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DEADHEAD TRIP MINIMIZATION IN CITY BUS TRANSPORTATION: A REAL LIFE APPLICATION

ABSTRACT

The quality of public transportation services is one of the most important performance indicators of modern urban policies for both planning and implementation aspects. Therefore, along with the size of the city, the significance of appropriate cost evaluation and optimization of all related transportation activities increases as well. One of the most important cost factors for the public transport agencies is naturally the fuel consumption of the vehicles. In this study, the attention is focused on the metropolitan bus transport service. The specific aim is to minimize a significant portion of total fuel utilization that occurs due to the so called deadhead trip or dead mileage, which is defined as the idle distance covered by the vehicle between the garage and the route terminal stops without carrying any passengers. In this study, the results of four mathematical models for minimizing the total deadhead trip distance covered in city bus services of Izmir are presented. The models vary due to the inclusion of garage capacity restrictions or operator distinction for supporting both operational and strategical decisions. All models are applied to the recent bus schedule data, which consist of 293 routes, 1,424 buses and 10 garages, for obtaining the optimal route bus-garage allocations and garage capacities. The results of the Decentralized-Capacitated model, which is appropriate for quick implementation, promise a 7.8% reduction in total dead mileage. While on the other hand, if all garage capacities can be expanded and the bus service is maintained only by one operator as modelled in the Centralized-Uncapacitated case, even a 31.4% improvement is possible in the long term. The environmental gains as well as the financial benefits to be achieved when the solutions are actually implemented, justify the practical contribution of the study.

KEY WORDS

urban transport planning, deadhead trip, bus-garage allocation, garage capacity planning

1. INTRODUCTION

Fuel consumption is one of the biggest cost factors for urban transportation agencies. In the scope of this case study, the attention is focused on the well-known problem related to this cost item, known as deadhead trip minimization. Deadhead trip or dead mileage is the distance covered by the buses between the garages and the terminal route stops, when they begin their routes in the morning and park at night without carrying any passengers. Even by small reductions in dead mileage obtained for each route, fuel costs would dramatically decrease as the route fleet sizes and the service areas grow. The amount of fuel spent on deadhead trips naturally depends on the actual garage capacities, the number of routes and the distances between the terminal route stops and the garages. Apart from the financial benefits reached by minimizing these idle trips, the long run environmental gains for the city are also very important.

Izmir, the third largest city and fair centre of Turkey, covers a metropolitan area of over 5,500 km^2 and has a population of about 4 million inhabitants [1]. Izmir Metropolitan Municipality has four public transportation system modes; bus, subway, ferry, and railway services. The city bus transportation system is administered by the Izmir Metropolitan Municipality ESHOT General Directorate in Izmir. In this study, using the classical transportation problem approach, four models were implemented for ESHOT General Directorate which deal with the allocation of 1,424 buses that operate on 293 routes to 10 garages with the objective of minimizing total deadhead trips. The solutions of these mathematical models enable the decision-makers to analyze the current situation better and to implement the necessary changes for the targeted system performance levels more easily. The software applications used for solving these problems and the database designed for this study will be integrated to form a part of a higher level decision support system which will handle all urban route scheduling and vehicle allocation issues of Izmir, both operational and tactical ones.

Before getting into the specifics of the problem, a review is presented of the related literature on deadhead trip minimization. The first studies were aimed at determining the optimal number of buses parked at each garage at nights and the corresponding line starting points [2, 3]. Waters *et al*. [4] determined the garage locations and the respective bus allocations by using discrete space models which consider both the increasing deadheading that was caused by breakdowns and accidents and the garage costs depending on the number of parked buses. Uyeno and Willoughby [5] developed a mixed integer programming model for a large urban transport operator in Canada that determines the locations, capacities, and the number of depots. Consequently, the operator firm gained a 4% reduction (560,000 $) in yearly operating expenses, and a 11% reduction in deadhead trips related expenses after they implemented the optimal results.

The bus allocation problem was also defined by two interrelated problems, one of which optimizes the number of required repair shops and the other assigns the buses to the lines in accordance with the bus types [6]. By integrating the deadhead and repair optimization problems, and reassignment of buses considering bus types, they solved such a type of bus allocation problem for a large bus operator (BMTA) in Bangkok via hierarchical approach, and reduced the out-of-service expenses by 42%. Prakash *et al*. [7] considered the bus-garage allocation problem with two objectives, solutions of which are non-dominated plans to allocate buses to the terminal points of their routes and to the parking garages at night. Willoughby and Uyeno [8] presented a heuristic method that allocates the buses of some specific lines to the same garage. This method was formed by two stages that allocate all of the buses of a line to a garage first, then assign other lines to alternative garages considering garage capacity constraints and it was implemented in the largest public transport company in Canada, VRTS. Willoughby [9] analyzed the locations of the garages of Vancouver Local Transit System in Canada and the allocation of the buses to these garages. The model also considered the capital investment costs for construction of new garages beside the deadhead trip costs. Using this model, a 5% reduction in total costs and a 12% reduction in deadhead trip expenses were obtained.

Dahiya and Verma [10] considered a class of the capacitated transportation problems by establishing their equivalence with a balanced capacitated transportation problem for dead mileage minimization. Kliewer *et al*. [11] discussed the multi-depot, multi-vehicle type bus scheduling problem to find schedules with a reasonable number of line changes. They used time space based networks for modelling to be able to consider line changes besides trips. Pepin *et al*. [12] compared the performance of five different heuristics; a truncated branch and cut method, a Lagrangian heuristic, a truncated column generation method, a large neighbourhood search heuristic and a taboo search heuristic for the multi depot vehicle scheduling problem. Xing *et al*. [13] solved the multi-depot capacitated arc routing problem for optimizing the total deadheading cost by a new evolutionary algorithm. They proposed an evolutionary framework that integrates the extended versions of three classical heuristics for the single-depot case from the literature. Besides the deadheading cost, they also incorporated the classical service and route penalty costs in their objective. Wei *et al*. [14] minimized the number of vehicles, deadhead and waiting time in a multi-depot multi-vehicle model by employing an improved ant colony optimization method combining ant colony system, max-min ant system and best-worst ant system.

Mathirajan *et al*. [15] dealt with a large size bus depot matching problem for India Bangalore Metropolitan Transport Corporation which had 30 depots and 5,031 buses. They compared the computational results of a set of heuristic algorithms with exact solutions to determine the efficiency of these algorithms for such large problems. In a more recent study, Kepaptsoglou *et al*. [16] developed a decision support system model that minimized deadhead costs by retaining the garages at ideal operating levels. The model was implemented for the bus operator in Athens, Greece, and the occupancy balance of the garages was conserved along with a 10% reduction in the expenses related to deadhead trips. Cortes *et al*. [17] developed an integrated strategy model that incorporated short turning and deadheading for a single transit line.

Our focus in this study is basically the bus assignment problem, which consists of assigning vehicles to depots for covering a given set of timetable trips, thereby creating the so-called vehicle services [18]. We consider route-bus allocations that are determined beforehand, and seek only to minimize the sum of operating costs due to all pull-in and pull-out trip distances covered between depots and route termini, briefly denoted here as deadhead trips. According to the 2010 national bus transportation statistics for the United States, 13.3% of a total of 2.4 billion bus miles covered corresponds to deadhead trips [19].

As observed in some of the studies mentioned above, urban public transportation services in Izmir are also carried out by several operator firms. In the case of city bus service operations, 8 out of the 10 garages investigated within this study and 80% of all buses belong to ESHOT Directorate itself, and the rest belongs to a subsidiary firm, IZULAS. Hence, the operator distinction should be considered in the modelling phase since both bus and garage ownerships differ.

In most studies in literature targeting deadhead, the focus is on solution methodologies rather than different modelling approaches due to the larger size of the problems involved. Unlike the previous examples from literature, we propose several models that consider the problem from different perspectives. The solutions to the developed models can be obtained through the use of commercial optimization software in reasonable times, and these constitute the basis for decision-making for the transport planning authorities.

The rest of the paper is organized as follows. The models used in our study are given in Section 2 and the respective solution results are presented in Section 3. In the last section, we conclude with a brief analysis and further research topics.

2. MODEL DEFINITIONS

The models presented in this study correspond to four scenario combinations with respect to two criteria, namely the inclusion of operator distinction and garage capacities. The first scenario is represented by the Centralized-Uncapacitated model. The problem defined by this model describes the case where all bus lines and garages are operated by a single firm and garage capacities can be expanded *ad libitum*. Since this is the least constrained model, its objective value is a lower bound for all scenarios. The solution of the model provides the target deadhead kilometre level according to the strategic and tactical planning perspectives.

The following three models are named similarly as Centralized-Capacitated, Decentralized-Uncapacitated, and Decentralized-Capacitated models according to the operator firm distinction or garage capacity criteria. For all the models, it is assumed that the buses which depart from their garages in the morning to the first or final route stops, return from the same stops to their parking garages when they finish their daily services. Hence, the total deadhead trips in the morning are equal to the total at night while parking the buses.

First the notation used in all of the four problems and models below is presented. Apart from the indices used, all parameters and decision variables are also listed.

Route index, $i \in I = \{1,\ldots,h\}$: Set of bus routes, where h = Number of routes,

Garage index, $j \in J = \{1,\ldots,g\}$: Set of parking garages, where g = Number of garages,

Route stop index, $k \in K = \{1,\ldots,s\}$: Set of termini for each route, where s = 2 (first and last stops),

Operator firm index, $f \in F = \{1,\ldots,p\}$: Set of operator firms, where p = Number of firms.

The problem parameters corresponding to route bus requirements, garage capacities, and the distances between all garages to terminal route stops are given below.

- d_{ijk} – the distance (in kilometres) of the k^{th} terminal stop of the i^{th} route to garage j,
- b_{ik} – the number of buses required for the k^{th} terminal stop of the i^{th} route,
- b_{ikf} – the number of buses operated by the firm f that are required for the k^{th} terminal stop of the i^{th} route,
- a_j – the capacity of garage j (number of buses),
- a_{jf} – the capacity of garage j for the operator firm f (number of buses).

There are two decision variable types, one used for the centralized and the other for the decentralized models.

- x_{ijk} – the number of buses which are parked in garage j, that are assigned to the k^{th} terminal stop of the i^{th} route,
- x_{ijkf} – the number of buses belonging to the operator firm f, which are parked in garage j, that are assigned to the k^{th} terminal stop of the i^{th} route.

2.1 Centralized-uncapacitated model

As defined above, all buses and garages are operated by a single firm and there are no constraints for the capacities of garages in this model. Therefore, the solution of this model indicates the critical and idle garages with respect to deadhead trips, so that the decision-makers could make comparative analyses for capacity expansion, reduction, or garage closure decisions for short-to-long term planning.

$$\min \sum_{i=1}^{h} \sum_{j=1}^{g} \sum_{k=1}^{s} x_{ijk} d_{ijk} \quad (1)$$

s.t.

$$\sum_{j=1}^{g} x_{ijk} = b_{ik}, \; \forall i \in I, \; \forall k \in K \quad (2)$$

$$x_{ijk} \in \{0,1,2,\ldots\}, \; \forall i \in I, \; \forall j \in J, \; \forall k \in K \quad (3)$$

The objective function (1) is the sum of products of the number of buses in garage-route stop assignments and the corresponding distances. The total or daily deadhead kilometre value for this problem, which will be used in comparison with the current status and the results of other models, is equal to twice this summation. As explained above, this objective value is only equal to the morning deadhead trips or the parking deadhead trips at night. The first set of constraints (2) describe the bus requirements, namely the demands of terminal route stops, whereas (3) restrict the decision variables to be non-negative integers.

2.2 Centralized-capacitated model

The difference of this model from the previous one is the following additional set of garage capacity constraints.

$$\sum_{i=1}^{h} \sum_{k=1}^{s} x_{ijk} \le a_j, \; \forall j \in J \quad (4)$$

where (4) simply forces the total of all route bus allocations to any garage not to exceed its given capacity. Therefore, the objective function value will be higher than the the one of the first model, as expected, but will nevertheless form a more realistic comparison base for the current situation.

2.3 Decentralized-uncapacitated model

This problem definition includes the operator distinction, which is the actual case in Izmir. But again as in the first model scenario, there are no garage capacity constraints here either.

$$\min \sum_{i=1}^{h} \sum_{j=1}^{g} \sum_{k=1}^{s} \sum_{f=1}^{p} x_{ijkf} d_{ijk} \quad (5)$$

s.t.

$$\sum_{j=1}^{g} x_{ijkf} = b_{ikf}, \; \forall i \in I, \; \forall k \in K, \; \forall f \in F \quad (6)$$

$$x_{ijkf} \in \{0,1,2,\ldots\}, \; \forall i \in I, \; \forall j \in J, \; \forall k \in K, \; \forall f \in F \quad (7)$$

The objective function (5) has the extra summation term over the operator firms to incorporate the decentralization as stated above. Similarly, the set of demand constraints (6) reflects the same change for the non-negative integer decision variables x_{ijkf} (7).

2.4 Decentralized-capacitated model

This model is the closest representation that corresponds to the current situation. The operator distinction is present as in the third model and the garage capacity restrictions (8) apply as they do in the second model.

$$\sum_{i=1}^{h} \sum_{k=1}^{s} x_{ijkf} \le a_{jf}, \; \forall j \in J, \; \forall f \in F \quad (8)$$

Certainly, the objective function value defined by (5) above will be the highest among all models. But from an operational planning perspective, the decision-makers will at least have the chance to estimate the minimum improvement they can accomplish in reducing the deadhead trips when they actually implement all optimal garage-route bus allocations.

In the next section, first the current situation of the city bus transport system regarding the deadhead kilometre levels as well as the garage utilizations is summarized. Then, using real system data, all model solutions are presented in comparison with the current status.

3. MODELLING RESULTS AND DATA ANALYSIS

First, the related city bus service parameters are presented below with the corresponding dead kilometre values. Second, the deadhead trip solutions are tabulated along with garage utilization values. The coordinates of all garages and all terminal route stops are provided by ESHOT General Directorate. Using these data on ESRI ArcGIS Network Analyst Extension software, which compute the feasible shortest paths in Izmir city road network, all the d_{ijk} distances that are used in all models have been obtained.

3.1 Description of the baseline state for Izmir City Bus Service

Izmir runs a considerably large bus service on 293 routes served by 1,424 diesel buses and 10 garages, which comprises the biggest portion of the city public transportation system. As stated in Section 1, the service is operated by two firms which differentiate the buses and the garages used. Also, for each route, only the two terminal stops (first and final) are considered.

Table 1 - Current capacity utilization and daily deadhead trips per garages, route stops and operators

	# of Buses on Route Stops			Deadhead Kilometres		
Garages	First	Final	Total	First	Final	Total
Gediz	32	179	211	485	2,678	3,163
İnciralti	94	99	193	707	1,493	2,200
Adatepe	42	208	250	143	1,572	1,716
Mersinli	71	131	202	509	1,954	2,463
Sogukkuyu	7	63	70	99	334	434
Cigli	23	158	181	439	2,061	2,499
Urla	0	11	11	0	205	205
Torbali	9	11	20	2	113	114
Stad	41	100	141	404	1,849	2,253
Belkahve	32	113	145	337	1,468	1,805
Operator Firms						
ESHOT	278	860	1,138	2,384	10,409	12,793
IZULAS	73	213	286	741	3,316	4,058
TOTAL	351	1,073	1,424	3,125	13,726	16,851

Recalling the notation given in Section 2, we have $h = 293$, $g = 10$, $s = 2$, $f = 2$ and

$$\sum_{i,k,f} b_{ikf} = 1,424,$$

or in other words 1,424 buses are required in total for the service demand over all the routes.

The current daily deadhead kilometre is computed as 16,851 kilometres by putting the route paths in use and present route-garage allocations in the geographic information systems software provided by Izmir Metropolitan Municipality. The related figures are summarized in *Table 1* with respect to three aspects.

In the following sections, the comparisons are based on the deadhead kilometre values for each firm or just their sum, depending on the model being decentralized or centralized. Thus, we use 12,793 km and 4,058 km daily levels for ESHOT and IZULAS respectively, as presented in *Table 1*. These values sum up to approximately 5.25% of the total mileage covered by all buses.

Regarding the diesel consumption figures, we are provided with the 50 l/100 km average rate for each bus, for the sake of simplicity. As for the fuel cost evaluations, diesel price per litre was taken as € 1.3147 [20]. Using these parameters, the annual deadhead fuel consumption cost amounts to € 4,000,000.

The detailed problem data for all route bus requirements, garage-stop distances, and capacities of garages were stored and read from MS Excel as inputs of optimization. Route-garage allocations in numbers of buses and corresponding deadhead kilometre values were the outputs of the software used, which is IBM ILOG CPLEX 12.1 optimization environment. ILOG OPL 6.3 language is chosen for the coding of mathematical models and the solutions are obtained using a PC with triple core, 4 GB RAM and 1.8 GHz processor in around 10 seconds for each model.

3.2 Solutions of the models

3.2.1 Solution of the centralized-uncapacitated problem

The lowest dead kilometre value (11,564 km) was obtained by solving this first model (Section 2.1) as expected. This solution provides a nearly 31.4% improvement by also finding the ideal garage capacities for the centralized way of service operation. Nearly half of the route-garage (161 routes) allocations are changed. If the optimal allocations are implemented, the annual amount of fuel savings will be around 965,000 litres. The results are summarized in *Table 2*.

3.2.2 Solution of the centralized-capacitated problem

Taking into account the actual garage capacities, the solution of this model (Section 2.2) provides a reduction of 21.7% in deadhead trips. All related figures are summarized in *Table 3*.

Table 2 - Solution summary for the centralized-uncapacitated problem

		Reduction		Annual Savings	
	Deadhead Km	Daily (km)	Rate	Fuel (l)	Cost (€)
ESHOT+IZULAS	11,564	5,287	31.4%	964,790	1,268,366

Table 3 - Solution summary for the centralized-capacitated problem

		Reduction		Annual Savings	
	Deadhead Km	Daily (km)	Rate	Fuel (l)	Cost (€)
ESHOT+IZULAS	13,198	3,653	21,7%	666,633	876,393

Table 4 - Solution summary for the decentralized-uncapacitated problem

		Reduction		Annual Savings	
	Deadhead Km	Daily (km)	Rate	Fuel (l)	Cost (€)
ESHOT	10,185	2,607	20.4%	475,960	625,723
IZULAS	3,652	406	10.0%	74,056	97,358
ESHOT+IZULAS	13,837	3,013	17.9%	550,016	723,081

Table 5 - Solution summary for the decentralized-capacitated problem

		Reduction		Annual Savings	
	Deadhead Km	Daily (km)	Rate	Fuel (l)	Cost (€)
ESHOT	11,736	1,057	8.3%	192,858	253,542
IZULAS	3,793	265	6.5%	48,384	63,608
ESHOT+IZULAS	15,529	1,322	7.8%	241,242	317,150

3.2.3 Solution of the decentralized-uncapacitated problem

The third model gives a solution alternative that is more appropriate for representing the real situation regarding operator distinction. The solution here gives an idea about what the ideal garage capacity levels should be when the city bus services are operated by two firms. The total daily deadheading is found as 13,837km reducing the current one by 17.9% (*Table 4*). By implementing the changes this solution implies, the garage assignments of 111 routes should be updated.

3.2.4 Solution of the decentralized-capacitated problem

The last model also includes operator firm distinction and additionally the garage capacity constraints, hence it is the most representative of all regarding the current situation. Real world restrictions, like the impossibility of garage capacity expansions near the city center or high costs incurred, puts the solution of this problem into the operational perspective. Therefore, the decision-makers could make use of the optimal route-garage allocations for short-term planning purposes.

The deadhead trip solution value of this model provides about € 320,000 annual saving due to fuel consumption, which is equal to a 7.8% improvement over the active allocations (*Table 5*). This can be accomplished by reallocating 49 routes to different garages than the current ones.

As stated above, this last model is preferred for justifying the results in the near planning horizon. Implementing the sufficient changes even partially will result in substantial benefits concerning both financial gains and applicability.

When the solutions for ESHOT are examined in detail, its Mersinli, Sogukkuyu and Urla garages are allocated to be fully utilized. As for IZULAS, the capacity of its Stad garage is used up for all the necessary route bus requirements (*Table 6*).

Table 6 - Garage utilization in the decentralized-capacitated problem

Garages	# of Buses Allocated	Current Capacity	Utilization (%)
Gediz	203	260	78.1%
İnciralti	234	250	94.0%
Adatepe	165	300	55.0%
Mersinli	240	240	100.0%
Sogukkuyu	70	70	100.0%
Cigli	193	250	77.2%
Urla	11	11	100.0%
Torbali	22	26	84.6%
Stad	170	170	100.0%
Belkahve	116	220	52.7%

4. DISCUSSION

According to the results of the model solutions presented in the previous section, the savings obtained by uncapacitated model versions are much higher than the capacitated ones as expected. For example, when examining the results for the decentralized modelling approach currently employed in Izmir, there is a 10.9% reduction in total deadheading distance with respect to the most constrained fourth model if the current garage capacities could be expanded (Tables 4 and 5). Moreover, the corresponding fuel cost savings will be more than doubled. In a way, the trade-off imposed by the investment costs for expanding garage capacities and the accompanying reduction in deadheading costs would be another critical decision factor whether or not to consider the optimal assignments proposed by the Decentralized-Uncapacitated model. Actually, a capacity expansion for 261 buses (14.5% of the total capacity of all garages) will be in question. In addition to budgetary constraints, the densely populated urban areas where some of the garages are located should be considered regarding spatial limitations.

Taking into account all the constraints regarding operator distinction and garage capacities, the last model (Decentralized- Capacitated) is clearly the most appropriate one for comparing with the current situation and easier to implement in a shorter planning horizon. By implementing the fourth model, the amount of deadhead kilometre will be reduced by 7.8%, and 240,000 l savings in fuel consumption will be achieved annually. But in the long term, when it can be settled on that the exchange of routes between firms can be applicable, the decision-makers can also benefit from the second model (Centralized-Capacitated) reaching a 21.7% reduction in deadhead trips and an annual saving of 667,000 l in fuel consumption.

Furthermore, the evaluation of this study in an environmental context becomes at least as important as the fuel cost reduction issue. In that respect, the optimization of the route-garage allocations and garage capacities proposed by this study will lead to a CO_2 emission reduction of at least 249 tons annually, in parallel to the decreasing bus kilometres in urban conditions [21]. When we evaluate this gain from another perspective, the absorption of that amount of CO_2 equals to the annual labour of 20,787 trees in one year or 41 hectares of trees on the average [22]. Hence, around 83,000 more citizens of Izmir will benefit from the corresponding O_2 gain produced by the current urban forestation, even when the least improving solutions of the Decentralized-Capacitated model are implemented. the related studies, such as the one by Li and Head [23], also focus on the environmental aspects such as the carbon footprint and toxic air pollutants besides the usual cost concerns of the public transportation. They evaluated the investment decisions regarding the purchase of new buses that use alternative fuel types, according to the emission reduction levels and the new operating costs incurred.

5. CONCLUSION

In this study, we developed bus allocation models for Izmir city bus service to minimize total deadhead kilometre, and obtained solutions for optimal route-garage assignments and garage capacities. The annual savings in fuel consumption justify the importance of this study, similar to previous examples reported in literature. Considering the operator distinction and garage capacity limits, the last model (Decentralized-Capacitated) forms the most appropriate comparison base with respect to the current situation, and can be easily implemented for operational planning.

The comparisons presented also depict the trade-off between the possible cost reductions and necessary investment costs required to accomplish those. Thus, besides the most representative model (Decentralized-Capacitated) that yields solutions in short times, it is also important to consider the other three modelling alternatives to gain different insights. In this respect, our study is another justification of the classical optimization approach by a large-scaled real life scenario. Therefore, it is shown that even small changes in operational perspective might contribute a lot, and help to generate new resources for longer term planning issues.

Apart from the costs incurred by fuel consumption, the environmental benefits by covering smaller distances are also presented regarding gas emissions. Although, the effects of these benefits might not be observed in near future, more general urban management policies accompanied with such optimization perspectives will surely add up to higher standards of living in the metropolitan areas in the long term. In this direction, new multi-criteria models can be developed for the case of Izmir to design and operate sustainable transportation systems to improve the overall quality of urban life.

As future study topics, more sophisticated and realistic models might be defined that deal with the differentiation of bus types for each operator and consider garage capacities with respect to different bus types. The maintenance issues can be investigated by including the garage-technician or garage-equipment assignments according to the types of buses used and garage utilization rates. Apart from the night parking perspective, mid-day parking garage assignment problem due to shifts in route-bus demands through the day is also worth further attention. In any of these approaches, the solution as well as the objective should sufficiently provide the assistance required by the decision-makers for transportation planning purposes.

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ÖZET

ŞEHİR İÇİ OTOBÜS ULAŞIMINDA ÖLÜ KİLOMETRE MİNİMİZASYONU: BİR GERÇEK HAYAT PROBLEMİ

Şehir içi toplu ulaşım hizmetlerinin kalitesi modern şehircilik politikalarının hem planlama, hem de uygulama süreçleri açısından en önemli performans ölçütlerinden biridir. Ulaşım hizmetlerine daliyetlerin azaltılmasıyla verimlilik artışının yanı sıra, şehrin büyüklüğüyle orantılı olarak ciddi maddi kazanımlar sağlanmaktadır. Bu da optimizasyonun yerel yönetimler ve işletici firmalar için önemini ortaya koymaktadır. Toplu taşımacılıktaki en önemli maliyet kalemlerinden birini, araçların yakıt tüketim giderleri oluşturmaktadır. Bu çalışma özelinde İzmir büyükşehir otobüs hizmetleri ağı ele alınarak, araçların sabahları garaj ile servisin başladığı ilk durak ve akşam servisin bittiği son durak ile garaj arasında yolcu taşımadan kat ettiği mesafelerin toplamı olarak tanımlanan ölü kilometrenin minimizasyonu hedeflenmektedir. Garaj kapasite kısıtlarının ve işletici firma ayrımının dahil edilmesine bağlı olarak farklılaşan ve operasyonel ve stratejik karar alma süreçlerini destekleyen dört matematiksel modelin çözümleri sunulmuştur. Tüm modellerde optimal hat otobüs-garaj atamaları ve garaj kapasitelerine ulaşabilmek için, 293 hatta çalıştırılan ve 10 garajda park edilen 1,424 otobüse ait güncel bir çizelge verisinden elde edilen gerçek parametreler kullanılmıştır. Kısa vadede uygulanması daha kolay olan Firma Ayrımlı - Kapasite Limitli model atamalarına göre ölü kilometrede %7,8'lik bir azalış öngörülmektedir. Diğer taraftan, garaj kapasitelerinde gerekli tüm artışların yapılabildiği Firma Ayrımsız - Kapasite Limitsiz model çözümleriyle, uzun vadede %31,4 seviyesine varan iyileştirmeler sağlanabilecektir. Maliyetlerdeki iyileşmeler yanında sunulan, çevresel açıdan önemli miktardaki kazanımlar da çalışmanın pratik değerini ayrıca vurgulamaktadır.

ANAHTAR KELİMELER

Şehir içi ulaşım planlama, ölü kilometre, otobüs-garaj atama, garaj kapasite planlama.

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