Transportation Strategies of Parking Supply and Usage Analysis

Ahmed A. Bakhsh
(Industrial Department, College of Engineering/ King Abdulaziz University, Saudi Arabia)
Email: aabakhsh@kau.edu.sa

Abstract: The demand for parking often exceeds the available supply. Off-street parking is limited and on-street parking is restricted, particularly in the city center. Parking supply is restricted by thousands of derelict, abandoned automobiles taking-up curb side parking space. Consequently, drivers stop in the middle of the street to unload passengers or cargo, creating additional congestion. This problem is exacerbated by the poor management of parking resources and often leads to double and triple parking. Robust parking management is necessary to achieve a good quality of life. A description of the proposed approach and recommendations that demonstrates the performance is provided.

Keywords: Jeddah, parking, traffic analysis zone

I. INTRODUCTION
Jeddah is a city on the coast of the Red Sea and is the major urban centre of western Saudi Arabia. It is the largest sea port on the Red Sea, and the second-largest city in Saudi Arabia after the capital city, Riyadh. With a population currently at 3.4 million people, Jeddah is an important commercial hub in Saudi Arabia. The vision of Jeddah puts it in the appropriate context in terms of its location and its cultural significance to Saudi Arabia, the region, and the world.

Private car travel is the most convenient mode of travel for many in Jeddah, and finding parking at each end of the trip is as important to most motorists as convenient travel on the highways. If parking is hard to find at either end of the trip, it detracts from the perceived quality of the trip. The quality of parking is also impacted by the simplicity of the parking design, the user costs, and the pedestrian connection between the parking and the ultimate destination. The importance of this element of the transportation network can best be understood by the importance local businesses and local residents place on it. While parking is very important, it does have its negative impacts on traffic flow, land area consumption, liveability

A good quality of life requires superior mobility through a well-developed transportation system comprised of infrastructure catering to private automobiles and public transport. Parking systems and strategies can and will support both private automobiles and public transport if they are well conceived. Safe and efficient automobile travel is often impeded by on street parking congestion. Moreover, chaotic and unorganized on street parking negatively impacts the safety and mobility of pedestrians and bicyclists as well. Passengers in cars ultimately become pedestrians, so footpath connectivity in a neighbourhood is essential in delivering those passengers safely and efficiently to their destination. When planning and designing parking facilities, it is important to consider pedestrian needs as well. A lack of adequate off street parking supply is a widespread problem that, among other things, hinders accessibility to motorists’ destinations. Nevertheless, high dependence on the automobile is supported by parking policies that dissuade the use of public transport.

The overarching theme of this research is two-pronged: first, there exists a severe parking space shortfall which was created by an inadequate supply of parking provided by the public sector; second, Jeddah must gradually move towards a higher use of public transport, which must be supported by parking policies and which will help to manage parking demand.

The remainder of this paper is organized as follows. The next section discusses previous related work on cars parking. In Section 3, Parking Supply and Usage Analysis are presented. The Existing Parking Supply and Deficiencies are shown in Section 4. The Existing Parking Deficiencies is presented in Section 5. The Recommendations are illustrated in Section 6.

II. PREVIOUS PRACTICES
Strategic management play significant role in the transportation systems. Strategy-as-practice is concerned with the implementation of strategy. Many practitioners recommended to define model that support a simulated strategic management for the whole transportation systems as similar as for organization that support the strategic management scheme and aligning strategy to targets, budgets, and initiatives places the organization in motion in...
order to recommend and forecast the continual process enhancement in term of the problem identification, test and propose strategy and scenario implementation [1].

In the last three decades, many kinds of models have been developed for controlling traffic. A study considered developing a decision support system for the future transportation network of a city in the north of France. Therefore, controllers of traffic have to treat a new lot of information and it becomes necessary to help them in order to maintain with demands and to come about to passengers' expectations and hopes. The model is run for current scenario of traffic in the city and assures that arrival times of vehicles are more regular on schedules [2].

On the other hand, growing congestion in metropolitan and suburban areas, coupled with increasing adoption of just-in-time practices among businesses, raises several interesting issues. A study considered an analytical framework for exploring the effects of congestion on performance, especially when low inventories under the JIT philosophy make operations susceptible to interruptions in supply. The framework is also useful for analyzing approaches to lessen the adverse effects of congestion [3]. Moreover, a study established a model for optimizing traffic system with ring roads, and providing a support for hesitant the strategy of evolving ring road in city centre district in many cities of China. The study established a stimulating model of ring road traffic systems and analyzes the traffic effects of ring road in the centre of a large city, counting the effect in vehicle's travel time and distance. According to the simulation, although a high-speed ring road reduces the travel time, it segregates the nature road network system and increases travel distance in the downtown. Moreover, it is uneconomical constructing a ring road to relieve traffic jams. This is a new way by establishing the simulation traffic model to explore the organization of ring road traffic systems [4].

Strategic management model is used to support decision makers with multiple objectives for optimal decision making. For instance, a decision should be taken to consider the optimality in constructing a new car parking while to keep in mind many objectives such as location of the parking, number of spots, cost of construction, quality of construction etc.

A number of researchers have successfully integrated stochastic computer simulation models with combinatorial optimization procedures that generate solutions for decision-makers. These integrated approaches often use nature-inspired search heuristics that also possess a stochastic feature of their own. These integrated simulation optimization approaches have been primarily designed to address single objective optimization problems. Only a few approaches have been designed for multi-objective optimizations that produce a set of Pareto optima. This Pareto optimal set often contains a very large number of solutions, which might be crushing to the decision-maker. A study proposed an innovative approach that effectively reduces the number of the solutions while considering the stochastic nature of the objective functions [5]. Many researchers and practitioners have primarily used strategic models and kept to develop new ones to improve the transportation systems. For instance, the ridership forecasting model is the essential element of the transit project development process, a reasonably high transit ridership forecasting model accuracy would be of great significance to the developments of public transport service level and urban transport environment. The needed process of travel demand forecasting model is analyzing the relationship between travel generation, distribution and Traffic Analysis Zone (TAZ) features. Dependent on the connection and forecasted future TAZ features, future travel generation and distribution could be anticipated. A study come up with an enhanced model called Transit Traffic Analysis Zone (TTAZ). The TTAZ delineating model proposed bears a potential for improving the accuracy of existing transit ridership forecasting models [6].

Strategic management models are designed for several purposes. They can be used to enforce the laws not only for actual design improvement. For instance, vehicles clamping is a common practice used these days to ensure parking rules are followed inside private parking areas such as a campus. A traffic simulation model is constructed to evaluate the effects of deploying parking rules on the traffic flow of vehicles inside such a campus [7]. In addition, the strategic management model can be used also to improve the performance of public cars management. A study investigates car parking as an exemplar site for empirical validation of the difficulties of merging multiple stakeholder interests. The study further argues that public management theory can be developed from consideration of such routine details of day-to-day life [8].

III. PARKING SUPPLY AND USAGE ANALYSIS

In order to focus the parking analysis on the areas of Jeddah with the greatest needs, data collection activities in the form of parking inventory and accumulation are concentrated on dense areas of Jeddah with large populations and high employment. Figure 1 depicts the parking study areas, which are divided into North, Central, South, and Perimeter areas. These areas have no political or geographic significance, but instead are defined so that the data could be presented in a readable and understandable fashion. All of the parking data collection activities are performed in the North, Central, and South regions. Population in Jeddah is reported to be just over four million people and the population in the North, Central, and South regions of the parking data collection area is approximately 3.5 million people. Thus, the parking field surveys are collected in a geographic area that contains almost 88 percent of the population.

All of the parking data are analyzed and summarized by traffic analysis zone (TAZ) and district. Figure 2, Figure 3,
and Figure 4 present a close-in view of the TAZs for the North, Central, and South parking regions. There are a total of 1,538 TAZs in the North, Central, and South parking regions and another 688 in the Perimeter parking region. The four combined regions include 2,226 TAZs.

Unlike the TAZs, the Jeddah Districts shown in Figure 5, Figure 6, and Figure 7, are geographic areas recognized as politically significant. Districts are sets of contiguous TAZs and are readily recognizable to citizens and visitors of Jeddah.

IV. EXISTING PARKING SUPPLY AND DEFICIENCIES

4.1 Parking Model

A parking model is developed in Excel format to estimate existing and projected future demands on a TAZ level. Overall study area demand is measured and disaggregated to the TAZs based on the land use. Land use and socio economic data utilized in the parking demand model included population plus square meters of retail, office, and industrial space. Population data accounts for the home-based residential component of parking demand and retail, office, and industrial land uses reflect the employment component. Employees are not the only commercial and industrial generator of parking demand; visitors, especially for retail centers and, to a lesser extent, office buildings, also contribute to parking demand.

The parking model development and calibration is accomplished in eight steps:

1. Input into the parking model land use data, parking space inventory data, and parking utilization information by TAZ.
2. Determine existing overall parking demand and parking demand by TAZ.
3. Make adjustments to parking supply to account for seasonal and daily variations that typically occur.
4. Use access to automobiles data to determine order-of-magnitude parking demand for the parking study area.
5. Develop an initial set of parking generation rates for population and the principal land use categories: retail, office, and industrial.
6. Set the parking generation rate adjustment factors, including building occupancy, percent trips by other modes, and shared parking and multiple purpose trips.
7. Conduct an iterative process of making adjustments to the parking generation rate factors until the model generated overall parking demand matches the measured parking demand.
8. Compare the model generated demand to the measured demand at the TAZ level.
9. The base unadjusted parking rates used in the parking demand model are as follows:
   - Residential Population: 1.00 spaces per car owned
   - Office: 3.00 spaces per 100 square meters

Retail: 1.75 spaces per 100 square meters
Industrial: 0.75 spaces per 100 square meters

Adjustment factors applied to these rates included building occupancy, walking mode, bicycle mode, transit mode, and shared parking. It is assumed that the buildings are at 90 percent occupancy. Overall, it is estimated that 25 percent of the trips would be via walking, except at industrial land uses, where 10 percent of the trips are assumed to be walking. Furthermore, bike trips are assumed to account for 10 percent of the person-trips except at industrial sites, were they are assumed to be only five percent. Only four percent of the trips are assumed to occur via transit, and this rate is assumed to be appropriate for all land use categories. Finally, a shared parking factor of 0.75 is applied to all land use categories to account for multiple-purpose trips.

4.2 Existing Parking Supply

Parking supply in Jeddah is comprised of on street spaces and off street spaces in lots, parking garages, and under buildings in the basement or on the ground level. Surface parking lots are categorized as either formal or informal, with informal defined as unimproved lots without pavement or formal markings.

The on street parking spaces are considered to be public in the sense that they are available to the public regardless of their destination or duration. Almost all the off street parking supply is considered private in that it is not available to the general public regardless of their destination or duration.

For example, the Toys-R-Us Store on Andalus Road has a parking lot adjacent to its building intended to be used by its customers and employees. This lot is a private facility because parkers with another destination besides Toys-R-Us should not park in it.

4.3 Assumptions and Methodology

The Study Area of Comprehensive Parking Supply and Usage Analysis, detailed parking supply and demand analyses are limited to 1,528 TAZs containing the vast majority of the population in Jeddah. Within those TAZs, all off street parking spaces to which the surveyors could gain access are inventoried. The surveyors counted the number of parking spaces and noted the location. They also described the general type of facility including surface formal or informal lot, basement or under the building parking, and structured (garage) parking. If the parking facility charged a fee, this is also noted.

While in the parking facility for the first time, the surveyors also counted the number of parked vehicles present, thus fulfilling the need to measure accumulation. In addition, the surveyors returned to the parking facilities within their area of responsibility and conducted another parked vehicle accumulation survey. Therefore, two parking accumulation surveys are performed at all off street parking facilities.

On street parking in Jeddah is informal at best, and little or no organization exists. In many locations, motorists park
where on street parking should be prohibited. In fact, an abnormal number of parking generators rely on street parking to fully meet their needs. The disorganized on street parking in Jeddah today makes counting the number of on street parking spaces impossible. As such, a methodology is developed to estimate on street parking supply that included measuring the linear length of local road segments and applying factors to the road segment that account for no parking zones, the standard length of a parking stall, a mixture of angle versus parallel spaces, and parking on both sides versus one side. Within each TAZ the linear meters of local roads is measured and the above factors are applied to estimate on street parking inventory. A sample review of some Jeddah streets and the professionals’ judgment lead to assume that 43 percent of a street’s curb face is available for on street parking. Thus, the balance of the curb face would be unavailable for parking because of driveways, sight distance, fire hydrants, and so forth. In addition, it is assumed that local streets are typically wide enough to accommodate parking on one side, but not both.

On street parking usage is measured from Google and Bing mapping, with the largest number being used in all cases. For some TAZs, parking accumulation is obtained for all on street parking spaces. In the other TAZs, a sampling technique is employed whereby approximately 15 to 20 percent of the on street supply is surveyed for parking usage. The sampled percent accumulation values are then applied to the total supply in that TAZ.

Therefore, the field data resulted in off street and on street parking inventory by TAZ, plus parking accumulation data broken into the two major inventory categories. To be conservative, the parking model excludes the inventory of on street parking supply along arterial and collector streets.

4.4. Summary of Total On and Off Street Parking Inventory

A summary of the total parking inventory by district in the parking survey area is broken down by on street and off street parking. All told, there are 441,476 parking spaces in the study area with 53 percent (233,849 spaces) located in on street facilities and 47 percent (207,627 spaces) in off street facilities. Figure 8 and Figure 9 illustrate density maps of total parking inventory by TAZ and by district, respectively.

4.5. On Street Parking Inventory

In the 1,528 TAZs where the parking surveys are conducted, there are an estimated 233,849 on street parking spaces. On street parking inventory density is shown by TAZ in Figure 10 and by district in Figure 11.

4.6. Off Street Parking Inventory

Off street parking inventory by TAZ is illustrated in Figure 12. In essence, this illustration displays off street parking inventory density, with the highest concentration of off street inventory depicted by the darker shades. In the legend, the reader can see that 2,501 to 7,220 parking spaces comprise the highest density of off street parking supply. Similar off street parking data is depicted in Figure 13, but it is shown by district and the total number of spaces is included. Three districts in the North parking area contain over 10,000 off street parking spaces. These are the only districts in the entire parking study area that contain more than 10,000 off street spaces. The majority of districts in the Central parking area have between 5,000 and 9,000 spaces. The South parking area contains minimal off street parking spaces, with three districts having between 97 and 161.

Two other off street parking inventory analyses are performed, including the average size of facilities and number of facilities, all on a TAZ level. The results of these analyses are depicted in Figure 14 and Figure 15.

It is clear from Figure 14 that the size of most off street parking facilities in Jeddah is small – usually less than 30 parking spaces. Only a few TAZs had average facility sizes over 400 spaces. In many locations, TAZs with average facility sizes over 900 spaces contained malls. One TAZ has a large parking lot to store new cars.

The number of off street parking facilities by TAZ is an indication of developers taking a proactive approach and providing enough parking to meet their own needs. In each TAZ where 36 or more parking facilities have been provided, all parking needs have been met and a surplus of supply exists. As shown in Figure 15, the highest concentration of parking facilities is located just west of the Ring Road and south of the airport.

Approximately 63 percent (130,010 spaces) of all off street parking spaces are in open at-grade parking lots. Basement or ground level parking facilities under buildings comprise 35 percent (71,791 spaces) of the off street inventory. Parking garages provide only two percent (5,826 spaces) of the off street inventory in Jeddah.

There are 6,146 parking facilities in the study area; 1,885 are open, 4,159 are in the basement of a building, and 102 are in multi-level parking garages. Off street parking inventory is also classified by formal versus informal, and is further stratified by district. Of the 130,010 parking spaces in surface parking lots, only 16 percent are in informal parking lots. There are 1,885 surface parking lots, and over two-thirds of these are formal parking lots. It stands to reason that some of the informal parking lots could be upgraded to formal parking lots as the parking system in Jeddah evolves and becomes more sophisticated.

4.7. Parking Rate

Only 12 parking facilities representing 2,448 spaces in Jeddah charge motorists to park in them. Most of the charge parking facilities assesses a fee of one to two SAR per hour.

4.8. Area Covered by Parking Facilities

Figure 16 depicts an estimate of the percent of area covered by parking facilities. The vast majority of the TAZs have 0 to 4 percent of their land consumed by parking facilities.
V. EXISTING PARKING DEFICIENCIES
The North, Central, and South parking zones in Jeddah contain approximately 3.5 million of the total population of just over 4.0 million persons. According to the household surveys, of the total Jeddah population, about 21 percent of the workers –or 865,000 people – have access to a car. This is assumed to be a good estimate of car ownership. Household surveys also listed the non-working population with access to a car, but that value is 2.7 million people which is unreasonable. In the primary parking study area, a population of 3.5 million yields an employee access to car, or car ownership value, of 735,000 cars.

Parking demand in the North, Central, and South study areas is estimated to be 630,000 spaces. This figure was determined by adding the peak accumulation of parked vehicles and adjusting that number to account for seasonal and daily variations not taken into consideration in the data collection activity. On street accumulation samples indicate that those spaces are operating an average of 37 percent above capacity.

Raw unadjusted parking supply in the primary Jeddah parking study area is 441,476 spaces. However, when examining parking surpluses and deficits, raw parking supply is often adjusted downwards to account for inefficiencies inherent in parking facilities, informal parking lots that are undesirable, and private parking lots not available to the general public.

After applying adjustment factors to the raw inventory and excluding current on street parking along arterials and collectors, the overall parking shortfall in the primary parking study area is estimated to be approximately 225,000 spaces. Hence, the estimated demand of 630,000 parking spaces exceeds the adjusted supply by 225,000 spaces.

Parking needs are more appropriately identified on a small area or community level; therefore the analysis examined parking supply and demand by TAZ and district. The parking model includes land use data by TAZ, and that data were used to disaggregate the overall study area parking demand into TAZs. Hence the land use data by TAZ, which has undergone a calibration process, was judged to be a good predictor of parking demand. On the TAZ level, some differences between the measured parking demand and the existing parking demand predicted from the land use data in the parking model were expected, and some were indeed identified. The differences are attributed to land use limitations, generalized parking generation rates, and measured parking demand that may not reflect peak conditions.

5.1. Existing Parking Needs
Detailed parking inventory and usage data are not collected in the Perimeter areas of Jeddah because development there is much less dense than in the North, Central, and South parking areas. Thus, the Perimeter areas of Jeddah are less likely to have parking space shortfalls. The existing conditions parking supply and demand analysis and resulting parking surplus or deficit is limited to the North, Central and South parking zones. Future parking needs will be quantified in all four parking zones (North, Central, South, and Perimeter).

The general status of parking conditions in Jeddah on a district level are not at the neighborhood or community level, but they do allow, in a broad sense, the magnitude of Jeddah’s parking deficiencies. Planning for and implementation of new parking supply should be organized at the district level, but carried out at a TAZ and neighborhood level. Fifteen of the 58 districts have an existing net surplus of parking supply. Most of those districts have only a few TAZs with an existing parking space deficit, and the deficit is modest. Development along the Red Sea has done a better job of providing adequate parking supply, so many of the surplus districts are located in that area of Jeddah. Another pocket of districts with a surplus of parking supply exists around the intersection of King Abdullah Road and Prince Majid Road.

Twenty-one districts fall in the category of having a parking space shortfall of 5,000 spaces or less. Eight of these are located east of the Ring Road where development is generally less dense and off street parking supply is more prevalent. The remaining 22 districts have parking space shortages of over 5,000 spaces. Of those remaining 22 districts, four have deficiencies of over 15,000 spaces and those are identified (in red) in Figure 17.

5.2. Existing TAZ Parking Needs
Figure 18 illustrates existing parking surplus or deficit for all 1,528 TAZs in the North, Central, and South zones of Jeddah. The data are stratified by five categories including a surplus, a deficit of 0 to 250 spaces, a deficit of 250 to 500 spaces, a deficit of 500 to 1,000 spaces, and a deficit of over 1,000 spaces. A deficit of 500 to 1,000 spaces might require a parking garage, depending on how concentrated the shortfalls are. Deficiencies over 1,000 parking spaces are substantial, and suggest the need for at least one parking garage depending on the level of parking demand concentration. Parking garages of less than 500 spaces may be inefficient and can be very costly on a per space basis.

Figure 19, Figure 20, and Figure 21 show TAZ parking surpluses or deficits in the North, Central, and South sections of Jeddah, respectively. Unlike Figure 18, these illustrations include the actual deficit within each TAZ. TAZs with a surplus of parking supply are shown in green, but the actual surplus number is not included. The Central region contains almost 60 percent of the TAZs and has a disproportionally high number of TAZs with deficits of more than 250 parking spaces. In all three regions, there are 300 TAZs with a deficit of 250 to 500 parking spaces, and that represents 19.51 percent of the total number of TAZs. One hundred twenty-four TAZs have a parking deficit of 500 to 1,000 spaces and 85 of those are located in the Central Region. That deficit range represents 8.06 percent of the total number of TAZs in the primary study area. There are 403 TAZs with a surplus of
parking supply and only 18.54 percent are located in the Central parking region of Jeddah. Moderate deficits of up to 250 spaces exist in 684 TAZs, with 142 located in the North region, 429 located in the Central region, and 113 located in the South region. Therefore, 1,087 of the 1,538 TAZs have no parking space deficit or only a moderate parking space deficit. Conversely, 451 TAZs have a high to severe parking space deficit of over 250 spaces.

VI. CONCLUSIONS AND RECOMMENDATIONS

6.1. Summary of Parking Needs
There are 56 districts in the Jeddah primary parking study area, and the vast majority contains at least one TAZ with a deficit of at least 250 parking spaces. Forty-five of the fifty-six districts contain at least one TAZ that has a parking space shortfall of 250 to 500 spaces. Likewise, 38 of the 56 districts have at least one TAZ with a deficit over 500 spaces. Jeddah has substantial parking space shortfalls and these have been quantified by TAZ.

Large deficits of parking supply exist in Jeddah because developers have not been required to provide adequate parking to meet their own needs. This has also resulted in developments relying too much on street parking to meet their needs. Moreover, poorly designed and poorly enforced on-street parking currently causes congestion in many sections of Jeddah.

6.2. Proposed Overall Parking Strategy for Jeddah
Three-pronged parking strategy to meet Jeddah’s existing and future parking needs are proposed as follow:

1. Meet existing needs through new public parking supply and on street parking management.
2. Require all new private development to meet its parking needs on site or through privately initiated, managed demand techniques (future parking needs). Jeddah Government will need to regulate private development parking through:
   a. Updated Jeddah Local Plan
   b. Rigorous site plan review
   c. Construction inspection
3. Transition to a public parking demand management strategy that supports the 30 percent public transport mode share goal and supports walking and biking

The recommendations contained herein are based on the basic premise that the Jeddah Government needs to take on the responsibility of meeting existing parking space shortfalls by developing a public comprehensive Jeddah Parking System comprised of parking garages, parking lots, and on street parking management including parking meters, signs, and markings. This recommendation recognizes that the private sector has not always adequately met its own parking needs. However, Jeddah Government shares some of the responsibility in that it allowed private development to occur without providing its own parking at appropriate levels. Developing a public Jeddah Parking System will be extremely costly, but is absolutely necessary to restore orderly conditions on streets and among developments.
Fig. 3. Central region TAZs.

Fig. 4. South region TAZs.

Fig. 5. North region districts.

Fig. 6. Central region districts.
Fig. 7. South region districts.

Fig. 8. Total parking space inventory by TAZ.

Fig. 9. On and off street parking space inventory by district.

Fig. 10. On street parking space inventory by TAZ.
Fig. 11. On street parking inventory by district.

Fig. 12. Off street parking space inventory by TAZ.

Fig. 13. Off street parking space inventory by district.

Fig. 14. Off street parking space average facility size by TAZ.
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Fig. 15. Off street parking facility inventory by TAZ.

Fig. 16. Percent TAZ area covered by parking spaces.

Fig. 17. Surplus/deficit of parking spaces by district.

Fig. 18. Surplus or deficit of parking spaces by TAZ.
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Fig. 19. Deficit of parking spaces by TAZ- north.

Fig. 20. Deficit of parking spaces by TAZ- central.

Fig. 21. Deficit of parking spaces by TAZ- south.

REFERENCES


