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Underground Car Parks/ *Les parcs de stationnement souterrains*

ITA Working Group No. 13, "Direct and indirect Advantages of Underground Structures"
Prepared by J.-P. Tareau

Abstract—*At a series of meetings held in Acapulco in May 1992, the International Tunnelling Association (ITA) Working Group no. 13 decided to launch a research programme on underground car parks. This introductory report, together with the associated articles, is the first study of the group concerning a specific use of underground space. With regard to identifying the advantages of the type of works considered in this paper, it restates the general approach addressed in the report, "General Considerations in Assessing the Advantages of Using Underground Space", adopted by the Working Group as a general introduction to all of its studies related to particular structures.*

Résumé—*Lors de ses réunions tenues à Acapulco en mai 1992, le Groupe de travail n° 13 de l'AITES a décidé d'engager une étude sur les parcs de stationnement souterrains. Le présent rapport introductif, ainsi que les articles qui lui sont associés, constitue la première étude du groupe portant sur une utilisation spécifique de l'espace souterrain. En ce qui concerne l'identification des avantages du type d'ouvrage considéré ici, il reprend la démarche générale exposée dans le rapport «Considérations générales sur l'évaluation des avantages de l'utilisation du sous-sol», établi par le groupe de travail comme introduction générale de l'ensemble des études relatives aux ouvrages particuliers.*

Why We Need Parking Space

The automobile is highly regarded as a convenient mode of transport. However, because of the need to provide a space where the car can be kept until we wish to use it, and to leave it when we have arrived at our destination (in order for us to carry out the activity which brought about the journey in the first place), the vehicle is now seen as an encumbrance. It requires accessible space, adapted to its needs, amounting to approximately 12 m^2 in size for European-type vehicles. This is the reason why automobile manufacturers are seeking to reduce the size of vehicles in their product range as much as possible, in response to concerns being expressed by urban users.

Parking requirements are thus directly related to both the existence and use of a vehicle.

The increase in the number of vehicles on the road and, in an urban environment, the tendency to use them for short journeys linked together to form a longer one, has been the main reason behind the growth in the need for parking space. The result has been a kind of "competition" to find space in areas of high population density.

Origine des besoins en stationnement

Le véhicule automobile est très apprécié comme moyen commode de déplacement. Mais parce qu'il lui faut un endroit où on peut le garder pour en disposer le moment venu ou pour le quitter une fois arrivé à destination et effectuer ce qui a commandé le déplacement, le véhicule est vu alors comme un objet encombrant qui demande un espace accessible, de forme adaptée, occupant environ 12 m^2 pour les véhicules de type européen.

C'est pour cette raison que les constructeurs d'automobiles cherchent à réduire au maximum l'encombrement des véhicules qu'ils proposent pour répondre aux préoccupations des utilisateurs urbains.

Le besoin de stationnement est ainsi lié directement à l'existence et à l'utilisation d'un véhicule.

La multiplication du nombre de véhicules et, en milieu urbain, la tendance à les utiliser pour des déplacements courts, enchaînés les uns à la suite des autres, ont largement accru ce besoin de stationnement. Il se traduit par une sorte de «compétition» pour l'espace dans les zones de forte densité humaine.

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On-street Parking

As the automobile has become commonplace in a large number of countries, it is no longer the object of precautionary care by its owner. Furthermore, since cars are designed to resist the inclemencies of the weather, and therefore numerous other trials and tribulations, and are often equipped with an anti-theft alarm, owners tend to feel that their automobiles can now largely "look after themselves." Apart from a few very coveted models, a vehicle can now normally remain outside and unsupervised for long periods without problems.

As a result, the most common parking practice is to leave the vehicle on the side of the public roadway or in spaces at ground level that are directly accessible from the roadway. In towns and cities that have not yet reached a high population density level, this is readily done; and, in the centre of densely-populated cities, this practice results in parking anywhere possible.

What people are looking for in what we will call the vehicle "garage" is a space adjoining the home, for the sake of convenience; and, preferably, a covered space, from the point of view of comfort. Unfortunately, in many cases such a space does not exist, and to provide it is considered superfluous spending. Therefore, people use the roads, or public areas made accessible by the roads, as garages.

In fact, the French have coined the phrase "voiture ventouse" (English translation: car leech? Is this the correct word?) to refer to illegally parked cars that clutter up public areas and remain parked in the same spot for long periods of time, sometimes exceeding several days.

The authorities have tried to take measures to overcome this phenomenon in the town and city centres of most countries that have a large automobile population. But such on-street parking is still allowed in countries that have experienced the automobile invasion more recently, and where there are practically no other places to park. Thus, in certain towns and cities, vehicles covered with tarpaulins to protect them from dust, and parked permanently next to the pavements or even on the pavement themselves, form a part of the landscape.

Obviously, in the towns and cities of countries where there is still only a small number of automobiles, the problem of "using up public areas" for vehicle parking has not yet become a matter for concern.

Off-street Parking

Off-street parking arises when growth in the population density of a town or city leads to an increase in the number of automobiles, which in turn results in:

- The construction of ground-level parking spaces away from the public roadway; and
- Solutions that make it possible to park cars on several different levels.

Regarding the latter option, progress in the use of reinforced concrete construction and metal construction opened the way for construction of the earliest parking structures. Extra floor support was needed because the weight that the floors of such structures and the ramps which link them have to withstand was much greater than for other types of construction works.

When the necessary land is available, the building of multi-story car parks does not present any particu-

Stationnement sur voirie

Avec sa banalisation dans un grand nombre de pays, le véhicule automobile n'est plus autant l'objet de soins précautionneux de la part de son propriétaire. De plus, conçu pour résister aux agressions climatiques, et donc à de nombreuses autres vicissitudes, muni de systèmes antivol, il assure en fait sa propre protection. Aussi, à part quelques modèles très convoités, un véhicule peut sans problèmes rester pendant de longues périodes sans être à l'abri et sans surveillance. De ce fait, la pratique de stationnement la plus courante est de laisser le véhicule en bordure des voies de circulation ou sur des espaces de surface directement accessibles à partir de ces voies.

C'est largement le cas dans les villes qui n'ont pas atteint des densités importantes et dans les centres villes, partout où c'est possible.

Pour ce qu'on appelle le «garage» du véhicule, ce qui est recherché, c'est un espace attenant au domicile, pour la proximité, et pourquoi pas couvert, pour le confort. Mais dans bien des cas un tel espace n'existe pas, ou est considéré comme une dépense superflue. C'est alors la voirie ou les espaces publics qu'elle rend accessibles qui servent de garage.

C'est ainsi qu'en français est apparu le terme de «voitures ventouses» pour désigner les véhicules qui accaparent l'espace public en restant stationnés au même emplacement pendant des durées pouvant dépasser plusieurs jours.

Le phénomène a été combattu dans la plupart des centres villes des pays à fort équipement automobile. Il reste admis dans les villes de pays à équipement automobile récent et où d'autres solutions de stationnement n'existent pratiquement pas. Ainsi, des véhicules recouverts d'une bâche qui les protègent de la poussière, garés en permanence en bordure de trottoir ou sur les trottoirs eux-mêmes, font partie du paysage de certaines villes.

Bien sûr, dans les villes de pays où la présence de l'automobile est encore réduite, ce problème de «consommation d'espace public» par des véhicules en stationnement n'est pas encore une préoccupation.

Stationnement hors voirie

C'est le phénomène conjugué de densification de la ville et d'augmentation de l'équipement en voitures qui a conduit à la fois à aménager des espaces de surface hors voirie pour le stationnement des véhicules et à trouver des solutions permettant le stationnement de véhicules sur plusieurs niveaux.

Sur ce dernier point, les progrès de la construction en béton armé ou de la construction métallique ont ouvert la voie aux réalisations les plus anciennes. Les charges à admettre sur les planchers de tels ouvrages et sur les rampes qui les relient entre eux étaient en effet largement supérieures à celles ayant cours pour les autres types de constructions.

Lorsque les terrains sont disponibles, la construction d'ouvrage de stationnement sur plusieurs niveaux au-dessus du sol ne pose pas de problèmes particuliers. Ainsi en Allemagne par exemple, c'est ce type d'ouvrage qui s'est imposé dans les villes reconstruites après-guerre.

lar problems. In Germany, for example, this type of structure became the rule in the towns and cities rebuilt after World War II.

Generally, however, the common way of making a number of low-cost spaces available, in order to accommodate ever more vehicles, was to develop large public squares in town and city centres, central islands on main avenues, wide pavements, and courtyards of buildings or the spaces which surround them.

Because the amount of surface space available for such development is not endless, we now must turn to off-street parking in multi-story structures in order to provide the number of spaces that are required in areas of high population density.

Parking in Multi-Story Structures

At about the same time, numerous towns and cities began to establish regulations requiring that a number of parking spaces be built on any plot of land where new construction was to take place. The number of spaces is determined according to the purpose for which the site is being developed, and the size of that development.

Taking into account the generally high price of such plots of land, construction companies or building promoters typically seek to exploit the opportunities offered by the plot to the full, and to utilise the multi-level space above ground for creating a maximum amount of "high class" space in their construction programme. This is particularly true where height limitations on buildings exist.

In areas of high population density in town and city centres, the outside surface space that is not built up is generally not sufficient to entirely fulfill the obligation to build a given number of car parking spaces. Therefore, in the majority of cases, the parking spaces are constructed in the basement of the building. This arrangement is doubly sensible because most of these buildings are high-rise and require deep foundations; and, therefore, the basement levels may as well have a practical use.

Unless there are special cases of controlled use of land, financial viability arguments also weigh heavily when considering whether to build multi-story car parks above ground in areas of high population density, where there are much more valuable uses to be made of the space. The same applies to certain existing car parks that are being replaced by structures which are more financially viable, such as offices, and integrating their parking facilities below ground.

The community is often called upon to take action to preserve a facility that plays a public service role and to try to remove it from the field of influence of market forces. It may also be called upon to make up any financial shortfall suffered by private operators in operating the facility, to set up financial structures to which it contributes, or even to begin granting concessions on land in the public sector, which relieves the burden of land costs.

There is no more room for on-street parking to expand in terms of available space. In fact, such space is shrinking in most city centres because of the establishment of pedestrian zones, the setting aside of the entire width of the roadway for traffic on main axes, and the creation of bus lanes for public transport. Off-street parking is also limited.

The only real method of increasing the parking capacity is to construct special parking zones, which,

Mais, en nombre de places et pour un coût moindre, ce sont surtout les grandes places publiques des centres villes, les terre-pleins de boulevards, les larges trottoirs, les cours d'immeubles ou les espaces les entourant, qui ont été aménagés pour accueillir toujours plus de véhicules. Les espaces de surface ayant leurs limites, c'est bien vers le stationnement hors voirie sur plusieurs étages qu'il faut se tourner pour pouvoir offrir le nombre d'emplacements de stationnement jugés nécessaires dans les zones denses.

Stationnement en ouvrages à étages

Parallèlement, nombre de villes ont pris des réglementations qui imposent la réalisation, sur la parcelle où doit prendre place une construction nouvelle, un nombre d'emplacements de stationnement qu'elles fixent en fonction de la destination de la construction et de son importance.

Mais, compte tenu du prix généralement élevé des terrains, les maîtres d'ouvrages ou promoteurs immobiliers cherchent à exploiter au mieux les possibilités des parcelles de terrain et à placer en étages au-dessus du sol le maximum des surfaces «nobles» du programme de leurs constructions. Ceci est particulièrement vrai lorsqu'il existe des limitations de hauteur pour les bâtiments.

Dans les zones denses de centre ville, les surfaces extérieures laissées libres par la construction ne sont en général pas suffisantes pour répondre totalement à l'obligation de réaliser le nombre fixé d'emplacements de stationnement. Dans la majorité des cas, ces emplacements sont donc réalisés en sous-sol de la construction, d'autant plus qu'il s'agit le plus souvent d'immeubles de grande hauteur aux fondations profondes. Les niveaux en sous-sol trouvent ainsi une utilisation intéressante.

Sauf situation spéciale de maîtrise foncière, ce sont également des arguments de rentabilité qui font que, dans les zones denses, les parcs de stationnement à étages en hauteur sont considérés comme peu intéressants au regard d'autres utilisations du sol. Il en est de même pour certains parcs existants qui sont remplacés par des constructions plus rentables, comme par exemple à usage de bureaux, intégrant en sous-sol leurs emplacements de stationnement.

La collectivité est souvent amenée à réagir pour conserver un équipement qui a un rôle de service public et le faire échapper aux lois du marché. De même, elle peut être amenée à suppléer à la carence des opérateurs privés en opérant par elle-même ou en mettant en place des montages financiers auxquels elle participe, ou bien encore en ouvrant des concessions sur son domaine public, ce qui annule le poids de la charge foncière.

Le stationnement sur voirie n'a plus capacité à augmenter en superficie, il est même en régression dans la plupart des centres villes avec l'installation des zones piétonnes, la réservation de toute la largeur de chaussée pour la circulation sur les grands axes, les réservations de couloirs pour les transports collectifs. Le stationnement de surface hors voirie est lui aussi limité.

Les moyens d'augmenter les capacités de stationnement dans de nombreuses villes très peuplées n'existent véritablement que dans la construction de volumes spécialisés, et dans les faits, plutôt en souterrain.

in many densely-populated cities, can only be placed underground.

In historical tourist cities such as Paris, we have even been brought to the point of building underground car parks for the numerous congestion-causing motor coaches that bring in the tourists and wait for them at the most frequently visited tourist sites.

Point of View of the Various "Parties" Concerned with the Parking Facilities

In the general report concerning the assessment of the advantages of using underground space (see pgs. 287–298), we have seen that in order to appreciate the advantages of underground works, it is interesting to observe the different points of view among the various "parties" involved.

In the same vein, for underground parking in particular we will distinguish successively:

1. The point of view of the parties directly concerned with parking facilities; and
2. The point of view of the parties concerned with the direct and indirect consequences of parking facilities.

Parties Directly Concerned with Parking Facilities

The parties that are directly concerned with parking facilities are:

1. The **owner**—i.e., the company that takes the initiative in building the structure, finances its construction and is the landlord. The owner may be:
   - an individual or a private body acting by right in a real estate holding that belongs to him; or
   - a public body, usually the technical department of a municipality that manages urban public space. It is the technical department that delivers construction permits in the public domain, whether the works are established at ground level or underground. In many cases, the public body "owner", through concessions to private companies, entrusts them with the care and attention of financing, constructing and operating the works.

The objective of the owner or the "concessionaire" in this case is the same as that of any other owner: i.e., to build the parking facility at the proper date and at a minimum cost.

2. The **motorists** who are likely to park their cars in the parking facility.

Motorists hope to find a place to park their cars as close as possible to their home or destination. They also require that the parking places at their disposal be inexpensive, comfortable, and provide the best possible security conditions.

3. The **company** (including the employees) **that operates** the parking facility.

The operating company seeks, above all, to attain a high level of income, and to reduce the operating costs. The employees want to perform their jobs under the proper working conditions, including security conditions suited to the parking facility.

4. The **local public authority**, i.e., the municipality.

Within the framework of its responsibility concerning urban planning, the local public authority seeks to improve the operation of urban public transport by defining and applying a circulation and parking policy, which is a condition essential to the growth of the city.

On en vient même dans des villes touristiques à caractère historique (Paris) à construire des parcs de stationnement souterrains pour les autocars nombreux et encombrants qui amènent et attendent les touristes sur les sites les plus fréquentés.

Le point de vue des diverses «Parties» concernées par les parcs de stationnement

Nous avons vu dans le rapport général sur l'appréciation des avantages de l'utilisation du sous-sol, qu'il était utile de se placer du point de vue des diverses «parties» concernées pour apprécier les avantages des ouvrages souterrains.

Nous distinguerons successivement:

1. Le point de vue des «parties» directement concernées par les parcs de stationnement,
2. Le point de vue des «parties» concernées par les conséquences directes et indirectes de la création de parcs de stationnement.

«Parties» directement concernées par les parcs de stationnement

Les «parties» directement concernées par les parcs de stationnement sont:

1. Le **maître d'ouvrage**, c'est-à-dire la société qui prend l'initiative de réaliser l'ouvrage, qui en finance la construction et qui en est le propriétaire. Ce maître d'ouvrage peut être:
   - soit une personne physique ou un organisme privé, agissant de plein droit dans une emprise foncière lui appartenant,
   - soit un organisme public, généralement service technique de municipalité, gestionnaire de l'espace public urbain et responsable à ce titre des autorisations de construction dans le domaine public, qu'il s'agisse d'ouvrages établis à l'air libre ou en souterrain ; observons que, dans de nombreux cas pour ce type d'ouvrage, l'autorité publique maître d'ouvrage confie à des intervenants privés, par le biais de concessions d'une durée déterminée, le soin de financer, réaliser et exploiter l'ouvrage ;

L'objectif du maître d'ouvrage, ou du concessionnaire, est le même que celui de tout maître d'ouvrage: il souhaite avoir la possibilité de réaliser le parc de stationnement à la date souhaitable et pour le coût minimal.

2. Les **automobilistes** susceptibles de garer leur voiture dans le parc de stationnement:

Ce que souhaite l'automobiliste, c'est trouver un emplacement pour garer son véhicule le plus près possible de sa résidence ou de son lieu de destination, ceci pour un prix minimum et dans les conditions de confort et de sécurité les meilleures.

3. La **société qui exploite** le parc de stationnement, ainsi que ses employés ;

Cette société recherche avant tout à atteindre un niveau maximum de recettes et à réduire ses coûts d'exploitation. Les employés, quant à eux, demandent à exercer leur métier dans des conditions adaptées au type de parc et assurant leur sécurité.

4. L'**autorité publique locale**, c'est-à-dire la Municipalité;

Dans le cadre général de ses responsabilités concernant l'aménagement urbain, l'autorité publique locale, en définissant et mettant en oeuvre une politique

Parties Concerned with the Direct and Indirect Consequences of Parking Facilities

The parties concerned with the direct and indirect consequences of parking facilities throughout their lifetime are:

1. The owner of the works (buildings and infrastructures) and of the surrounding space, public and private, existing or planned.

The owners hope to bear no loss on account of the construction or operation of the parking facility, and, if possible, to benefit from capital gains related to the construction of the work.

2. The city dwellers who use the facilities and the surrounding space—in other words, the individuals who live, stay in or conduct an activity there.

These individuals hope to bear no loss whatsoever, i.e., neither disturbances due to construction nor disruption due to operation of the parking facility. If possible, they want to benefit from the facility, in terms of improved living conditions or improved conditions in managing their activities.

3. The companies who operate or manage the facilities and surrounding space (shopkeepers, infrastructure and public space administrators, etc.).

The objectives of these companies relate, above all, to their income and operating costs.

4. The local public authority, i.e., the municipality.

In the framework of its responsibility vis-à-vis the local and regional authority, the local public group must arbitrate among the following various aspects of its policy:

- *Optimization of the city's operation: economic, social, cultural, educational, etc.*
- *Protection of the urban surroundings.*
- *Protection and increased status of urban sites, especially with respect to their historical and natural heritage value.*
- *Managing local public finances.*

Direct Advantages of Underground Car Parks

First, it must be stressed that the very nature and importance of the advantages presented by using underground space for car parks in urban areas are obviously variable, according to the greater or lesser influence of various factors, such as:

- The location: level of population density and congestion of the site, rules governing ground level construction work and the nature of the underground environment,
- The level of economic constraints on building and operating such structures.
- What contribution that the construction of such structures makes to the implementation of local government policies regarding transport, parking and, generally speaking, town planning.

The direct advantages of underground car parks are the advantages they present in comparison with other parking solutions—whether on-street parking, or off-street parking in open-air multi-story car parks—that offer the same functions.

en matière de circulation et de stationnement, cherche à améliorer le fonctionnement des transports urbains, condition essentielle à l'essor de la cité.

"Parties" concernées par les conséquences directes et indirectes de la création de parcs de stationnement

Les «parties» concernées par les conséquences directes ou indirectes de la création de parcs de stationnement, tout au long de sa durée de vie, sont les suivantes:

1. Les **propriétaires ou maîtres d'ouvrage** des ouvrages (bâtiments, infrastructures,...) et espaces environnants, publics ou privés, existants ou projetés.

Ceux-ci souhaitent ne subir aucun préjudice du fait de la réalisation ou de l'exploitation du parc de stationnement et, si possible, profiter de plus-values du fait de la création de l'ouvrage.

2. Les **citadins** utilisateurs des ouvrages et espaces environnants, c'est-à-dire les personnes qui y vivent, y séjournent, ou y mènent une activité.

Ces personnes souhaitent ne subir aucun préjudice ni trouble de jouissance du fait de la réalisation ou de l'exploitation du parc de stationnement et, si possible, profiter d'améliorations de leurs conditions de vie ou d'exercice de leurs activités du fait de la création de l'ouvrage.

3. Les **sociétés qui exploitent ou gèrent** les ouvrages et espaces environnants (commerçants, gestionnaires des ouvrages, des infrastructures et des espaces publics,.....).

Les objectifs de ces sociétés concernent avant tout les recettes et les coûts d'exploitation.

4. L'**autorité publique locale**, c'est-à-dire la Municipalité.

Dans le cadre général de ses responsabilités vis-à-vis de la collectivité territoriale, l'autorité publique locale doit arbitrer entre divers aspects suivants de ses politiques:

- *Optimisation du fonctionnement de la cité : vie économique, sociale, culturelle, éducative,....;*
- *Protection du cadre de vie urbain;*
- *Préservation et valorisation des sites urbains, notamment des patrimoines historiques et naturels;*
- *Gestion des finances publiques locales.*

Les avantages directs des parcs de stationnement souterrains

Il convient au départ de souligner que la nature et l'importance des avantages offerts par le sous-sol pour y implanter les parcs de stationnement en zone urbaine sont évidemment variables selon l'influence plus ou moins forte d'un certain nombre de facteurs, comme par exemple :

- La localisation : densité et encombrement du site, réglementation de la construction au sol, nature du sous-sol,
- Le poids des contraintes économiques sur la réalisation et l'exploitation des parcs de stationnement,
- L'apport de la réalisation de tels ouvrages dans la mise en oeuvre des politiques des autorités locales en matière de déplacements, de stationnement et, plus généralement, d'aménagement urbain.

Regardless of whether the car park structure is at ground level or underground, its internal organisation and the principles on which it runs are the same. The differences lie essentially in the possibilities for its location, in the methods used for construction, and in certain matters related to its operation (lighting, ventilation and safety), which have a resultant effect on costs.

Analysis of these direct advantages may be carried out by examining two main categories of factors:

1. Factors related to the car park structure itself.
2. Factors related to the external effects caused by the building and operating of the car park structure.

Factors Related to the Car Park Structure Itself

Conditions of its insertion into the environment

As for many underground works, the condition of integration into the environment is one of the main assets in favor of underground parking facilities.

As noted above, under "Parking in Multi-Story Structures," the available parking spaces in town or city centres are highly coveted, rare and, therefore, expensive.

With regard to ground-level carpark structures, the following reasoning applies:

- Either they are not considered sufficiently financially viable, in other than a few specific cases, to occupy land that was expensive to acquire; or
- It is preferable to build other public works with greater public use in their place.

An advantage of underground structures is that they can be built under the areas at ground level which need to remain free of any construction works, thereby permitting more lucrative use of planning permission rights attached to a plot of land.

Protection against certain environmental conditions

Underground parking facilities can protect motorists and their vehicles against harsh weather (cold, heat, rain, snow, hail). It is hardly necessary to recall how unpleasant it is to get into a car that has been parked several hours under a torrid sun, or which has a thick layer of ice on the windshield and windows.

Underground parking facilities provide an unquestionable essence of comfort. aboveground multi-story parking facilities also supply certain advantages in comparison to open-air parking facilities. However, fewer of these advantages accrue to aboveground parking lots because, unlike underground parking facilities, their interiors are not completely protected from weather extremes (e.g., temperature similar to exterior temperature, air currents, etc.).

Quality of services offered to users

Particularly in urban areas, the underground usually represents a precious "space" that is adaptable as the most appropriate location for the establishment of a parking facility. In fact, it is known that the criteria of proximity, even of a direct connection with the areas to be served by the structure, are quite important in the matter of parking.

Les avantages directs des parcs de stationnement souterrains sont les avantages qu'ils présentent par rapport aux autres solutions de stationnement, soit sur voirie, soit hors voirie dans des ouvrages à étages établis à l'air libre et ayant les mêmes fonctions.

Que l'ouvrage de stationnement soit à l'air libre ou en souterrain, son organisation interne et ses principes de fonctionnement restent les mêmes. Les différences résident essentiellement dans les possibilités de localisation, dans les modes de construction et dans certaines modalités d'exploitation (éclairage, ventilation, sécurité), avec traduction dans les coûts.

L'analyse de ces avantages directs peut s'effectuer au regard de deux grandes familles de facteurs:

1. Facteurs relatifs à l'ouvrage de stationnement proprement dit.
2. Facteurs relatifs aux effets externes générés par la construction et l'exploitation de l'ouvrage de stationnement.

Facteurs relatifs à l'ouvrage de stationnement proprement dit

Conditions d'insertion dans l'environnement

Comme pour beaucoup d'ouvrages souterrains, les conditions d'insertion dans l'environnement constituent un des principaux atout en faveur des parcs de stationnement souterrains.

Nous avons signalé précédemment dans la partie «Stationnement en ouvrages à étages» que, les espaces libres en centre ville étant extrêmement convoités, rares et donc chers, les ouvrages de stationnement à l'air libre:

- Soit, ne sont pas jugés suffisamment rentables—sauf cas d'espèces—pour occuper ces espaces chèrement acquis;
- Soit, des équipements publics de plus grand intérêt leur sont préférés pour y être réalisés.

Les ouvrages souterrains ont alors l'avantage de pouvoir être réalisés sous des surfaces qui doivent rester libres de toutes constructions, ce qui permet une utilisation intéressante des droits à construire attachés à une parcelle de terrain.

Protection contre certaines conditions d'environnement

Les parcs de stationnement souterrains offrent aux personnes et à leurs véhicules une protection contre les rigueurs des climats, qu'il s'agisse de chaleur extrême, de grand froid ou de précipitations (neige, pluie ou grêle). Il est sans doute banal de rappeler à cet égard qu'il est tout aussi désagréable de monter dans une voiture qui a stationné pendant plusieurs heures en plein soleil ou dont les vitres sont couvertes d'une épaisse couche de glace.

Les parcs de stationnement souterrains apportent donc un élément de confort incontestable. On observera néanmoins que les parcs de stationnement à étages établis en élévation au dessus du sol présentent à cet égard eux aussi des avantages par rapport au stationnement à l'air libre. Mais ces avantages sont moindres que ceux des parcs souterrains, car leur conception est généralement telle qu'ils ne protègent pas complètement des intempéries (température proche de celle de l'extérieur, courants d'air, etc.)

Qualité des services offerts aux utilisateurs

Le sous-sol représente, d'une façon générale et particulièrement en site urbain, un précieux «gise-

As the candidates for the use of underground space have increased, the use of this space has often been carried out in a disorderly way. However there are many examples that demonstrate that without the use of the underground, certain parking facilities could not have been built where they were needed. When parking facilities cannot be built in such locations, they lose much of their justification to be built at all.

One such example is the construction of the Mont Blanc car park (in Geneva, Switzerland), which is dug out at the bottom of the lake, right next to the city centre. Another is the underground car park in Sydney, constructed in rock only a short distance away from the docks. The spiralling ramp structure has a direct connection to the well-known Sydney Opera House (Pells 1994).

A ground-level structure does not have this advantage of direct connection unless it is actually a part of the building that it serves; and this is not a very widespread architectural solution. One example that approaches this concept places buildings on piles which overhang the ground level, set aside for vehicle parking under cover of the construction. Another strategy involves large urban operations "on slab", in which the slab is placed one or two stories above the natural ground level to hide traffic movement and vehicle parking.

In contrast, parking facilities incorporated into the foundations of buildings and directly linked to the ground level parts which they serve are very commonly built.

In certain old districts, where finding a place to park is virtually impossible, some property owners do not hesitate to finance the buying-up of the lower sections of their buildings in order to build the highly coveted parking spaces.

With respect to the quality of services offered to users, parking structures built beneath public areas have the advantage of being directly connected to roadways, so that they can be located right next to the attractive places that are often the ultimate destination of drivers.

The fact that many users are reluctant to use underground parking facilities is quite a paradox when we consider that underground public car parks are often superior in terms of comfort (decoration, signposting, general atmosphere, etc.) and have more facilities to ensure public safety (e.g., surveillance by closed-circuit television, intercom systems) than their counterparts at ground level.

As for the design of underground public parking facilities, in just a few years we have moved from a purely practical design that merely groups car-parking spaces together, to facilities that have been carefully planned to meet the comfort and safety needs of car drivers, whether at the wheel or on foot. Everything possible has been done to provide a clear sense of orientation and location, both in the interior of the facilities and in relation to the exterior. This has been accomplished through the use of colors and decor, evenly distributed lighting, and more by admitting shafts of natural light, as well as by creating "background noise" aimed at reducing feelings of underground isolation. What actually is required is to implement measures to overcome the often evil connotations that are associated with the underground work in most cultures.

ment d'espace» permettant notamment d'adopter la localisation la plus appropriée pour l'établissement d'un parc de stationnement. On sait en effet que les critères de proximité et même de liaison directe avec les lieux à desservir sont très importants en matière de stationnement.

Les «candidats» à l'utilisation de ce «gisement d'espace» sont certes de plus en plus nombreux et son utilisation s'effectue de façon souvent désordonnée. Mais nombreux sont les exemples qui démontrent que, sans le recours à l'utilisation du sous-sol, certains ouvrages de stationnement n'auraient pu être localisés à l'emplacement justifiant pour une grande part leur réalisation. Lorsque les ouvrages de stationnement ne peuvent être réalisés à de tels emplacements, il n'est plus justifié de les construire.

On peut citer par exemple la réalisation du parc de stationnement du Mont-Blanc à Genéve, affouillé en fond de lac, à proximité immédiate du centre ville. De même, la réalisation à Sydney, à peu de distance des bassins du port, d'un parc de stationnement souterrain dans la roche, avec une liaison directe avec l'Opéra bien connu.

Un ouvrage à l'air libre ne possède cet avantage de localisation et de liaison directe que s'il est intégré à la construction qu'il dessert. Ce n'est pas une solution architecturale très répandue. S'en rapprochent les immeubles sur pilotis qui surplombent le niveau du sol laissé au stationnement des véhicules sous le couvert de la construction. S'en rapprochent aussi les grandes opérations urbaines «sur dalle», ladite dalle se trouvant à un ou plusieurs niveaux au-dessus du sol naturel et dissimulant les circulations et le stationnement des automobiles.

Par contre, sont réalisés couramment des volumes de stationnement intégrés aux fondations des immeubles, directement en relation avec les parties à l'air libre qu'ils desservent.

Dans certains quartiers anciens où trouver une place de stationnement relève de la gageure, certains propriétaires n'hésitent pas à financer la reprise en sous-oeuvre de leurs immeubles pour réaliser les emplacements convoités.

Dans le domaine de la qualité des services offerts aux utilisateurs, les ouvrages de stationnement réalisés sous le domaine public ont l'avantage d'être directement en relation avec les voies de circulation et peuvent être situés à proximité immédiate des lieux attractifs générateurs de déplacements.

De façon paradoxale, sachant la réticence de nombreux utilisateurs potentiels à fréquenter les ouvrages souterrains de stationnement, les parcs publics souterrains sont souvent mieux traités sur le plan du confort (décoration, signalétique, ambiance) et de la sécurité des personnes (surveillance par circuit vidéo, interphones) que leurs homologues à l'air libre.

Dans le domaine de la conception des ouvrages souterrains de stationnement, tout au moins pour les parcs publics, on est en effet passé en quelques années de la conception purement fonctionnelle d'ensembles d'emplacements pour le stationnement des voitures à des lieux pensés pour le confort et la sécurité de l'automobiliste, qu'il soit au volant du véhicule ou à pied.

Il est fait appel à tout ce qui peut aider au repérage intérieur et au repérage par rapport à l'extérieur, aux couleurs et à la décoration, à un éclairage uniformément réparti et à l'apport éventuel d'un puits de lumière naturelle, à un fond sonore atténuant la sensation d'isolement. Il convient en effet

Construction costs

The construction costs for underground parking facilities are, of course, almost always higher than for facilities constructed in the open air.

However, if we take land costs into account, open-air facilities may be greatly penalised because of the high cost of land in urban areas. This factor is independent of the problem of architectural integration, which is often the reason that aboveground structures are disfavored.

Parking facilities that are constructed under public property are not subject to land costs. However, it must be pointed out that this consumption of space, even though seemingly free, nevertheless entails an implicit cost for the community, inasmuch as:

- The space considered cannot be employed for another use; and
- The structure that is built will hamper, or even prohibit, the future realisation of other works or infrastructures.

In recent years, the advantages of implanting a structure under public property have been increasingly reduced because of the requirements and restrictions that are prescribed to reduce the harm to the environment during the construction period. Such requirements include reducing the construction time, maintaining traffic, and maintaining or protecting trees and green spaces.

For parking facilities, as for other structures, an underground setting is no longer a source of satisfaction in itself. In addition, the nuisances caused by the construction of the underground structure must be reduced to a minimum.

Factors Related to the External Effects Caused by the Construction and Operation of the Parking Structure

The effects caused by the parking structure are all of the consequences, both favorable and unfavorable, that the construction and operation of the structure impose on the other parties concerned.

The basic causes underlying construction of underground parking structures are:

- Opposition to the building of aerial car park structures;
- Or, inversely, encouragement or even pressure to build underground parking facilities.

Nuisances

By their very nature, underground car park structures protect the outside world from nuisance caused by the noise emitted by the movement of vehicles inside the facility. However, this advantage must be weighed against the need to ventilate the interior of the structure. The ventilation system is a possible source of noise on the outside because of the vents needed for supplying or extracting air. The vents are also a source of localised pollution because they expel contaminated air.

Visual impact

A ground-level parking structure is difficult to incorporate into its environment, especially in town and city centres where laws regulate the protection of historic property. One possibility is to locate the facility in the middle of a "construction island", so that it has no visible façades. However, the configuration de combattre la connotation souvent maléfique qui s'attache au monde souterrain dans la plupart des cultures.

Coûts de réalisation

Le coût de construction proprement dit des parcs de stationnement souterrains est bien sûr toujours supérieur à celui des parcs établis en ouvrages à l'air libre.

Cependant, si l'on prend en compte le coût des acquisitions foncières, les ouvrages à l'air libre peuvent être lourdement pénalisés en raison du niveau élevé des prix des terrains en site urbain. Ceci bien sûr indépendamment des difficultés de leur insertion architecturale, lesquelles provoquent la plupart du temps le rejet pur et simple de telles constructions.

Les parcs de stationnement construits sous le domaine public ne supportent pas de coût d'acquisitions foncières. Observons cependant que cette consommation d'espace, même gratuite en apparence, comporte néanmoins un coût implicite pour la collectivité, dans la mesure où l'espace considéré ne pourra être utilisé à d'autres usages ou que la construction qui y est faite gênera, voire interdira la réalisation ultérieure d'autres ouvrages ou infrastructures.

Mais les avantages de l'implantation sous le domaine public au plan du foncier sont de plus en plus hypothéqués par les exigences et contraintes imposées à la réalisation de ces ouvrages en matière d'impacts sur l'environnement en phase de construction : délais réduits, maintien des circulations, protection ou maintien des arbres et espaces verts,...

Pour les parcs de stationnement comme pour d'autres ouvrages, la mise en souterrain n'est donc plus un motif de satisfaction en soi. Il faut en plus que les nuisances engendrées par la construction de ces ouvrages souterrains soient les plus faibles possibles.

Facteurs relatifs aux effets externes générés par la construction et l'exploitation de l'ouvrage de stationnement

Les effets externes générés par l'ouvrage de stationnement sont l'ensemble des conséquences, favorables ou défavorables, que la construction et l'exploitation de celui-ci impose aux autres «parties» concernées.

Les facteurs qui suivent sont à l'origine:

- soit des oppositions à la réalisation d'ouvrages de stationnement à l'air libre,
- soit, inversement, des encouragements, voire des pressions, pour réaliser des parcs de stationnement souterrains.

Nuisances

Par leur nature, les ouvrages souterrains de stationnement protègent l'extérieur des nuisances dues au bruit émis par la circulation de véhicules à l'intérieur. C'est un avantage à confronter à la nécessité de ventiler l'intérieur de l'ouvrage, cause possible de bruits à l'extérieur, au droit des débouchés des baies de prise ou d'extraction d'air, ces dernières étant par ailleurs la source d'une pollution localisée (rejet d'air vicié).

Impact visuel

Un ouvrage de stationnement à l'air libre reste difficile à insérer dans son environnement, surtout

of plots of land rarely permits such a layout, unless regrouping involving other neighboring structures allows slightly more flexibility.

Underground parking structures are confronted with this type of difficulty only when they are placed under public areas, because of the presence at ground level of the car access ramps, stair openings or elevator shaft openings for pedestrians, and air vents for the internal ventilation system.

Underground car parks make it possible to return the surface to its original condition; they can even provide the opportunity for a completely new layout for the surface. In many cases, it is principally because of car parks built under large public squares that these squares have reattained an architectural order that disappeared from view with the invasion of parked cars; or that green spaces have recovered their former charm.

Civil defense

Certain underground parking structures are intended to be equipped to serve as shelters in case of nuclear attack.

Indirect Advantages of Underground Car Parks

In most cases, use of the underground environment is the only option that is technically possible for the realization of parking facilities, or which permits consensus to be reached among the various parties concerned with the construction of such structures.

This means that if we do not use the underground solution to construct the structure in its appropriate location, we must either give up the project or select another, less effective solution, in terms of both services offered to the motorists and the effect on the urban environment.

In such a situation, of which there are numerous examples, what needs to be done is to compare the underground parking option, not with a hypothetical ground level option (which is technically impossible or almost unanimously rejected as unacceptable), but rather with :

1. The option of "doing nothing at all", i.e., maintaining or developing the existing situation, which is often unfavourable or even intolerable;
   However, most cities cannot afford to "do nothing" in this domain, considering the deteriorated conditions noted in circulation and parking, and with the detrimental effects on urban life (space occupation, various nuisances, loss of time, etc.) that result from these conditions.
   or
2. A less favourable solution regarding parking or circulation conditions or the urban environment.
   Among the solutions that can be a recourse is to restrict the use of automobile in city centres. This restriction, when applied, has certain drawbacks for the economic life of the city. We can also designate that the parking facilities be located in the outskirts of the city, and provide

dans les centres des villes où le patrimoine historique impose des règles de protection. Une possibilité est de le localiser au coeur d'un ilôt de construction, sans façades visibles. Mais la configuration des parcelles permet rarement une telle disposition, à moins qu'un regroupement avec d'autres constructions environnantes n'autorise plus de souplesse.

Les ouvrages de stationnement souterrains ne sont confrontés à ce type de difficulté que dans le cas d'une implantation sous des espaces publics, en raison des émergences que constituent les rampes d'accès pour les voitures, les débouchés d'escaliers ou les édicules d'ascenseurs pour les piétons, les prises d'air et les bouches d'évacuation du système de ventilation interne.

Les parcs de stationnement souterrains peuvent permettre de restituer le niveau de surface dans son état antérieur, ou être mis à profit pour réaménager complètement la surface selon de nouvelles dispositions. C'est principalement le fait des parcs de stationnement construits sous de grandes places publiques, plantées ou non, qui leur font retrouver une ordonnance architecturale perdue de vue avec l'envahissement des voitures en stationnement ou qui redonnent tout leur agrément aux espaces verts qui s'y trouvaient.

Protection civile

Certains ouvrages souterrains de stationnement sont prévus pour être équipés et servir d'abri contre les retombées radioactives.

Les avantages indirects des parcs de stationnement souterrains

Dans la plupart des cas, l'utilisation du sous-sol est la seule solution techniquement envisageable pour la réalisation de parcs de stationnement ou pour obtenir un «consensus» entre les diverses parties concernées par la réalisation de tels ouvrages.

Cela signifie que, si l'on ne recourt pas à la solution souterraine pour réaliser l'ouvrage projeté dans sa localisation souhaitable, on doit alors, soit renoncer purement et simplement au projet, soit adopter une solution moins performante au plan du service rendu aux automobilistes ou à celui des impacts sur l'environnement urbain.

Dans une telle situation, dont les exemples sont nombreux, il convient donc de comparer la solution souterraine de stationnement, non plus avec une hypothétique solution à l'air libre, techniquement impossible ou rejetée presque unanimement, mais avec:

1. Soit la solution consistant «à ne rien faire», c'est-à-dire correspondant au maintien et à l'évolution, souvent défavorable, voire inadmissible, des conditions de stationnement et de circulation.
   Or, la plupart des villes ne peuvent se permettre de «ne rien faire» dans ce domaine, compte-tenu de la dégradation constatée dans les conditions de stationnement et de circulation et des importants effets négatifs qui en résultent sur la vie urbaine (occupation de l'espace, nuisances diverses, pertes de temps,...).
   ou:
2. Une autre solution moins favorable au plan des conditions de stationnement ou de circulation, ou au plan des impacts sur l'environnement urbain.

various measures to induce motorists to park their vehicles there and use public transport to journey into the city.

In this case, it is only logical to attribute all of the advantages of the services offered by the underground parking structures entirely to the use of the underground environment.

These advantages, which we refer to as "indirect advantages", concern:

- Vehicle owners.
- The users of other modes of transport.
- Various economic players.
- The community.

The advantages accruing to each of these groups are discussed below.

Vehicle Owners

Underground parking facilities allow vehicle owners to find additional possibilities for parking their vehicles adjacent to or close to their homes, and for parking near their journey's destination.

As a means of removing illegally parked vehicles from the public highway—and thus, the source of congestion which slows down traffic or blocks access completely to certain areas—underground parking structures obviously improve the overall traffic flow. Actually, they remove the motive of parking illegally because of a lack of spaces, which is always the reason for a certain degree of tolerance in others when faced with parking offences.

The Users of Other Modes of Transport

In the same way, surface modes of public transport also benefit from the construction of underground parking structures because the general traffic flow is improved, and many instances of illegal parking on the transport routes can be dealt with more readily.

Economic Players

The increase in the available stock of parking spaces is viewed as an important factor in the "good health" of the economic activity of the town or city. The potential client car users are less likely to give up their journeys into town if there are better conditions of access and, especially, better parking facilities have been provided.

In the same way, companies that employ staff who travel a great deal will be more likely to set up or to maintain their town or city centre location—which is, after all, the best place to do business, even if its reputation is often a little tarnished by traffic problems and parking difficulties.

The Community

The community benefits from the construction of underground parking facilities because it is able to reserve public areas to be used as they were originally intended: for movement, meetings and business, relaxation and leisure activities.

Parmi les solutions pouvant constituer un recours, citons les restrictions à l'usage de l'automobile dans les centres villes qui, lorsqu'elles sont réellement appliquées, présentent certains inconvénients pour la vie économique de la cité. Citons également la réalisation de parcs de stationnement à la périphérie des villes, accompagnée de mesures diverses d'incitation des automobilistes à y laisser leurs véhicules et à utiliser les transports publics pour leurs déplacements dans la cité.

Dans tous ces cas, il est logique de porter l'ensemble des avantages liés aux services offerts par les ouvrages souterrains de stationnement intégralement au crédit de l'utilisation du sous-sol.

Ces avantages, que nous qualifions «d'avantages indirects», concernent:

- Les possesseurs de véhicules.
- Les utilisateurs des autres modes de déplacement.
- Les divers acteurs économiques.
- La collectivité.

Les possesseurs de véhicules

Les possesseurs de véhicules trouvent des possibilités supplémentaires pour le garage de leur véhicule en liaison ou près de leur résidence, ainsi que pour le stationnement à proximité du lieu de destination de leur déplacement.

En venant décharger les voies de circulation du stationnement interdit qui gêne la progression des véhicules ou l'accès à certains secteurs, les ouvrages de stationnement apportent une amélioration certaine à la circulation générale. En effet, ils font disparaître le motif du manque d'emplacements qui conduit toujours à une certaine tolérance vis-à-vis des situations d'infractions.

Les utilisateurs des autres modes de déplacement

De la même manière, les transports collectifs de surface bénéficient de la réalisation des ouvrages de stationnement dans la mesure où est améliorée la circulation générale et où, sur leurs itinéraires, les nombreuses situations de stationnement interdit peuvent être combattues sans arrière-pensée.

Les acteurs économiques

L'augmentation de l'offre de stationnement est vue comme un facteur important de «bonne santé» pour l'activité économique de la ville. Les clients potentiels utilisateurs de la voiture risquent moins de renoncer à leurs déplacements vers le centre si les conditions d'accès et surtout de stationnement sont bonnes.

De la même manière, les sociétés ayant du personnel amené à se déplacer souvent seront moins rebutées à s'installer ou à conserver leur installation dans le centre ville, lieu privilégié des échanges mais dont l'image est souvent ternie par les difficultés de circulation et de stationnement.

La Collectivité

La collectivité bénéficie de la réalisation d'ouvrages de stationnement souterrains en pouvant récupérer les espaces publics pour leur véritable vocation, la circulation, la rencontre et les échanges, le repos.

The resulting improvement in the ability to move around is also an advantage for the community. The reduction in time wasted in traffic jams leads to increased productivity. Less traffic moving at slow speeds means less pollution from vehicle exhaust emissions. The fewer the hindrances for surface public transport, the better the productivity in the transport sector—and, therefore, the lower the operational costs.

The advantages associated with higher levels of economic activity are also advantages for the community in general, which sees an increase in its income from various taxes on sales transactions made, as well as on urban rehabilitation projects.

Underground Car Park Construction Costs

All of the advantages cited above obviously need to be weighed against the costs of building underground parking facilities.

These costs are extremely variable, depending to a large extent on the methods to be used and the problems presented by construction. The methods and problems themselves arise from the structure's environment, the nature and difficulty of the ground in question, and the need for total or partial maintenance of traffic movement on the surrounding roadways.

As for other types of structures, either at ground level or underground, data concerning costs is rarely found and often inaccurate. In an attempt to improve this situation, the Animateur of the Working Group circulated a questionnaire to members of the ITA and to other possible external sources of information, with a view to gathering together such data. Unfortunately, the responses received were relatively few, and therefore did not allow any meaningful analysis.

Be that as it may, it has been established that in cases where the same services and functions are offered, the cost of underground parking structures is almost always distinctly higher than their ground-level counterparts. However, as the above discussion indicates, the question is often not so simple, since it is normally a choice between building an underground structure or doing nothing at all—which, as we have seen, also has consequences for the economic and social life of an urban area.

Essentially, the problem is to find the necessary financing for such construction work. And in fact the car drivers, who are the providers of finance at the end of the chain, usually are not prepared to pay a price for parking facilities that will allow the costs to be recouped or the works to be amortised over a satisfactory time period.

In some cases, regulations are being relaxed and positive mechanisms even put into place to facilitate the construction of car park facilities: for examples, subsidies are available in Italy; very low or even 0% interest rates are given on loans in Japan; and concessions are granted in respect of public property in France.

L'amélioration de la circulation est aussi un avantage pour la collectivité. En effet, moins d'heures perdues dans les embouteillages se traduisent par une meilleure productivité. Moins de circulation au ralenti c'est aussi moins de pollution due aux gaz d'échappement. Moins de gêne pour les transports collectifs de surface, c'est une meilleure productivité de ces transports et des coûts d'exploitation moindres.

Les avantages pour l'activité économique sont aussi des avantages pour la collectivité en général qui voit augmenter ses ressources liées aux taxes diverses sur les transactions marchandes, sur les mutations urbaines, etc.

Les coûts de réalisation des parcs de stationnement souterrains

Tous les avantages évoqués précédemment sont bien sûr à mettre en balance avec les coûts de réalisation des ouvrages souterrains de stationnement.

Ces coûts sont très variables, dépendant étroitement du mode et des contraintes de réalisation, eux-mêmes fonction de l'environnement de l'ouvrage, de la nature et de l'encombrement du sous-sol, du maintien total ou partiel des circulations dans les voies environnantes.

Comme pour d'autres types d'ouvrages, qu'ils soient souterrains ou aériens, les données concernant les coûts sont rares et imprécises. Pour essayer d'y remédier, l'animateur du groupe de travail a fait passer auprès des membres et auprès d'autres sources d'informations, un questionnaire destiné à recueillir de telles données. Hélas, les réponses obtenues à ce sujet ont été trop peu nombreuses pour permettre une analyse significative.

Quoi qu'il en soit, à fonctions et services égaux, il est établi que le coût des parcs de stationnement souterrains est nettement plus élevé que celui des ouvrages à l'air libre. Mais, comme on l'a dit plus haut, la question ne se pose guère en ces termes puisqu'elle se limite le plus souvent à soit réaliser un ouvrage en souterrain, soit ne pas en réaliser du tout, avec toutes les conséquences qui en découlent pour la vie économique et sociale en zone urbaine.

Le problème consiste donc essentiellement à trouver les financements nécessaires à de telles réalisations. En effet, les utilisateurs finaux (automobilistes) ne sont généralement pas prêts à payer un prix qui permettrait d'envisager un amortissement de l'ouvrage sur des durées satisfaisantes.

Aussi, des réglementations ou des mécanismes sont-ils mis en place dans quelques pays pour faciliter les politiques de construction d'ouvrages de stationnement: ouverture de subventions en Italie, de prêts à taux faible ou nul au Japon, concessions du domaine public en France.

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Underground Car Parks in France: a Case Study

French Tunnelling Association (AFTES) Working Group "Direct and Indirect Advantages of Underground Structures"

Prepared by J.-P. Godard and J.-P. Tareau

Abstract—*Like cities in most other countries, French cities are faced with serious parking shortages. This paper gives an overview of parking policies in France and of the measures taken in this respect, especially regarding the use of urban underground space for parking facilities.*

Résumé—*Comme dans la plupart des autres pays, les villes françaises sont confrontées à des problèmes de stationnement. Cet article donne une vue générale des politiques françaises en matière de stationnement et des mesures prises dans ce domaine, principalement en ce qui concerne l'utilisation du sous-sol urbain pour l'aménagement de parcs de stationnement.*

1. Introduction

Car parks have developed along with cars, and have generated a considerable body of knowledge about their conception, construction and operation. Even when integrated into other buildings, they have a unique, easily identified function. It is interesting to consider the specifics of such structures and why most of them, particularly in France, have been built underground.

To investigate the reasons behind this phenomenon, a report was written in 1993 for Working Group No. 15 of the French tunnelling association AFTES (Association Française des Travaux en Souterrain) on the subject of "Direct and indirect advantages of underground structures". That report was presented to the corresponding Working Group of the International Tunnelling Association (ITA) at its meetings in Amsterdam in April 1993. This paper presents the main findings of the report.

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2. Ground Level: a "Natural" Parking Area

In the 1950s, in France as in other industrial countries, the population very rapidly became equipped with motor vehicles, and individual vehicles in particular.

At the same time, in those town centers in France that had not sustained extensive destruction during the World War II, there remained a great many historic buildings, some of which were very old. Adjacent coach houses, outbuildings and other areas soon proved insufficient for use as garages for the ever-increasing numbers of vehicles. Thus, of necessity, roadways and public areas were gradually monopolized in order to fulfill this function (see Figs. 1 and 2).

In cases where town centers had to be rebuilt, they were usually built according to spacious town plans that called for large roadways. These rebuilding schemes introduced new parking areas, located mainly at ground level in the town hub or surrounding the town center plot. Examples of such development are found in Dunkerque, Calais, Le Havre, and Lorient.

Without further emphasizing the postwar craze for automobiles, one of its advantages (although admittedly increasingly less the case at present) was the means, available at all times, to travel quickly from door to door. From this point of view, ground-level parking was seen as the most desirable type of parking.

Thus, in areas that also had the advantage of a temperate climate (a

Advantages and Disadvantages of On-Street Parking

In addition to the advantages of proximity, parking alongside pavements or on pavements offered advantages in terms of use of surface areas. Indeed, the space taken up by a typical vehicle parked on the street averages just 12 m². The areas required for driving maneuvers related to on-street parking are primarily dedicated for automobile or pedestrian traffic.

In comparison, for car parks, the driveways, ramps and area occupied by the structure (for multi-story car parks), whether the facility is a ground-level lot or a parking structure, bring the average mobilized surface area per vehicle space up to approximately 25 m²—i.e., almost double the area of an on-street space.

Disadvantages associated with on-street parking include:

- The surface areas mobilized to the detriment of other uses.
- Hazards due to on-street driving maneuvers or obstructions in visibility.
- Interference with pedestrian traffic.
- It is visually unpleasant from an aesthetic point of view.

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Pergamon

Figure 1. Ground-level parking monopolizes all the accessible spaces (photo: CETUR/J. P. Tareau).

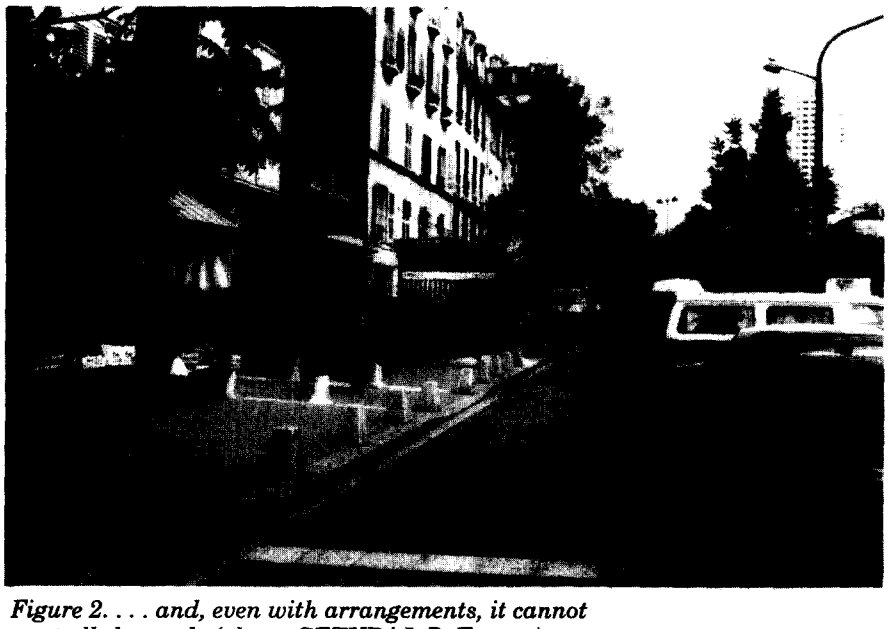

Figure 2. . . . and, even with arrangements, it cannot meet all the needs (photo: CETUR/J. P. Tareau).

factor is not limited to France), ground-level parking became the culturally "natural" mode of parking, not only in town centers but in other urban areas as well.

3. Factors Encouraging Underground Parking

One result of the rapid increase in automobile use was the widespread practice of on-street parking. Generally, wherever traffic requirements were not vital, curb parking was systematically used. Large public squares in town centers, and even wide streets and central zones on the large avenues, were open to parking during the last century.

But even these possibilities have become limited, particularly in town centers where the roadways have remained very narrow, as is the case in many cities in the south of France (Montpellier, Aix-en-Provence and Avignon, for example).

By the early 1960s, as the existing parking areas were proving insufficient, two significant events occurred:

1. The first parking structures appeared (in 1964, the car park under the esplanade of the Invalides in Paris was opened); and

2. Regulations were approved that limited the duration of parking in town centers (thereby creating so-called "blue zones").

The over-occupation of ground-level areas by parking naturally led to the construction of parking facilities off the roadway. As a result, nearly all large towns in France today have at least one public parking structure.

Towns with a population exceeding 100,000 usually have an average of more than two car parks, whereas towns with more than 500,000 inhabitants usually have approximately 10 car parks. The average capacity of the public car parks is typically 400 to 500 spaces. In contrast to structures built during the late 1960s and the early 1970s, almost none of the more recently constructed facilities have more than 1,500 spaces. The exceptions are car parks built at the same time as a shopping mall in a town center.

Some other urbanization schemes have appeared in which the roadway use is totally dedicated to vehicle traffic and some specific areas to parking, the whole of which is set on a different level from the spaces reserved for pedestrians. This type of "on-slab" town planning can be found in new towns and in some rebuilt districts, such as La Défense and Le Front de Seine in Paris.

Thus, public car parks in town centers may take the form of ground level lots (although their numbers are diminishing) or parking structures (generally referred to as "multi-story car parks" in transportation planning).

A number of factors have increasingly encouraged placing such structures underground.

In the case of **public ownership**, several factors apply (see Fig. 3):

- A concern with aesthetics: e.g., a desire to renovate a "Main Square" that has been invaded

Survey of Parking Structures in France

A Syncoparc (National Trade Union of public car park holders) survey conducted in April 1990 in towns with populations exceeding 30,000 provided the following data.

The survey counted 608 public paid-admission parking structures, representing 300,100 spaces. Of the 608 total parking structures, 105 were in Paris. Of those structures not located in Paris, 327 were underground, 52 were mixed (i.e., partially underground), and 90 were aboveground.

GTM Company, the major promoter of car park facilities in France, has reported that about two-thirds of the parks it has built are underground.

by vehicles, and thereby to restore its original architectural arrangement.

- The possibility of granting plots of land under public ownership for the purpose of building public services structures.
- Underground space in well-located areas that provide opportunities for profitability of such structures.
- The ability to perform the construction works, for large numbers of parking spaces, without excessive technical difficulties or worksite constraints.

To the above factors a favorable economic context can be added—at least, we should say, until the first "oil crisis" occurs. With regard to **private ownership**, private car parks used by the public are found mainly in Paris and in Nice. In other towns, they are usually car parks attached to a department store or a shopping mall.

The main purpose of other privately owned facilities, referred to as "commercial garages," is not parking but, more often, automobile sales and/or maintenance. In this case, surface areas unused by the main activity of the structure are rented out as parking space. A number of these commercial garages, located in town centers, provide hourly or half-day parking formulas. However, this type of parking facility has tended to disappear under the pressure of real estate expenses and the more profitable use of building rights attached to the mobilized plots.

Factors encouraging construction of privately owned parking structures include:

- In many cases, a legal obligation to provide parking spaces when new structures are built.
- Less accounting for underground areas in calculating land-use coefficients.

In order to make full use of building rights, parking spaces are generally provided below new buildings. A move toward this type of private structure has begun, but thus far has been limited to Paris, mainly in districts where development of a commercial "hypercentre" has greatly increased land taxes. The cost of this type of development is very high in view of the technical constraints: between 180,000 and 260,000 FF, excluding tax, and including all of the firms' costs. There is no direct return on such structures; they are especially profitable for the increased value of buildings, more than for leasing.

In the same way, construction of buildings whose sole purpose is for parking has proven to be, with the exception of particular cases, hardly worthwhile in financial terms because of low demand, which is often rein-

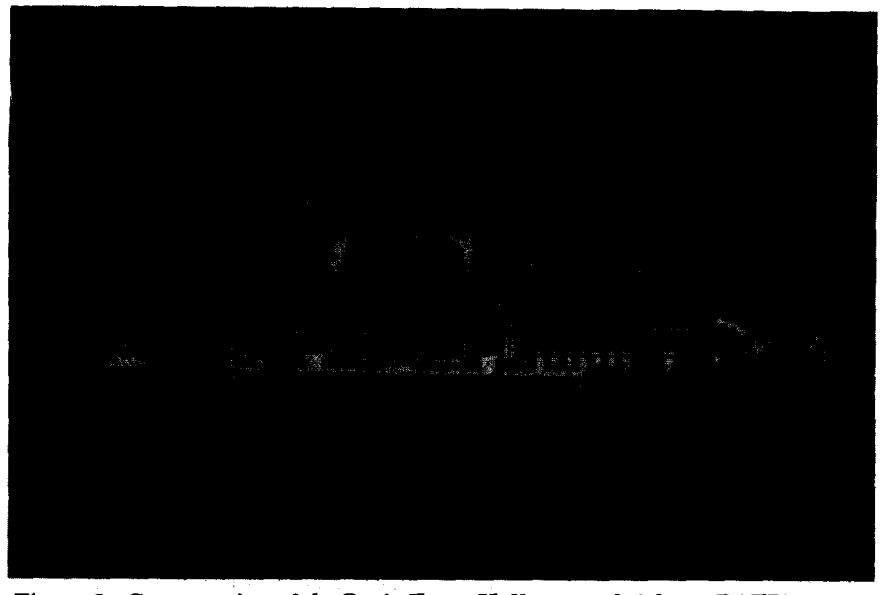

Figure 3. Cross-section of the Paris Town Hall car park (photo: RATP).

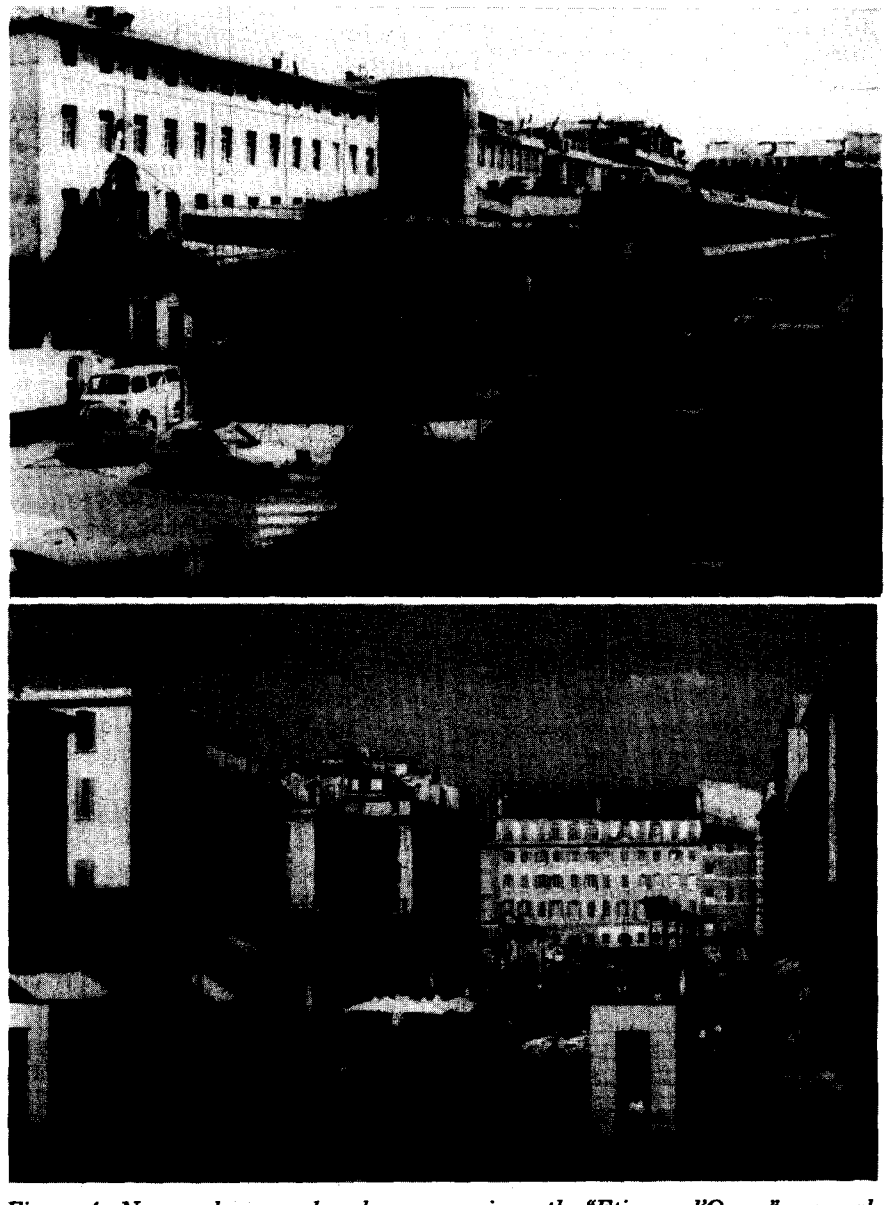

Figure 4. Now underground and more spacious, the "Etienne d'Orves" car park in Marseille gave surface space to the pedestrians (photo: Ducoux - Barège).

forced by constraints originating from their proximity to historic buildings or a location in a protected sector.

Aboveground vs. Below-ground Car Parks

Aboveground multi-story car parks in town centers are found in particular circumstances. They may be associated, for example, with an historic location (see Fig. 4); a real estate opportunity (the most typical are those built on the location or above covered markets); or a specific characteristic of the subsoil (rock, underground water table). A number of these are not true aboveground structures because they support traffic slabs or serve as bases for complex operations.

Some "mixed" multi-story car parks, comprising a few stories underground and the rest aboveground, also have been built.

On the urban periphery, car parks are usually at ground level only, or aboveground if greater capacity is considered necessary (see Fig. 5). A few underground car parks are found in the centres of commercial areas on the outskirts of large cities. Specific sites may be created at the termini of public transportation lines, or near stations that are well-serviced by and easily accessed from these lines.

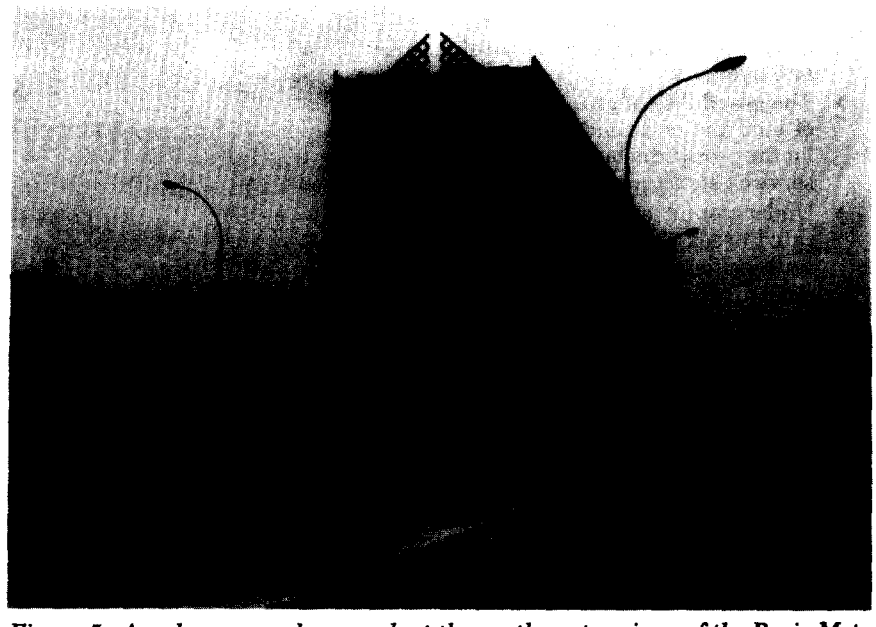

Figure 5. An aboveground car park at the southern terminus of the Paris Metro Line No. 7 (photo: RATP).

Aboveground Vs. Underground Car Parks

Car parks above the ground may have the advantage of more flexible phasing of parking, but the phasing concept may also be applied to underground car parks. For example, parking levels under the Cité Mondiale du Vin in Bordeaux can be used as and when the amount of use changes.

A car park above ground level can be destroyed to make room for something else. For example, the Palais car park in Rouen, which has 723 places above ground level, is destined to be replaced by an underground car park (1,500-vehicle capacity) with a building on top.

In contrast, future demolition of an underground structure is difficult to envision. And, short of envisaging its destruction, the reconversion of an underground car park is a difficult and delicate task. Nevertheless, some little-used Paris car parks have been converted for use as preliminary car impound lots.

Underground car parks may have advantages in other areas. For example, underground works are less sensitive to seismic wave effects, especially if the environment is similar and the shapes are not too angular.

4. Curbing Disorganized Use of Ground-Level Parking Space

Traffic/Parking Regulation

In the late 1970s, the following regulation measures pertaining to the use of cars in towns, especially in city centres, began to be enacted:

- Automobile access to town centers was restricted, in order to create pedestrian zones.
- Ground-level public transportation traffic (bus lanes, trams) was given priority.
- Streets that had been overrun by vehicles were "reclaimed" through redevelopment.
- Parking time limits were increasingly monitored by means of pay parking lots and appropriate surveillance (see Fig. 6).

The restrictions and costs resulting from these measures have had a number of consequences, including:

- Motorists have tended to switch to free or less monitored parking areas; and
- A lack of garages on roads adjacent to housing for residents.

At the same time, money for such investments became available, and the increase in the numbers of public car parks under construction resulted in the establishment of special regulations pertaining to them.

A circular of 3 March 1975 relates to covered car parks; and an appended Technical Directive Order of 31 January 1986 governs regulates car parks with areas greater than 100 m^2 and less than 6,000 m^2, attached to dwellings. Car parks with areas greater than 6,000 m^2 and less than 20,000 m^2 are subject to regulations for establishments listed for environmental protection (Circular of 4 November 1987 on the revised version of Order number 331).

In addition, consulting an architect is now compulsory, even for underground car parks.

This combination of factors has been reflected in increased costs, as well as a decrease in the number of structures provided in town centers for "hourly" clients.

The 1970s were used profitably, particularly in Paris, to tackle residential parking needs through construction of specific structures, under both public and private ownership.

5. The Underground Car Park: Evolution of a "Product"

Public underground car parks in France have evolved over the years by benefiting from the lessons learned from previous achievements. Recently built structures clearly convey the message that the owners are not dealing with users who are more or less "obliged" to use the facility, but rather with a "clientèle" that can choose among rival offers, including the more desirable surface parking. The underground car park has thus become a "product" in its own right, with specific rules for design and interior layout.

As a result of technological advances, the newer underground parking structures require few pillars, and some require none (through the use of pre-

stressed girders)—an arrangement that makes parking operations easier and which also permits better overall visibility.

Parking spaces are wider and therefore more accessible. The lighting is installed above the parking places rather than above the traffic paths, providing a more comfortable arrangement for drivers and passengers leaving or returning to the vehicle. In addition to providing increased lighting levels, a major effort is being made to maintain this level of lighting over the longer term. Some car parks are even arranged around a central shaft to allow in the maximum amount of natural light (a recent example is the Méditerranée car park near the Gare de Lyon in Paris).

Pedestrian movement, including persons with reduced mobility, are being taken into consideration, as demonstrated through the provision of elevators, wider lanes and stairways. The concern with needs of pedestrians is also reflected in the interior markings for car parks. For example, different colors and/or signs are used to differentiate the levels of the facility; and signs bearing street names and symbols are used to relate the outside environment to the interior of the car park.

To improve efficiency, paying machines have been designed to reduce exit waiting times and make different forms of payment easier to accept. Reception halls and facilities such as telephones, toilets, etc., are provided to increase the comfort of users.

In the same way, a major effort is being made to fit out the underground premises where the staff have to work. These improved surroundings can help the employees carry out their duties of welcome and surveillance efficiently.

In earlier parking structures, many of these "decorative" points were considered space-consuming additions that would be little appreciated in the underground. However, experience has shown them to be necessary, if not essential, to the appeal of such car parks. In the past few years, artists' contributions have even appeared in the car parks: in Lyon, for example, artists are asked to come in very early in the design stage. Throughout the project, the aim is that "clients shall feel good" in the underground parks.

To further this aim, everything that contributes to the security of the property and the people who use it and work in it is provided, from video surveillance networks and intercom systems to staff patrols and reserved access arrangements.

Unfortunately, very few of these services have been incorporated into car parks attached to private buildings. As a result, people who have a parking space underground in these buildings often prefer to leave their vehicles up on the road, rather than having to drive around in places where they feel uneasy.

6. A Necessary Adaptation to an Increasingly Constraining Underground Environment

Underground car parks are no different from other buried structures when the geological and hydrogeological conditions of the site are considered. Particularly in an urban environment, these conditions are not always favorable. Since towns are often built near a waterway, the bothersome

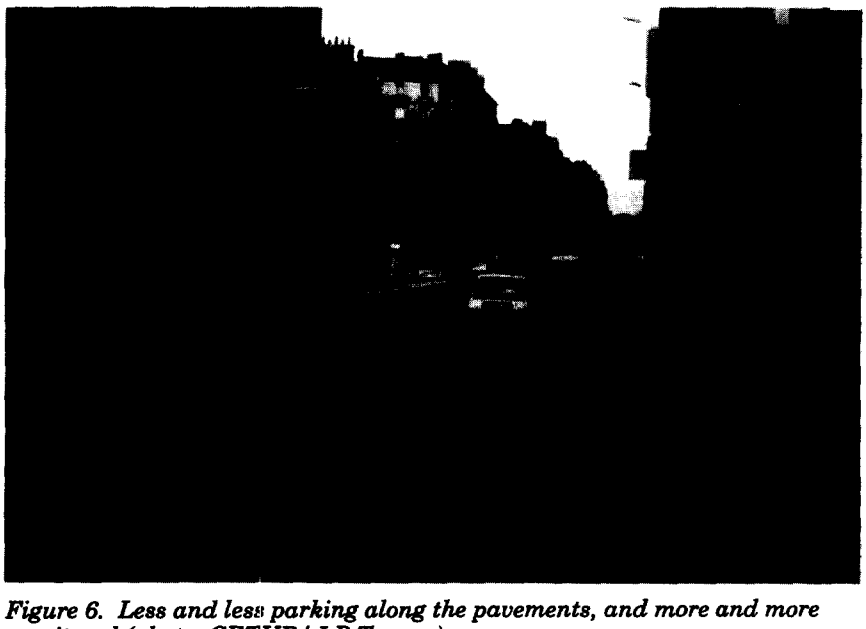

Figure 6. Less and less parking along the pavements, and more and more monitored (photo: CETUR/J.P.Tareau).

Traffic Organization

Generally speaking, the following city planning layouts are found in French towns:

- **A central pedestrian area** (with the network of streets organized accordingly).

In this case, access for private vehicles is prohibited permanently or at certain times (from late morning to late afternoon, for example, in connection with commercial activity). Access for delivery vehicles and for town residents who own garages is also a problem.

In several towns, ground-level public transportation has been preserved within these pedestrian areas.

- A central ring road, opened during this century in areas formerly occupied by fortifications. Here a boulevard (not always circular or simple) fulfills several purposes: protection of the town center, control and distribution of arriving traffic, and provision of parking spaces in areas not used for traffic.

A central ring road demarcates town centers in which traffic and parking are regulated:

- By a traffic scheme prohibiting or discouraging drivers from crossing the town center directly from one end to another, unless a number of large roads have been provided for this purpose.
- By parking regulated for duration, combined in some cases with payment or conditional access (retractable boundaries are used in some towns).

- **Possibly a few crossing roads**, mainly provided for traffic. On such roads, not only parking but also stopping may be prohibited.

Thus, the governing parking policy, as expressed by the town layouts, is based on prohibited sectors, traffic schemes, ground-level parking payment, and authorizing access to the center for utility vehicles only. At the same time, use of public transportation is emphasized, with traffic priority granted or with exclusive rights of way (possibly underground), giving easy and attractive access to strategic areas.

presence of the water table, and of composite soils varying between alluvial deposits and rubble, frequently must be taken into account in construction planning.

Psychological and Safety Aspects

Regulations applying to covered car parks were originated from fears relating to fire hazards, intoxication by exhaust fumes, and power failures that might cause panic. From such considerations came the obligation to divide areas by walls and to provide air locks with solid doors to exits and stairs for pedestrians, in order to counter the spread of possible fires.

In first-generation car parks, safety and psychological factors were badly overlooked, leading to unsafe recessed nooks and loss of visibility in certain areas. These aspects and others, including weak lighting, narrow stairways, low levels of activity at most times, and a certain amount of negligence with regard to maintenance, contributed to the apprehensive feelings generally noted among persons using underground areas.

Though there are far fewer assaults and less vandalism, as well as undoubtedly less theft from cars (not to mention actual car thefts) in underground car parks, the few episodes that do occur are often amplified by the press, which knows that a large majority of its readers have not yet changed their negative opinions about such car parks.

However, real progress has occurred in the last few years in making parking lot clients feel secure and providing them with greater comfort in car park use. Artistic expression in particular has come into greater use in car parks. These aspects have been expressed as "minimal requirements" in the Quality Charter for car parks granted by the City of Paris. This document also emphasizes maintenance as an important aspect of long-term quality.

These considerations are reflected in the methods typically used to carry out excavations and for calculating the required resistance against soil pressure. (Methods such as slurry walls are not further discussed here, since they are have become rather commonly understood and applied).

The hydrogeological aspects are also notable with regard to the stability that must be provided to the structure. This often involves the need to install either substantial inverts or drainage systems supplemented by continuous pumping out of the infiltration water. If this work is not carried out, the structures may be unable to withstand a rise in the water table effectively. In such a case, the lower levels may require flooding to make them heavier for a short time. On special sites, some works are designed to be floodable if the water level rises: the car parks of the Remparts in Besançon and the Maison de la Radio in Paris are examples.

The underground is increasingly being used for structures and infrastructure required for the functioning of the city: power lines, water and passenger transport systems, waste water disposal, etc., especially in the public sector.

Thus car parks, particularly those in the public sector, are faced with a set of constraints that influence the project from design to construction and beyond, when the car park is in service. These constraints originate from the fact that the car park normally will be constructed on an attractive urban site that is congested at ground level and congested underground, and which is characterized by often uncertain, if not dubious, underground quality (e.g., with regard to the water table).

The constraints occur at three stages:

1. Design.
2. Construction.
3. Operation.

All three types of constraints translate into increased costs, especially for construction. The constraints associated with each stage are discussed below.

Constraints in the Design Stage

The challenge at the design stage is to fit a functional "box" into an available, but rather inflexible, space.

The increasing the number of underground structures has made it possible to benefit over time from:

- Better knowledge of the formation of the underground/subsoil in sought-after sectors and a more accurate tracking of the real occupancy of these spaces.
- The development of appropriate excavation and support techniques, and better mastery of the use of prefabricated components.
- Computerized three-dimensional project display techniques, which make it easier to fit a structure as precisely as possible into a limited space.

For functional purposes, the underground car park should be linked to the surface traffic network. However, there are often constraints on the optimal siting of links with the ground level (through car and pedestrian access, for example). Some of these constraints are posed by regulations relating to protected sectors and areas that house historic buildings; others include the need to provide exits from elevators, guard rails for ramps and stairways, and ventilation openings, etc.

Finally, conflict often arises over the external appearance of the structure. For example, one planner may argue for discreet positioning of the facility, while another might propound the need for a more prominently visible structure that can be immediately identified by approaching motorists.

Constraints in the Construction Phase

Limitations on ground space availability usually mean that the work has to be carried out on small areas of acquired land. The work is all the more challenging because very often traffic cannot be prohibited completely in the sector where construction is taking place.

Advanced techniques are used for working in such restricted spaces, by removing debris quickly and building as swiftly as possible. To accomplish this, methods used in France include:

- The Latin cutter, developed by Solétanche for drilling at a low height of about 5 m.
- "Mole" work, involving installing the slabs of the various levels as the excavation progresses.
- "Semi-mole" work, involving installing girders only in order to reestablish the ground level quickly, for traffic circulation and storage of worksite equipment.
- The Perforex method, suggested for removing restraints on the surface. The method uses mechanical precutting for a gallery and supports the concrete vault on lateral beams. The beams rest on piles installed as the work progresses and anchored under the last underground level planned. The method makes it possible to create as many parallel galleries as necessary.

New techniques can be seen even for car parks underneath buildings, such as the Haussmann-Provence op-

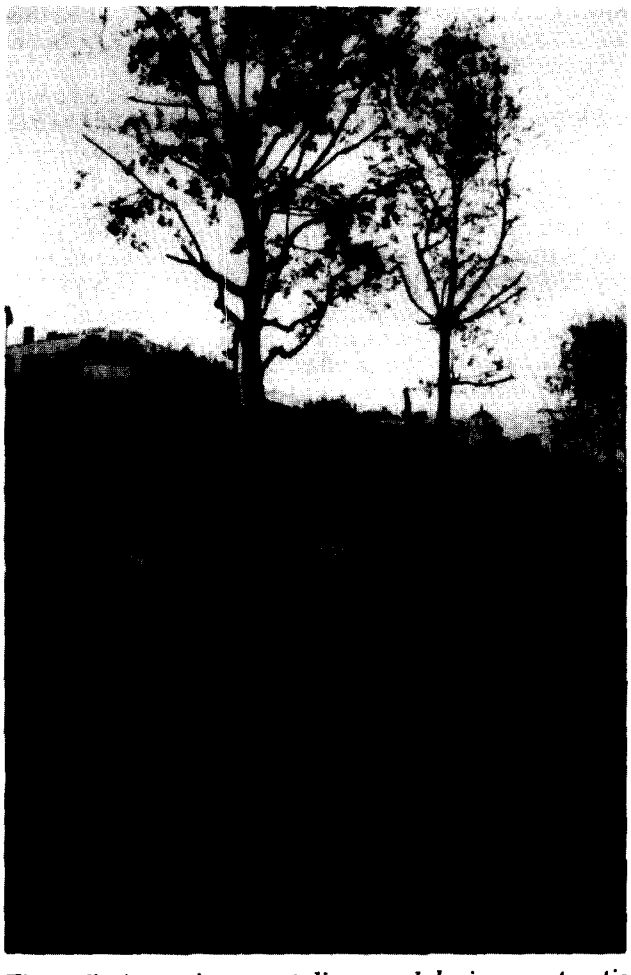

Figure 7. An ancient crypt discovered during construction is displayed in a corner of the Martroi car park in Orléans (photo: GTM).

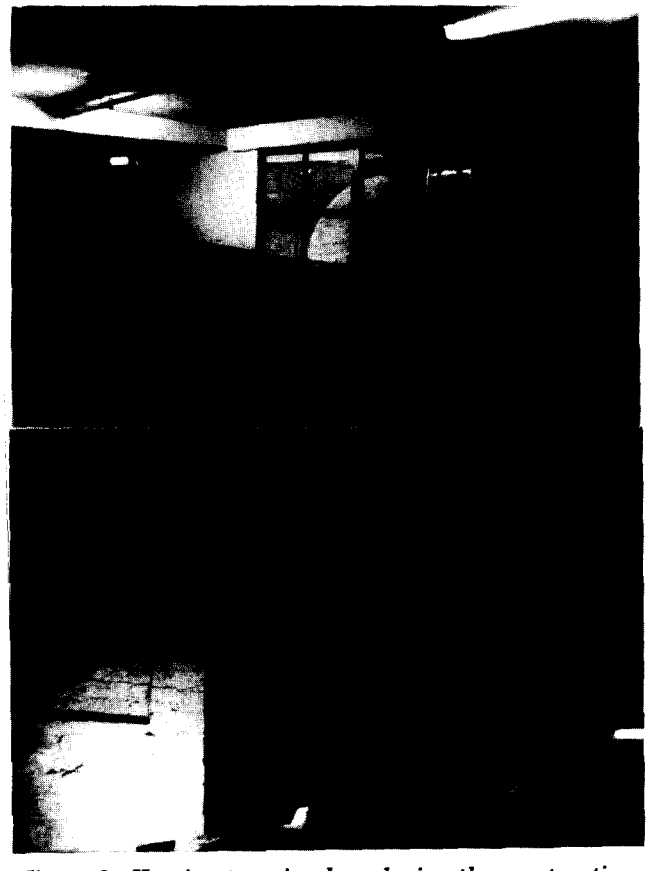

Figure 8. Keeping trees in place during the construction of the Champs Elysées car park in Paris (photo: GTM).

eration in Paris. The first-phase construction of a transfer slab based on piles makes it possible to perform the work on 10 underground levels while simultaneously creating six stories of offices on the commercial ground floor of the building.

The construction period also depends on the risks created by the true nature of the grounds encountered (e.g., by inrushing water or behavior of soils in the excavation phase) and the proximity of structures *in situ*.

Construction time is also consumed by the need to:

- Divert networks.
- Protect and aid archaeological discoveries (see Fig. 7 and section below).
- Protect trees (see Fig. 8 and section below).

All of these aspects have to be considered in the design phase in order to decide on the appropriate methods of execution.

Archaeological discoveries

For the concessionary, builder and granting authority, archaeological discoveries represent both a constraint and an opportunity.

The constraint is the construction time delays posed by such discoveries, as well as the additional direct or indirect costs incurred. In this respect, French legislation is particularly strict. Concession agreements prescribe specific provisions permitting risks for the concessionary to be reduced if they are the result of archaeological finds discovered in the course of the construction work.

On the other hand, these discoveries also represent opportunity, since car park construction occasionally allows sites and archaeological remains to be shown off to advantage. Archaeological finds have been made at construction sites Lutèce, André Honorat and Soufflot in Paris; and at the Jules Verne and Général de Gaulle construction sites in Marseille.

Car park structures displaying archaeological finds include the Notre-Dame car park in Paris, Martroi car park in Orleans, and the Musée car park in Grenoble. In a corner of the Martroi car park, an 8-m-high crypt has been built. The crypt is accessible to the public and preserves the remains of a thirteenth-century door, which can also be seen from the first levels of the car park.

Tree preservation

Another constraint to construction is the need to preserve elements of the natural environment. For the Champs-Elysées car park in Paris, 21 out of 31 plane trees were preserved *in situ* in large, separate boxes supported on the ceiling of the upper level slab after it had been directly cast under the bottom of the crates. The extra cost to the firm was calculated at 375,000 FF per tree preserved.

For the new Remusat car park in Paris, an "umbrella vault" formed of drilled metal tubes was installed under trees on the site before excavation, during underpinning and on completion of the roofing.

Constraints in the Operational Phase

Potential constraints to underground car parks in the operation phase include:

- Lighting needs.
- Provisions for air exchange and detection of harmful gases, fumes, fires, etc.
- The need to pump out infiltration water, and to collect water inrushes or accidental spills.

In order that they may be permanently operated, these required elements impose emergency power supplies, which are also useful for any elevators that may need to be installed.

7. Alternative Approaches to the Planning and Design of Car Park Facilities

Public/Private Participation

Several years ago, the planned Saint-Martin-Rivoli car park operation in Paris could not proceed because of the difficulty of recovering the very high cost of its construction. However, the restoration of a private building next to the site created the opportunity to build the car park, thanks to financial participation by the promoter of the building.

The agreement between the car park concessionary and the private developer essentially provides:

- *For the developer:*
- A partial extension of the first underground floor of the building to that of the car park, which may be used for the duration of the concession;
- Vehicular access from the public car park to the building's parking areas situated underground.
- *For the concessionary:*
- Incorporation in the building of a stack for extracting polluted air from the public car park, and a pedestrian exit with an elevator for handicapped access;
- Substantial participation in the funding of the public car park.

As a result of this agreement, the Saint-Martin Rivoli car park was constructed, and was opened in 1994.

8. Car Park Costs

It is difficult to cite average costs of car parks, because conditions vary considerably among the works. To provide a case, let us say that it is difficult to construct a space above ground for less than 40,000 FF excluding tax, and an underground space for less than 100,000 FF excluding tax (1992 values). More typically, aboveground car parks cost 60,000 FF per parking place, and underground car parks cost 130,000 FF per place (in fact, the most recent structures in Paris reveal costs exceeding 200,000 FF per place).

Thus, in oversimplified terms, an underground parking space can be considered to cost double that of one above ground level.

The cost of the interior fittings is estimated to represent more than 20% of the construction costs.

The differences in operational costs vary much more in terms of the way in which the car park is managed (number of places, rotation rates, opening hours, etc.) than in relation to the type of construction. The operational costs may vary between 3,500 FF and 5,500 FF per parking place, in 1992 values.

Given this restrictive framework, the period when it was possible to build large car parks has been superseded by the present situation, which limits construction to smaller car parks that are more difficult to run. This has led to the development of "centralised technical management" systems, which relay back to a central station the alarms and operational data for a group of car parks within a neighboring area. Remote control facilities can also be included in the system.

The gradual reduction in economically feasible sites in the public sector has mandated the best possible use of the spaces available. This situation has resulted in extending old structures on site (as in the recent extension of Places de la Bourse et Vendôme in Paris); operating joint underground works; and taking advantage of other parts of the public sector, e.g., under the canal in Sète.

Combined Works

- The car park above the Saint-Lazare railway station in Paris.
- The adjacent Châtelet car park and RER terminal in Saint Germain en Laye.
- The central Paris traffic control station next to the Lutèce car park, which includes parking spaces for the police cars from the Préfecture.
- The Préfecture car park in Marseille (under construction). Level -1 is reserved for police vehicles and has been calculated to withstand an explosive charge placed on level -2. An underground pedestrian link is planned between level -1 and the police station.
- The Cantini/Castellane car park (under construction) in Marseille. Pedestrian access is linked to the mezzanine of the Castellane métro station.
- Many direct pedestrian links between car parks and shopping areas.

Other "combined use" car parks, such as the Parc des Halles (1982) in Chartres, and the Musée (1988) and Terray (1991) parks in Grenoble, have been designed so that they can be equipped to counter the effects of atomic fallout.

9. Parking Needs and Public Policy

It is difficult to talk of parking "needs" because they are practically unlimited. Individuals will choose to use their cars if the conditions for using them are satisfactory, or at least if conditions are sufficiently bearable that they are not likely to be persuaded to take another form of travel. In this sense, city parking and travel policies are linked.

With regard to parking, public policy objectives are often contradictory.

On the one hand, policy-makers can seek to organise the parking of vehicles which drivers have thought it useful and necessary to bring to the city centre, despite measures intended to dissuade them from doing so. The underlying assumption here is that travel by car is a necessity and a condition of economic activity.

This concept has led to rules limiting the period of on-street parking in areas where access is still very much in demand. The majority of existing car parks are found right in the city centre (under the Grand'Place, for example) or immediately next to the shopping area.

On the other hand, traffic/parking policy can be developed to favor the residents of the city centre. Unlike the situation in many other countries, towns and cities in France remain very concerned with keeping inhabitants in their centres. In general, however, dwellings in those centres date from an age when there were not so many cars. Consequently, the vehicles that residents in the centre own (even though fewer in number than cars on the city outskirts) are parked en masse in the street, to the detriment of other users.

The margin for maneuvering between these policy objectives, and on which the majority of parking policies hinge, is based on vehicles used for commuting from home to work.

Because these journeys result in concentrations of traffic in the morning and evening and to the long-term parking which they require, the public transport alternative generally is aimed at reducing the numbers of these vehicles. If the parking needs result-

Underground Car Park Networks

When new car parks are to be constructed in the immediate vicinity of old ones, communication between them via short underground sections can be planned. For example, the Canourgue car park at Montpellier is to be linked with the Arc de Triomphe car park via an 80-m tunnel; the Préfecture car park in Marseille is to be linked with the Félix Baret car park; the Haussmann-Provence car park is to be linked with the Haussmann-Mogador car park; and the Champs-Elysées car park in Paris is to be linked with the George V car park.

In the same spirit of efficiency, interest has been revived in car parks utilising computerised parking, which allows more vehicles to be parked in a given area.

Along with these techniques, the "right" to the underground is also changing—in terms of both ownership of the underground and the land value that can be placed on it, and the duties and obligations incumbent on the respective owners of these overlapping, stacked-up networks of underground structures.

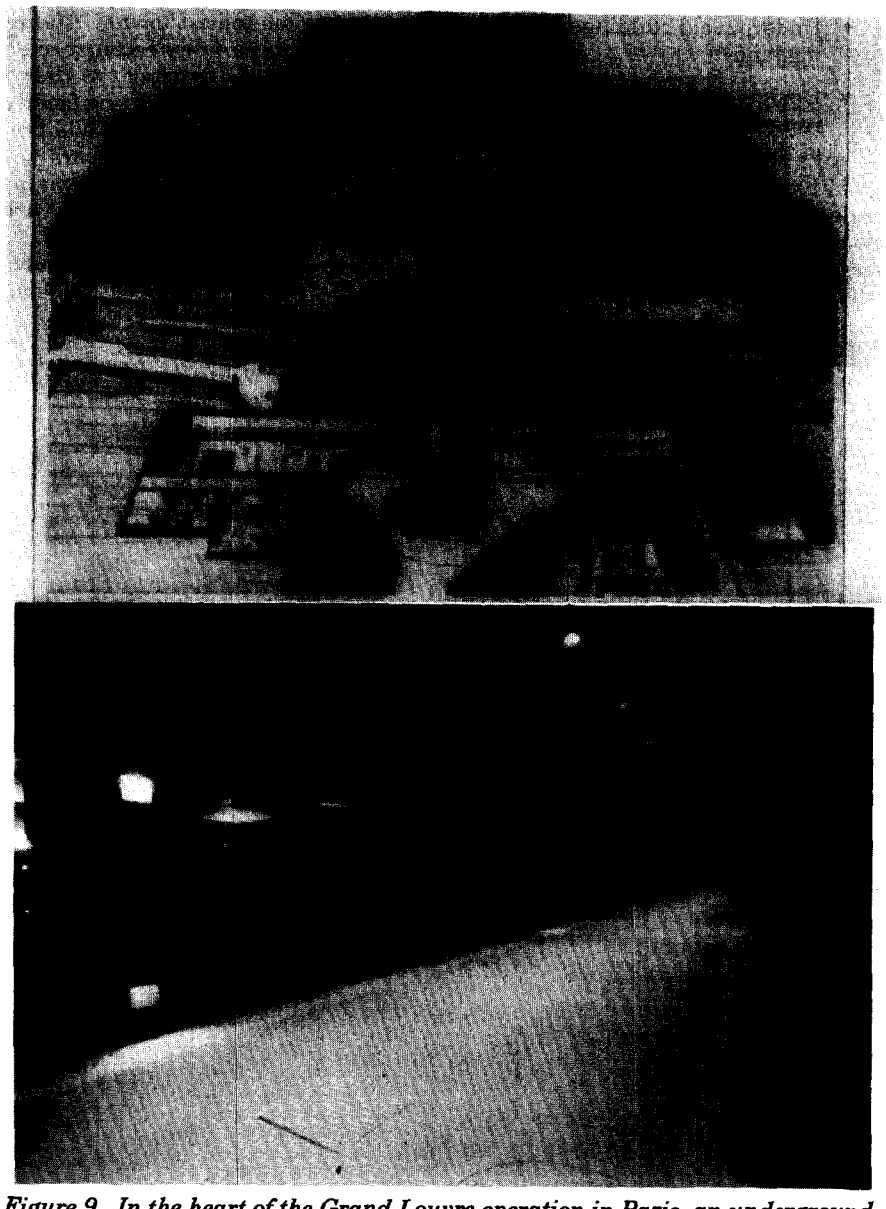

Figure 9. In the heart of the Grand Louvre operation in Paris, an underground car park with 80 spaces for coaches (photo: Etablissement Public au Grand Louvre).

ing from these commuting journeys cannot be met at the workplace (usually because of insufficient space available, staff competing for a few spaces, or advantages given to some employees), vehicles are driven out towards spaces on the outskirts, or drivers must pay prohibitive charges to park in the city.

Present policies thus tend to reserve the street for traffic, and parking, if allowed at all, is permitted for only a short period. Long-term parking is directed towards off-street sites or to a distance that may be travelled in a time considered in keeping with the parking duration. At the same time, the battle against prohibited parking is being stepped up.

In some cases, special provisions in on-street parking regulations are made for residents. In other cases, city or town councils have decided to invest in residential car parks (through sale, leasing, or subscription), when no special market has encouraged private owners to invest in them.

The density of inhabitants and the types of activities occurring in the city centre are the main parameters for evaluating, if not the parking "needs," then at least the potential demand.

Car Parks for the Future

The following points summarise the above discussion:

- Fewer and fewer on-street parking opportunities are available.
- Construction techniques for parking structures have become more sophisticated.
- Potential sites for such structures are increasingly rare.
- Parking "clients" exist.

A number of towns have started to work on new building programmes for public car parks and are carefully monitoring the actual construction of parking under private building programmes.

For these new structures, it is not really a question of "underground" or "above ground level," in spite of the cost and the fact that smaller-scale facilities are more difficult to run. Rather, it is a question of choosing between "the underground solution" or "doing nothing".

This is less the case in outlying districts and in special situations such as those involving new stations, proximity to a public transport station, or service to an outside shopping centre. Under these conditions, there will be no hesitation to:

- Dig deep—structures with six or seven underground levels are becoming common;
- Use the latest building techniques astutely;

- Underpin old buildings for parking; and
- Design complex property arrangements to make the best use of the sites.

Although the car parks currently under construction are designed exclusively for private cars, some allow for large vehicles such as touring coaches, which create a considerable disturbance in some tourist towns. An underground car park has recently come into service in the heart of the Grand Louvre operation in Paris: the facility has 80 spaces for coaches, in addition to some 600 spaces for private cars (see Fig. 9). Other sites, including 75 places in the Paris-Bercy operation, are planned.

Some underground car parks have already been constructed with a beam height on the first underground level that is clearly above the usual 2 m or 2.10 m, to accommodate an increasing range of types of private vehicles—those with four-wheel drive, high wheels and cabs and, in shopping areas, merchants' commercial vehicles.

In France, at least for the city and town centres, the future of parking lies in off-street—and consequently, underground—construction. □

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Underground Car Parks: International Case Studies

ITA Working Group No. 13, "Direct and Indirect Advantages of Underground Structures"

Abstract—*This paper summarizes the reports from members of the ITA Working Group "Direct and Indirect Advantages of Underground Structures" on underground parking conditions in various ITA countries.*

Résumé—*Cet article présente les rapports sur le stationnement en souterrain dans divers pays membres de l'AITES. Certains de ces rapports ont été fornis par des membres du groupe de travail de l'AITES sur les "Avantages directs et indirect des ouvrages souterraines."*

ITA Working Group No 13, "Direct and Indirect Advantages of Underground Structures," has begun analyzing the advantages of subsurface structures. The Group has chosen underground car park facilities as the subject of its initial study. This report is based on case studies presented to the Working Group at its meetings in 1993 and 1994, and on other contributions from ITA national groups. Contributors are acknowledged at the end of the section for each country.

Sweden:

Underground Parking Facilities in Stockholm

A. Parking Use in Stockholm

In connection with the ongoing modification of the townscape of Stockholm, a number of trends related to traffic and parking may be observed. Among them is a distinct trend towards increasing ambitions concerning the environment in terms of cleaner air, decreased noise levels, and reduced numbers of cars in the urban environment, particularly in the central areas of Stockholm.

In principle, the inner city of Stockholm may be divided into three main areas:

1. The Old Town, for which historical preservation regulations are in force.
2. The central city area, which houses offices, commercial and cultural facilities, etc.
3. The remainder of the inner city, which sustains a mixture of housing, offices and commercial facilities, although housing is both predominant and politically favoured.

In the Old Town, current regulations for vehicular traffic are restrictive; certain streets are closed to vehicles and parking space is very limited. Nevertheless, politicians are now demanding even stricter restrictions, with a view toward preserving the environment, including the old buildings in this area. Because housing is dominant and encouraged in the Old Town, access and parking will become even more difficult and obstructed unless the underground is considered as a possible resource.

In the central city and areas adjoining it, a number of underground parking garages have been built over a rather long period of time. In order to (1) meet the demands from offices and commercial facilities; (2) reduce the number of vehicles parked in the streets; and (3) facilitate pedestrian and distribution traffic, additional garages, mostly underground, are under study. During peak hours, the parking demand exceeds supply: however, the traffic policy view is basically to discourage any increase in private car traffic, by improving public transport to meet transportation needs.

Even in the less central parts of the inner city, a number of underground parking garages have been built, although the cost for parking there is considerably higher in comparison to on-street parking. In most cases, however, such garages are built where particularly favourable ground conditions are at hand, and often in combination with the use of the garages for civil defense purposes.

Recently, political decisions have been made to invest large amounts in new traffic infrastructure in Stockholm, comprising:

- An orbital freeway system (Stockholm Ring Road), the new parts of which are mostly underground, close to the inner city;
- A peripheral cross-link in the western part of greater Stockholm; and
- Improvements in various public transport systems.

Where the orbital freeway intersects with public transport lines, underground parking facilities could have the advantage of permitting direct access to platforms. Wherever possible, direct underground connections to central parking areas from the freeways should be provided, to decrease congestion above ground.

The basic concepts behind these new investments are to (1) restrain private traffic inside the orbital freeway, (2) decrease through-traffic in this area, and (3) improve public transport. When completed, these new projects are intended to improve traffic and environmental conditions considerably in Stockholm.

In order to assure that the entire area inside the orbital freeway is provided with adequate transport access,

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there will be a need in any case for both roads and parking facilities in this area. In this connection, the use of the underground for access and parking will certainly become even more important in order to achieve the goals and objectives for an improved environment in Stockholm.

B. Existing Rules, Cases and Costs

Limitations on Central City Traffic

At present, no limitations exist; however, some limitations will be instituted as part of the current Ring Road Project around Stockholm. Although the planned ring roads and traffic into the city will be subject to fees, this issue has not yet been systematically resolved.

Demands for parking space in the outer areas of Stockholm are expected to increase. Stockholm Traffic (SL) currently is responsible for preparing an overview of existing parking space and for future expansion of this space. The Stockholm City Parking Company (Parkeringsbolaget) is actively involved in these investigations.

Parking in the Central City

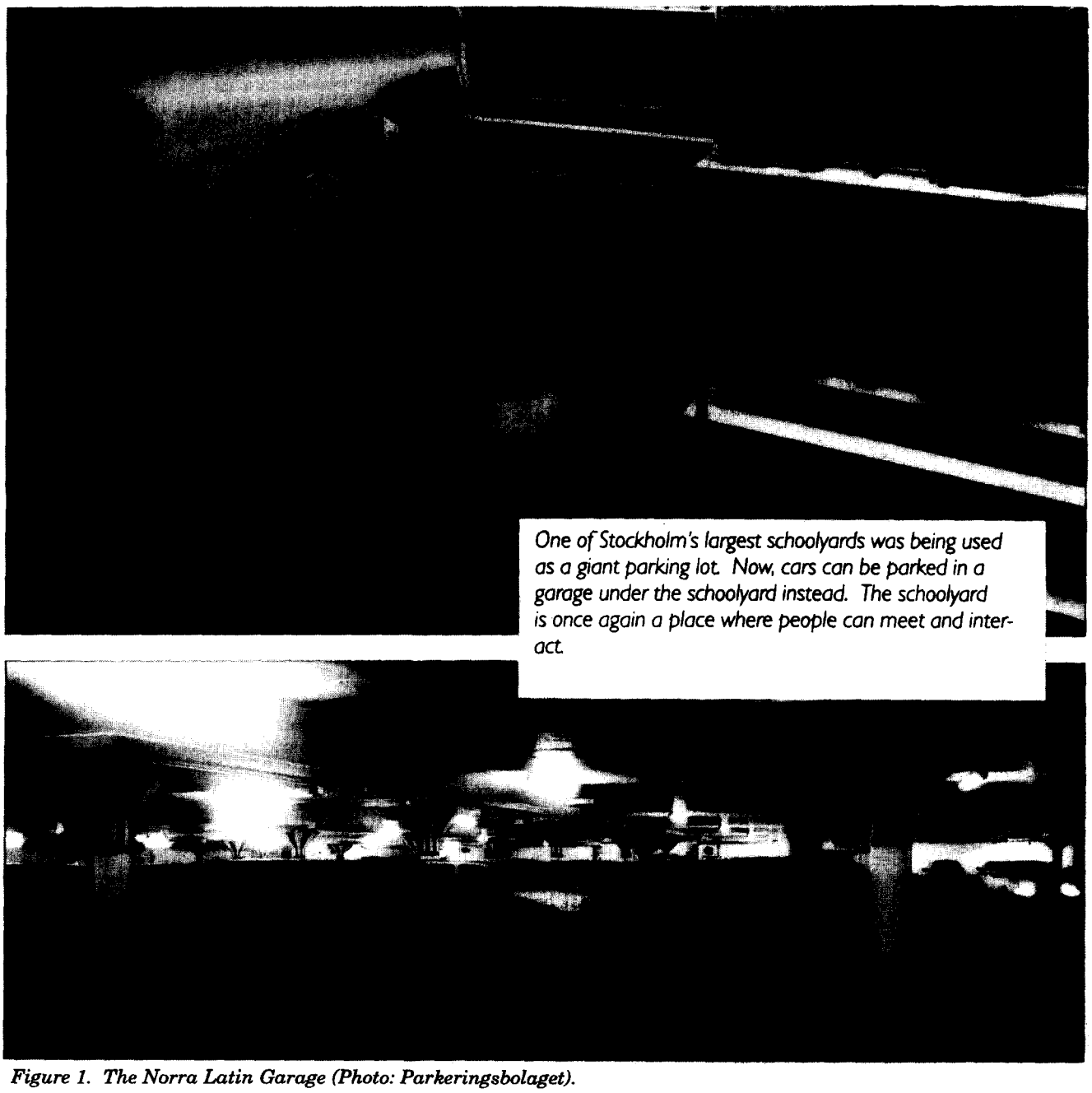
The main regulation is that parking is not permitted in the central city on weekdays, except on Saturdays and the day before holidays between 0800 and 1800 hrs. During this time, ordinary road-users may pay a fee to park in specially assigned space in the street or in garages, in order to avoid impeding the loading and unloading of goods and the passage of public transport.

Domestic Parking

"Domestic parking" refers to parking for longer than 24 hours for a lower fee in the vicinity of one's residence. Signs in each area inform drivers of the one night a week when the streets in question must be free from cars for cleaning purposes. To obtain a domestic parking permit, a road-user must be registered at the actual address stated on the permit, and must be the registered owner of the car.

The domestic parking fee may be paid in one of two ways:

- By a monthly card (SEK 250); or
- By using parking meters at a



One of Stockholm's largest schoolyards was being used as a giant parking lot. Now, cars can be parked in a garage under the schoolyard instead. The schoolyard is once again a place where people can meet and interact.

Figure 1. The Norra Latin Garage (Photo: Parkeringsbolaget).

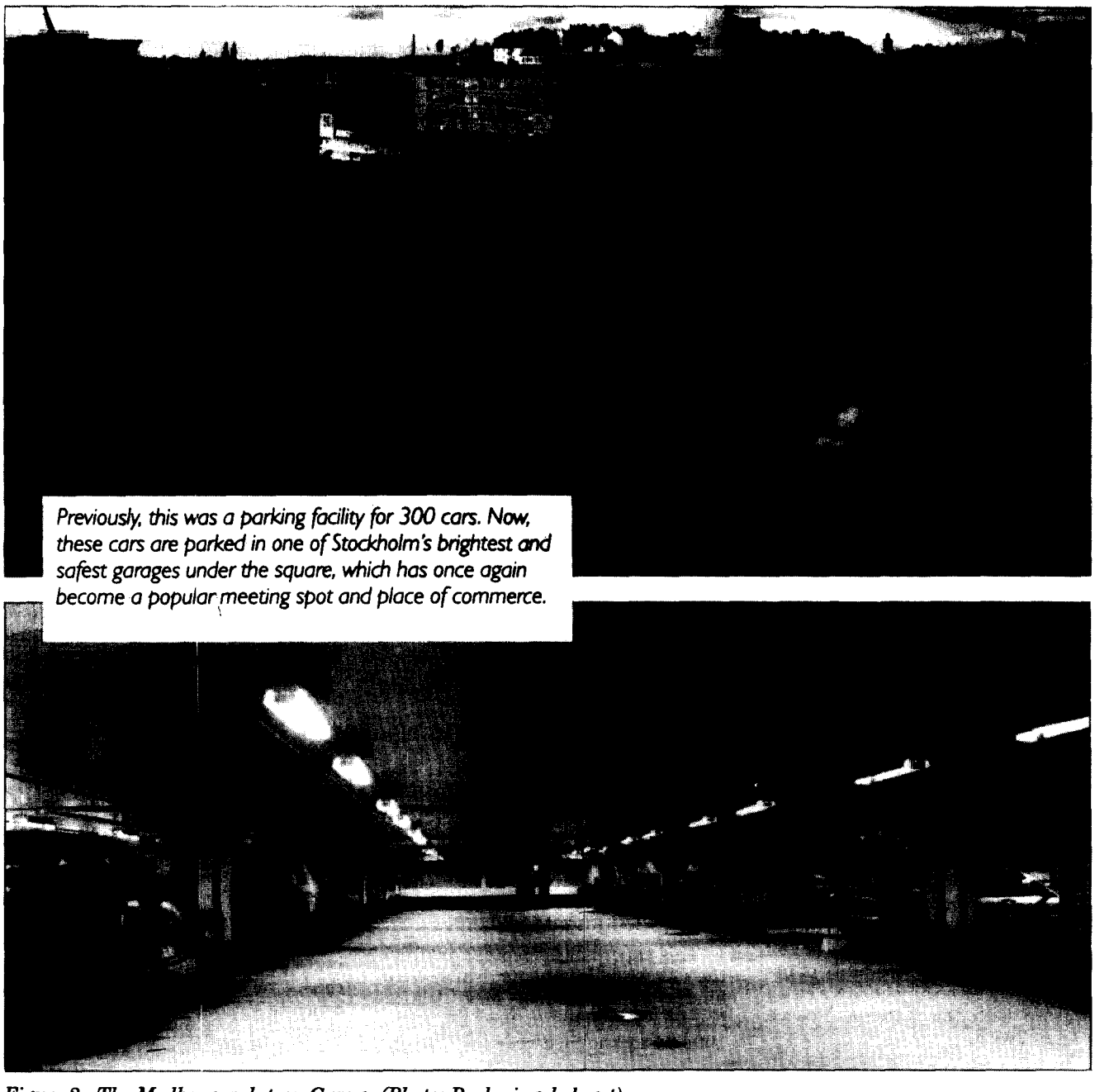


Figure 2. The Medborgarplatsen Garage (Photo: Parkeringsbolaget).

lower rate (SEK 15/day between 0800 and 1800 hrs; thereafter, parking normally is free).

Domestic parking permits are not valid on private parking grounds or in garages. Certain exceptions apply on some streets (e.g., Norr Mälarstrand and Strandvägen).

Utility Parking Permits

The utility parking permit has been established for those professional categories of workers who have a demonstrated need to park their utility vehicles near their workplace. This permit also allows parking in streets where parking normally is not allowed. A parking card ("P-card") permits a maximum of two hours of parking. Utility parking permits are not valid for garages. The fee for this type of permit is SEK 5000/year.

Traffic Developments in Stockholm

From 1945 to 1991, the number of buses and cars in the central city of Stockholm gradually increased from about 40,000 to more than 600,000 vehicles a day.

The number of parking places in the inner city can be divided as follows :

- Total number of spaces: approx. 90,000.
- On-street parking: approx. 25,000 spaces.
- Garages and parking facilities: approx. 65,000 spaces (of which Parkeringsbolaget runs about 17,000).

Examples of Subsurface Parking Facilities

The Norra Latin Garage (Fig. 1). This garage, constructed in 1988–89 under the school yard of Norra Latin, was a Parkeringsbolaget project. The 200 total parking places are combined with an air shelter comprising five rooms, with a total capacity of 2,100 people. Construction cost: SEK 50 million, SEK 20 million of which was spent for the air shelter.

The Medborgarplatsen Garage (Fig. 2). Medborgarplatsen, in the southern portion of Stockholm's inner city, was once one of Stockholm's most important train stations and commercial locations. Here, an entirely new section of the city is emerging. Parkeringsbolaget renovated an old, dilapidated

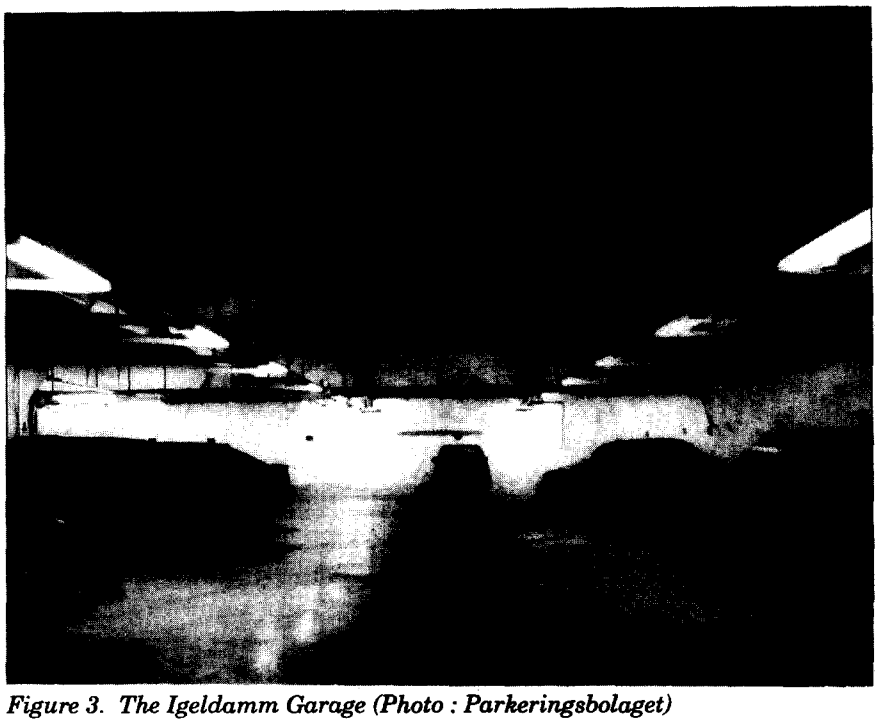


Figure 3. The Igeldamm Garage (Photo : Parkeringsbolaget)

garage and several storage areas underneath it to create a modern garage for more than 300 cars.

The Igeldamm Garage (Fig. 3). This garage, constructed in rock at Igeldammsgatan street, was built as an air shelter by the National Rescue Services Board. Today it is used by Parkeringsbolaget as a long-term parking garage for 65 cars. The construction was partly financed by Parkeringsbolaget.

The Tegnerlunden Garage. This garage, being built in rock under Tegnerlunden Park, has a total of 152 parking spaces. The possibility of using the garage as an air shelter is being discussed with the National Rescue Services Board.

Construction of the garage began in 1994. The estimated construction cost is approximately SEK 23 million.

Other Planned Garages. A structure under Carl Gustav Lindstedt Street, near St. Erik's Hospital, is planned to provide space for about 220 cars.

A garage planned under Kungsholmen Gymnasium, constructed by a joint venture of SISAB, the National Rescue Services Board and Parkeringsbolaget, will provide 150–300 parking places. An air shelter will be provided in conjunction with the project.

Operation Costs

As a rough estimate, and in comparison with an aboveground parking facility, an underground garage cannot be said to have lower operation costs. These costs depend on other parameters, such as:

- Whether the facility offers short- or long-term parking;
- Staffing levels;
- Operating hours;
- Whether parking meters or gates are used; and
- Whether the facility is private property or leased.

In general, it can be said that operating costs for an underground garage in Stockholm are between SEK 150 and SEK 250 per parking space per month.

Acknowledgments

This paper has been prepared from the following documents, which were kindly transmitted by Mrs. Annica Nordmark (SveBeFo, Box 49153, S-100 29 Stockholm, Sweden):

- A report prepared with the assistance of two city planning architects (Part A) and the Stockholm City Parking Company (Parkeringsbolaget) (Part B).
- The document, "Parking facilities that create a better civic environment in Stockholm", issued by Parkeringsbolaget.

Australia:

The Sydney Opera House Underground Car Park

The Sydney Opera House is an important landmark in the historic area of Sydney. Its location on Bennalong Point commands an impressive view of the Sydney Harbour Bridge, and it adjoins Government House grounds and the Royal Botanic Gardens. These features, in addition to its exciting architecture and renown as a cultural venue, attract numerous visitors: every year, 1.4 million patrons and 2 million tourists visit the Opera House.

Unfortunately, the features that add to the appeal of the Opera House also have created significant difficulties in providing vehicle access to it. In particular, the lack of car parking facilities presented a problem after the Opera House opened in 1973.

These parking needs are now met by the Sydney Opera House car park, known as the Bennelong Point Parking Station (Fig. 4). This car park is the first helical underground parking station, comprising 12 stories and providing 1,100 parking spaces (Fig. 5). It consists of a freestanding double-helix concrete structure, wrapped around a central intact core containing linking drives and service tunnels. The huge,

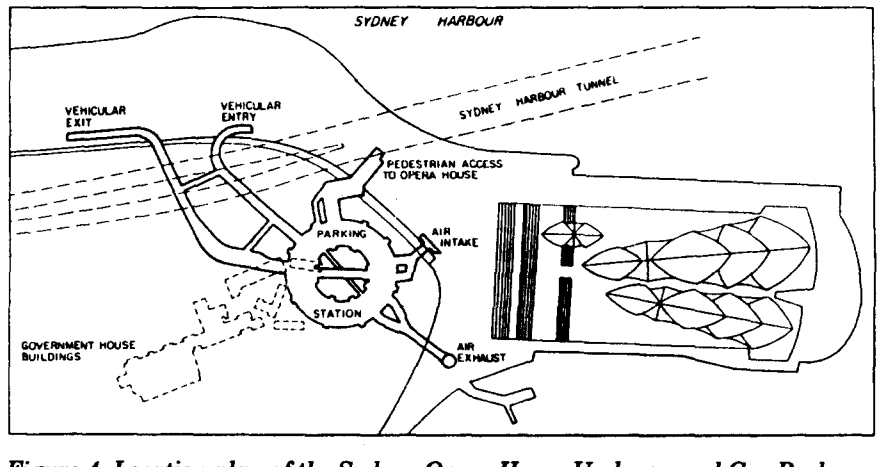


Figure 4. Location plan of the Sydney Opera House Underground Car Park (Source: Pells 1993).

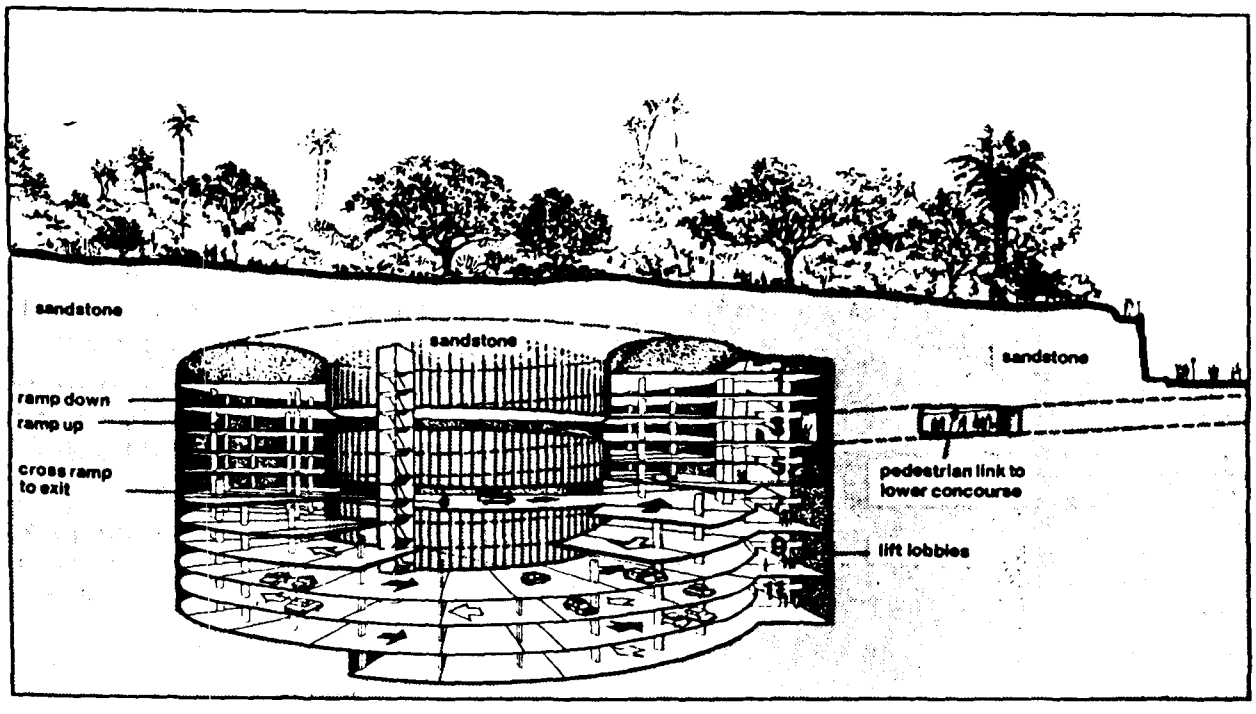


Figure 5. Architect's sketch of the double-helix Sydney Opera House Underground Car Park (Source: "Earthmover and civil contractor—Project report" [July 1992]).

doughnut-shaped cavern has been created with an outer diameter of 71.2 m and an inner diameter of 36.4 m. The structure is 32 m high, and extends some 28 m below sea level.

Vehicle access to the parking station is via tunnels from Macquarie Street, which had to pass over the top of the Sydney Harbour Tunnel (Fig. 6). This constraint dictated that the cavern be constructed as close as possible to the ground surface.

In order to avoid detracting from the aesthetic appeal of the area, all works had to be done without disrupting the surface, within either the Botanic Garden or the forecourt of the Opera House. Because the cut-and-cover method was precluded by these environmental constraints, the car park was constructed within the Royal Botanic Gardens, entirely underground. One feature of the design was that the existing established fig trees above the car park should not be affected by its construction or operation.

The rock cover above the cavern is just 7–9 m thick, of variably weathered Sydney sandstone, overlain by 1 to 2 m of soil of the Royal Botanic Garden. The helical concrete structure does not provide long-term support for the rock cover, the largest unsupported span of which is 17.4 m. The various challenges involved in the design and construction of this car park have been reported at conferences and in technical literature (Pells 1993).

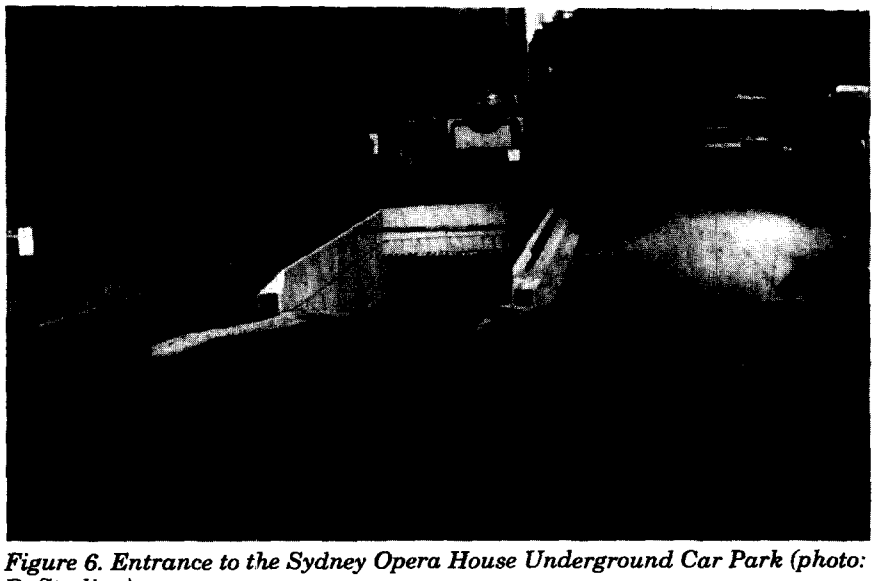


Figure 6. Entrance to the Sydney Opera House Underground Car Park (photo: R. Sterling).

This world-famous case study significantly illuminates the advantages of underground structures in achieving solutions that simultaneously preserve the environment and meet the parking needs associated with much-visited public places.

Acknowledgments

This paper has been prepared by the Animateur of the ITA Working Group from the documents listed below, which were kindly transmitted by P. J. N. Pells (Pells Sullivan Meynink Pty Ltd, Hunters Hill, Australia).

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U.S.A.:

Policy Considerations for Parking Structures in Major U.S. Cities

At the April 1993 ITA meeting in Amsterdam, Working Group No.13, "Direct and Indirect Advantages of Underground Structures," decided to

continue further investigation into underground parking structures in the ITA member countries, focusing on the major cities.

The United States group decided to address the question from a policy point of view, since the future design and construction of such space is dependent not only on past practice, but on current economic conditions; and, just as significantly, on the forces that are driven by laws, regulations and public policies.

Summary

The automobile has played an increasingly major role in providing access to the major cities of North America. With the exception of the three cities of New York, Chicago and Boston, which have continuously developed major transit systems since the turn of the century, all U.S. cities have relied on cars for commuting and commerce.

More than 80% of commuting and commerce trips involve the automobile in major U.S. cities—with the exception of Los Angeles, where the percentage is significantly higher.

Cities have moved from an open policy of general permissiveness in accommodating the automobile by providing parking space within the city, to a policy of strict regulation by code and approvals.

The limitations on underground parking used to be economics (i.e., the cost of providing underground parking spaces) and practical aspects (not everyone had a car). Now the limitations are accomplished by policy and regulation.

Whereas regulations once were concerned with providing a minimum number of parking spaces to assure commercial viability and access, now they are more concerned with environmental impact and, therefore, with limitations on parking.

Downtown—Commercial Building Parking Provisions

It is likely that in the U.S., major buildings will continue to be constructed with a minimum number of underground parking spaces, depending substantially on lot area, geology, and total area of the building.

For larger buildings, the owner generally wants to maximize the total number of on-site parking spaces, regardless of regulations. In some cities, notably Chicago, parking is often constructed above grade and may, in fact, be above the first commercial level but below the upper floor uses (see "Case Examples," below).

The conclusion that may be drawn is that the number of underground spaces in downtown high-rise commercial buildings generally depends on:

- The total floor area;
- The actual space possible for parking;
- Limits imposed by geotechnical and structural conditions; and
- The ability of the owner to fund the cost of the space.

Downtown Public Parking—Underground Structures

In contrast, public parking facilities are limited directly by public policy, laws and regulations, and less by fluctuating market considerations.

In particular, in the U.S., there are no "pro-auto" policies for any central downtown zone, even in Los Angeles. A possible exception is Washington, D.C., where the federal government, even while passing laws (such as the Clean Air Act) that elsewhere discourage increases in auto use in the central city, subsidizes parking (usually in open lots) for government employees. This arrangement also sets an example and precedent for private workers and encourages auto use in the central city.

Major Factors Influencing Current Parking Structures in U.S. Cities

The driving factors that shape the use of parking of all types—and, for large, dense U.S. cities, underground parking in the central business district—are:

1. Availability of convenient, efficient low-cost mass transit.

2. Physical restraints: access problems (infrastructure limitations), long driving times, cost of city access and parking.

3. Limitations caused by environmental conditions and constraints, specifically the non-attainment of requirements of the Clean Air Act and the subsequent restrictions and corrective actions imposed by the regulatory bodies.

4. Although the issues are current, actions generally restrict access by autos. Since auto volume tends to increase absolutely, all factors being equal, the trend is to restrict parking in the central cities and not to expand the infrastructure that provides cars with access to the city.

In this respect, Boston is an interesting exception, because the road access and infrastructure in that city are being substantially improved and several underground parking structures have been constructed (Post Office Square and North Station 2; rehabilitation of the Common Parking Garage). However, due to non-attainment of the Clean Air Act provisions, the city is subject to a parking freeze (restriction on the total number of commercial parking spaces in the city).

5. Security. Deficient public transit security will encourage the use of autos. Inferior parking location security and/or negative perceptions of security will discourage the use of parking facilities.

The current response by building owners to this concern is to construct only secure parking facilities that are open, well-lighted and patrolled. This environment essentially discourages construction of underground parking structures.

Case Examples and Overviews

Boston

As noted above, the City of Boston currently is subject to a parking freeze—an absolute limit on the total number of commercial parking spaces in the city.

Private use spaces are not affected by the freeze—that is, a structure can add spaces provided that they are not for sale, lease or commercial use. The spaces are, however, regulated by the zoning laws.

The focus now is on how the spaces are used, as well as the absolute number of spaces. Design issues (building floor area, FAR, access for autos, costs, structure) are also considered, but by other departments.

The City has a Transportation Access Plan that requires the city and developers to analyze the impact of traffic and new volumes of vehicles during a building's development.

There is no requirement for above- or below-grade development. All planning issues are site-specific.

New York

Major issues for New York today are global ones of safety, security and attainment of the requirements of the Clean Air Act.

Because New York is a major non-attainment zone, the city is taking steps to restrict the number of autos—and especially the number of single-driver autos—entering the central city.

Employers have to reduce single-driver autos by 40% through the use of restrictions on any parking, encouraging public transit use and not subsidizing parking.

New York has found that small restrictions in parking levels have a big effect on the use of transit and reduction of auto use, because of the large numbers of commuters entering the Central Business District each day.

New York's current policy is that reallocation of transportation resources is essential to the continued viability of the city.

Chicago

Discussions with transportation engineers in Chicago (not City personnel) indicate a general lack of city policy specifically dealing with

parking: that is, current policy neither encourages or discourages parking facilities. In addition, the question of underground vs. surface or elevated seems to be simply a practical question dependent on economics, need and subsurface conditions.

Above grade/sandwiched parking construction

In Chicago, there has been significant use of a type of parking that allocates the first (ground) floor level to street commercial use, puts parking on the next set of floors (sometimes as many as 8–10 floors) and then adds other uses—either office or residential—above the parking levels.

Examples of this type of construction include Marina Towers, Water Tower Place (which also has underground parking) and the Hancock Center.

City-owned parking: open space uses

Apart from downtown buildings, with some underground parking limited by subsurface conditions (primarily the water table), the city has built below-grade parking structures, usually with parkland on top. An example is the current rehabilitation of Granite Park, at the lake shore.

Preservation of parkland is a high priority for Chicago.

San Francisco

San Francisco is constructing very little commercial downtown space at the moment. Within the last 10 years, significant structures have included the Convention Center and the Gateway office/commercial development.

One urban planner/architect commented that there is very little, if any, policy about parking and commercial development, at least compared to other cities. Most buildings constructed in the 1980s have underground parking, but it is not very extensively developed.

It will be necessary to follow up with the City Planning and Transportation Departments in some depth to determine how much underground parking currently exists in San Francisco.

Acknowledgments

This report was prepared by John Reilly, a member of ITA Working Group No. 13 (present address: John Reilly Associates, 1101 Worcester Road, Framingham, MA 01701, U.S.A.).

Some material for this report was obtained through discussions with the City of Boston, City Transportation Office; transportation engineers in Chicago; and urban planners in San Francisco.

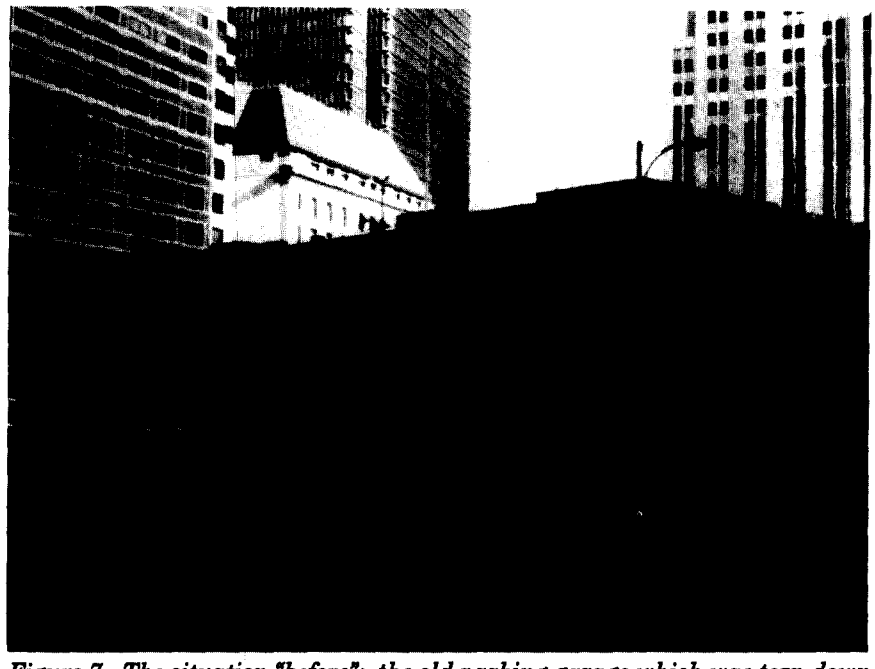

Figure 7. The situation "before": the old parking garage which was torn down.

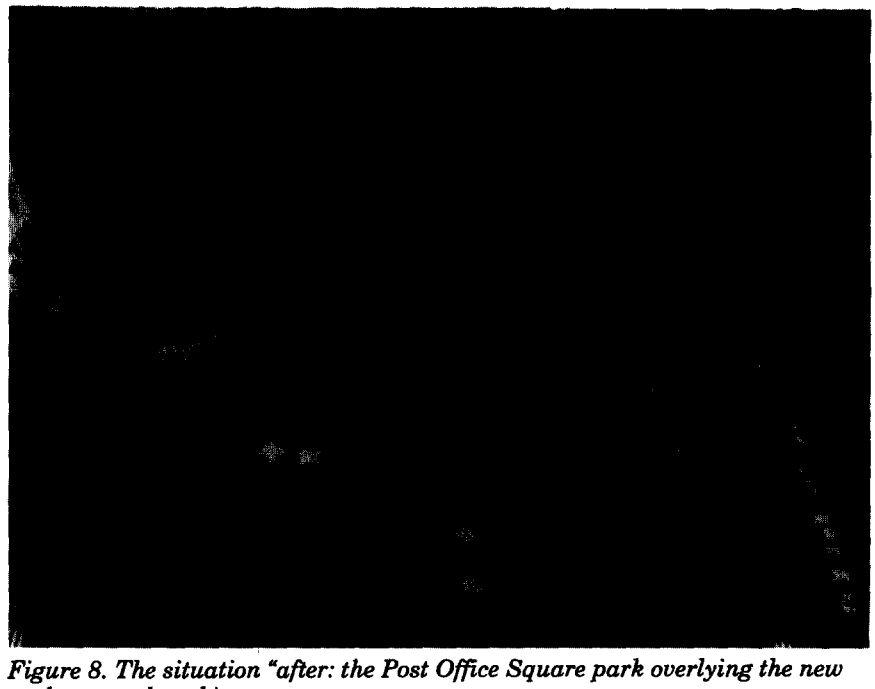

Figure 8. The situation "after: the Post Office Square park overlying the new underground parking garage.

The Post Office Square Underground Parking Garage in Boston

In 1982, a group of business and civic leaders, concerned about the lack of open space in downtown Boston, began discussions to plan an urban park for Post Office Square, a 1.7-acre site in the heart of Boston's downtown financial district.

Following legal incorporation as the Friends of Post Office Square, Inc. in 1983, the new civic corporation introduced a unique proposal for the site: replace the aging Post Office Square Garage with a combination public park and underground parking facility (Figs. 7 and 8). This proposal met the important need for public green space in downtown Boston while offering area office workers and downtown shoppers a convenient and expanded underground parking facility.

In 1987, after four years of extensive planning and complex negotiations, Friends of Post Office Square—a group that includes many area buildings owners and tenants—was able to purchase the garage site from the city of Boston and launch the long-awaited development.

The $80-million Post Office Square Park and Garage has been developed through a unique public/private part-

Figure 9. The Post Office Square redevelopment features a landscaped public park atop the underground garage.

nership between the city of Boston and The Friends of Post Office Square. All profits from the development are to be distributed to the City of Boston General Fund and to the City of Boston Park Trust Fund for the maintenance of other city-owned parks. After the capital costs of the project have been repaid to investors (estimated to be within 40 years), ownership of the garage will revert to the city of Boston.

The new garage was completed in the fall of 1990. Work then began on what the group had long envisioned at street level: a richly landscaped public park in the center of downtown Boston (Fig. 9). The park was opened to the public in June 1991.

Post Office Garage Construction

A state-of-the-art construction technique designed to streamline below-ground construction and minimize traffic disruptions was used on this project, which involved Boston's deepest excavation at the time.

Using the "Top/Down" (or Milan) construction method, the general contractor constructed the new seven-level underground parking facility from the top level down, eliminating the conventional need for a deep hole with the structure subsequently built from the foundation up.

An evolving construction practice in the United States, and one used commonly in Europe and the Far East, the Top/Down method was introduced to Boston for the below-grade construction of Rowes' Wharf on Boston Harbor, and has since been used for other underground construction in the city.

The Top/Down technique offers many construction advantages. It eliminates the tiebacks or internal bracing ordinarily necessary to secure retaining walls. Moreover, because Post Office Square is a busy and congested downtown location, use of the Top/Down method allowed workers to use the top of the site as a staging platform throughout the construction of the project, minimizing traffic tie-ups common to such large-scale projects.

Parking Amenities

Parking garages as a rule are destinations of convenience, not choice. The new 1,400-car-capacity Post Office Square garage promises to be a destination of both convenience and choice by offering an outstanding location in the heart of the city's financial district, with easy access to and from the region's highway system, and superior design and services.

The advanced security systems, in-house car cleaning services, and high staff ratio are intended to ensure a safe and convenient parking experience for patrons of the seven-level facility. To create a parking facility that was easy to use, as well as bright and cheerful, a great deal of attention was paid not only to the architectural features of the lobby areas, but also to the level of illumination, quality of signage, and other environmental details.

Perhaps the best dividend of the project is the public park gracing the top of the garage, where motorists and pedestrians alike are welcome.

Summary

The Post Office Square Garage has yielded several direct and indirect benefits to the public.

Direct Benefits

Construction of the new underground parking garage increased parking capacity at the site by nearly 50% over the old surface garage.

The increased capacity results in increased revenues to the city of Boston, and greater convenience for auto traffic.

Moving the parking structure to an underground location also allowed construction of a park and much-needed green space in the heart of Boston.

Indirect benefits

The addition of 2 acres of green space (trees and grass) can help mitigate air pollution in the area through photosynthesis, providing environmental and health benefits.

The open space offers psychological relief for people in the area. It also promotes good health by offering workers and others the opportunity to take coffee breaks and lunch in an outdoor environment.

Acknowledgments

This report was prepared by Susan Nelson, a member of the ITA Working Group No. 13 (present address: Executive Director, American Underground-Construction Association, 511 - 11th Ave. So., Suite 248, Minneapolis, Minnesota 55415, U.S.A.

Boston Garden/North Station Redevelopment

A major transportation center for more than 160 years, Boston's North Station is undergoing redevelopment that will transform it into a hub of diverse activity.

The new complex will hold an underground 1,300-car garage, a multimodal transportation center, and a new Boston Garden arena. The owner, Massachusetts Bay Transportation Authority, also is considering plans for future air rights developments over the station platform area.

The North Station rail terminal is a key element of Boston's transportation system. Four major commuter lines terminate there, as well as the Orange Line (a rapid transit line) and the Green Line (a light-rail transit line). Central to this redevelopment project is the station itself. Its structure will incorporate a five-level underground garage, the Green Line, and support for the new Boston Garden.

Atop the existing North Station is Boston Garden. Built in the mid-1920s, it had become antiquated by 1990 standards. The city permitted the arena's owner, the Delaware North Corporation, to build a new arena immediately behind North Station, placing it on a

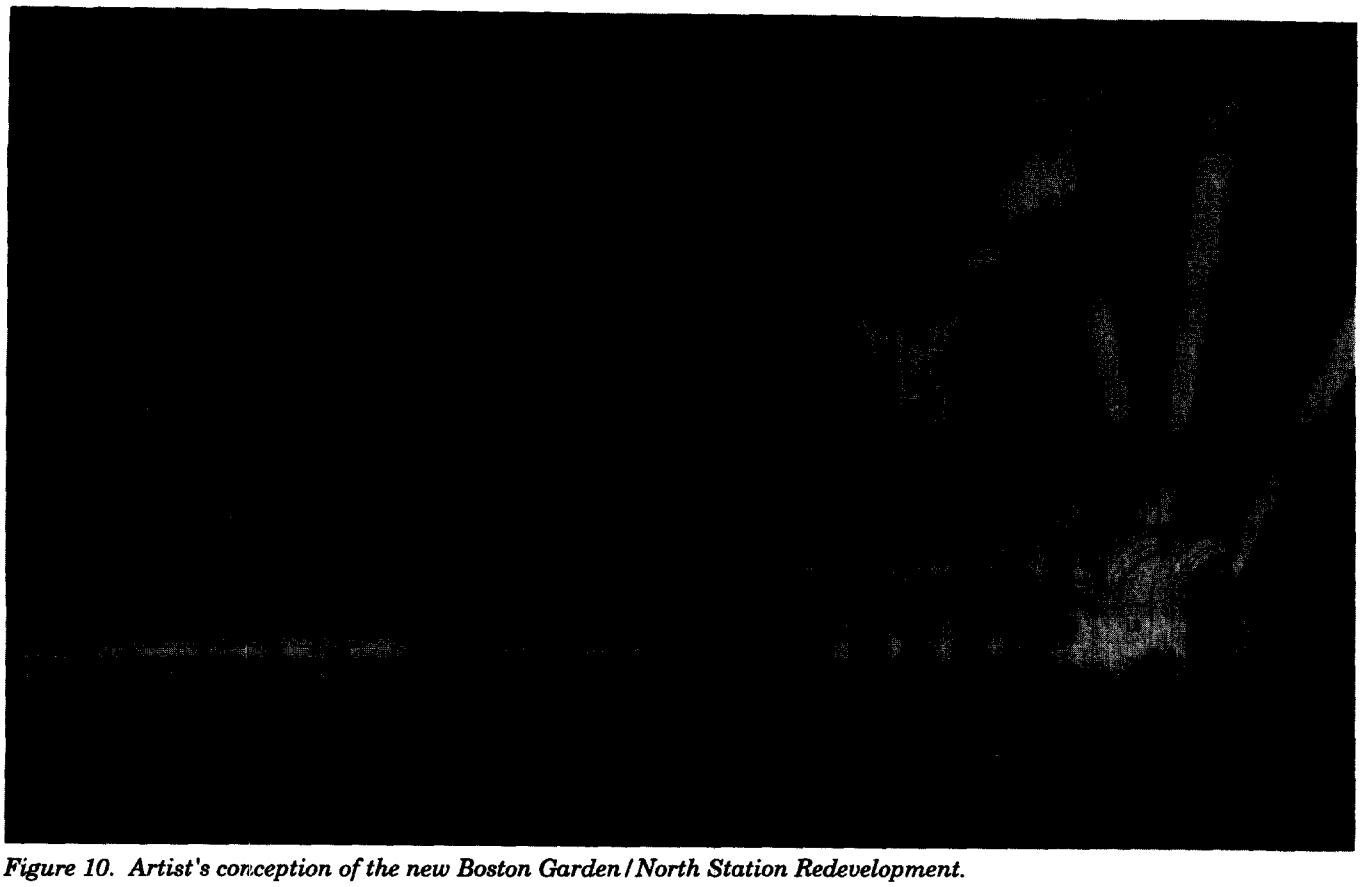

Figure 10. Artist's conception of the new Boston Garden/North Station Redevelopment.

critical turn of the relocated Green Line. To accommodate this awkward placement, the Green Line was incorporated into the structure of the subsurface garage, which will support the future Boston Garden above it.

The result is a layer of structures tied integrally to each other. The 1,300-car garage extends five levels down. Two levels down, the Green Line will pass through the garage structure. The commuter rail station is above the garage at ground level, and the new Boston Garden will be above the rail station (see Fig. 10).

All of the expansion work extends down some 60 ft. below grade. Because the project site was originally part of the Charles River, it is predominately composed of fill. Water pressure and the varied fill mixture prevent the use of the tieback bracing systems that are conventionally used for deep excavation. "Up-down" construction using slurry walls was chosen to solve resulting excavation and foundation problems and to allow construction above to rise at the same time that the below-ground structure is being built.

Other development is proposed in the North Station area, including two new 350-ft.-tall office towers, a hotel and additional parking facilities. Planning for this project involves coordination with many of Boston's agencies in order to comply with the many environmental regulations, as well as to ensure access for hospitals, housing, and businesses in the area.

In addition, the Massachusetts Department of Public Works plans a major expressway that will directly affect trackwork into North Station. This new roadway also will pass through the site of a signal tower that controls the switching and interlocking in the area, as well as an entire rail network extending northward some 40 miles. Relocating this signal tower is a crucial element of the project.

Acknowledgment

This report was prepared from materials provided by the Massachusetts Bay Transportation Authority (Boston, Mass.), STV Group.

South Africa:
Underground Car Parking in South Africa

In general, the development of urban areas in southern Africa has been fairly recent, compared to major cities in Europe and elsewhere. Moreover, cities in South Africa have been subject to town planning and formal laying-out from the early days, and the population densities have not reached the levels found in other countries.

This formal town layout planning has resulted in comparatively wide roads. In addition, the per capita car ownership in the urban areas has not reached the levels found overseas, although it is now increasing. Therefore, parking problems in South Africa are not considered as critical as they are in European cities.

Specific Aspects of Individual Cities

Johannesburg

South Africa's capital city is founded upon extremely hard rock, and therefore the cost of underground excavation is high. The redevelopment of the central business district has led to extensive development of basement car parking.

Extensive investigations are being carried out to assess the potential for an underground commuter system, either conventional or light rail; however, except in the central business district, the cost of tunnelling would appear to be higher than the cost of obtaining land for an aboveground system. City officials see that one alternative to providing car parking facilities may be a transport system that offers an alternative to private car ownership.

Durban

The central business district of Durban is situated on the coastal plain and the general ground level is some 7 m above sea level. Consequently, all of the buildings in the central city area are founded on piles or massive raft foundations and, wherever possible,

the basement floors are situated above sea level or the water table.

Basement parking is provided in all new office and commercial developments. A recent development includes an underground car park with a basement founded at sea level, and a formal park developed at ground level to provide open space.

A number of aboveground multistory parking garages have been developed, all operated on a private commercial basis.

Cape Town

Use of dedicated underground parking structures does not appear to be increasing in Cape Town, although a number of such structures have been completed recently in the central business district, the Waterfront and in Claremont. Others are in an advanced stage of planning, and still others are in the feasibility assessment stage.

These car parks typically are relatively simple structures constructed in open excavation. Primary concerns relate to access and egress, which generally need to be integrated acceptably into the adjoining road network. Other issues that must be addressed include traffic impact, the diversion of services and traffic during construction, and the acknowledgment of the concerns of adjoining property owners and tenants during the frequently disruptive construction phase, when interim access to adjacent properties is necessary.

Pretoria

At present, there are no restrictions on the use and access of private cars in the city center of Pretoria.

Following an investigation of integrated transport and urban development, the Pretoria Council adopted a policy to provide a balanced transport system. Such a system considers private and public transport, as well as land use, in ensuring that all land use is efficiently served by the transport system.

The parking policy set forth in the 1974 Pretoria Town Planning Scheme prohibits parking in the core section of the city center. In the rest of the city center, parking generally is required at the rate of 1/56 m^2 for offices and 1/116 m^2 for retail space. Developers may provide more parking than that required.

Parking garages in Pretoria city center may be aboveground, in basements or a combination. The two largest underground garages are Sammy Marks Square, which takes up approximately half a block, and Strydomplein, which takes up a full block. (The blocks are approximately 210 m by 130 m.) All underground structures are built by conventional methods of bulk excavations with sheet piles. The basements are normally only two floors deep.

Port Elizabeth

Little underground parking has been provided in Port Elizabeth.

The general policy with regard to the parking in the central business district, as stated in the 1990 Transport Plan Parking Policy:

- Restricts parking during peak periods on selected arterials, to ensure the most efficient use of available road capacity; and
- Ensures the provision of long-term and short-term parking by development controls, to maintain the viability of all business activity centres.

In addition, the Central Business District Parking Policy dictates that all new developments should provide on-site parking and loading facilities in accordance with the guidelines issued by the Department of Transport or pay a financial contribution in lieu thereof, to be determined by the relevant local authority. Funds levied on developers in this manner are used to provide and manage parking facilities and to reduce the existing shortfall in parking revenues.

Bloemfontein

The existing on-street parking situation has been reassessed, and it is anticipated that the existing number of parking bays can be doubled.

Private developers will be encouraged to provide an additional 1,250 parking bays as a first option, with an extension of an existing aboveground parking facility as a second option for some of the requirements.

East London

Although there is no real shortage of long-term parking in the city center, there is a shortage of short-term parking during peak periods.

This need is expected to be met by providing open-air parking.

City center Car Parking

City center car parking requirements are normally met in four major ways:

1. Through conventional street parking, controlled where appropriate by parking meters.

2. By multi-story car parks provided by the local authorities.

3. By multi-story car parks provided by private enterprise.

4. Through requirements of town planning schemes, under which any new development in a city center must provide car parking for its own users and for visitors to the development. For example, in some areas, one parking bay is required for every 50 m^2 office space in the development.

Because of the comparatively low cost of land in the central city areas of South Africa, aboveground, multi-story stand-alone car parks are still the most economic option. However, this situation is likely to change in the future as city centers continue to develop. At this stage, there is a natural resistance on the part of vehicle owners to pay high charges for car parking when development density in some city centers is still comparatively low.

In redevelopment schemes where car parking has had to be provided, the basic design has included two or three floors of parking provided below the road level, where the geological conditions permit (e.g., above the water table).

Summary

The development of car parking in South Africa has primarily been at or above ground level (for economic reasons), together with some basement parking associated with development of office and commercial properties in the major cities.

It is expected that the future development of underground parking will depend on the economic balance between construction costs and land costs.

Acknowledgment

This report was prepared by the South African National Council on Tunnelling (present address: P.O. Box 61019, Marshalltown—Transvaal 2107, South Africa).

The Netherlands:

The Parking Situation in the Netherlands, and Particularly in Amsterdam

Introduction

In the past few years, a great deal of study and debate has taken place in Amsterdam on the question of car parks—generally, underground car parks. This represents a change from the situation in the recent past. For years, inner-city policy in particular was based on the assumption that the available parking space, most which consisted of on-street parking, must be sufficient, in terms of both its nature and its capacity.

The fact that the question of underground parking is now being seriously reconsidered does not, however, mean that a more liberal attitude is being

taken towards the number of parking spaces. On the contrary, both national and local governments are making efforts to achieve more stringent parking standards and to take advantage of the opportunities offered by parking regulation for influencing the use of cars. However, this policy also aims to safeguard access to the economic activities of cities, where the numbers of inhabitants and jobs are still increasing, while in cities such as Amsterdam increasing importance is being attached to the quality of public space. The latter consideration generally implies a desire for parked cars to be out of sight and thus, preferably, underground.

This paper first examines the developments in national and municipal parking policy more closely, and then considers a number of plans for underground car parks in Amsterdam.

Developments in Parking Policy

Current parking policy in cities in the Netherlands is strongly influenced by the government's national mobility policy. The Second Transport Structure Plan, which was published some years ago, predicted a 70% increase in car traffic over the next 20 years if policy was not changed. Such a large increase was considered to be unacceptable, both because of its impact on the environment and because of the unavoidable problems with capacity and access that it would cause.

The Second Transport Structure Plan sets forth a large number of plans and an extensive set of measures intended to bring about a shift from cars to public transport and bicycles, so that the increase in car traffic can be kept down to 35% (nationally) or even 20% (near the big cities).

The restrictions on the growth of car traffic should, of course, go hand in hand with making transport alternatives more attractive.

To achieve this, the regular infrastructure policy has been intensified (especially in the area of public transport), and supplemented by additional measures designed to restrict less essential car traffic. Experience to date has shown that expanding public transport is not enough in itself to persuade car drivers to abandon their cars in favor of trains, buses or trams. The attractiveness of using cars has to be "doctored" to some extent at the same time, or else the improvements in public transport will be a waste of effort.

The additional measures mainly relate to **siting policy** (in which the siting of offices and businesses is linked to the accessibility of the area, with stricter parking standards as set forth by the government); and to **parking policy** (through more widespread introduction of paid parking and a steep increase in parking fees).

In addition, car driving itself is going to become more expensive. One idea that has been discussed is a peak driving sticker—a kind of admission ticket and fee for the use of roads during peak hours.

The government has to see to it that this policy is also carried out in practice. One way that it is doing so is by requiring regional transport plans as a precondition for funding of traffic projects (the traffic and transport system in the Netherlands is almost completely paid for by the government). Implementation of the national policy must be included in these regional transport plans, particularly in the plans for regions surrounding the big cities.

However, many of these implementation plans have revealed that the targets of the national policy tend to be somewhat high. Thus, for example, the siting policy has numerous consequences for the competitive relationships between local authorities, which want to attract new businesses and office buildings. The local authorities are therefore demanding that implementation of the siting policy should be supervised (e.g., by the province or by the government) to ensure uniformity. At the same time, they are requesting additional scope for tailoring the policy to take local wishes into account.

The government itself also is having difficulty in boldly introducing an increase in the costs of car travel per kilometer: in Parliament, this unpopular step faces considerable opposition.

Whatever the outcome, regional transport plans are now being prepared everywhere, and one consequence of this is that more attention is being given to parking. The details of the parking policy—where to introduce paid parking, at what rates and for what periods of time—are left entirely to the local authorities.

If the national parking policy is successful, parking spaces will become relatively scarce, and more attention will need to be given to the location, size and use of the available parking capacity. The way in which this is done will differ from city to city, depending primarily on the character of the city center and the office and business sites. In cities with a historic city center, such as Utrecht and Amsterdam, a condition of scarce parking space is considered normal and is more accepted, because few people would wish to demolish historic buildings in order to make space for car parks and their access roads.

Elsewhere, in cities such as The Hague and Rotterdam, there are many more new buildings in the city center. Used primarily for offices, these buildings generally incorporate on-site parking space. The use of these city centers is also much less mixed, so that there is hardly any requirement for parking space for residents. However, the siting policy affects zoning for new commercial buildings everywhere, in terms of stricter parking standards (1 parking space for every 5 or 10 jobs) in the central areas, which are easily accessible by public transport.

Amsterdam's Parking Policy

In the Amsterdam region, the City of Amsterdam has been collaborating for some time with 16 neighboring local authorities in the areas of land use planning, the environment, economic development, public housing, and traffic and transport. A traffic and transport plan for this region has recently been brought forth. This plan also includes a stricter parking policy, along with numerous other measures which, taken together, are designed to achieve a better balance between the quality of life and accessibility. It is an ambitious plan, for which a total investment of some Dfl. 15 billion in infrastructure will be needed

The regional traffic and transport plan was officially approved by the Regional Council in October 1993. Meanwhile, Amsterdam is simultaneously busy—fully in the spirit of the regional plan—developing a plan for reducing car traffic in the city center, an area filled with historic buildings, and accommodating more than 80,000 residents, as well as 80,000 jobs.

Amsterdam has, of course, been attempting for some time to steer car traffic in the inner city in the right direction, with the aid of traffic management schemes, city center plans, and plans for separate tram lanes and cycles routes. Several of these plans have been put into practice and have resulted in improvements, but clearly they are not sufficient: the environmental standards are substantially exceeded on various streets, the number of traffic accidents is still too high, and public transport is still much too slow on various parts of the network.

Nevertheless, positive developments have taken place recently. One of the most important of these is that Amsterdam has succeeded in getting its parking situation back under control. After years without any means of handling the problem of large-scale illegal parking and non-payment of parking fees effectively, wheel clamping and towing now ensure that parking spaces are available for visitors who need them.

A second important development is that the government is now making substantial funds (about Dfl. 2 billion) available to Amsterdam to invest in the construction of a number of new metro and light rail lines that are es-

sential for improving the accessibility of the city center.

Third, it appears that more support for the mobility policy is developing among the population, perhaps because people are becoming more conscious of environmental damage to the city.

In an attempt to increase the involvement of the population in political decision-making (the turnout percentages at elections were showing a declining trend), a referendum—the first of its kind in Amsterdam—was held in March 1992. As the subject of this referendum, the council chose the traffic policy to be implemented in the city center. Voters were asked whether they wanted to continue with the existing approach, or whether they would prefer to see a more drastic reduction in car traffic.

A small majority of the voters (53%) declared themselves in favor of making the city center freer of cars; however, the turnout rate was extremely low, at just 28%. The council nevertheless decided to respect the verdict of the voters and to prepare a step-by-step plan that would result in a further reduction of car traffic in the city center. Bearing in mind the narrow margin between supporters and opponents of this approach, it appeared sensible to introduce the changes gradually rather than suddenly. The first two steps involve carrying out a series of small adjustments, primarily by modifying existing plans.

A Traffic and Area Design Plan is currently being drawn up as the third step in the phased programme. This plan will analyze the measures needed to achieve the desired reduction in car traffic. The main instrument to be used for this purpose is parking policy. Long-term parking for commuter traffic is treated as a "nonessential" category. After studying a number of scenarios, an approach has been chosen that will distinguish between distances, placing more emphasis on parking for residents than for visitors, depending on the character of the area. The "visitors" concerned are mainly those travelling to the central shopping area, to their offices on business, and to visit residents, facilities and museums.

The proposal will probably involve removing about 20% of the total number of parking spaces expected by 2005, the year of the plan. This scheme will reduce car traffic by approximately 30%, rather than the 50% that originally was proposed as a target. Although hard evidence of the economic effects of traffic measures is always hard to obtain, a 50% reduction was considered to place too great a strain on the economic functioning of the city center, since the bulk of this reduction would have to be achieved by reducing visitor parking still further.

In addition to parking, the plan pays extensive attention to improving public transport. The two new metro lines, including the North-South line, which will substantially improve access to the city center, will not be ready until the end of the period covered by the plan. In the interim, further improvements will be made to the existing tram line network. In order to be able to carry out these improvements properly, a one-way traffic system is being developed on the radial roads also used by trams.

Trams are to be given still higher priority in the traffic control programs at intersections, in order to increase their speed and regularity.

As its name indicates, the Traffic and Area Design Plan concerns not only traffic, but also the desire for better design of public places. The large number of on-street parking spaces frequently detracts from the urban beauty of the historic city center. Some experience in improvements of public areas was recently gained when a number of streets and squares in Amsterdam were redesigned.

The overriding belief is that making the layout of the streets and squares more attractive will yield economic as well as aesthetic benefits, as the number of visitors and their patterns of spending will be influenced favorably by the improved design. Of course, this work will also benefit Amsterdam's residents themselves, who are, after all, the city's most frequent visitors.

The relationship with underground parking also emerges in the proposals for face-lifting and improving the quality of public places. The plan proposes that a large number of on-street parking spaces (7,000 of the existing 20,000 spaces) should be removed so that the space thus freed can be redeveloped. A proportion of these parking spaces will then need to be "rebuilt" in new underground car parks. Thus arises the apparent paradox that a policy aimed at reducing the number of parking spaces actually will work in favor of underground car parks.

Specific Plans

Amsterdam has some experience with underground car parks, but only a few have been built. Many problems will need to be solved in the historic city center, including how to fit the parking facilities into the generally tight space and how to construct them, given the difficulties posed by Amsterdam's soft soil.

In 1993, the City made a start on its parking strategy by carrying out a study to identify possible sites for car parks in the city center. The car parks would be open to the public, have a capacity of between 100 and 500 parking spaces, and primarily serve visitors (but also residents if necessary). More than 20 sites were identified where there was sufficient space for a car park. These sites were evaluated on the basis of the following criteria:

- **Accessibility** (Is the site on a main car traffic route? Will vehicles driving in and out cause congestion? Is public transport to important points in the city center available?).
- **Parking situation** (Is there high demand for parking at the site or in the area directly surrounding it, showing that a car park is needed? Has parking control already been introduced?).
- **Function for visitors** (How many functions that attract the public and how much shopping space are located within range of a car park on that site? For the moment, this range is assumed to extend out to a maximum walking distance of 500 m).
- **Function for residents** (How many residents live within 500 m walking distance of the site?).
- **Relationship of the site to existing carports** (To what extent do the ranges of existing and already planned public car parks overlap with the range of the site under consideration?).
- **Relationship with intensification of land use** (Can an increase in the need for parking spaces in the immediate surrounding area be anticipated due to the construction or redevelopment of buildings?).
- **Zoning plan** (Do the conditions set forth in the zoning plan permit construction of a car park?).

Based on these criteria, which were also weighted to some extent (so that, for example, ease of access and the site's potential for serving visitors were weighted somewhat more heavily), a list of preferred sites was drawn up. Five sites emerged as having the best potential.

Naturally, this study was no more than a first, exploratory round. Since then, it has been followed up in the form of a feasibility study, which is due to appear shortly. The possibilities for constructing underground car parks at five sites (see Fig. 11) are examined in greater depth in the feasibility study; however, these five sites are not exactly the same ones recommended in the first report, as a result of new developments or technical problems.

The feasibility study looks in greater depth at the urban development situation, the traffic situation (including the situation during construction), the civil engineering aspects (state of the soil, method of building, costs and duration of building), operational and

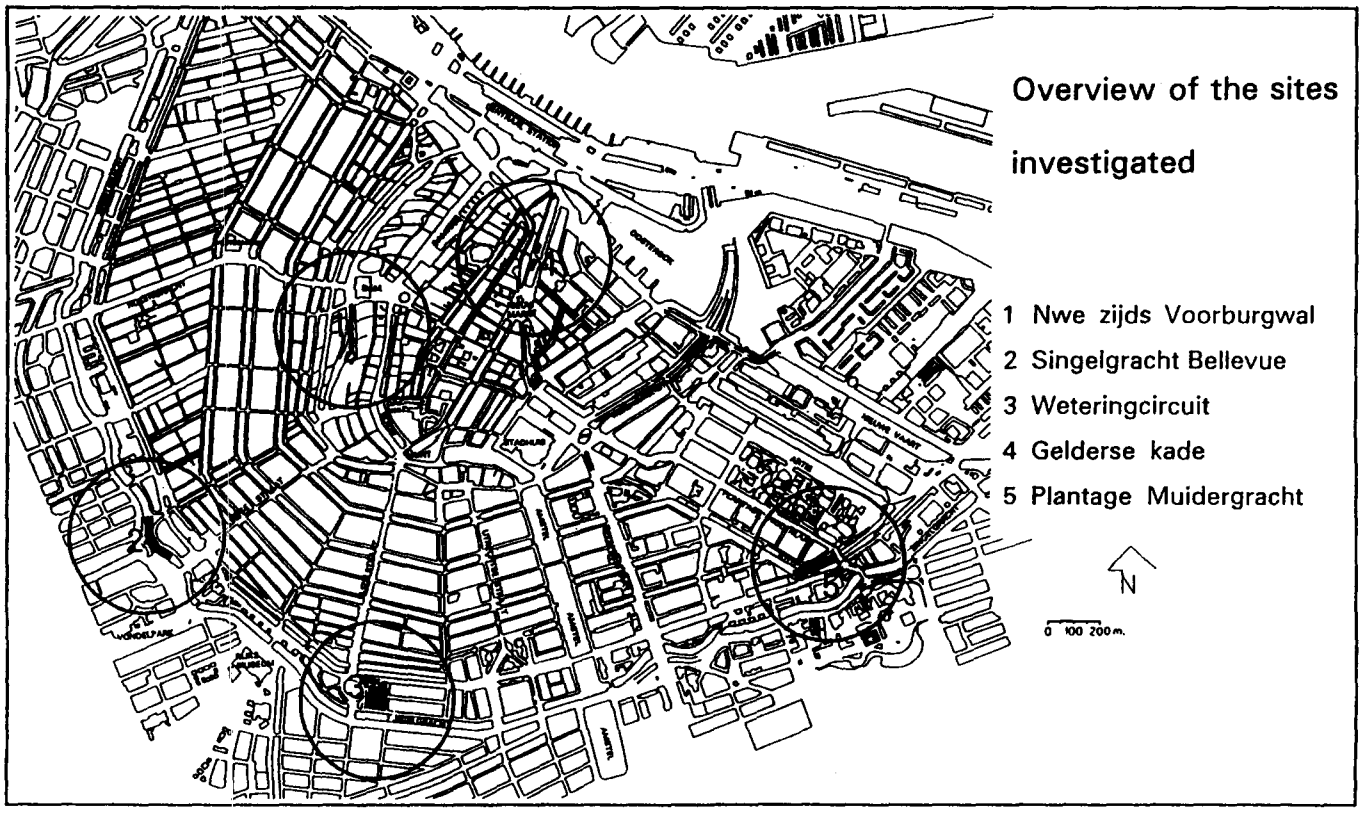

Figure 11. Overview of the five sites investigated in a feasibility study of underground car parks in Amsterdam.

management aspects, and the environmental aspects (the presence of any soil contamination, and the approach to be taken with regard to air pollution and noise pollution).

The study will likely conclude that despite the heavy investment costs per parking space, the results for three of the five sites are encouraging, even taking into account the margins of uncertainty used. It is therefore to be expected that these sites will play a role in the further development of Amsterdam's Traffic and Area Design Plan.

Numerous additional problems will have to be solved in the process, including the question of whether the municipal parking control department, which now controls on-street parking and is at present thriving financially on this revenue, must also play a major part in the operation of new public car parks. The relationship between rates for parking in car parks and on-street parking is, of course, an important factor here.

It also remains to be seen how the residents will react to the nuisance of construction activities. In addition to the three or five car parks mentioned above, building initiatives for two or three more car parks are already in progress. Construction of the new metro lines also will leave traces on the surface, even if the bored-tunnel technique is chosen.

In addition to all this, there is the part of the Traffic and Area Design Plan that will introduce one-way traffic on a number of streets and transform large numbers of parking spaces into attractive public areas. Undoubtedly this is an ambitious programme for the next ten years!

In any event, the likelihood that the public will accept underground car parks seems to be much greater than was possible ten years ago. One of the factors responsible for this change is, again, the fact that in the last few years Amsterdam has succeeded in bringing adherence to parking regulations back up to the mark, so that the situation of a car park standing almost empty while illegal parking in its immediate surroundings goes unpunished now belongs to the past.

The lesson that can be drawn from all this is that a car park must be an integral part of the parking regime in a larger area—and not a separate, independent element within it.

Acknowledgment

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Germany:

Urban Underground Parking in Stuttgart

Traffic Situation

An analysis of the traffic situation in the Stuttgart region shows a marked increase in traffic during the 1980s, with a considerable increase mainly on the fringes of the city. For example, from 1981 to 1988, the incoming and outgoing individual transport at the borders of Stuttgart rose from approximately 582,000 vehicles per 16 hours to approximately 683,000, corresponding to an increase of about 28%. The predictions that had been made with regard to transport development in the future clearly had been surpassed.

The census taken in 1987 revealed that more than 40% of Stuttgart's local work force are commuters. Of these commuters, 62% arrive by car, while 38% use public transport. In 1970, 50% of the commuters used their own cars and 47% used public transport.

This shift towards individual transport shows the important role of the automobile as a means of transport in Stuttgart. A similar trend may be observed in all major cities in Germany. The cities in our new federal states are currently experiencing the same phenomenon, with the difference that this process is now coming about in a greatly accelerated manner.

The demand to provide an adequate number of parking facilities is in con-

flict with other prerogatives of the City administration. Pedestrian zones and landscaping of green space are aimed at improving the attractiveness of the city center; but the roads that ensure the accessibility and functioning of the city center are nearing the limits of their capacity.

The roads can accommodate parked vehicles only up to a certain limit. Land in the city is so expensive and valuable that, as a rule, it is not used for the creation of new parking lots. The average vehicle movement is assessed at only two hours daily; the vehicle is parked for the remainder of the day. Thus, parked vehicles generate certain problems in terms of capacity and distribution of parking space.

2. Parked Vehicles

Owners of parked vehicles may be categorized as businesses; clients and customers; commuters; and residents.

The parking space concept of the city of Stuttgart gives the following special considerations to the different types of traffic:

- *Commercial traffic* includes transport of goods and business-related trips. The demand for parking is to be fully met.
- Although *client and customer traffic* is on the increase, it is also subject to great fluctuations. It is not possible to fully meet this demand.
- Individual *commuting* to and from places of employment is possible by alternative modes of transport. The City's efforts are aimed at creating new parking only in those instances when special needs are to be met, such as parking for handicapped staff, company carpools or clients.
- On the other hand, the *residential demand* for parking is to be met as fully as possible. Ideally, residential parking lots should be located as close as possible to the residential neighborhoods they serve, in order to effectively promote the concept of living in the city. Eliminating the shortage of parking facilities will help prevent the exodus of citizens to neighboring communities.

On the basis of the actual demand, the following objectives governing park space planning for Stuttgart have been identified:

- New construction projects in the city center will satisfy only a limited parking demand because the benchmarks prescribed by the Building Code of the State of Baden Wuerttemberg have been markedly lowered in Stuttgart. At the same time, these benchmarks represent the maximum parking capacity to be provided in the city center.
- The number of public parking stalls located in existing underground and aboveground parking spaces, as well as in parking lots in the city center, will not be increased.
- The occupation and equal distribution of parking spaces available in parking facilities are being improved and made more efficient through implementation of a parking guidance system (see *section below*).
- Client and customer traffic in search of a parking stall, as well as the adverse effects on the environment through noise and pollutants, will be reduced with the help of a parking guidance system (see section below).
- Parking space availability in public streets or on squares is being downgraded in order to discourage permanent parking. Roads are being redesigned and rededicated (i.e., to require special parking permits). The remaining parking space is being reallocated, and special attention is being given to the needs of residents. Short-term parking and deliveries will continue to be allowed; however, business and permanent parking are being ousted from the area and encouraged to use public transport. To date, four areas of Stuttgart—Stockach, Stitzenviertel, Heugsteigviertel and the court district, and Kemer neighborhood—have been designated for residential parking, which is reserved for residents who hold special parking permits.
- The development and provision of parking for the residents in the city center of Stuttgart are given priority. The special parking provisions for residents are to be complemented by related measures, such as the construction of residential underground parking spaces in residential neighborhoods. As a rule, residential parking spaces are to be realized as underground structures so that the land surface can be considered in the urban design.
- To reduce traffic in the city center, more park-and-ride (P+R) facilities will be required to accommodate vehicles owned by commuters. A state-of-the-art parking guidance and information system will direct vehicular traffic directly to P+R facilities, thus ensuring its integration with public transport (see section below).

The development of the parking space volume from 1954 to 1983 (Fig. 12) shows a dramatic decrease in parking space available on streets and public squares in the city center. This downward trend is continuing. The number of parking spaces in aboveground parking lots has largely remained unchanged, although a substantial increase in spaces in private areas can still be observed.

3. Parking Facilities in Stuttgart

The development of residential parking facilities in the populous neighborhoods located near the city centers, the expansion of existing parking space on private properties, and the construction of P+R facilities on the outskirts of the city are possible stimuli for the construction of underground parking. In areas where there is a shortage of public parking, parking lots, and particularly underground parking lots, have proven expedient. The design of attractive parking facilities throughout the city—in the city center, in residential areas and on the city outskirts—is a requirement for upgrading public urban space.

In areas located near the city center, offices, cultural amenities and shops can be erected on top of underground parking lots. The construction of underground parking lots neither precludes nor restricts urban development. Moreover, if a construction project cannot be realized at the same time, because of problems with financing or building regulations, the construction of an underground parking need not be automatically postponed. In Stuttgart, for example, two decades after an underground parking facility was completed, a school and cultural complex was built on top of it.

The space on top of underground parking lots located in residential neighborhoods can be adjusted according to the conditions characteristic of each neighborhood. Garages constructed under roads and squares allow for the rededication of the latter for their original purpose through redesign of the urban space, after the garage construction is completed. In urban renewal areas, it is possible to implement a specific set of urban design goals in connection with an underground construction project.

The urban district of Stuttgart-West is one of the most populous districts in all of Germany. Because the area experienced a relatively low level of destruction during World War II, urban design structures dating from the nineteenth century have been preserved more or less in their entirety. Housing is located next to commercial zones, and the traditional road network cannot accommodate the demands of vehicular as well as stationary traffic.

In the early 1970s, the Stuttgart-West district experienced the exodus of young families. This trend was only halted through a program to upgrade the neighborhoods. Measures designed to downgrade roads have reduced the disruptions caused by traffic and added parking space. Disruptive businesses have been relocated away from their locations in residential neighborhoods. In one such case, a dye works and a furniture factory were demolished, and the site was reclaimed for a new, 340-stall underground parking facility. The surface of the underground structure meets the needs of the residents, as it accommodates the playground of a nursery, sporting facilities and a community center. The improvement of the neighborhood has also encouraged private modernization efforts in the surrounding buildings.

The application of structural measures near the access to parking facilities is particularly important. For example, specially designated turnoff lanes ahead of congested junctions facilitate easy access to parking garages. In some cases, the designation of access lanes to parking facilities can reduce parking space needed in the city center. Such an arrangement has no negative impact on either the traffic flow or network capacities. Indeed, the option of overtaking a traffic jam approaching a red light has a positive effect on drivers, and makes these parking facilities more attractive to potential users. Particularly at the outskirts of the city, the users can gain time by using P+R facilities equipped with transport management systems.

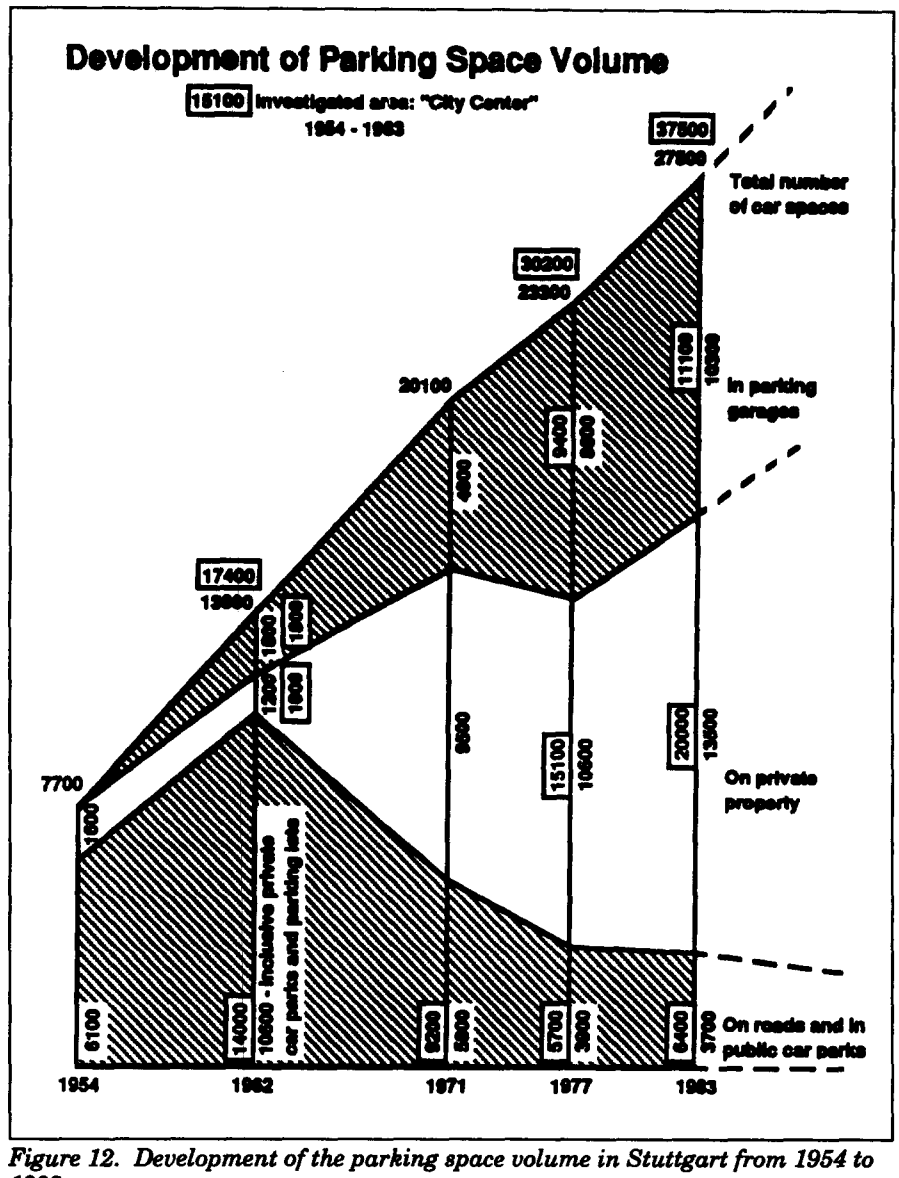

Figure 12. Development of the parking space volume in Stuttgart from 1954 to 1983.

4. Design of Underground Parking Facilities

The guidance of vehicles inside a parking facility depends on the topography, the width and the length of the site, as well as the size of the premises. Examples of the following different types of architectural design of parking lots are found in Stuttgart:

- Simple, straight entrance and exit ramps.
- D'Humpy ramps.
- Unending ramps.
- Spiral entrance and exit ramps.
- Modified versions of the above types.

Based on its experience, the Civil Engineering Office in Stuttgart has recommended that particular attention be to be given to user-friendly design, as well as security, for such parking facilities. Many people are uncomfortable in parking lots, particularly underground parking lots, because they are claustrophobic, afraid to get lost, or afraid of mugging. Features that tend to enhance these fears are to be dealt with specifically and eliminated in the design of new parking lots.

For example, pillars, which impair vision and maneuvering, are to be avoided, particularly in parking facilities with a high turnover. An architectural design that eliminates pillars and extends over two rows of parking stalls and a traffic aisle, creates the illusion of space and a greater sense of openness in the parking area. Because vacancies are visible from a farther distance, even sloppy parking results in only a minor loss of parking space and drivers' time.

With regard to the arrangement of the individual parking stalls, one-way traffic, angled parking on both sides, a stall width of 2.30 m, and an aisle width of 5 m have proven to be user-friendly measures, despite the overall large spanning capacity (this construction mode results in a total structure width of 16 m or more). A diamond-shaped frame construction allows for low story heights of 2.70 m, as well as for relatively thin structures of 25 cm in the aisle area. In recent years, underground parking lots designated for short-term parking have been designed specifically as diamond-shaped frame structures. The construction costs have been reasonable.

Residential parking areas, reserved exclusively for long-term parking with little turnover, typically are executed as a modified, more economical version of the above arrangement, with stall widths of 7.50 m and individual supports for parking stalls. Compared to short-term parking facilities, a lower standard applies to residential parking lots.

To increase user-friendliness, the use of color and adequate lighting of parking decks are indispensable. Clear directional signs facilitate orientation to parking stalls. Wide stairways and elevators improve accessibility. Emergency calling systems, parking stalls reserved for women, and the presence of parking attendants make both un-

derground and aboveground parking facilities more attractive and more acceptable to the general public.

5. Parking Guidance System

In addition to structural and operational criteria, other factors that influence parking habits are the distance from a parking facility to the closest pedestrian zone and the means of charging and paying for parking. It has been observed in Stuttgart that during peak times, many parking facilities reach their level of capacity, while others in the immediate vicinity still have some vacancies. In this connection, efforts have been aimed at improving this situation with the help of a parking guidance system designed to improve and better coordinate distribution of the vehicles among all parking facilities in the area. One goal of this plan is improve the efficiency of those parking facilities that are located at the periphery and which have a higher rate of vacancies.

The parking guidance system directs the motorists in search of a parking facility to the nearest vacancy, recommending the optimum route. A reduction in the traffic searching for parking space helps reduce the impediments for the through traffic, as well as reducing noise pollution and automobile exhaust fumes.

In 1988, all public parking lots in the Stuttgart city center became part of a dynamic parking guidance system, which was implemented in three stages. On the approach roads leading to the city center ring road, at the junctions and the entrance roads to the parking facilities, variable message signs were mounted to provide motorists with up-to-date numeric information on vacancies in a given area or parking facility. The signs display two or three options, in order to allow drivers to select the vacancy that is closest to their destination.

Currently, a total of about 8,000 parking stalls distributed throughout 22 underground and aboveground parking lots, as well as carparks, are connected to the parking guidance system. The completed system cost approximately 3.5 million DM, and the annual operational costs are calculated at 150.000 DM.

Thanks to the modular structure of the guidance system, new facilities can be hooked up to it at any time. Data transfer stations installed at the control center of each parking facility enable the operators to respond to changes in vacancies as they occur. Parking stalls reserved for permanent parking can be converted to short-term parking. The computer calculates the vacancies in all parking facilities every two minutes, then recalculates the updated numeric display on every display field of the 45 variable message signs.

Traffic studies were carried out before and after the parking guidance system was installed. The results indicate that since the system was installed, distribution of vehicles among all parking facilities has become more evenly distributed. The waiting periods in front of the facilities have been reduced dramatically, and the adverse effects on the environment caused by the running cars have been halved. However, a survey of users of parking facilities revealed that while 85% of them are familiar with the parking guidance system, 35% do not take advantage of it.

6. Transport Management

The Stuttgart parking space concept, which focuses on parking restrictions in the city center, designation of residential parking zones and the introduction of parking guidance systems, provides the components of the city's future local and regional transport management.

In 1992, the State of Baden-Wuerttemberg, the City of Stuttgart, and nine enterprises from the automobile, electronics and communications sector, formed a consortium, creating the Stuttgart Transport Operation by Regional Management (STORM). The consortium's major goal is enhanced cooperation and coordination between individual vehicular transport and public transport.

STORM describes a technologically operative concept which, as a first step, aims to improve the efficiency of the existing infrastructure. In the second step, advanced information processing technologies will be introduced in an experimental stage involving seven pilot projects. After the trial period is over, the systems will be introduced city-wide on a permanent basis.

STORM is based on a data link among all regional and local control centers serving individual and public transport. The other projects focus on ways of influencing travelers' choices at the beginning of their journeys, their routes, and their driving habits, as well as the mode of transport they use.

The decision in favor of individual transport should not be considered irrevocable. P+R information installed at the main approach roads is designed to encourage motorists to use public transport. Message signs should provide dynamic P+R information, including:

- Up-to-date information on the traffic situation on the roads ahead.
- Information on parking space available in the city center.
- Information on the schedules and the departure times of public transport.
- A numeric display of vacancies in the nearest P+R facility.

In the suburbs of Stuttgart (Stuttgart-Degerloch district), along federal highway 27, a new P+R facility was completed in 1993. The parking lot, which is located near a tram stop serving three tram lines, can accommodate a maximum of 1,000 cars. The first dynamic P+R information was established near the entrance to this P+R facility. In the fall of 1994, another P+R facility that includes an information display was put into service near the suburban railway station Stuttgart-Vaihingen.

In addition to the P+R information system, STORM is experimenting with ways to optimize the utilization of parking facilities, and is performing field trials involving restricted access for parked vehicles.

7. Costs

Setting up a dynamic P+R system necessitates a system of collecting traffic data at the major roads, as well as a data link with the public transport control centers. Once these technical arrangements are completed, the costs incurred by the additional equipment required for P+R facilities—such as hardware/software, wiring, and variable message signs—amount to approximately 1.5–2 million DM. The price range results from the costs for the cables, which can vary for each individual case.

The construction costs for one parking stall in an aboveground parking facility range from 15,000 to 20,000 DM. The costs for soils preparation and treatment, development, design, environmental protection, and urban design requirements (such as landscaping of rooftops) determine the definitive cost level.

The construction costs for one parking stall in an underground parking are much higher. The construction techniques required in the densely populated urban districts of Stuttgart, including relocation of water ducts, groundwater lowering, observation of settlements, safety measures for buildings in the immediate vicinity—as well as compliance with building regulations, fire protection, ventilation, escape routes, movement of groundwater table—have a major influence on costs. The construction costs for one parking stall in an underground parking range from 30,000 to 50,000 DM. In some cases, the costs have exceeded that upper limit.

In the Stuttgart region, in areas where solid rock formations in the lower strata exist, a special version of underground parking structure, referred to as a parking "cavern", has evolved.

Construction costs are estimated at 45,000 DM for each parking stall. Complementary installations, to ensure that this type of cavern can also be used as fallout shelter, add about 10% to the overall costs.

To offset the aforementioned construction costs, the City currently charges a redemption charge ranging from 25,000 DM for one parking stall in the city center, to 18,000 DM in commercial zones, to 11,000 DM in other parts of the city. These sums must be invested in new parking facilities to be constructed within the next decade. Planners also hope to invest these funds in new parking guidance and information systems.

8. Conclusion

This discussion has illustrated the level of expenditure involved in the construction of underground parking facilities. Office buildings, banks, insurance companies and department stores accept high constructions costs, because the provision of parking space for their clientele is part of their customer service and makes them more competitive.

Residential parking facilities represent a voluntary service provided by the City for its citizens. All of the existing residential parking facilities were erected during times of prosperity, i.e., in the 1980s. Their financing was secured by the revenue from redemption charges levied on parking space. However, the operation of these facilities is unprofitable: the rental charges by no means cover the operational costs. Because of the subsidizing role assumed by the City, in harder times residential parking facilities constitute a heavy burden for the City's budget.

In light of Stuttgart's current budgetary problems, the possibilities for creating new public underground parking lots have become minimal. As a result, the provision of parking space in residential areas has increasingly shifted to road space. Parallel parking, to this day the predominant form of parking, is increasingly being replaced by transverse parking which, to some extent, encroaches on the sidewalk space.

Dynamic guidance and information systems are increasingly being implemented in the city center. While measures related to transport technology do not provide any additional parking facilities, they are designed to improve the efficiency of existing ones. As a result of these systems, an individual parking stall is used for longer periods at a time and has a higher turnover. In addition, these systems allow parking facilities located at a greater distance from the city center to be used more efficiently.

From the point of view of urban design, transport technology and financing, there are no plans to expand the existing parking capacities in Stuttgart. However, there is potential for further development of parking in connection with the commercial and business districts.

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Acknowledgments

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Belgium:

Public Policy of the City of Gent Regarding Parking and Underground Car Parks

Like all other cities in Flanders, Gent is confronted with increasing parking problems in its city center. In discussing the City of Gent's policy on parking and underground car parks, this paper concentrates on the Gent South City Development Project, which is currently being implemented.

The City of Gent has identified the following measures to manage the flow of traffic, reduce the problems of parking, and bring about a more people-friendly inner city:

- Judicious location of residential areas, industry and facilities, so that they are within easy reach of the main traffic routes.
- General construction regulations that compel the contractors to provide the required parking facilities for new buildings.
- Promotion of public transport and bicycling.
- Reception of long-term parking on the outskirts of the city, near public transport stops;
- Application of a "Park and Ride" system.
- Implementation of a traffic circulation plan for the inner city, comprising a network of one-way traffic systems that open up short-term parking facilities on the outskirts of the city center.

Gent has more than 3,000 aboveground, pay-as-you-park spaces, which are controlled by about 30 traffic wardens; and an additional 1,900 public, underground or indoor parking spaces.

The profits from council-run car parks come mainly from parking meters and automatic car parks; and are largely invested in the building of new car parks on the edge of the city center.

For several years, various urban development studies have highlighted the southern part of the city as the ideal place for building underground public car parks. As a result, both the public sector and the private sector have invested in large projects for Gent South.

Two major projects have been constructed in the vicinity of Wilsonplein. The first is the Urbis complex, a mulifunctional project combining shops, offices and private residences. Part of the building houses the provincial administration of east Flanders. The Urbis complex offers underground parking with 500 spaces.

On the other side of the Wilsonplein, the Council built an Administrative Center to house its main public services. This building has a gross surface area of 24,500 m^2 and includes a dual-level underground car park with 300 spaces open to office personnel and the public.

In view of the unique opportunity that existed to link these two underground complexes by building a third car park, and thereby operating a combined car park with approximately 1,100 parking spaces, the Council decided to accept NV Naparc's request to enter into negotiations on the project. Although all of the parties concerned agreed in principle with the concept of the third car park, it was only after long negotiations that the Council, NV Urbis and NV Naparc managed to reach agreement over the establishment of a government-issue concession on the ground below the Woodrow Wilsonplein, and on the commercial operation of the three car parks.

In the agreement establishing a government-issue concession, the Council and NV Naparc granted a concession on the ground below the Woodrow Wilsonplein for a period of 60 years. In exchange, NV Naparc agreed to build an underground, fully equipped car park with at least 300 spaces on

this ground. Because the entrances and exits cross each other's properties, the three parties granted an *incorporeal hereditament* allowing access to the premises involved.

The Administrative Center was put into operation in February 1995, and the Urbis Complex was due to open in late April 1995.

Urban Development as Part of the Car Park Construction

Before examining the car park and its operation in detail, let us consider some of its consequences for urban development.

The new car park can be optimally divided in terms of the traffic circulating above and below ground.

Unquestionably, the car park, with its shared entrances and exits, has solved a few traffic problems that would otherwise have arisen had both projects been built independently.

The car park is easily accessible by city-bound traffic from the E17 and E40 and from the south periphery of the city. The lot also is within walking distance of the city center and the major shopping streets, and lies within reach of a number of socio-cultural establishments such as the City Library and the Vooruit Reception Hall.

The car park facility helps eliminate traffic circulating unnecessarily around the city center, looking for parking space. In doing so, the lot reduces the parking problems in the city center and creates a more people-friendly urban domain.

The car park development was accompanied by a few renovations to squares in the city center, such as the recently renovated Sint-Baafsplein, whereby a number of parking spaces are due to disappear.

The following changes were to be carried out after the works, and partially during the works:

- The Vlaanderstraat between Wilsonplein and Lippensplein will be free of traffic. There are foundations for two-way public transport combined with bicycle paths.
- With the exception of public transport, traffic from Lammerstraat to Sint-Annaplein and back will no longer be routed over the Wilsonplein.
- A secondary entrance in a helicoidal form will provide easy access to the car park from the city center.
- Traffic from the E17 exit to Zuidparklaan will be led directly to the underground car park. Traffic wishing to penetrate deeper into the city center will be led off via the Zuidstationstraat.
- In the Zuidstationstraat, public transport will only be able to travel in the direction of Wilsonplein.
- On the H. Frere Orbanlaan, the one-way city-bound traffic will be led in via Sint-Lievenspoort to the Graaf van Vlaanderenplein. Public transport will have its own lanes between the trees and along the Zuidparklaan.
- Bus route 70/71 will run from the Tentoonstellingslaan via the J. De Bruyckerdreef to the Zuidparklaan and the Graaf van Vlaanderenplein, and will cross the traffic on the Zuidparklaan at a set of traffic lights.

The construction of the underground car park presented the ideal opportunity for a full reorganization of the public transport routes in this area.

The adjacent Graaf van Vlaanderenplein will have a new tram and bus station, provided by the Flemish Transport Company (De Lijn). This connection will combine all public transport stops and will form the link between regional and city transport.

The re-laying of the partially pedestrianised square above the car park, with more attention to the needs of cyclists and pedestrians, improved the environment in a more qualitative sense. The image of the south as the entrance to Gent from its outlying regions benefits the city as a whole. Moreover, the square itself has become a destination, with benches and opportunities for cafe terraces and street life.

The required restructuring of the road infrastructure in Gent South required the advance agreement of all the highway departments involved: the Gent City Council, the Flemish Community (Department of the Living Environment and Infrastructure), and the Flemish Transport Company (De Lijn).

The Protocol agreement, agreed by the Community Board on 26 April 1993, included provisions on the distribution of costs for the construction of the entrances and exits to the underground car park, the re-laying of the road infrastructure, and the facilities for public transport. The agreement stated that the planned road works must be completed within a period of three years after receipt of the construction license.

The design studio NV S.W.K. of Gent was appointed to design the road infrastructure and monuments, and to coordinate the design dossiers.

Operation of the Car Park

The car park itself has two entrances: one main entrance, with two lanes continuing on from the Zuidparklaan; and a secondary, helicoidal entrance near the Frankrijkplein. There is one common exit with two lanes in the Rooseveltlaan, connecting with the car park under the Stedelijk Administratief Centrum.

The main entrance has two lanes, consisting of an open section and a closed section. The works were contracted to De Meyer-Maes of Gent for 68 million, including VAT, after a limited invitation to tender.

The costs for the open part were paid by the City of Gent, and are eligible for subsidy with rights to withdrawal from the Investment Fund. The costs for the closed section were prefinanced by the City, but will be entirely refunded by the Flanders Transport Company (De Lijn).

The secondary entrance near the Frankrikplein, the so-called helicoidal entrance, was paid for by the City of Gent. Its construction was allocated by private contract to De Meyer-Maes of Gent for 1,9 million, including VAT.

The exit was constructed by NV Pieters-De Gelder of Wetteren, as part of the works for the Stedelijk Administratief Centrum.

This complex was set up through estate leasing by the Gemeentekrediet van Belgie.

The car park is large enough to allow for a profitable and efficient operation, even after office hours. However, from a practical point of view, it is desirable that the management and commercial operation of the three car parks be undertaken by one and the same party.

After negotiations, an agreement was reached between the City of Gent and NV Urbis. The contract stipulates that NV Urbis will supervise the management of the car park for 20 years under the Stedelikk Administratief Centrum. It also stipulates the conditions by which the City may enter a number of car parks under the commercial operation of NV Naparc. NV Naparc will handle the commercial operation of the car park on the understanding that unoccupied parking spaces in other car parks may also be used.

The costs incurred by NV Naparc as the manager of the three car parks will be recovered on the basis of an administration account. This administration account will distinguish between costs that are directly attributable to an owner (e.g., heating, lighting, electricity) and indirect costs (e.g., supervision of personnel) that are difficult to attribute directly. The direct costs will be calculated in proportion to the number of parking spaces. The indirect costs will be divided by means of an apportionment key, which will assume that 30% of the costs are the result of commercial operation. The remaining 70% will be distributed among the three owners of the parking spaces and *pro rata* to the number of spaces owned.

In return for the management fee, the city will receive 600 entrance tickets, which can be used 24 hours a day, seven days a week. The 600 entrance tickets will be valid for 325 parking spaces. Seventy-five tickets, reserved for service vehicles, will apply to permanently reserved spaces. The remaining 525 tickets will give the right to a total of 1,250,000 parking hours per year. Finally, it was agreed that the entire car park must be accessible to hourly parkers between at least 7:00 a.m. and midnight, for a period of three years.

This arrangement will be assessed after the three-year period, after which the opening hours will be determined in consultation with the three parties. Subscription holders will have access to the car park 24 hours a day, seven days a week.

We may conclude that the city authorities of Gent have chosen the right time and location to construct a new public car park, in collaboration with various parties from both the public and the private sectors, with the aim of improving the traffic problems of the inner city and thereby contributing to a better public domain in the qualitative sense.

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Japan:

At or Below Ground Level? Urban Parking Facilities in Japan

The question of whether to build "at or below ground level?" is not easily decided. Even though a decision eventually is made on the basis of a comprehensive appraisal of the various factors that can be anticipated for each of the two alternatives, it is very often the case that those factors which can be quantitatively evaluated in a manner convincing to everyone are limited, and opinion differs with regard to the other factors. This may be due to the effect of the sensibility or psychology of the persons making the appraisal; or, in some cases, to the effects of some conflicting interest.

When a decision cannot be reached through quantitative evaluation only, a conclusion may be arrived at by majority decision among the parties concerned. However, although such a process may be democratic in nature, it is liable to the intrusion of excessive conviction based on insufficient knowledge, or on an apprehensive state of mind.

Because a parking facility can take the form of either an aboveground of an underground structure, parking facilities provide an excellent example of the choice to build "at or below ground level?" However, it must be stated at the outset that this paper does not provide a final answer to this question.

1. Urban Parking Facilities in Japan: the Current Situation

The scope of this analysis of urban facilities is limited to those facilities that have been established by national or local governmental bodies in Japan, based on their urban plans. The study also includes facilities that have been established by private sector entities primarily, but with some form of participation by national or local governmental bodies. Although this participation may take various forms, the common denominator is that compliance with an urban plan is required.

Parking facilities can be divided into the following three groups, based on their location in relation to the surface (see Fig. 13):

1. Surface (flat) structure.
2. Aboveground (elevated) structure.
3. Underground structure.

The latter two types of parking structures can be further categorized as mechanized or non-mechanized, depending upon whether the vehicle is moved into its parking space by mechanical means or by its own power.

Viewed historically, the oldest form of vehicle parking is street parking, followed by multi-level elevated facilities and, more recently, underground facilities, which originally were conceived in pursuit of more efficient land use. Since the introduction of mechanized parking, efficiency through multi-level construction has been increasingly emphasized.

2. Historical Trends in Parking Facility Construction in Japan

With the rapid advance of motorization, traffic congestion in Japan's cities intensified remarkably during the latter half of the 1950s, resulting in oppression of pedestrians by vehicles and simultaneous deterioration of the urban environment.

In 1971, Japan adopted a policy intended to restrain the entry of motor vehicles into urban areas; to reconsider the merits of public mass transportation facilities such as subways and buses; and, at the same time, to promote a conversion from "traditional" street parking to off-street parking, and thereby increase the supply of parking facilities.

At present, street parking is forbidden in Japan's large cities, except where parking meters are installed. However, what is the actual situation at present? Where street parking for five minutes is allowed, many vehicles are observed to exceed the five-minute limit; and, to make matters worse, double-parking is a common occurrence. Moreover, law enforcement to curb such illegal parking is intermittent and ineffective. The principal cause of urban street congestion in Japan's urban areas is illegal parking such as this; and the primary offense is long-term parking of small trucks and commercial vehicles for handling goods.

Some might argue that such illegal parking is a necessary evil that must be allowed in order to maintain local commercial activity. However one views the situation, increased construction of parking facilities is a matter or urgent necessity in the utilization of underground urban space in Japan.

Figure 14 shows the 319 urban parking facilities that were constructed throughout Japan from 1960 to 1990. It can be seen at a glance that the surface parking facilities have small capacities. On the other hand, the capacities of aboveground and underground parking facilities are widely distributed, ranging from 150 to more than 1000 vehicles.

The figure also shows that parking facility construction accelerated as a whole beginning in 1970. However, the construction of surface parking facilities shows a slight decelerating tendency around 1990. This decrease in construction is thought to be very strongly related to the fact that the supply of urban sites had become noticeably deficient by that time.

Figure 15 shows the share of total parking capacity for each of the three locational types of parking facilities. The share of mechanized facilities is also shown. The fact that surface facilities account for only a small share of the parking capacity is not surprising. However, the fact that the share of elevated facilities is clearly greater than that of underground facilities may be interpreted to indicate the existence of a large potential demand for underground parking facilities.

As an example, the share of total parking capacity of each type in the two cities of Tokyo and Nagoya is shown in Table 2. The fact that underground facilities account for a large share is strongly suggestive for future parking facility construction in Japan.

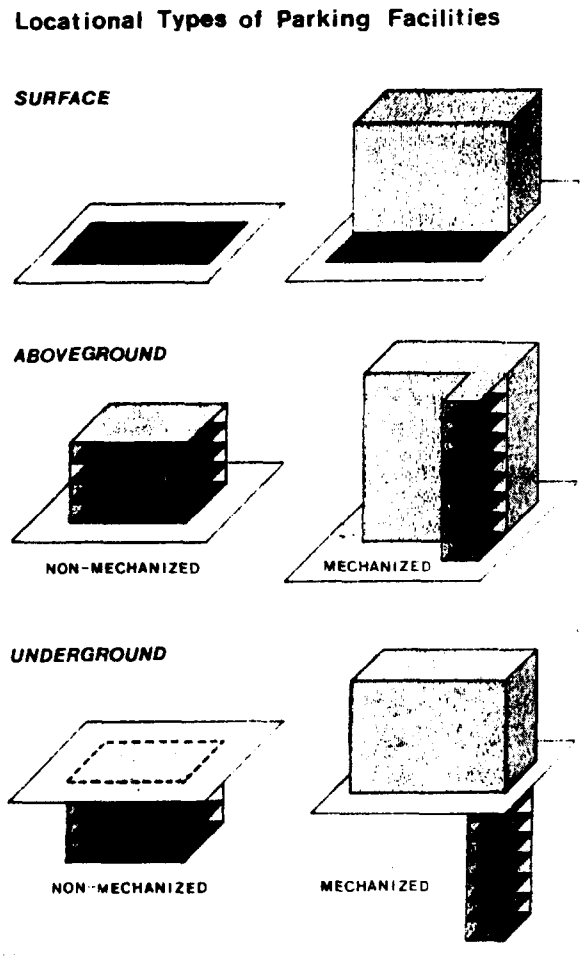

Figure 13. Structural types of parking facilities, categorized by location in relation to the surface.

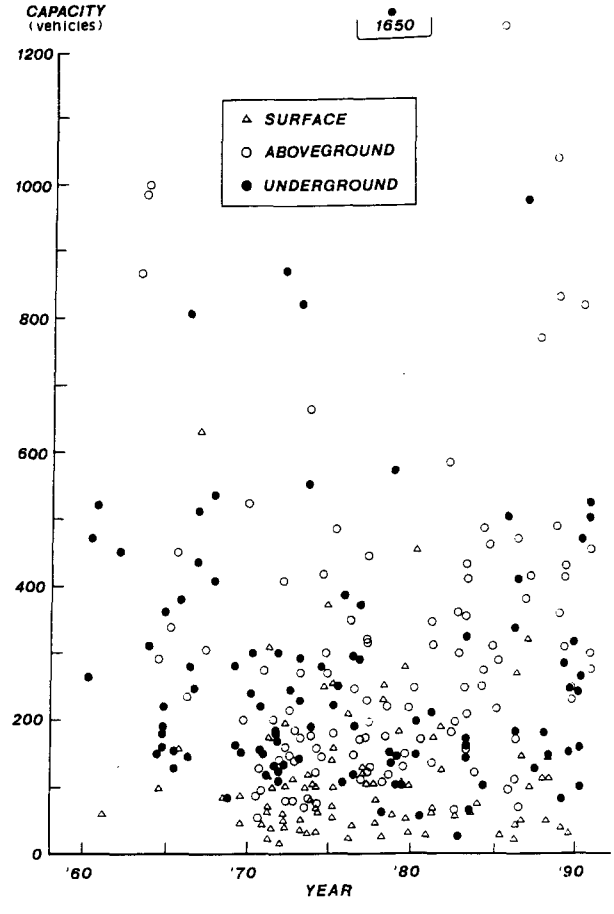

Figure 14. Parking facilities constructed in Japan from 1960 to 1990, categorized by location in relation to the surface.

3. Comparison of Characteristics of the Three Types of Parking Facilities

Although it is desirable that parking facilities be constructed in or as close as possible to the zone in which the demand originates, this goal has become difficult to achieve. Accordingly, parking facilities aboveground and/or underground are being constructed in conjunction with large buildings that are part of urban redevelopment projects. If such an arrangement is not possible, usable space must be sought underground, beneath public land such as street and parks. Furthermore, because the space at shallow depths below streets is almost always occupied by existing facilities such as subways or utility tunnels, parking facilities constructed later must be built to a deeper level, despite the resulting increase in construction costs.

Figure 16 shows the average construction cost per vehicle, including land acquisition cost, for certain ranges of parking capacity for the three locational types of parking facilities. Because these are average costs, based on the data for the 319 facilities throughout Japan (shown in Fig. 14), and computed without separating out mechanized facilities, which include expensive equipment, the results are extremely rough. However, the following characteristics can be deduced:

1. The construction costs for small-capacity underground facilities are extremely high.

2. For surface and aboveground parking facilities, the land acquisition portion of total construction cost is of a magnitude that cannot be ignored. However, the figure indicates that the land acquisition cost is zero for surface facilities that have a capacity of 410 or more vehicles. In fact, this finding represents only a single facility, which was constructed on a former river bed, i.e., on existing public land.

3. The construction cost for large-capacity facilities is high, irrespective of their locational type.

The fact that the construction costs for underground parking facilities (as shown in Figure 16) are very high may reflect the unique ground conditions that exist in Japan. Almost all large cities in Japan are located on deep Quaternary deposits that are bearing, thus

Table 2. Share of parking capacity in the cities of Tokyo and Nagoya.

Locational Type of Parking Facility	City	
	Tokyo	Nagoya
Surface	2.9%	0.0%
Aboveground	24.8%	5.8%
Underground	72.3%*	94.2%

*Includes 5.6% mechanized facilities.

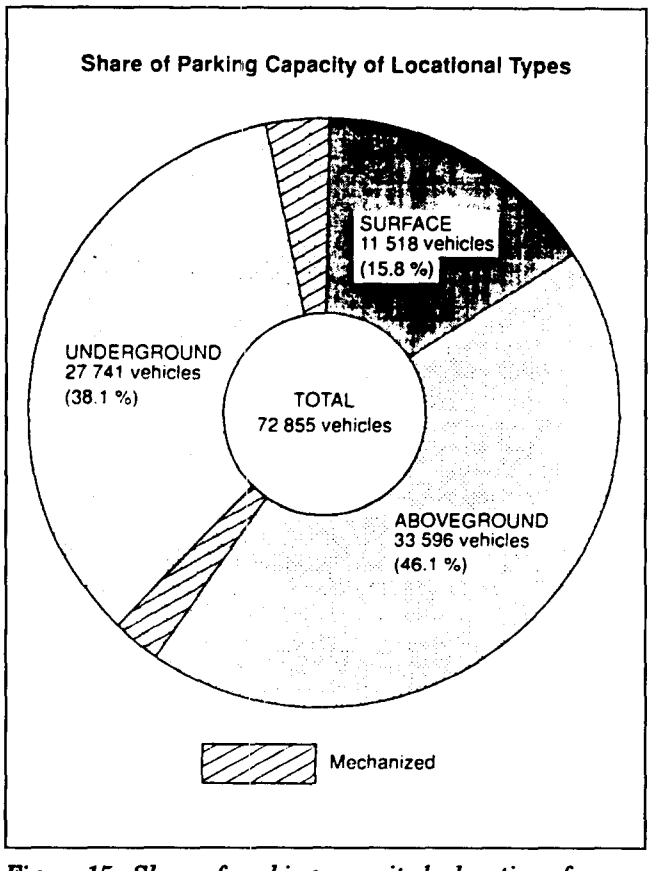

Figure 15. Share of parking capacity by location of structure in relation to the surface.

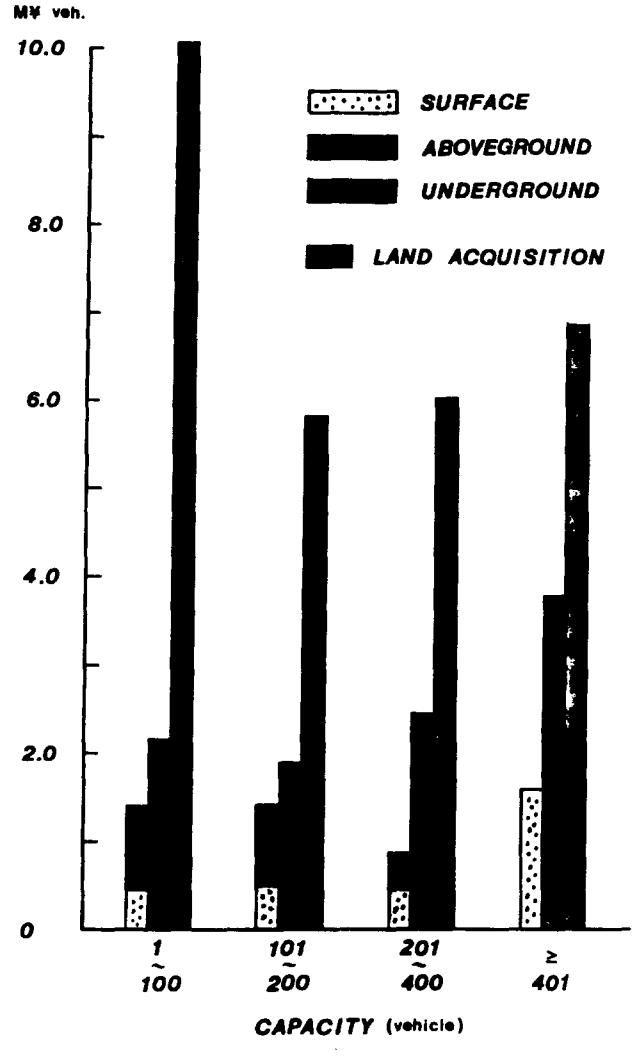

Figure 16. Construction costs of parking facilities.

necessitating significant construction expenditures for ground support and water cut-off at the excavated surface.

A comparison of the characteristics of the various locational types of parking facilities is shown in Table 3. The non-quantifiable items in this table have been evaluated by inference from numerous examples of public structures in urban areas and related information, and are not definitive. With respect to the quantifiable items, underground facilities are clearly at a disadvantage in comparison with the other two types. Nonetheless, the share of underground parking facilities will probably grow to exceed that of the other types in the future, for two main reasons:

1. In the larger cities, it has become difficult to find surface space for parking facilities.

2. Given the growing public concern regarding urban aesthetics and surface harmony, powerful resistance is expected to increase against new construction of surface and aboveground parking facilities. □

Acknowledgment

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Table 3. Characteristics parking facilities, by location in relation to the surface.

Locational Type of Parking Facility	Quantifiable Factors					Non-quantifiable Factors		
	ConstructionCost	Required Floor Area* (m^2/veh.)	Required Surface Area* (m^2/veh.)	Operating Expense	Ease of Converting/ Rebuilding Facility	Users' Psychological Feelings	Urban Aesthetics	Annoyance to the Environment
Surface	Slight	20–30	20–30		Free		Poor	Disagreeable (engine noise and exhaust gases)
Aboveground (non-mechanized)	Medium	25–35	5–7 (5-tier)	Energy for lighting	Difficult		Poor	Disagreeable (engine noise and exhaust gases)
Aboveground (mechanized)	Large	15	3–5	Maintenance costs for transfer machines	Difficult		Poor	
Underground (non-mechanized)	Large	30–45	0	Energy for lighting; maintenance costs for transfer machines	Impossible	Uneasy		
Underground (mechanized)	Huge	15	0	Maintenance costs for transfer machines	Impossible			

* Based on guidelines of the Japan Society of Parking Engineering.