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**TOSHKENT DAVLAT
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Articles are published in Uzbek, Russian, and English, ensuring a wide-reaching audience and fostering cross-cultural academic exchange. As a beacon of academic excellence, the "Journal of Transport" continues to serve as a vital conduit for knowledge dissemination, collaboration, and innovation in the transport sector and related fields.

Methods for identifying factors influencing the complexity of urban bus routes

F.B. Amirkulov¹ 

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Abstract: This article provides an in-depth analysis of the key factors for assessing the complexity of urban public transport, particularly bus routes, their resulting impacts, and applicable technological tools. Factors such as route geometry, number and density of stops, number and type of intersections, pedestrian crossings and railway crossings directly affect service quality and travel time reliability. The research employs GPS monitoring system technologies. Using GIS software such as QGIS, methods for route optimization and visual complexity analysis are demonstrated. This empirical and analytical approach serves to enhance the economic efficiency of urban bus transport, improve the level of passenger needs satisfaction, and develop additional policy and planning measures through comprehensive statistical analysis. The results provide practical recommendations for modernizing urban transport systems.

Keywords: bus routes, urban transport, travel time reliability, complexity, QGIS, unscheduled stops, simulation, service quality

Shahar avtobus marshurtlari murakkabligiga tasir qiluvchi omillarni aniqlash uslublari

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Annotatsiya: Ushbu maqolada shahar jamoat transporti, xususan avtobus yo'nalishlarining murakkabligini baholashga qaratilgan asosiy omillar, ular keltirib chiqaradigan ta'sirlar va qo'llash mumkin bo'lgan texnologik vositalar chuqur tahlil qilinadi. Yo'nalish geometriyasi, bekatlar soni va zichligi, chorrahalar soni va turi, Piyodalar o'tish joylari va temir yo'l izlari bilan keshishgan kabi omillar xizmat ko'rsatish sifatiga hamda qatnov vaqtining ishonchililigi bevosita ta'sir etadi. Tadqiqotda GPS monitoring tizimlari texnologiyalari qo'llanilgan. QGIS kabi GIS dasturiy ta'minotdan foydalanib, marshrut optimallashtirish va murakkablikni vizual tahlil qilish usullari ko'rsatib o'tiladi. Mazkur tajribaviy va analitik yondashuv shahar avtobus transportining iqtisodiy samaradorligini oshirishga, yo'lovchilar ehtiyojlarini qondirish darajasini yaxshilashga hamda chuqur statistik tahlil qilish orqali qo'shimcha siyosiy va rejalashtirish choralari ishlab chiqishga xizmat qiladi. Natijalar shahar transport tizimini modernizatsiya qilish bo'yicha amaliy tavsiyalar beradi.

Kalit so'zlar: avtobus yo'nalishlari, shahar transporti, qatnov vaqti ishonchiligi, murakkablik, QGIS, rejasiz to'xtashlar, simulyatsiya, xizmat sifati

1. Kirish

Avtobus yo'nalishining murakkabligi (bus route complexity) avtobus yo'nalishi loyihalashtirish va ekspluatatsiyasidagi murakkablik darajasini ifodalaydi [1],[4]. Bu tushuncha fazoviy (geometrik) unsurlarni – masalan, burilishlar soni, chorrahalar zichligi, yo'nalishning to'g'ridan-to'g'ri yoki o'ramaligi – hamda to'xtashlar chastotasi, tirbandlik darajasi, svetofor boshqaruvlari, to'xtash bekatlari va haydovchi xatti-harakatlari kabi operatsion omillarni ham o'z ichiga oladi [2],[5].

Murakkabligi yuqori bo'lgan yo'nalishlar odatda tor ko'chalardan o'tishi, tez-tez yoki kutilmagan to'xtashlarni o'z ichiga olishi va turli xil yo'l-transport boshqaruvlariga duch kelishi mumkin [1],[3]. Natijada bunday yo'nalishlarda odatda qatnov vaqtining uzayishi, ekspluatatsiya

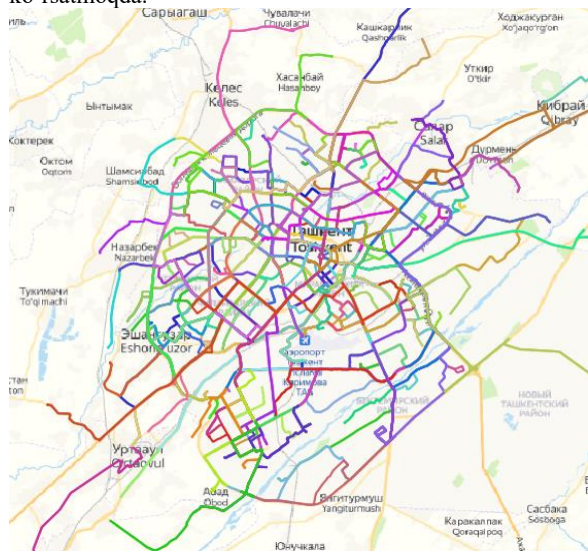
xarajatlarining oshishi va qatnov jadvaliga rioya qilishdagi qiyinchiliklar yuzaga keladi [4]. Bunga qarama-qarshi ravishda, kesishmalari kamroq va aniqroq yo'nalishga ega bo'lgan marshrutda odatda qatnov vaqtlari barqarorroq, xizmat ko'rsatish ishonchiligi esa yuqoriroq bo'ladi [2]. Yo'nalish murakkabligiga ta'sir qiluvchi omillar: burilishlar soni chorrahalar zichligi yo'nalishning to'g'ridan-to'g'ri o'tganligi (directness) to'xtash bekatlari orasidagi masofa (stop spacing) yo'lovchilar talab darajasi (passenger demand) tirbandlik darajasi (congestion levels) svetofor va boshqa yo'l-transport boshqaruv vositalari (traffic control devices) xisoblanib bular yo'nalishdagi avtobuslar ish faoliyatiga sezilarli ta'sir ko'rsatadi.

Hozirda Toshkent shahrida 167 ta (1-rasm) yo'nalishlarda 1700 tadan ziyod avtobuslar ishlab turibdi. Kunlik qatnovlar soni 21234 tani tashkil etmoqda va ularda o'rtacha 800000 dan ortiq yo'lovchi o'z manzillariga yetkazilmoqda. Yo'nalishli avtobuslarning oraliq

 <https://orcid.org/0009-0009-8419-1820>



intervallari yo'lovchilarning oqimini va yo'nalish murakkabligini hisobga olgan holda 8-10 daqiqani tashkil etmoqda. Ushbu yo'nalishlarda yo'lovchilarga hozirda 7 turdagi rusumli avtobuslar, ya'ni Mercedes-Benz LF, Isuzu, Man, Saz LE, Yutong, King Long, Elektrobustlar xizmat ko'rsatmoqda.



1-rasm. Toshkent shahridagi mavjud avtobus yo'nalishlar tarmog'i

2. Tadqiqot metodologiyasi

Ushbu murakkabliklar sabab avtobuslar ish faoliyatida muammolar yuzaga kelmoqda. Masalan: Shahar avtobus yo'nalishlarining umumiy murakkablik darajasini belgilovchi omillardan quyidagilar belgilangan

1. Har bir bekatdan o'tadigan avtobus yo'nalishlari sonini.
2. Har bir chorrahadan o'tadigan avtobus yo'nalishlari sonini.
3. Har bir tartibga solingan va solinmagan piyodalar o'tish joyidan o'tadigan avtobus yo'nalishlari sonini.
4. Har bir temir yo'l izi bilan kesishgan joydan o'tadigan avtobus yo'nalishlari sonini qayd etish mumkin.

Marshurtning murakkabligiga ta'sir qilivchi ko'rsatkichni aniqlash va tahlil qilish jarayonini quyidagi bosqichlar asosida tashkil etish maqsadga muvofiq:

Shahar avtobus yo'nalishlarini QGIS dasturida raqamlashtirish

Avvalo, shahardagi barcha avtobus yo'nalishlari (boshlang'ich va oxirgi bekatlar, yo'nalish chiziqlari) elektron shaklga o'tkaziladi. Buning uchun QGIS dasturida har bir yo'nalish bo'ylab mavjud barcha ko'cha va ko'chalarning geografik koordinatalari raqamlashtiriladi.

Shahardagi jami bekatlarni, tartibga solingan va solinmagan chorrahalarni, tartibga solingan va solinmagan piyodalar o'tish joylarni va temir yo'l izlari bilan kesishgan nuqtalarni QGIS dasturida raqamlashtirish

Keyingi bosqichda, shaharda faoliyat olib borayotgan barcha rasmiy avtobus bekatlari (bekat nomi, manzili, joylashuvi), Chorrahalar (chorraha turi, tartibga solingan solinmaganligi, manzili, joylashuvi), piyodalar o'tish joylari (turi, tartibga solingan solinmaganligi, manzili, joylashuvi),

temir yo'l izlari bilan tutashgan nuqtalar (manzili, joylashuvi) QGIS yordamida spatial (geografik) ma'lumotlar bazasiga kiritiladi. Bu bekatlar alohida qatlam (layer) sifatida saqlanib, har birining aniq koordinatalari, nomeri yoki identifikatorlari belgilab chiqiladi.

Ushbu yo'nalishlarni QGIS dasturida bekatlarga, chorrahalarga, piyodalar o'tish joylariga, temir yo'l izlari bilan kesishgan nuqtalarga birlashtirish

So'ngra har bir avtobus yo'nalishiga tegishli bekatlar chorrahalar, piyodalar o'tish joylari, temir yo'l izlari tanlanadi va QGIS dasturida yo'nalish qatlamiga bog'lab chiqiladi. Natijada, har bir bekatdan chorrahadan, piyodalar o'tish joylaridan, temir yo'l izlaridan o'tadigan yo'nalishlar soni aniqlanadi. Mazkur bosqichda fazoviy (spatial) tahlil usullaridan foydalanish, masalan, bekat va yo'nalish qatlamlarini kesish (intersect) yoki tutashtirish (join) amallarini bajarish orqali bekatlarning qaysi yo'nalishlarga tegishli ekanligini avtomatik ravishda aniqlash imkonini beradi.

Natijada olingan ma'lumotlar asosida bitta bekatdan o'tadigan avtobus yo'nalishlari soni haqida aniq raqamli ko'rsatkichga ega bo'lamiz va shahar avtobus yo'nalishlari murakkabligini baholashda ushbu omilni ham inobatga olish mumkin bo'ladi.

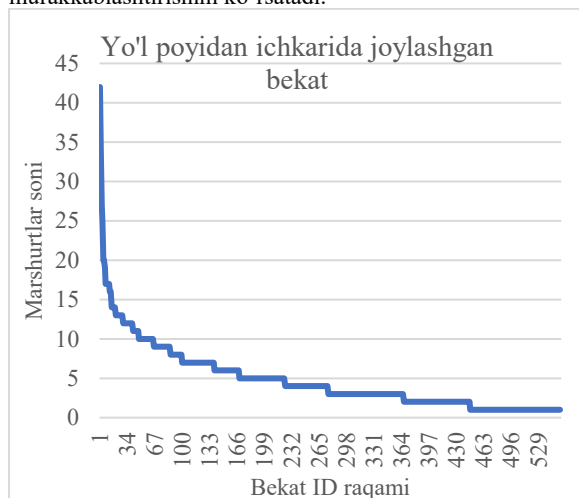
Tadqiqot natijalariga ko'ra, bugungi kunda Toshkent shahridagi yo'nalishli avtobuslarga xizmat ko'rsatuvchi 3055 ta oraliq bekati mavju, (2-rasm) shundan 2426 tasi yo'l poyida joylashgan va 629 tasi yo'l poyidan ichkarida joylashgan bekat xisoblanadi. Poytaxtda jami 43 ta bekatlardan Avtobus yo'nalishlarining boshlanish yoki oxirgi bekati xisoblanadi. Eng zich joylashgan hudud sifatida poytaxtning Mirobod tumani aytish mumkin. Bekatlarning bunday o'zaro yaqin joylashuvi avtobusning tez-tez to'xtashiga olib kelib, marshurtning murakkablashishiga va qatnov vaqtining uzayishiga sabab bo'ladi. Buning natijasida yo'lovchilar oqimini tartibga solish, avtobuslar harakati jadvaliga rioya qilish va transport oqimini boshqarish murakkabligi ortadi. Ayniqsa, bir-biriga yaqin bekatlar atrofida tirbandlik va yo'lovchilar tiqilinchlari ko'payishi mumkin, bu esa marshrut umumiy murakkablik darajasini sezilarli ravishda oshiradi.



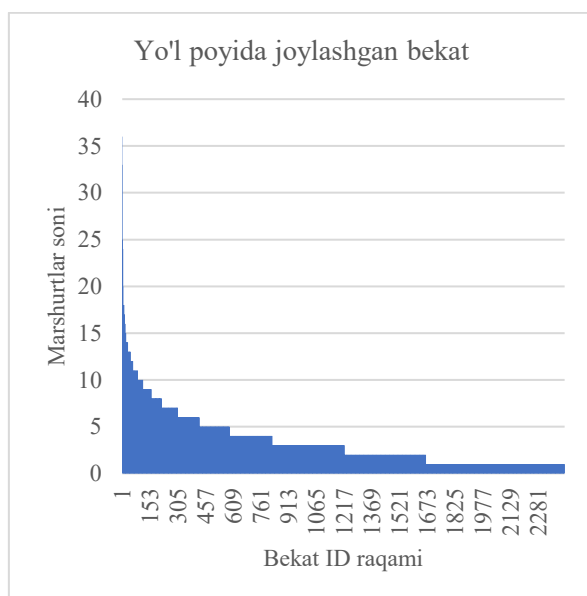
2-rasm. Toshkent shahridagi mavjud avtobus bekatlar

Toshkent shahrida yo'l poyida joylashgan yagona bekatdan 35 tadan ortiq avtobus yo'nalishlari, yo'l poyidan ichkarida joylashgan boshqa bir bekatdan esa 40 dan ziyod

avtobus yo'nalishlari o'tgani aniqlandi(3-4-rasm). Bu omil bekatlardagi yo'lovchi oqimini boshqarish va marshrutlarni samarali tashkil etish jarayonini yanada murakkablashtirishini ko'rsatadi.



3-rasm. Yo'l poyidan ichkarida joylashgan avtobus bekatlardan o'tuvchi yo'nalishlar



4-rasm. Yo'l poyida joylashgan avtobus bekatlardan o'tuvchi yo'nalishlar

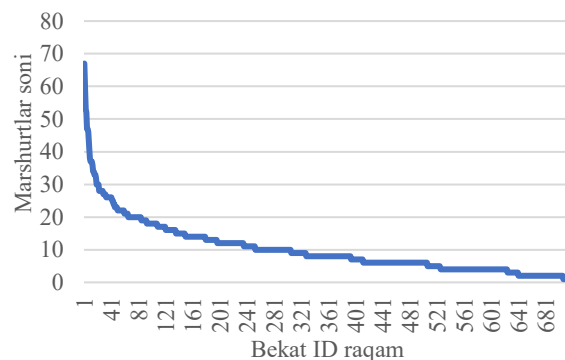


5-rasm. Chorrhahalardan o'tadigan avtobus yo'nalishlari

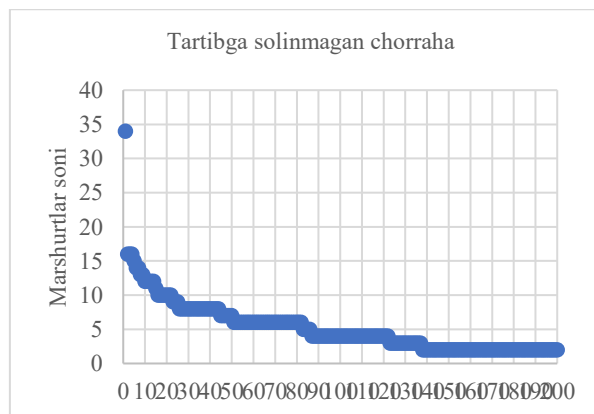
Toshkent shahridagi jami 167 ta avtobus marshurtlari shahrning turli chorrhahalaridan o'tgan bo'lib ularning jami soni qariyb 1013 ta ekanligi ma'lum bo'ldi. (5-rasm). Ushbu chorrhahalarning 717 tasi tartibga solingan chorraha 231 tasi tartibga solinmagan chorraha va 65 tasi harakat aylanma harakat tashkil etilgan chorraha ekanligi ma'lum bo'ldi.

Tatqiqotga ko'ra tartibga solingan chorrhadan eng ko'p o'tgan avtobus marshurtlari soni 70 taga yaqin (6-rasm). Tartibga solinmagan chorrhadan eng ko'p 35 ta atrofidan avtobus o'tganligini ko'rishimiz mumkin. (7-rasm). Chorrhadan o'tadigan avtobus yo'nalishlari soni qancha ko'p bo'lsa, transport oqimining kesishishi shuncha ortib, yo'llarda tirbandlik va to'xtab qolishlar tez-tez yuz berishi mumkin. Bu esa avtobuslarning belgilangan jadvalga rioya qilishini murakkablashtirib, yo'lovchilarning kutish vaqtini uzaytiradi hamda chorrhani tashkil etish va boshqarish ishlarini qiyinlashtiradi. Natijada, mazkur chorraha transport infratuzilmasida "murakkab nuqta" sifatida ko'rib chiqilishi va qo'shimcha rejalashtirish, boshqaruv choralarini talab etishi mumkin.

Tartibga solingan chorraha

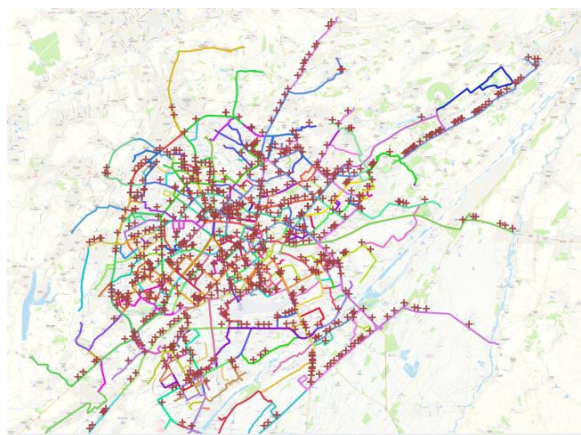


6-rasm. Tartibga solingan chorrhalarga to'g'ri keladigan marshurtlar



7-rasm. Tartibga solinmagan chorrhalarga to'g'ri keladigan marshurtlar

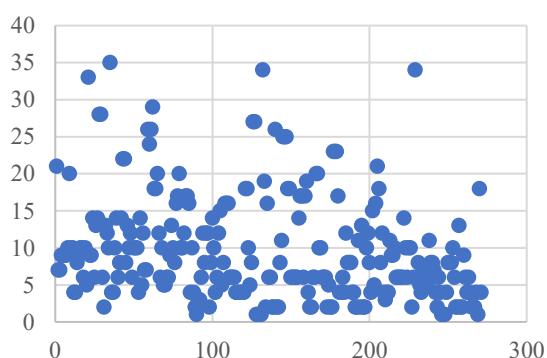
Toshkent shahridagi mavjud avtobus yo'nalishlariga jam 830 ta piyodalar o'tish joyi bilan kesishadi. (8-rasm). Shundan 273 tasi tartibga solingan piyodalar o'tish joyi bo'lsa 557 tasi tartibga solinmagan piyodalar o'tish joyi xisoblanadi.



8-rasm Avtobus yo'nalishlarining piyodalar o'tish joyi bilan kesishadigan nuqtalari

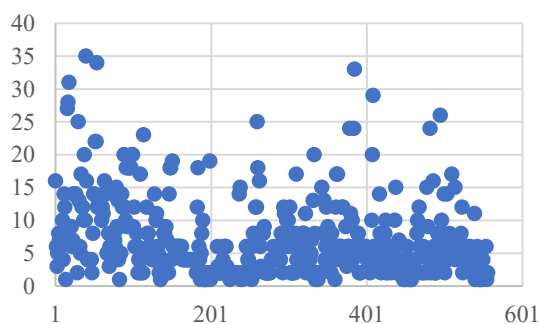
Avtobus yo'nalishlarining piyodalar o'tish joyi bilan kesishishi qanchalik ko'p bo'lsa, ushbu hududlarda tezlikni pasaytirish, to'xtash va piyodalar harakatiga ustunlik berish zarurati ortadi. Toshkent shahridagi tartibga solingan piyodalar o'tish joyidan eng ko'p 35 ta avtobus yo'nalishi o'tgan, (9-rasm), Tartibga solinmagan piyodalar o'tish joyidan 30 tadan ko'proq avtobus yo'nalishi o'tgan. (10-rasm). Bu esa transport oqimi sekinlashishi, bekat va chorahalarda kutish vaqtining ko'payishi hamda xavfsizlik choralari kuchaytirish zaruriyatini keltirib chiqaradi. Shu sababli, bunday o'tish joylari sonining ortishi avtobus marshrutining murakkablik darajasini oshirib, rejalashtirish va boshqaruvda qo'shimcha chora-tadbirlar talab etadi.

Tartibga solingan piyodalar o'tish joyi



9-rasm. Tartibga solingan piyodalar o'tish joyi bilan kesishadigan marshurtlar

Tartibga solinmagan piyodalar o'tish joyi



10-rasm. Tartibga solinmagan piyodalar o'tish joyi bilan kesishadigan marshurtlar

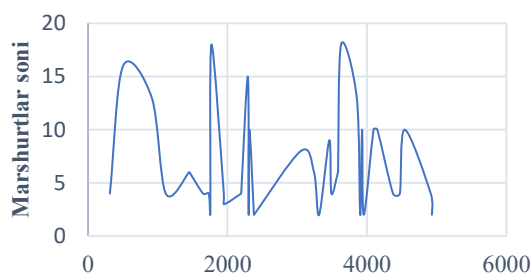
Toshkent shahridagi mavjud avtobus yo'nalishlariga jam 42 ta nuqtada temir yo'l izlari bilan kesishadi. (11-rasm.)



11-rasm. Avtobus yo'nalishlarining temir yo'l izlari bilan kesishadigan nuqtalari

Toshkent Shahrida jami temir yo'l izlari bilan eng ko'pi 18 ta avtobus marshurti eng kam 2 ta avtobus marshurti kesishadi. (12-rasm). Temir yo'l izlari bilan kesishadigan avtobus yo'nalishlari ko'pincha qo'shimcha xavfsizlik va boshqaruv choralari talab qiladi. Poyezd o'tgunga qadar kutish va harakatlanish cheklavlari tufayli avtobuslar belgilangan jadvaldan kechikib qolishi, yo'lovchilar uchun kutish vaqti ortishi mumkin. Bu omillar marshrutning umumiy murakkabligini oshiradi hamda transport rejalashtirishda qo'shimcha e'tibor va resurslar sarflashni talab etadi.

Temir yo'l izidan kesib o'tgan marshurtlar soni



12-rasm. Temir yo'l izlari bilan kesishadigan avtobus marshurtlar soni

3. Xulosa

Xulosa qilib aytganda, yuqorida keltirilgan bosqichlarni bosqichma-bosqich amalga oshirish orqali, QGIS dasturida shahar avtobus yo'nalishlari hamda bekatlarni, shuningdek chorahalar, piyodalar o'tish joylari va temir yo'l izlari bilan kesishadigan marshrutlarni ham raqamlashtirish hamda ular o'rtasidagi fazoviy bog'liqlikni aniqlash mumkin bo'ladi. Natijada, bitta bekat, choraha yoki piyodalar o'tish joyidan o'tadigan avtobus yo'nalishlari soni har bir kesimda aniqlandi. Ushbu raqamli ko'rsatkichlar shahar miqyosida avtobus qatnovini rejalashtirish, bekatlarning o'zaro uzviyligini baholash, yo'lovchilar oqimini muvofiqlashtirish, shuningdek, temir yo'l kesishmalarida yuzaga keladigan qo'shimcha xavfsizlik va kechikish holatlarini inobatga olish orqali jamoat transporti tizimidagi murakkablik darajasini aniqlashda muhim ahamiyat kasb

etadi. Aniqlangan ma'lumotlar, shu jumladan har bir bekat yoki kesishma kesimida nechta avtobus yo'nalishi mavjudligi, transport tizimini optimallashtirish yoki yangi yo'nalishlarni rejalashtirish bo'yicha strategik qarorlar qabul qilishda zarur asos bo'lib xizmat qiladi. Mazkur yondashuv natijasida kelajakda bekatlar joylashuvini va transport yo'nalishlarini takomillashtirish orqali jamoat transporti xizmatlarini sifatli tashkil etish va yo'lovchilarga qulaylik yaratish imkoniyati paydo bo'ladi.

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