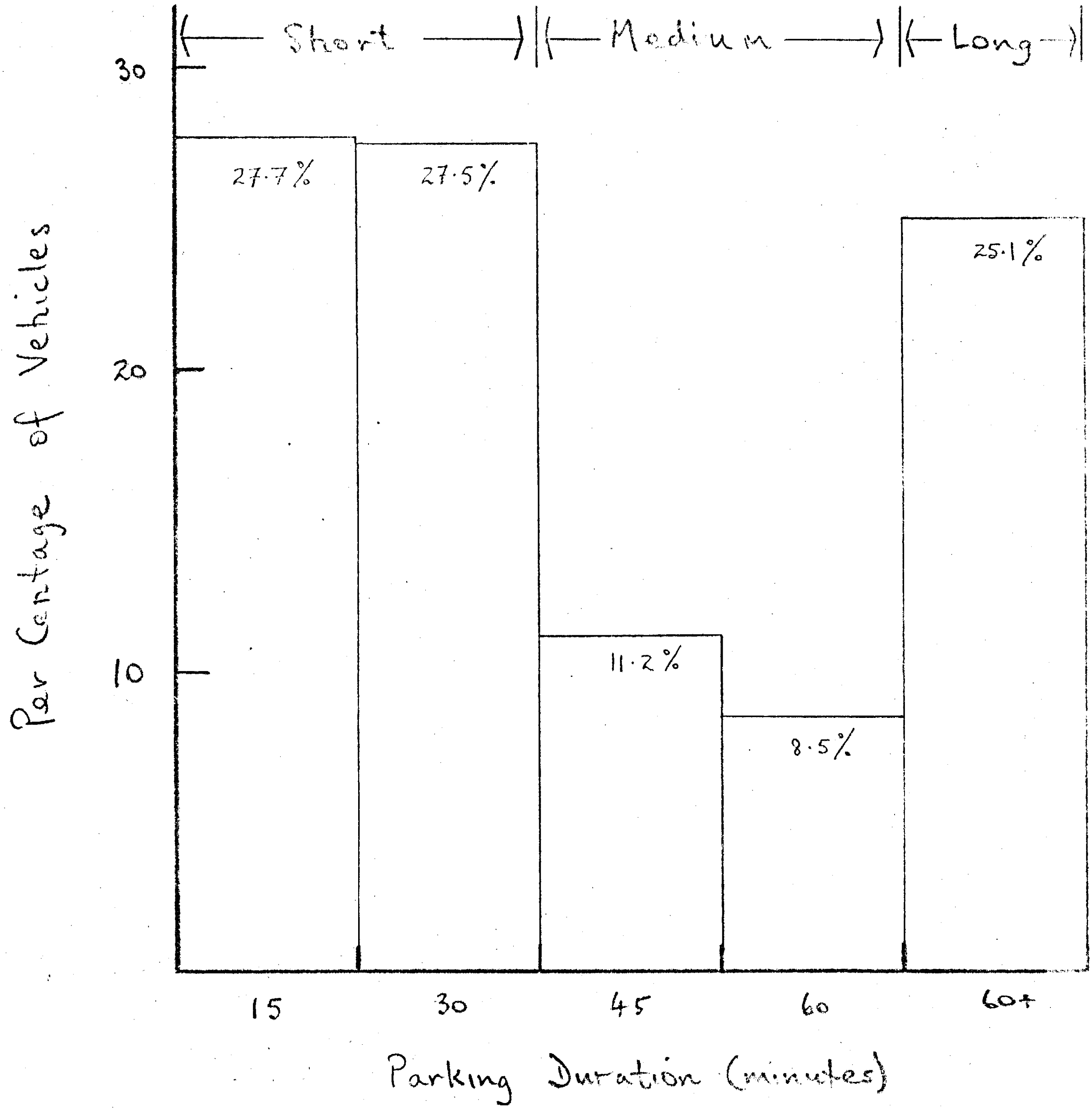



Figure E2. Summary of Durations of Parking, University Plaza, July 21, 1975.
Source: Table E1.

Appendix F. "Incidents of Illegal Parking, University Plaza, July 21, 1975."

The incidents of illegal parking per frame are illustrated in Table F1. The Parking Demand figures represent the sums of legal and illegal parking demand. The source for the legal parking demand is Table G1 in Appendix G, and is the occupancy value for each time slice.

| Frame | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Parking Demand* | 265 | 298 | 297 | 274 | 288 |
| Illegal Parking | 1 | 5 | 9 | 8 | 7 |
| % Illegal Parking | 0.4% | 1.7% | 3.1% | 3.0% | 2.5% |

Table F1. Illegal Parking per Frame, University Plaza, Monday, July 21, 1975.

* denotes stall parking and illegal parking demand.

Appendix G. "Parking Accumulation, University Plaza, July 21, 1975."

In order to derive arrival and departure rates between successive frames, an artificial element must be created. This is known as the "time slice" and in this study is the 15 minute interval between consecutive fly-overs. Vehicles which appear in Frame 2, for instance, are considered to arrive in the 15 minute interval prior to frame 2 (i.e.) in Time Slice 1. A similar assumption is made for departing vehicles.

Both turnover and occupancy values per time slice are illustrated in Table G1, and a graphical representation is shown in Figure G2.

| | | Mission 1 | Mission 2 |
|---|---|---|---|
| | Frame 1 | 11:30 a.m. | 11:45 a.m. |
| Time Slice 1 | | | |
| | Frame 2 | 11:45 a.m. | 12:00 noon |
| Time Slice 2 | | | |
| | Frame 3 | 12:00 noon | 12:15 p.m. |
| Time Slice 3 | | | |
| | Frame 4 | 12:15 p.m. | 12:30 p.m. |
| Time Slice 4 | | | |
| | Frame 5 | 12:30 p.m. | 12:45 p.m. |

Figure G1. Relationship between Time Slices and Film Frames.

| | Initial Parking Demand | Time Slices 1 | 2 | 3 | 4 | Residual Parking Demand |
|---|---|---|---|---|---|---|
| 1. Arrivals, (A(t)) | 264[a] | 102 | 85 | 66 | 88 | |
| 2. Parking Accumulation ( Arrivals) | | 366 | 451 | 517 | 605[b] | |
| 3. Departures, (D(t)) (= Turnover) | | 74 | 90 | 88 | 71 | |
| 4. Turnover Accumulation ( Departures) | | 74 | 164 | 252 | 323[c] | |
| 5. Occupancy ( Arrivals - Departures) | 264 | 292 | 287 | 265 | 282 | 282 |
| 6. Stalls demanded in parking (Occupancy +1 due to bus in 2 stalls | 265 | 293 | 288 | 266 | 283 | 283 |

Table G1 Parking Accumulation Summary, University Plaza, July 21, 1975. All values are listed as vehicles.

(a) Initial Parking Demand; (b) Total Parking Accumulation: (c) Total Turnover

<u>Deductions</u>: (1) Average rate of arrival per time slice (15 minutes)

$$= \frac{\text{Total Parking Accumulation - Initial Demand}}{\text{No. of Time Slices}}$$

$$= (605 - 264)/4 \quad 86 \text{ vehicles}$$

(2) Average rate of departure per time slice (15 minutes)

$$= \frac{\text{Total Turnover}}{\text{No. of Time Slices}} = \frac{323}{4} \quad 81 \text{ vehicles}$$

(3) Average Occupancy over the 4 Time Slices
is given by (292, 287, 265, 282)/4
= 282 vehicles.

Range of vehicles = (Max. - Min.)/4
= (292-265)/4 7 vehicles

Range in % = (7/282)x100% 2.5%

Thus Average Occupancy = 282 vehicles ± 2.5%

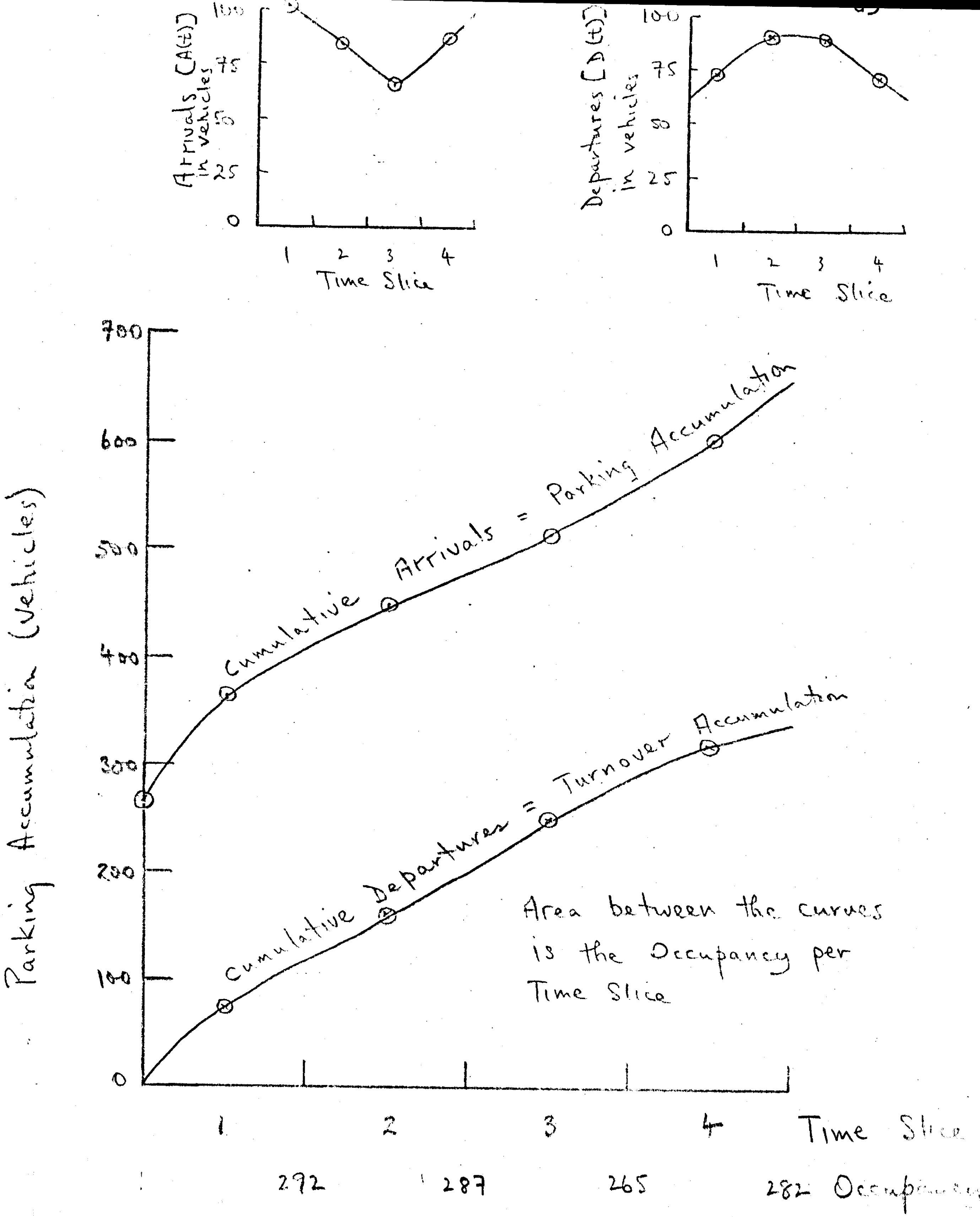



Figure E2. Arrivals, Departures, Parking Accumulation, Occupancy, and Turnover

Appendix H. "Effectiveness of Internal Circulation Network, University Plaza, July 21, 1975"

In general, good signing in the form of pavement markings aids in the efficiency of the internal circulation network. The signing within the University Plaza is poorly considered, confusing, too small to be effective, and has not incorporated both parcels into a uniform network. These ailments are illustrated in Figure H1.

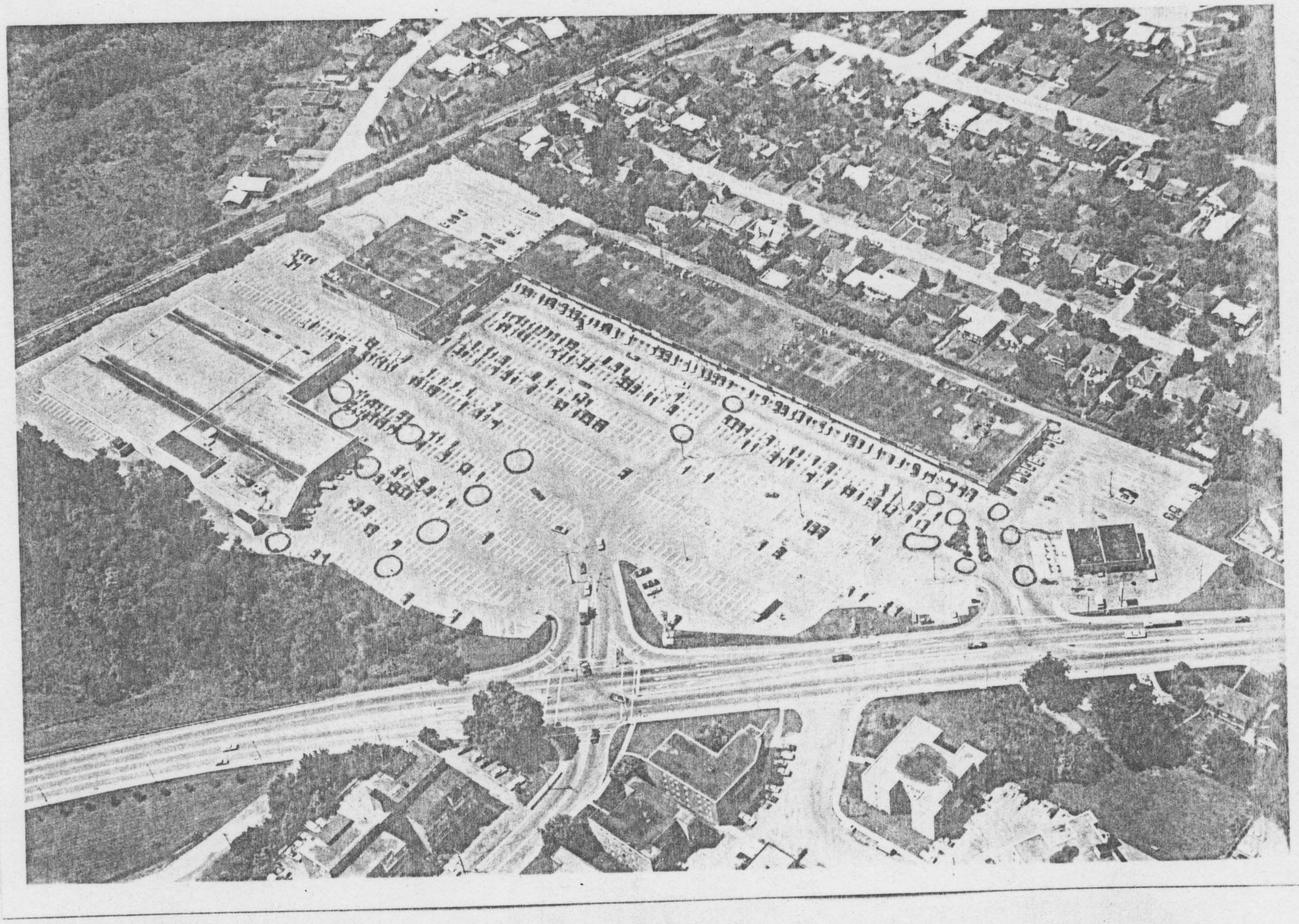


Figure H1 Inadequate Signing (Pavement Markings) at the University Plaza. The circles encompass guiding arrows painted on the asphalt surface.

Appendix I. "Deducing Stall Use by Pavement Stains"

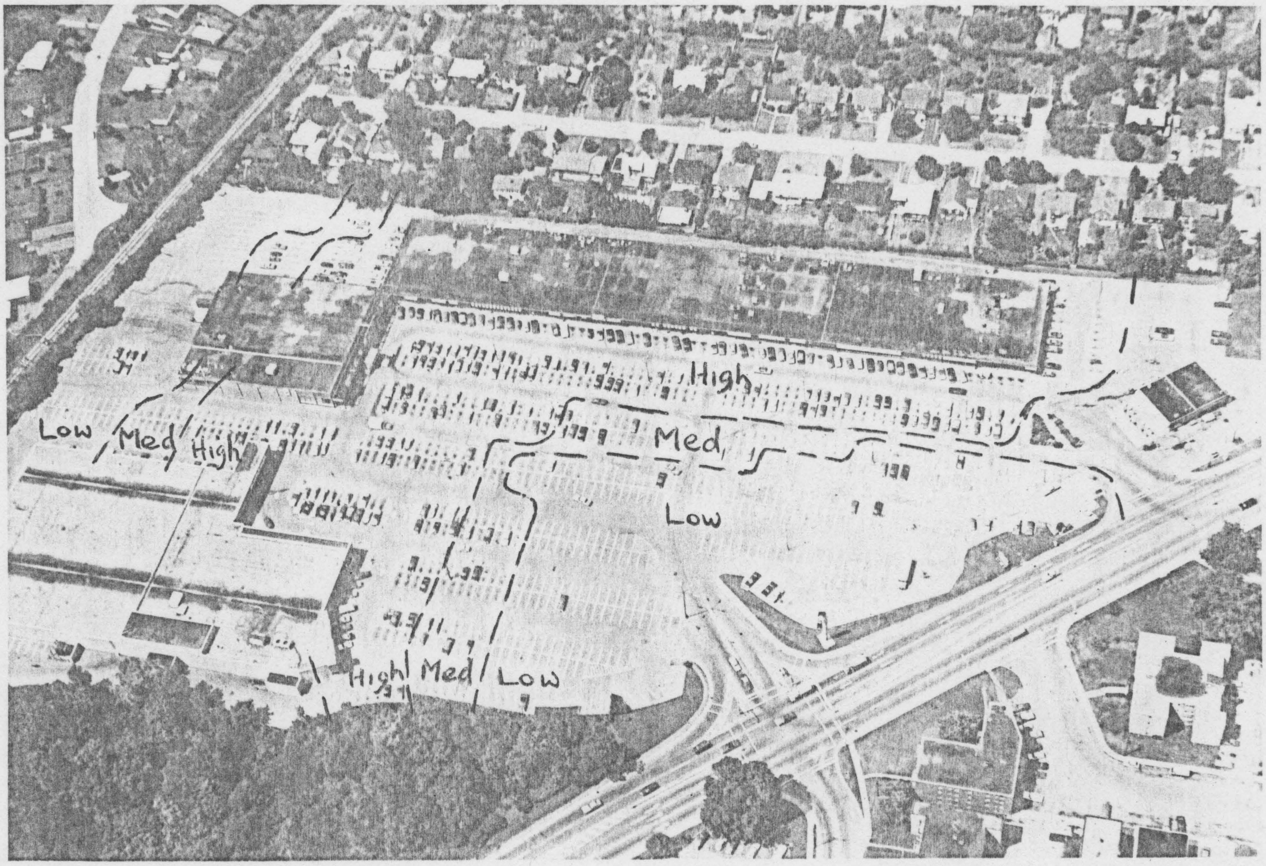



Figure I1. Intensity of Parking Demand Deduced by Pavement Stains

Due to continual deposition of oil on the asphalt, the intensity of parking demand may be deduced by the degree of the stain interpreted from aerial photographs. The greater is the stain, the greater use the stall undergoes. Arbitrary values of high/medium/low intensity of use are supported by extracted data.

Appendix J. "Supply of Parking, Greater Hamilton Shopping Centre, July 28, 1975."

| Land Use Designation | Location on Imagery* | Number of Stalls |
|---|---|---|
| 1. Residential (Apartments) | 1 | 104 |
| 2. Isolated retailing(Loblaws) | 2 | 291 |
| 3. " " (Brewers Retail) | 3 | 60 |
| 4. " " (Canadian Tire) and Cinemas) | 4 | 221 |
| 5. " " (Dominion) | 5 | 454 |
| 6. Southern perimeter | 6 | 307 |
| 7. Eastern perimeter | 7 | 196 |
| 8. The Centre Mall, south lot | 8 | 932 |
| 9. The Centre Mall, east lot | 9 | 124 |
| 10. Isolated retailing (Sears) | 10 | 34 |
| 11. Northern perimeter | 11 | 373 |
| 12. The Centre Mall, north lot | 12 | 1260 |
| | Total site parking | 4356 stalls |

* Refer to Figure J1.

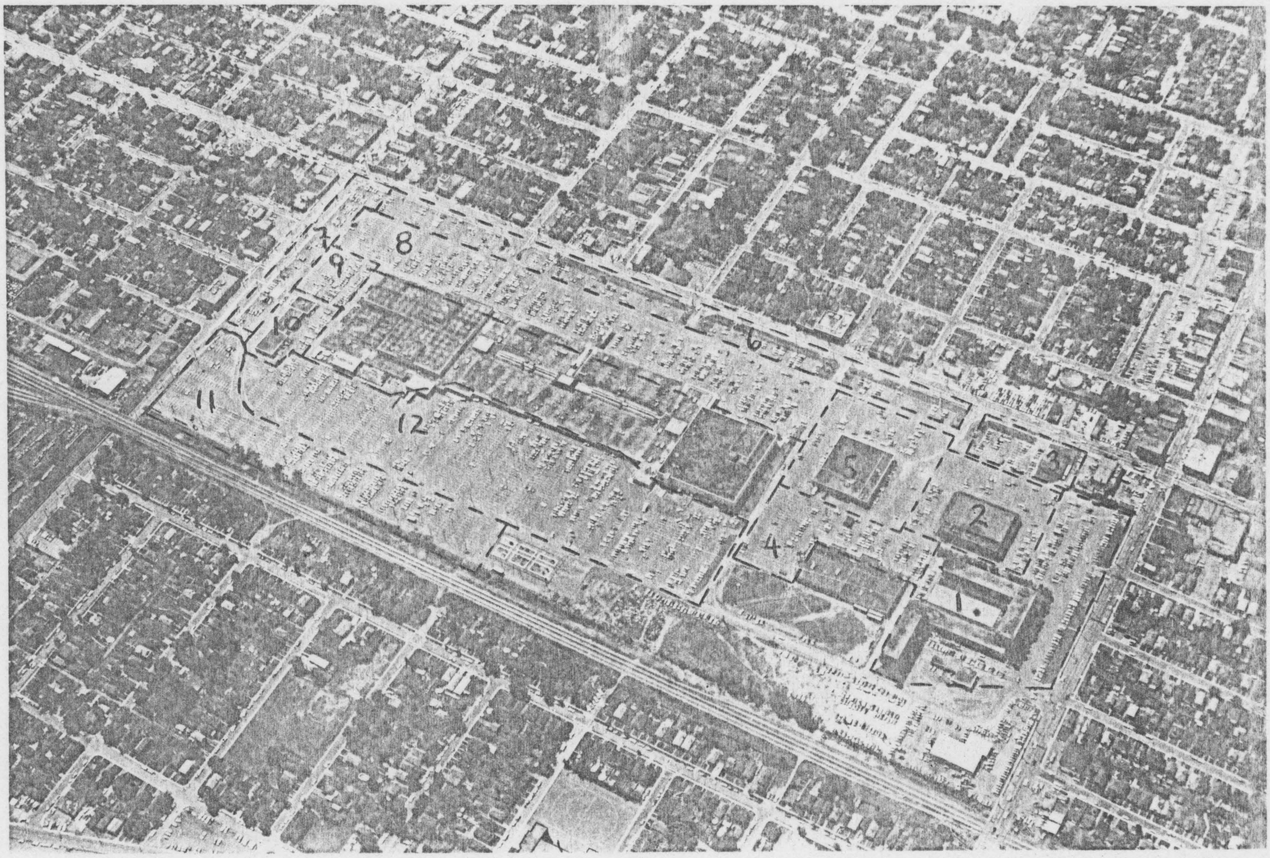


Figure J1. Site Partitioned into Parking Areas.

| Legend: | | |
|---|---|---|
| 1. | Residential | parking lot |
| 2. | Loblaws | " " |
| 3. | Brewers Retail | " " |
| 4. | Canadian Tire/Twin Cinemas | " " |
| 5. | Dominion | " " |
| 6. | Southern perimeter | " " |
| 7. | Eastern perimeter | " " |
| 8. | The Centre Mall, South | " " |
| 9. | The Centre Mall, east | " " |
| 10. | Sears | " " |
| 11. | Northern perimeter | " " |
| 12. | The Centre Mall, north | " " |

Appendix K. "Occupancy Values for GHSC"

The demand for service, measured in terms of occupancy has been extracted from the imagery and is illustrated in Figure K1.

| Frame | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Time | 11:45am | 12 noon | 12:15pm | 12:30pm | 12:45pm |
| Passenger Cars | 1587 | 1650 | 1758 | 1916 | 1802 |
| Non-passenger Cars | 27 | 27 | 36 | 31 | 41 |
| Total Occupancy | 1614 | 1677 | 1794 | 1947 | 1843 |

Figure K1. Occupancy values for GHSC

Occupancy peaks at 12:30 p.m., indicating an increasing demand for parking service until this time.

Appendix L. "Incidents of Illegal Parking, GHSC"

| Time | 11:45 am | 12 noon | 12:15 pm | 12:30 pm | 12:45 pm |
|---|---|---|---|---|---|
| Frame | 1 | 2 | 3 | 4 | 5 |
| Legal Parking Demand | 1614 | 1677 | 1794 | 1947 | 1843 |
| Illegal Parking | 12 | 14 | 22 | 21 | 22 |
| Total Parking Demand | 1626 | 1691 | 1816 | 1968 | 1865 |
| % Illegal Parking | 0.7% | 0.8% | 1.2% | 1.1% | 1.2% |

Figure L1. Per Centage Illegal Parking, GHSC

Illegal parking peaks in Frame 3 (12:15 p.m.) at 22 vehicles (1.2%). This small figure constitutes little threat to the efficiency of the internal circulation network at the GHSC.

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