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OPTIMUM DESIGN OF PARKING-LOTS WITH MULTIPLE VEHICLE TYPES, PARKING FEES AND SERVICE CLASSES

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Abstract: Many facilities like airports, train stations, etc. provide parking-lots for vehicles. Vehicles that arrive are of multiple types (with different parking space requirements) and often demand different kinds of parking services – some want long-term parking while others short-term. Parking fees also impact demand for parking. Hence, in addition to the question (i) how big (in terms of capacity) should a parking-lot be, the following questions are also relevant: (ii) how should the total capacity be distributed among the different vehicle types and service classes and (iii) how much should the parking fees be? In this work the authors attempt to answer these questions. The answers depend on what the transport planner wishes to achieve. For example, one planner may want to minimize the probability of not finding space in the parking-lot while another may want to minimize the operator's revenue loss. Here, mathematical programming (MP) formulations for various types of objectives are developed and solved. The constraints to the problems arise out of service quality and space restrictions, and parking fee requirements. A parking-lot behaves as a capacity-constrained, multiple-server queuing system where the capacity and the number of servers are equal to the number of parking-stalls in the parking-lot. In this problem, the state of the system is represented as $n=[n_{1,1},\cdots,n_{(i,j)},\cdots,n_{(I,J)}]$ where $n_{(i,j)}$ is the number of spaces occupied by vehicles of type i and service class, j. P(n), the probability that the system is in state n, turns out to be a non-linear expression (involving finite series sums) of variables like, parking capacity $C_{(i,j)}$, mean arrival-rate $\lambda_{(i,j)}$, mean parking duration $\delta_{(i,j)}$, parking fee, etc. Thus the MP formulations involve constraints and objectives that are non-linear functions of the decision variables of which $C_{(i,j)}$ are integers. This makes the problem a non-linear, mixed integer-programming problem – a problem class that is notoriously difficult to solve using traditional techniques. Consequently, Genetic Algorithms (GA) is used to determine the optimal solutions. In order to establish the quality of these solutions, for some special cases, piece-wise approximations for P(n) are developed and used to obtain optimum solutions using analytical methods. These when compared with GA-based solutions indicate that GA provides good solutions. Finally, based on the optimum solutions obtained here, an attempt is made to develop rules-of-thumb that can be easily employed to arrive at good design solutions for parking-lots with multiple vehicles types, parking fees and service classes.