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Research Article / Araştırma Makalesi

OPERATIONAL PLANNING AND OPTIMIZATION SYSTEMS IN PUBLIC TRANSPORT OPERATORS

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ABSTRACT

Public transport system consists of different components such as roads, vehicles, stops, facilities, driver personnel and passengers. It is necessary to do comprehensive plannings for each components of transportation system. Physical components such as roads, vehicles, facilities etc. are the main infrastructures required to realize public transport service and necessitate highest investments. Thus, planning must start already before infrastructure investments for a successful public transport system. This first step is described as transport planning. Secondly, timetable and operational planning must be performed in order to make optimum use of resources for a successful operation. This planning step to increase the performance and efficiency of operation is named as resource planning and optimization or operational planning and optimization. In this paper, a work for operational planning and optimization was carried out for various cities in Turkey. It was explained how operators can plan their vehicle and driver resources optimally by using planning and optimization software. Furthermore, many topics such as tracking vehicle maintenance intervals, maximization of driver satisfaction, informing passengers about planned departure times at stops, planning for extreme cases, decision making for right investments, integration with the fleet management and ticketing system are touched upon as well as the results were evaluated.
Keywords: Operational planning and optimization, resource management, fleet management.

TOPLU ULAŞIM OPERATÖRLERİ İÇİN OPERASYONEL PLANLAMA VE OPTİMİZASYON SİSTEMLERİ

ÖZ

Toplu taşıma sistemi; yol, araç, tesisler, durak, işletme personeli ve yolcu gibi önemli bileşenlerin bir araya gelmesinden oluşur. Başarılı bir toplu taşıma sistemi gerçekleştirmek için sistemi oluşturan tüm bileşenler için kapsamlı planlamaların yapılması gerekmektedir. Toplu taşıma faaliyetlerinin gerçekleşmesi için gerekli olan altyapı yani yol, araç ve tesisler gibi fiziki bileşenler en pahalı yatırımlardır. Bu sebeple başarılı bir toplu taşıma sistemi için planlamaya altyapı yatırımları yapılmadan önce başlanmalıdır. İlk aşamada yapılması gereken planlama ulaşım planlaması olarak tarif edilmektedir. Ulaşım planlamasının ardından kaynakların en iyi şekilde kullanılmasına yönelik olarak sefer planlaması ve işletme planlaması çalışmalarının mutlaka yapılması gerekmektedir. İşletmenin performasının ve veriminin artırılmasına yönelik olarak yapılan bu planlama çalışmalarına kaynak planlaması ve optimizasyonu ya da işletme planması ve optimizasyonu adı verilmektedir. Bu çalışmada, işletme planlaması ve optimizasyonu ağırlıklı bir planlama çalışması Türkiye'nin çeşitli şehirleri için yapılmıştır. İşletme planlaması ve optimizasyonu yazılımları kullanılarak toplu taşıma işletmelerinin araç ve personel kaynaklarını nasıl en iyi şekilde kullanacakları ayrıntılı olarak açıklanmıştır. Bunun yanında araçların bakım periyotlarının takip edilmesi, işletme personelinin memnuniyetinin artırılması, duraklarda bekleyen yolculara seferlerle ilgili en sağlıklı bilgilerin verilmesi, olağan üstü durumlarda en iyi işletme planının en kısa sürede belirlenmesi, doğru yatırımların yapılması ve işletme planlarının filo yönetim sistemi ve ücret toplama sistemi ile entegrasyonu gibi pek çok konuda Türkiye için çeşitli örnekler üzerinde çalışmalar yapılmış ve sonuçları değerlendirilmiştir.
Anahtar Sözcükler: İşletme planlaması ve optimizasyonu, kaynak yönetimi, filo yönetimi.

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1. INTRODUCTION

Planning process underlies advanced public transport systems of the developed countries. Planning must exist in each step including design, construction and operation. In this paper, planning phases required for a successful public transport system are illustrated briefly, which are transport planning, trip planning and operational planning. These three constantly interact with each other and have a dynamic structure. These plans must be revised within certain periods of time and they must be applied definitely (Figure 1).

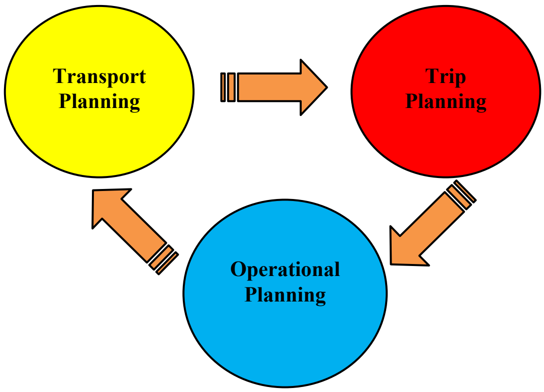


Figure 1. Planning Phases in Public Transport

In order to have a public transport system of a good quality, one has to know the area served by this public transport system very well. Generally speaking, public transport is a system composed of various components such as road, infrastructure, facilities, vehicle, driver, passenger and operator. Only if all these components come together, we can speak about public transport. Components such as infrastructure, facilities, vehicles are among all the most expensive investments. That is why there is a strong belief that a high-quality public transport system will be per se available by investing huge amounts to those. However, big investment amounts without planning do not contribute to an efficient operation as expected. Planning must start early enough before determining the public transport routes. This is defined as transport planning. After this step, trip and operational planning phases must come for a successful public transport operation [1].

2. TRANSPORT PLANNING IN PUBLIC TRANSPORT

Transport planning has to be performed by decision-making authorities in order to foresee the possible challenges and use the resources most efficiently. Parameters playing a role in transport planning can be summarized as population, age groups, income status, labor force and socio-economic indications. While each of these can be handled individually, investigating them together within the scope of transportation and identifying mobility patterns is a quite hard work. The more because human behaviors also have to be dealt with and this brings an uncertainty in the process.

Two main variables in transport planning are time and location. How will people travel, from where to where, when and how long? Transport planning mainly searches answers to these questions. Invention of automobiles and rapid progress in automotive technology brought up a strong belief that the mobility problems can be solved by cars and roads. New roads were built and cars were manufactured constantly especially in developed countries. Number of cars in the whole world amounted to 250.000 in 1907, whereas jumped to 500.000 after the emergence of Ford Model T and eventually went up to 50 million after the Second World War. Currently the annual production is over 70 million. However, environmental problems such as congestion, insufficient road infrastructure and parking places, high consumption of energy resources increased as well with the increase in car ownership. Social life was also affected negatively by car-dominant mobility. In order to cope with these issues, transport planning concept was introduced at the beginning of 1950's. A well-organised transport planning is a prerequisite for an efficient transportation. Four-step transport model is a generally accepted technique for passenger as well as freight transport among transport experts. This four-step model consists of trip generation, trip distribution, modal split and traffic assignment (Figure 2) [2].

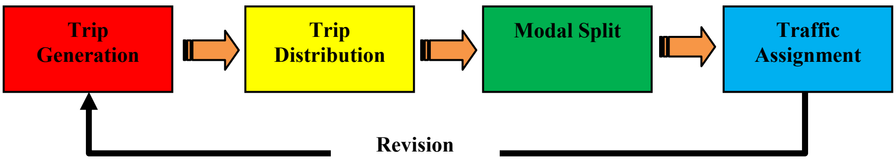


Figure 2. Transport Planning Steps

2.1. Trip Generation

Trip generation and attraction is generally known as trip generation. It is the numeric expression of the mobility in a specific region. The number of trips realized in this region is determined by this investigation. The first step for trip generation is dividing the study area into zones. If one works on a country-scale for Turkey, such zones can be provinces of Turkey. If the scale is a city, then towns or city quarters can be zones. The most important point here is to provide a homogenity within the zones. Generations are the trips starting in that zone and attractions are the trips ending in that zone. Trip generation models give results as trips/day (passenger) or tons/day (freight). Even if it is a hard task to determine when and how often people travel to where, it is still possible to get this information for instance by carrying out surveys, utilizing technology or doing observations (Figure 3).

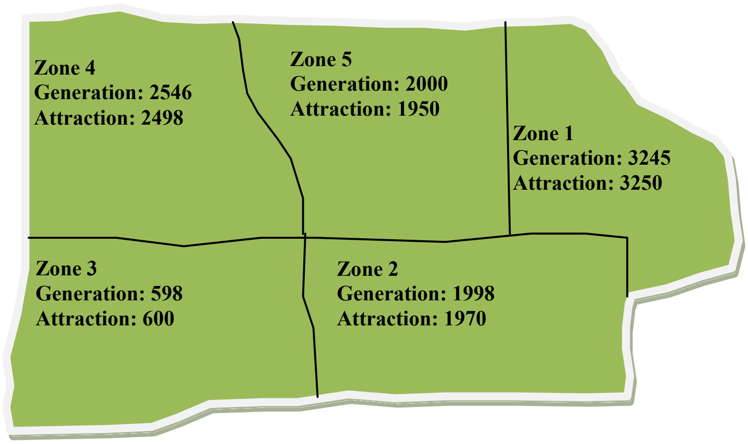


Figure 3. Dividing the Study Area into Zones and Trip Generation Values (Trips/day)

2.2. Trip Distribution

Aim of trip distribution step is to detect in which region each of the trips ends. Here can be deduced where people travel from their home-zones due to various purposes such as work, leisure, education. Taking trip distributions between all provinces in Turkey into consideration, which would mean a matrix of 81x81. The summed values of each row give us emitted trips, of each column attracted trips. Like trip generation, trip distribution information can be gathered by surveys, technology systems and observations. In the figure below, it is shown as an example where the trips starting from zone 4 are leading to.

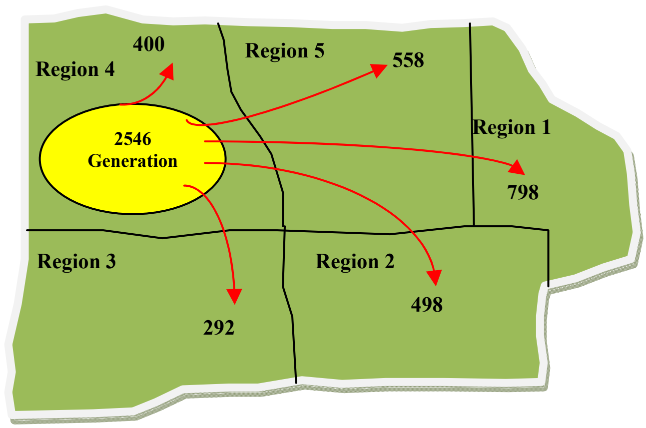


Figure 4. Trip Distribution (trips/day)

2.3. Modal Split

Modal split answers the question "By which means of transport are the trips realized?". The answers can be for example private car, bus, railways, cycling or walking. Income level, value of time, price, comfort, punctuality, direct connection are typical parameters affecting this choice. The mathematical expression of modal split is named as modal split model. Transport experts try to find out the demand percentage of each transport mode by these models (Figure 5).

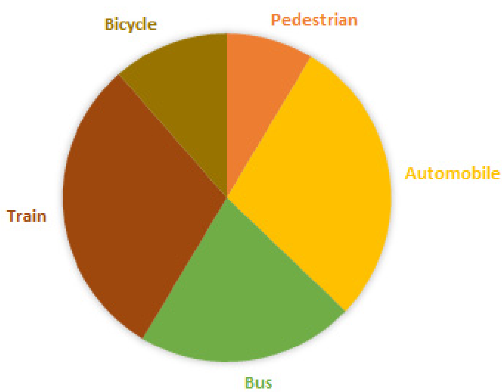


Figure 5. Illustration of Modal Split

2.4. Traffic Assignment

Last step of the four-step model is the traffic assignment. It is in other words the simulation of trips on the available roads and road systems. Like other steps, there are various approaches and models in traffic assignment as well. Here the trips are assigned on road and road systems, so the amount of trips on each road can be seen. Different scenarios such as construction of new roads or improvements in other road systems can be tested in this step. In the figure below, an assignment graph obtained by the PTV Visum transport planning software is shown.

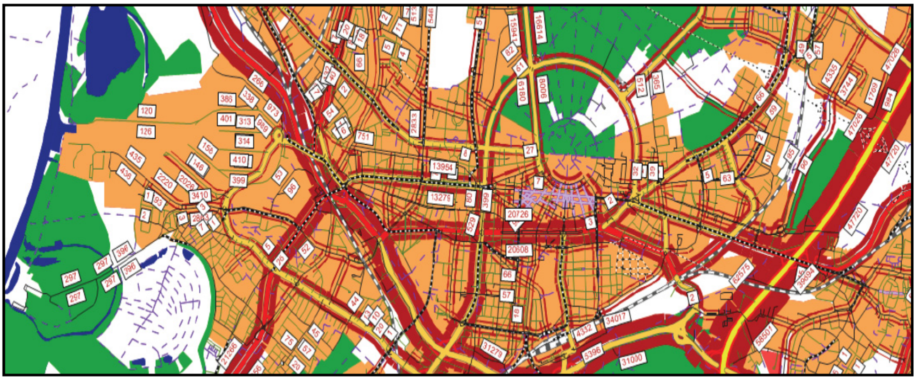


Figure 6. Screenshot Output of a Traffic Assignment (PTV, Visum)

3. TRIP AND OPERATIONAL PLANNING IN PUBLIC TRANSPORT

3.1. Trip Planning

After the steps stated above, for public transport it continues with trip planning. Travel demand is calculated in transport planning and has to be covered by the transport offer. Therefore, trip frequencies of public transport systems are determined here considering the capacities of different modes. In railway literature, these trips are named as time tables. Time tables were firstly prepared and published for the trains operating in Paris-Lyon route in 1885. Afterwards, big improvements have been made and nowadays time tables are produced by complex computer programs. These programs are called Train Plannnig Systems (TPS). Likewise, time tables and graphs for bus operators are also generated by similar computer programs. Trip planning programs create trips taking transport network features, infrastructure and other operational properties into account. These programs also help in long-term decision-making processes about infrastructure and vehicle invesments by deriving various scenarios [1].

3.2. Operational Planning

The last step of planning in public transport is the planning of vehicles and operational personnel. If we think about a bus operating company, buses and bus drivers are the most essential resources of this operation. In a tram/subway operator, these resources would be rolling stock and drivers. In a typical bus operation, operational plans are generated within certain periods in order to realize the trips announced to passengers. These plans consist of bus and driver plans. Usually these plans are made firstly for one day from operation begin to operation end. Afterwards, daily plans are combined and weekly/monthly periodic plans are generated.

A bus plan is the circulation of a certain type of bus during the day starting from leaving the depot in the morning until coming back to depot at night. In this circulation, all the activities the bus carries out is a part of this plan. Bus plan normally comprises of passenger trips and layover times at the end points of the trips, but can also include non-passenger trips, connecting trips from one line to another, waiting times at certain points of network or fuel/cleaning services during the day. For each bus in operation, these plans have to be set-up.

Drivers, which are the other important operational resources are planned in the same manner. These are often called driver plans or better said duty plans. A duty plan is the circulation of a driver during the day starting from his duty begin until he finishes his shift. Similar to bus plans, all the activities the driver carries out is a part of this plan. Duty plans must involve all components about the tasks of the driver such as passenger trips, non-passenger trips, preparation times, submission/take-over times, and break times. For each driver, these plans have to be set-up. The main purpose of the operator is to realize the trips as announced to the passengers. Therefore, for each trip a vehicle as well as a driver has to be assigned, none of the trips should remain unscheduled. For each trip there can be predefined rules, such as this trip will be performed by an articulated bus, the driver has to have a qualification to drive this articulated bus etc. Moreover, there might exist other rules for vehicles and drivers. Maximum km a vehicle can cover, layover times at end stops, vehicle maintenance intervals, work and driving times of drivers, break rules, which lines they can work are other typical rules that have to be considered by the planners and at the same time restrict the operational plan. Preparation of these plans manually is quite difficult since vehicles and drivers are constantly on the move in the city, even these manual plans are far away from being efficient for the operator. As the vehicle fleet and accordingly number of drivers increases, this evolves rapidly to a mathematical optimization problem. This problematic can easily be solved by computer aided standard softwares aimed exactly to this phenomenon. By the help of these softwares, the most optimum results for the operator is reached in a very short time without leaving any unscheduled trips.

Every operator has to obey the guidelines stated in the laws and legislations. For example, work and rest times of drivers have to comply with the rules given in Labour Law or Road Traffic Law. Besides, each operator might have defined some more detailed rules for drivers via union agreements. Rules like driving times, break times, daily/weekly work times, weekly/annual off-days or holidays, overtime rules, tracking periodic medical checks, qualifications allowing to drive a specific vehicle type, driver groups (senior driver, woman driver etc.), depot the driver is assigned to, duty start/end points, ratio of split duties are generally rules that are specified by the operator itself. Again for the vehicles, similar rules can be defined to achieve more efficiency and dynamism taking also the topography of the city into account. Additionally, rules like periodic maintenance intervals of vehicles are defined by the manufacturers and given to the operator. The second step is to run an optimization taking all these rules or restrictions into account. Matching thousands of trips correctly with buses and drivers by guaranteeing to comply with all the rules in a manual way is a quite hard work. Even plans are prepared manually; it involves in itself a big optimization and saving potential. By means of sophisticated computer systems, this optimization potential can be revealed.

It is very important to determine what to optimize in these systems. One can save vehicles by minimizing the required vehicle numbers or save drivers, also the dead-head 72ilometres (which are non-revenue trips but have to be performed) can be minimized. Furthermore, factors like driver satisfaction, robustness of the timetable can also affect the optimization. Perhaps not all these factors can be optimized simultaneously, but here the priorities of the operator play a role. Operator often seeks a balance between those. In other words, a plan may have saved many vehicles, but can cause more dead-head 72ilometres. In this case, the operator typically tries to reach his desired result by cost-weighting those factors according to their importance.

Some basic rules put down by the operators can directly impact on the optimization potential. As an example, allowing buses to change lines during the day can lead to serious savings from vehicles. Likewise, if split duties are allowed (the duty type that the driver works on the peak morning and evening hours, and does not work in between), big savings from number of drivers can be achieved. Here, the operator himself has to compare the different alternatives and choose one for his productive plan. These operational planning softwares hence support the decision making process as well by setting up different operational scenarios. Questions like what will be the impact of opening new lines in terms of resources, is it possible to deal with it with the current resources or do new resources have to be made available can be answered prior to those changes very easily.

The next step after planning is the assignment and dispatch. In the assignment part, anonymous vehicle and duty plans are assigned to “real” vehicles and drivers. In this way, a one-to-one match with plan and resources is achieved. At this point, since it is about real vehicles and drivers, it is important to know the availability of each of these resources. For instance, a vehicle must not be given to service if its maintenance is due or if the air conditioning is not working. In such situations, the system must avoid assigning this vehicle to the plan and give appropriate warnings to the dispatcher. The same applies to the drivers. Weekly off-days, annual holidays, nightly rest times, monthly work times etc. Are taken into account for a correct assignment. Availability of drivers according to these rules is the decisive point. If medical check is a prerequisite for a driver to work on the bus, tracking of this check must be available in the system. Qualifications of drivers such as which type of vehicle to drive or on which lines to serve must be considered during these assignments as well.

Based on the plans and assignments of the operator, print-outs are produced in the system. These print-outs are the interfaces to the passengers, vehicles and drivers. Looking at passenger side, a passenger needs the information which bus line has trips at what time from which stop. For this, departure schedule print-outs can be generated in the system. On this print-out, various information like line number, direction, name of the stop, other upcoming stops, operating day and departure times are displayed. These print-outs can also be shared in internet for a better catchment. Looking at vehicle side, vehicle cards including all the movements of this vehicle during one day can be prepared as print-outs, and these cards are placed on the vehicle before it leaves the depot. All the activities of the vehicle on that specific day are summarized to-the-minute on this card. From the driver point of view, the duty plan of the driver is prepared as a print-out as well and submitted to the driver at the beginning of his duty. In this way, the driver can see on which lines he works, where and when he gets his break. If driver plans are prepared for a longer period (like monthly roster plan), this plan is prepared in the system too and shared with the drivers. All this information is based on one single system, which is the already mentioned operational planning software. Recently, information for drivers is rather shared in online systems than on paper. This has led to driver internet portals in the operators. Internet portals or Webclients help drivers to stay always updated about their daily duties and off-days, but also provides operators savings from the whole paperwork and extra workflow processes. In this portal, a driver can see the daily duties assigned to him, and see when he has off-days. He can also contact the dispatcher by messaging when needed, and sends requests for possible duty changes. The driver can hence be informed immediately about short-term changes. This increases driver satisfaction and at the same time avoids other possible communication problems.

Even though the main purpose is to realize the operations as planned, the nature of public transport leads to possible disturbances during the operation, resulting in deviations from the plans. These deviations must also be tracked in the system. For example, if a vehicle breaks down during the operation, or a driver does not show up in the morning due to a sickness, the dispatcher must interfere in the system, find reserve vehicles/drivers easily and assign them. The system must give a good support to the dispatcher by finding a reserve vehicle/driver with the same qualification and still complying with the rules. This part of operation is called daily dispatching. With the help of a daily dispatch module, all the payrolls of drivers by taking not only the planned but also the realized duties are generated correctly in the system [3].

4. CASE STUDIES ABOUT GENERATING OPERATIONAL PLANS

In this work, case studies aimed at preparing operational plans are carried out for different cities of Turkey. For these applications, softwares IVU.rail and IVU.plan from the company IVU Traffic Technologies are used. Further work on developing whole operational plans is going on. The already performed works are summarized in the following parts.

4.1. A Case Study for Izmir

A study for the bus operator of the city of Izmir (ESHOT) has been done. Operational plans according to the rules and trip frequencies of ESHOT are prepared and consequently the departure schedule print-outs are generated in the IVU.plan system. An example is shown in Figure 7 for the stop “Fahrettin Altay Aktarma Merkezi”. These print-outs can be placed at stops and shared in internet for passenger information [4].

a)

b)

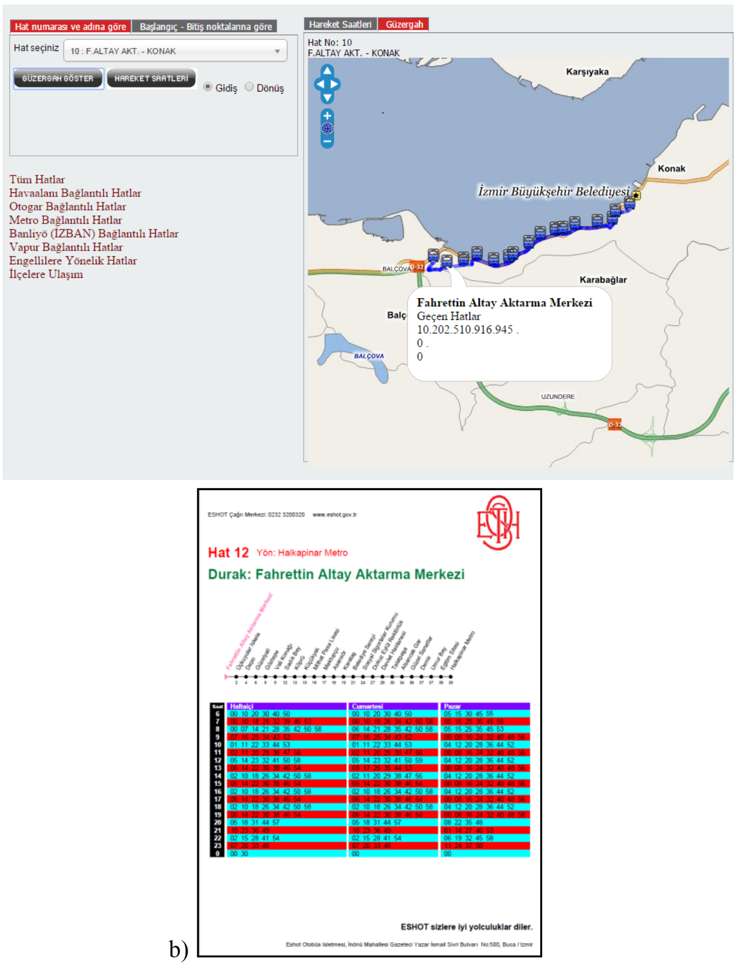


Figure 7. Generating departure schedule print-out by operational planning software (ESHOT, IVU) a) Fahrettin Altay Transit Center b) Departure Schedule Print-out

4.2. A Case Study for Sakarya

A comprehensive study has been started for the city of Sakarya for public transport operational planning. For this purpose, a base system for the public transport infrastructure is setup. Information about the location of bus-stops and alignment of bus lines are collected via on-site works. Private bus operations, minibuses and dolmus system is also included in the Sakarya Public Transport Info System. The figure below shows a screenshot from the system. This study is shared in internet for public usage (http://zet-group.com.tr/STBS.html). User can get info about different lines, position of the stops and other attraction points of the city [5].

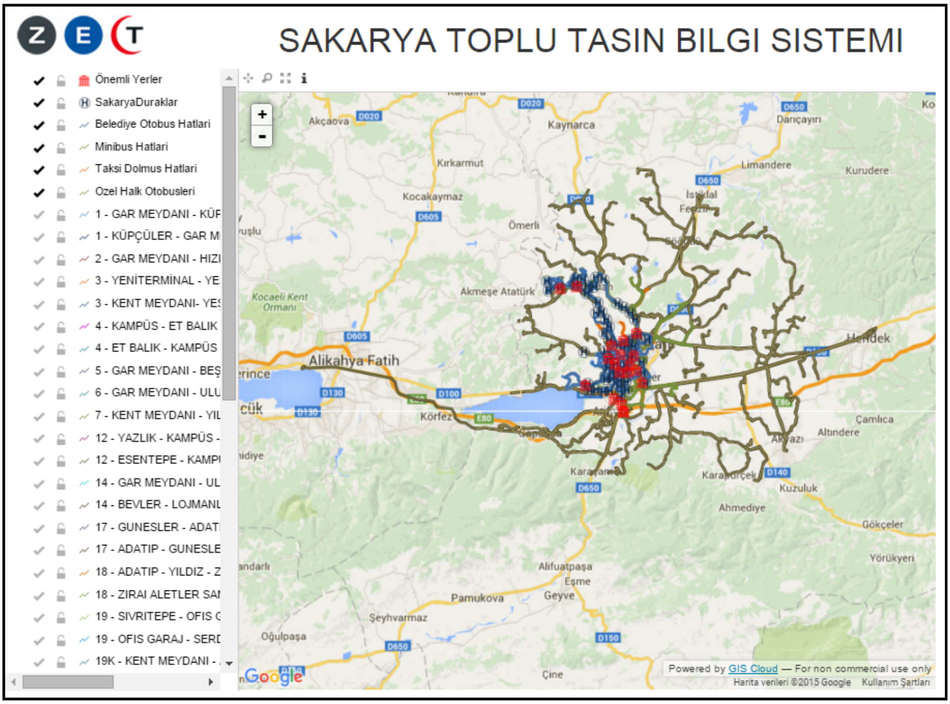


Figure 8. Sakarya Public Transport Info System (http://zet-group.com.tr/STBS.html)

4.3. A Case Study for Bursa

A study has been made for BURSARAY, rail system operator of the city of Bursa, to generate optimal operational plans. This study was performed for the 2 BURSARAY lines, Emek-Arabayatağı and Üniversite-Arabayatağı. Taking the current timetables and network of Bursaray, it was shown that daily operations can be executed with 38 duties instead of 44 duties as it is now. In the figure below, a screenshot from this study is displayed [6].

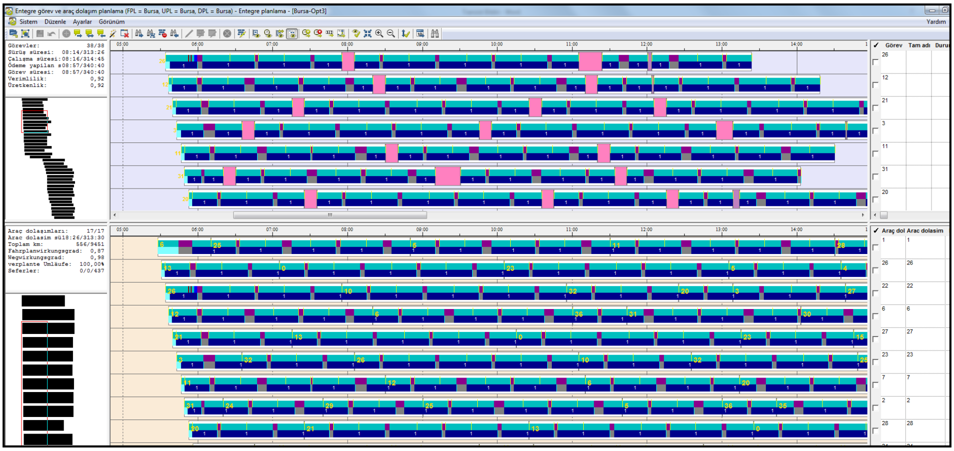


Figure 9. BURSARAY Driver Duty Planning (BURSARAY, IVU)

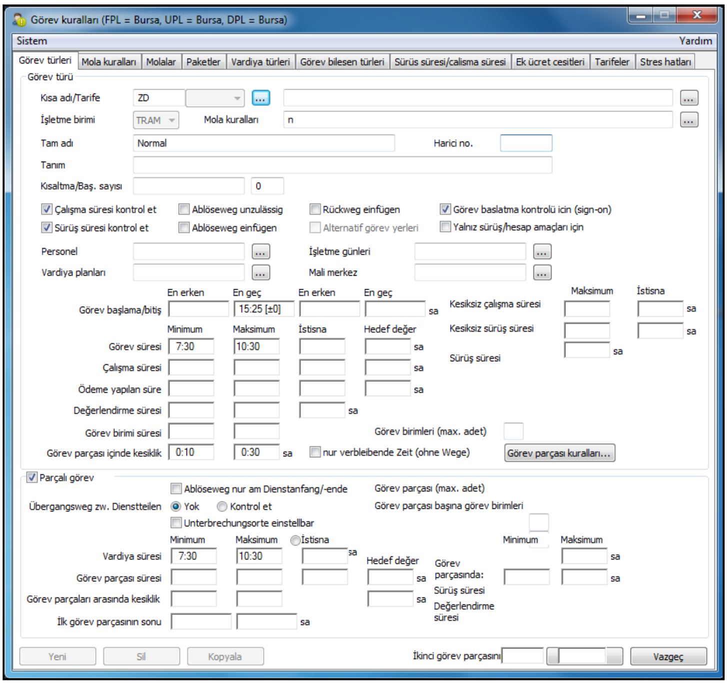
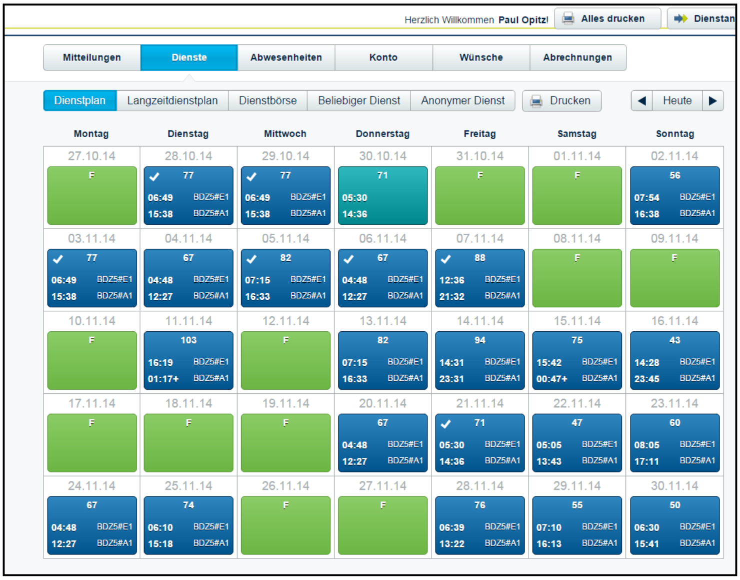


Figure 10. Inserting driver work rules and guidelines into the system (BURSARAY, IVU)

4.4. A Case Study for IETT Istanbul

A study has been conducted for Metrobus system of Istanbul, which is operated by IETT, the bus operator of the metropolitan city. Current trip frequencies and operational guidelines are taken as basis for this study and as an example, departure schedule print-outs for the stop

Zeytinburnu were generated. Additionally, duty plans produced by the system were made available in the Webclient portal as well [7].



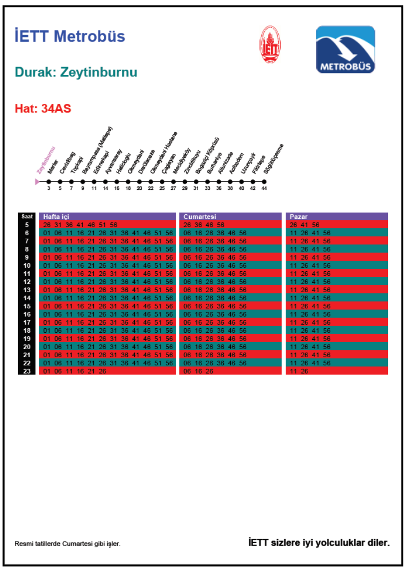


Figure 11. Webclient portal and Metrobus departure schedule print-outs (IETT, IVU)

5. CONCLUSIONS

Rapid urbanization brings cities of Turkey many problems in term of transportation. Many people think to solve this problem by having a private car, resulting in a high car ownership. Due to insufficient transport infrastructure and transport offer, traffic congestions and other environmental problems are inevitable. Municipalities keep on purchasing new public transport vehicles and extend their fleet to handle those. Fleets that are not extended within a plan are not operated properly during the operation as well, where many problems occur in terms of vehicle and driver workload. Vehicles can break down in the middle of the service since maintenance due dates are not held, drivers can cause serious fatal accidents due to the high workload. Besides, passengers seek their own solutions in shifting to private cars due to uncertain timetables, constant delays or broken-down vehicles.

Public transport operators have to have a planning system before investing huge amounts on purchasing new vehicles, even to determine lines and analyse the demand of the city. One of the most important steps of this is the operational planning and optimization. Operational planning at least enables the operators to optimize their current operation. Moreover, different scenarios can be analysed to choose the best one. Vehicle and driver needs in the future can be foreseen better. Apart from providing economic benefits, it increases the motivation and satisfaction of the driver personnel, hence helps their errors decrease. With this system, also passengers are informed better to plan their daily routines. Passengers who know when their bus departs from their stops and arrives at their destination use more public transport and contribute to the reduction of traffic congestion in the cities. To sum up, all public transport operators need to have a planning system to carry out a modern operation.

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