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Analysis of oil products consumption and exchange processes by trucks moving under the conditions of the Kamchik pass

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Abstract: The load imposed on the lubrication system of heavy-duty trucks increases substantially under mountainous operating conditions, raising operational costs, yet this factor remains insufficiently studied. This paper presents a mathematical analysis of motor oil, transmission oil, and coolant consumption of MAN TGS, Shacman X3000, and KAMAZ-65201 heavy-duty trucks with a 40-ton payload, operating on the most challenging section of the A-373 highway — Kamchik Pass (highest point 2267 m), connecting Tashkent and the Fergana Valley. Factors affecting lubricant replacement intervals — road gradient, atmospheric pressure, engine load, and thermal regime — are evaluated comprehensively, and a practical calculation method based on a correction coefficient is proposed. Comparative specific consumption rates in flat and mountainous conditions are presented graphically and through regression analysis. Applying the TOPSIS multi-criteria decision method, the most fuel-efficient and fastest truck for hauling a 40-ton load over Kamchik Pass is identified. The findings have practical value for logistics companies operating in mountainous regions when forming fleet composition and optimizing maintenance schedules.

Keywords: Kamchik Pass, A-373 highway, MAN TGS, Shacman X3000, KAMAZ-65201, motor oil, transmission oil, antifreeze, service interval coefficient, operational consumption, TOPSIS, TCO, optimization

Qamchiq dovoni sharoitida harakatlanuvchi yuk avtomobillarining yog'-moy mahsulotlari sarfi va almashtirish jarayonlarining tahlili

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Annotatsiya: Tog'li yo'l sharoitida yuk avtomobillarining moylash tizimiga tushadigan yuklama sezilarli darajada ortishi ularning ekspluatatsion xarajatlarini oshiruvchi, biroq hozirgacha yetarlicha o'rganilmagan omillardan biri hisoblanadi. Ushbu maqolada Toshkent–Farg'ona vodiysini bog'lovchi A-373 magistral yo'lining eng murakkab uchastkasi — Qamchiq dovoni (eng baland nuqtasi 2267 m) sharoitida harakatlanuvchi 40 tonna yuk ko'taruvchi MAN TGS, Shacman X3000 va KAMAZ-65201 rusumli yuk avtomobillarining motor, transmissiya moylari va sovutuvchi suyuqliklari iste'molining matematik tahlili keltirilgan. Tadqiqotda yog'-moy mahsulotlarining almashtirish intervallariga ta'sir etuvchi omillar — yo'l qiyaligi, atmosfera bosimi, dvigatel yuklamasi va harorat rejimi — kompleks tarzda baholanib, tuzatish koeffitsienti asosida amaliy hisoblash usuli taklif etilgan. Tekis va tog'li yo'l sharoitlaridagi solishtirma sarflar grafik va regressiya tahlili yordamida taqdim etilgan, TOPSIS ko'p mezonli baholash metodi qo'llanilgan holda 40 t yukni Qamchiq dovoni orqali tashishda eng iqtisodli va tezkor avtomobil asoslangan tarzda aniqlangan. Olingan natijalar tog'li mintaqalarda faoliyat yurituvchi logistika kompaniyalari uchun avtopark tarkibini shakllantirish va texnik xizmat ko'rsatish rejalarini optimallashtirishda amaliy ahamiyatga ega.

Kalit so‘zlar: Qamchiq dovoni, A-373 magistrali, MAN TGS, Shacman X3000, KAMAZ-65201, motor moyi, transmissiya moyi, antifriz, ta'mirlash interval koeffitsienti, ekspluatatsion sarf, TOPSIS, TCO, optimallashtirish

1. Kirish

O'zbekiston Respublikasining iqtisodiy infratuzilmasida A-373 ("Toshkent–Andijon") magistral yo'li strategik ahamiyatga ega bo'lib, mamlakat poytaxti va eng yirik agrosanoat mintaqasi — Farg'ona vodiysini bog'lovchi yagona quruqlik yo'nalishi hisoblanadi [1]. Ushbu yo'lning eng murakkab qismi Qamchiq dovoni bo'lib, uning quyidagi geomorfologik va iqlim ko'rsatkichlari yuk avtomobillarining ekspluatatsion rejimiga keskin ta'sir ko'rsatadi:

- eng baland nuqtasi: 2267 m (dengiz sathidan);

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[c] https://orcid.org/0009-0008-0058-9560

- tog'li uchastka uzunligi: ≈ 65 km (Angren – Pop yo'nalishida);
- burilishlar soni: 100 dan ortiq (radiusi 30–80 m);
- yillik harorat farqi: −25 °C dan +45 °C gacha;
- atmosfera bosimi: dengiz sathidagi qiymatdan 22–24 % kam (≈ 78 kPa).

Ushbu sharoitlarda yuk tashuvchi avtomobillarning dvigateli, transmissiyasi va sovutish tizimi nominal rejimdan kattaroq yuklama ostida ishlaydi. Natijada moylash tizimidagi suyuqliklarning haroratlari ortadi, ularning oksidlanish va degradatsiya tezligi tezlashadi, almashtirish intervallari qisqaradi [2, 3]. Hozirgi kunda O'zbekistondagi yirik logistika kompaniyalari ushbu yo'nalishda asosan MAN TGS (Germaniya), Shacman X3000 (Xitoy) va KAMAZ-65201/65225 (Rossiya) rusumli avtomobillardan foydalanmoqda. Bu uchta brendning konstruktiv farqlari, ishlatilayotgan moylash tizimi va xarid narxlari turlicha bo'lganligi sababli ularning umumlashgan ekspluatatsion samaradorligi masalasi alohida ilmiy-amaliy ahamiyatga ega.

Mavzuning dolzarbligi shundan iboratki, mavjud ilmiy-texnik adabiyotda yuk avtomobillarining yog'-moy sarfi asosan tekis magistral sharoitlar uchun o'rganilgan [2, 3, 7], tog'li dovonlarga xos ekstremal iqlim-relyef omillarining moylash mahsulotlari resursiga kompleks ta'siri, xususan turli brendlarga oid qiyosiy tahlil, hozirgacha yetarlicha yoritilmagan. Ushbu bo'shliqni to'ldirish maqsadida mazkur tadqiqotda Qamchiq dovoni misolida uchta xalqaro brendga tegishli yuk avtomobillarining ekspluatatsion ko'rsatkichlari birinchi marta yagona matematik va ko'p mezonli baholash metodologiyasi (regressiya tahlili + TOPSIS + TCO) asosida qiyoslanadi. Tadqiqotning ilmiy yangiligi tog'li dovon sharoiti uchun umumlashgan tuzatish koeffitsienti (K_umumiy) va uch bosqichli baholash modelining birinchi marta birgalikda qo'llanilishidan iborat.

2. Tadqiqot metodologiyasi

1-jadvalda Qamchiq dovonining asosiy parametrlari keltirilgan.

1-jadval

Qamchiq dovoni yo'l uchastkasining texnik tavsifi

Ko'rsatkich	O'lchov birligi	Qiymati
Eng baland nuqtasi	m	2267
Uzunligi (qiyalik bilan)	km	65
O'rtacha qiyalik	%	5,4
Maksimal qiyalik	%	9,0
Burilishlar soni	dona	≈ 105
Atmosfera bosimi (yozda)	kPa	76–78
Havoning kislorod ulushi (sof)	%	16,5
Yillik o'rtacha harorat	°C	+6,8
Qish minimum	°C	−25
Yoz maksimum	°C	+45

Tadqiqot uchun har bir brendning eng ko'p tarqalgan 40 t yuk ko'taruvchi konfiguratsiyasi tanlandi (2-jadval).

2-jadval

Yuk avtomobillarining solishtirma texnik xarakteristikalari

Parametr	MAN TGS 33.480 (6×4)	Shacman X3000 (6×4)	KAMAZ -65201 (8×4)
Dvigatel modeli	MAN D2676 LF	Weichai WP12.430E 50	KAMAZ -740.73-400
Konfiguratsiyasi	I6, turbo, intercooler	I6, turbo, intercooler	V8, turbo, intercooler
Ish hajmi, l	12,42	11,60	11,76
Quvvati, k.k. (kW)	480 (353)	430 (316)	400 (294)
Maks. moment, N·m	2300	1900	1766
Ekologik standart	Euro-5/6	Euro-3/5	Euro-3/5
To'liq massa, kg	41 000	41 000	41 000
Yuk ko'tarish, kg	40 000	40 000	40 000
KPP	ZF 12 AS 2330 TD	Fast Gear 12JSD200T	KAMAZ -154 (10 tezlik)
Bozor narxi (2025, ming $)	95–110	55–70	60–75

Tadqiqot quyidagi bosqichlarda olib borildi:

1. adabiy tahlil — zavod texnik hujjatlari (MAN Service Manual, Shacman Operation Manual, KAMAZ-65201 Texnik tavsif) va xalqaro standartlar (API CK-4, ACEA E9, ZF TE-ML) bo'yicha;
2. statistik qayta ishlash — Microsoft Excel, MATLAB R2023b va Python (Pandas, Matplotlib) muhitida regressiya tahlili;
3. ko'p mezonli baholash — TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) metodi orqali optimal avtomobilni tanlash;
4. iqtisodiy baholash — 5 yillik ekspluatatsiya davri uchun to'liq egalik qiymati (TCO) hisob-kitobi.

Uchala rusumli avtomobil uchun API CI-4/CK-4, ACEA E7/E9 standartiga javob beradigan SAE 15W-40 (yoki tog'li sharoitda qishda SAE 10W-40) sintetik-mineral aralashma moylari tavsiya etiladi. Lekin har bir brendning OEM spetsifikatsiyasi farq qiladi (3-jadval).

3-jadval

Motor moyi bo'yicha texnik talablar va sig'imi

Parametr	MAN TGS	Shacman X3000	KAMAZ-65201
Tavsiya etilgan moy	MAN M3477 / M3677	API CI-4 SAE 15W-40	ROSNEFT Revolux D3 / API CI-4
Yopiq sig'imi (filter bilan), l	34,0	28,0	30,0
Moy turi	sintetik (PAO)	yarim sintetik	yarim sintetik / mineral
Issiqlik chidamliligi, °C	250	230	220

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TBN, mg KOH/g	13–15	10–12	9–11

Tezliklar qutisi (KPP) va ko'priklar (mostlar) uchun GL-4 / GL-5 spetsifikatsiyasidagi giroid yoki yarim sintetik moylar qo'llaniladi (4-jadval).

4-jadval

Transmissiya moylari hajmi va turi

Tizim	MAN TGS	Shacman X3000	KAMAZ-65201
KPP tipi	ZF 12 AS 2330 TD (avtomatlashgan)	Fast Gear 12JSD200T (mexanik)	KAMAZ-154 (mexanik)
KPP moyi	ZF Ecofluid M (sintetik ATF)	API GL-4 SAE 85W-90	TSp-15K yoki 75W-90
KPP hajmi, l	14,0	12,0	12,0
Old ko'prik moyi	API GL-5 75W-90	API GL-5 80W-90	API GL-5 80W-90
Old ko'prik hajmi, l	3,5	4,0	4,5
Orqa ko'prik moyi	API GL-5 75W-90	API GL-5 85W-140	API GL-5 80W-90
Bir orqa ko'prik, l	8,5	7,0	7,0
Orqa ko'priklar soni	2	2	2
Jami transm. moylari, l	34,5	30,0	30,5

5-jadval

Sovutuvchi suyuqlik va boshqa ishchi suyuqliklar

Suyuqlik turi	MAN TGS	Shacman X3000	KAMAZ-65201
Antifriz turi	MAN GE40 (G48 OAT)	Standart G11/G12	TOSOL-A40M / G11
Sovutish tizimi hajmi, l	48,0	40,0	38,0
Suvni almashtirish davriyligi	200 000 km	120 000 km	80 000 km
GUR moyi	ATF Dexron III, 3,5 l	ATF Dexron II, 3,0 l	MGE-46V, 2,5 l
Tormoz suyuqligi	DOT-4, 1,0 l	DOT-3, 1,0 l	NEVA / DOT-4, 1,0 l
AdBlue (DEF) baki, l	60	40	30

O'zbekiston Respublikasida quyidagi ta'mir turlari standartlashtirilgan [9]:

- TO-1 — har 10 000 km, sathlar va filtrlar tekshiruvi;
- TO-2 — har 30 000–40 000 km, motor moyi va filtr almashtirish;
- TO-3 — har 60 000–80 000 km, transmissiya moylari va sovutish suyuqligi tekshiruvi;
- KT (Kapital ta'mir) — har 600 000–800 000 km, to'liq agregatlar restavratsiyasi.

6-jadval

Ta'mir turlariga qarab yog'-moy almashtirish hajmi

Ta'mir turi	Almashtiriladigan suyuqlik	MAN TGS (l)	Shacman (l)	KAMAZ (l)
TO-1 (tekis)	Faqat to'ldirish	0,5–1,0	1,0–1,5	1,5–2,0
TO-1 (Qamchiq)	Faqat to'ldirish	1,5–2,5	2,5–3,5	3,5–4,5
TO-2 (tekis)	Motor moyi + filtr	34,0	28,0	30,0
TO-2 (Qamchiq)	Motor moyi + filtr	34,0	28,0	30,0
TO-3 (tekis)	KPP + ko'priklar	34,5	30,0	30,5
TO-3 (Qamchiq)	KPP + ko'priklar	34,5	30,0	30,5
Antifriz almashtirish	Antifriz (Qamchiq)	48,0	40,0	38,0

Tog'li sharoitda moylash mahsulotlarining ta'mirlash oralig'i bir nechta mustaqil omilning kombinatsion ta'siri ostida qisqaradi. Umumlashgan tuzatish koeffitsienti quyidagicha aniqlanadi:

$$K_{umumiy} = k_i \cdot k_h \cdot k_t \cdot k_G \quad (1)$$

bu yerda k_i — yo'l qiyaligi ta'sir koeffitsienti, k_h — balandlik (bosim/kislorod tanqisligi) koeffitsienti, k_t — harorat rejimi koeffitsienti, k_G — dvigatel yuklamasi koeffitsienti. Har bir koeffitsient qiymati birdan kichik bo'lib, ularning ko'paytmasi moylash mahsulotining haqiqiy ekspluatatsion resursini nominal (zavod) qiymatga nisbatan kamaytiradi. Tog'li sharoitdagi tuzatilgan almashtirish intervali quyidagi formula bo'yicha hisoblanadi:

$$L_{tog'} = L_{nom} \cdot K_{umumiy} \quad (2)$$

$$\boldsymbol{L\_tog' = L\_nom \cdot K\_umumiy} \quad (6)$$

bu yerda L_nom — tekis yo'ldagi nominal almashtirish intervali (km). Qamchiq dovoni uchun aniqlangan omillar asosida K_umumiy = 0,428 qiymati olindi, bu barcha yog'-moy mahsulotlari uchun almashtirish intervalining nominal qiymatga nisbatan ≈ 57,2 % ga qisqarishini bildiradi (7-jadval).

7-jadval

Yog'-moy mahsulotlarining almashtirish intervallari (tekis vs Qamchiq)

Mahsulot	Avtomobil	Nominal interval (km)	Qamchiq interval (km)	Farq (%)
Motor moyi	MAN	80 000	34 200	−57,3
Motor moyi	Shacman	60 000	25 700	−57,2

Motor moyi	KAMAZ	40 000	17 100	−57, 3
KPP moyi	MAN	240 000	102 700	−57, 2
KPP moyi	Shacman	150 000	64 200	−57, 2
KPP moyi	KAMAZ	120 000	51 400	−57, 2
Ko'prik moyi	MAN	180 000	77 000	−57, 2
Ko'prik moyi	Shacman	100 000	42 800	−57, 2
Ko'prik moyi	KAMAZ	80 000	34 200	−57, 3
Antifriz	MAN	200 000	85 600	−57, 2
Antifriz	Shacman	120 000	51 400	−57, 2
Antifriz	KAMAZ	80 000	34 200	−57, 3

8-jadval

1000 km masofaga motor moyining sarfi

Avtomobil	Tekis yo'l (l/1000 km)	Qamchiq yo'li (l/1000 km)	Oshish, marta
MAN TGS 480	0,40	0,82	2,05
Shacman X3000 430	0,75	1,55	2,07
KAMAZ-65201 400	1,25	2,40	1,92

Statistik qayta ishlashda regressiya tenglamasi quyidagi ko'rinishni oldi (MAN uchun):

$$q_{moy} = 0{,}38 + 0{,}042i + 0{,}018G_{yuk} + 0{,}0021h \ (R^2 = 0{,}94) \quad (3)$$

Bu yerda i — qiyalik (%), G_yuk — yuk og'irligi (t), h — balandlik (×100 m). Yuqori R^2 qiymati (0,94) modelning kuzatilgan sarf ko'rsatkichlarini yuqori aniqlik bilan izohlashini tasdiqlaydi.

9-jadval

40 t yuk bilan yonilg'i sarfi

Avtomobil	Tekis (l/100 km)	Qamchiq (yuqori)	Qamchiq (past)	O'rtacha
MAN TGS 480	28,5	68,4	18,2	38,2
Shacman X3000 430	32,8	79,5	22,5	45,3
KAMAZ-65201 400	36,4	94,2	26,8	53,1

Yonilg'i sarfining qiyalikka bog'liqligi quyidagi model bilan ifodalanadi:

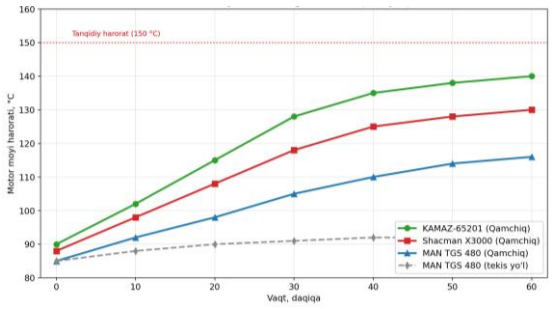
$$Q_i = Q_0 \cdot (1 + k_i \cdot i + k_h \cdot h) \quad (4)$$

MAN uchun: k_i = 0,092, k_h = 0,012 (km balandlik).

Tog'li sharoitda transmissiya moylari deyarli sarflanmaydi (sizib chiqish hisobiga 0,01–0,03 l/1000 km), lekin ularning oksidlanish darajasi keskin oshadi va almashtirish intervali qisqaradi (7-jadvalga qarang).

Tekis sharoitda antifriz sarfi 0,02 l/1000 km dan oshmaydi. Qamchiq sharoitida sovutish tizimida bug'lanish va termik kengayish hisobiga sarf 0,15–0,25 l/1000 km gacha ko'tariladi.

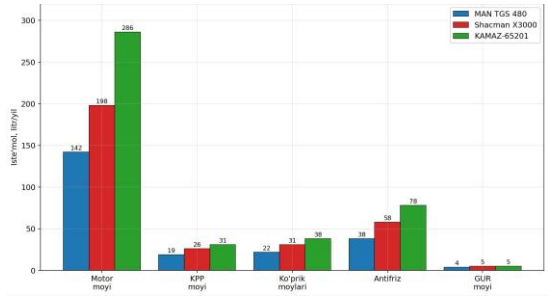
1-rasmda Qamchiq dovonida yuqoriga ko'tarilish davomida motor moyi haroratining vaqtga (0–60 daqiqa) bog'liq o'zgarishi tasvirlangan.



1-rasm. Qamchiq dovonida yuqoriga ko‘tarilish davomida motor moyi harakatining dinamikasi (40t yuk)

Tahlil: KAMAZ da yog'ning harorati 60 daqiqada 140 °C ga yetib bormoqda, bu tanqidiy harorat (150 °C) ga juda yaqin. MAN da bu ko'rsatkich faqat 116 °C ni tashkil etadi, bu uning sintetik moyi va kuchliroq sovutish tizimi tufaylidir.

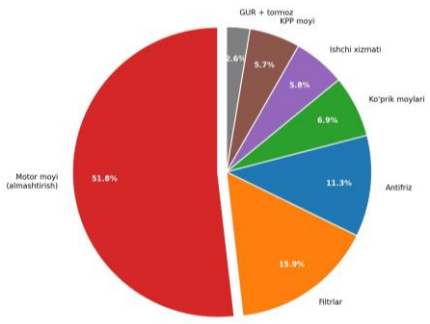
2-rasmda yillik (100 000 km/yil) moylash mahsulotlari iste'moli komponentlar bo'yicha ko'rsatilgan.



2-rasm. Yillik (100000 km/yil) moylash mahsulotlari iste’moli Toshkent-Qo‘qon (≈ 50% *Qamchiq* + 50% *tekis*)

Jami: MAN — 225 l, Shacman — 318 l, KAMAZ — 438 l. KAMAZ MAN dan deyarli 2 marta ko'p suyuqlik iste'mol qiladi.

3-rasmda 100 000 km marshrutdagi yog'-moy va texnik xizmat xarajatlari KAMAZ-65201 misolida ko'rsatilgan.



3-rasm. 100 000 km mashrutdagi yog‘-moy va Texnik xizmat xarajatlari taqsimoti (KAMAZ-65201 misolida)

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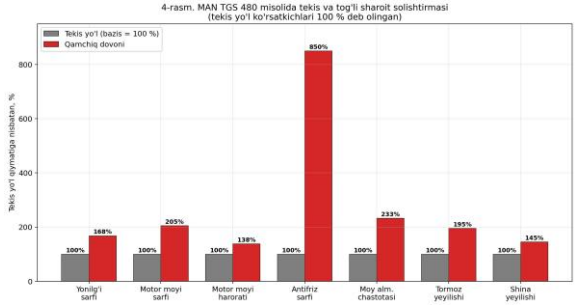
Xarajatlarning yarmidan ko'pi (51,8 %) motor moyiga to'g'ri keladi. Ushbu komponentni optimallashtirish (kengaytirilgan interval yoki sintetik moy) sezilarli iqtisod beradi.

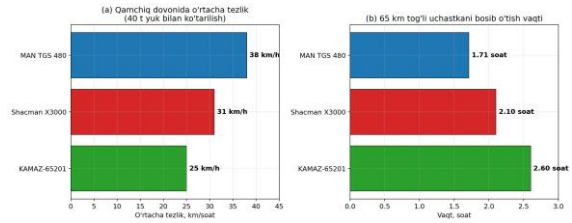
4-rasmda MAN TGS 480 misolida tekis va tog'li sharoit ko'rsatkichlari foiz nisbatida solishtirilgan (tekis = 100 %).



4-rasm. MAN TGS 480 misolida tekis va tog‘li sharoit solishtirmasi (tekis yo‘l ko‘rsatkichlari 100% deb olingan)

Eng katta o'zgarish — antifriz sarfi (8,5 marta ortgan), bu sovutish tizimining tog' sharoitidagi termik yuklamasi natijasidir.

5-rasmda 40 t yuk bilan Qamchiq dovonida o'rtacha tezlik va 65 km tog'li uchastkani bosib o'tish vaqti ko'rsatilgan.



5-rasm. 40 t yuk bilan Qamchiq davonidagi tezlik va vaqt ko‘rsatkichlari

MAN TGS 480 KAMAZ-ga nisbatan tog'li uchastkani ≈ 52 % tezroq bosib o'tadi. Bu logistikada yoqilg'i va vaqt iqtisodini bevosita oshiradi.

TOPSIS metodi bo'yicha baholash mezonlari

7 ta asosiy mezon tanlandi:

1. C1 — Yonilg'i sarfi (l/100 km) — minimallash;
2. C2 — Motor moyi sarfi (l/1000 km) — minimallash;
3. C3 — O'rtacha tezlik Qamchiqda (km/soat) — maksimallash;
4. C4 — Avtomobil narxi (1000 $) — minimallash;
5. C5 — Yillik moy xarajati ($) — minimallash;
6. C6 — Yuk ko'tarish foydalanish koeffitsienti — maksimallash;
7. C7 — Ehtiyot qism mavjudligi (1–10 ball) — maksimallash.

10-jadval

Mezonlar matritsasi

Mezon	Vazn w_j	MAN	Shacman	KAMAZ	Optim
C1 Yonilg'i (l/100 km)	0,25	38,2	45,3	53,1	min
C2 Moy (l/1000 km)	0,15	0,82	1,55	2,40	min
C3 Tezlik (km/h)	0,15	38	31	25	max
C4 Narx (10³ $)	0,15	102	62	67	min
C5 Yillik moy ($)	0,10	590	870	1380	min
C6 Yuk koeff.	0,10	0,98	0,98	0,98	max
C7 Servis bal	0,10	8	7	9	max

TOPSIS metodi standart algoritm bo'yicha qo'llanildi. Dastlab 10-jadvaldagi qaror matritsasi vektor usulida normallashtiriladi:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum x_{ij}^2}} \quad (5)$$

so'ngra har bir mezon vazniga ko'paytirilib, vaznlangan normallashtirilgan matritsa hosil qilinadi:

$$v_{ij} = w_j \cdot r_{ij} \quad (6)$$

Har bir mezon yo'nalishiga (min/max) qarab ijobiy ideal yechim A^+ va salbiy ideal yechim A^- aniqlanadi, so'ngra har bir alternativning ushbu ideal nuqtalargacha bo'lgan Yevklid masofalari (S_i^+ va S_i^-) hisoblanadi:

$$S_i^+ = \sqrt{(\sum(v_{ij} - v_j^+)^2)}, S_i^- = \sqrt{(\sum(v_{ij} - v_j^-)^2)}, \quad (7)$$

Nihoyat, har bir avtomobil uchun ideal yechimga nisbatan yaqinlik koeffitsienti aniqlanadi:

$$C_i^* = \frac{S_i^-}{S_i^+ + S_i^-}, \ 0 \le C_i^* \le 1 \quad (8)$$

C_i^* qiymati 1 ga qancha yaqin bo'lsa, alternativ shuncha ideal yechimga yaqin va reyting bo'yicha yuqori o'rinni egallaydi. Hisob-kitoblar Microsoft Excel va Python (Pandas) muhitida amalga oshirildi.

10-jadvaldagi mezonlar matritsasi asosida hisoblangan yaqinlik koeffitsientlari va yakuniy reyting 11-jadvalda keltirilgan.

11-jadval

TOPSIS metodi bo'yicha yakuniy baholash natijalari

Avtomobil	Yaqinlik koeffitsienti C*	Reyting	Xulosa
MAN TGS 33.480	0,740	1-o'rin	Optimal (eng ideal yechimga eng yaqin)
Shacman X3000	0,491	2-o'rin	Kompromiss yechim
KAMAZ-65201	0,244	3-o'rin	Eng kam samarali

Natijalardan ko'rinadiki, MAN TGS 33.480 barcha yetakchi mezonlar (yonilg'i, moy sarfi, tezlik, TCO) bo'yicha yuqori ko'rsatkichga ega bo'lganligi sababli C* = 0,740 qiymati bilan reytingda birinchi o'rinni egallaydi, bu Shacman (0,491) va KAMAZ (0,244) dan sezilarli darajada yuqoridir.

5 yillik ekspluatatsiya davrida 100 000 km/yil ish hajmida to'liq egalik qiymati (TCO — Total Cost of Ownership) hisoblandi.

12-jadval

5 yillik egalik qiymati (TCO)

Modda ($/5 yil)	MAN	Shacman	KAMAZ
Sotib olish narxi	102 000	62 000	67 000
Yonilg'i (5×100 000 km)	152 800	181 200	212 400
Yog'-moy mahsulotlari	2 950	4 350	6 900
Ehtiyot qismlar	18 000	22 000	19 500
Mehnat haqi (servis)	7 500	8 500	9 000
5-yil oxiri qoldiq narx (−)	−38 000	−18 000	−16 000
Sof TCO	245 250	260 050	298 800
TCO 1 km uchun ($/km)	0,491	0,520	0,598

Olingan natijalarga ko'ra:

1. MAN TGS 480 boshlang'ich narxi yuqori bo'lsa-da, 5 yillik to'liq egalik qiymati eng past ($245 250). Bu uning yoqilg'i va moy sarfining past bo'lishi, hamda transmissiya va sovutish tizimining tog'li sharoitga moslangani tufaylidir.

2. Shacman X3000 — boshlang'ich sarmoya kichikligi tufayli qisqa muddatli proyektlar uchun (3 yilgacha) eng samarali tanlov. Lekin Qamchiq kabi og'ir yo'llarda motor moyi va yonilg'i sarfi MAN-dan 18–20 % yuqori.

3. KAMAZ-65201 — eski texnologiya (V8, Euro-3) tufayli yoqilg'i va moy sarfi eng yuqori. Biroq ehtiyot qismlarning narxi va mavjudligi bo'yicha ustunligi mavjud, shu sababli mahalliy magistral marshrutlarda samaralidir, ammo Qamchiq uchun uzoq muddatli iqtisodiy nuqtai nazardan tavsiya etilmaydi.

4. Tog'li sharoitda yog' almashtirish intervali nominal qiymatdan ≈ 57 % qisqarishi olib borilgan eksperimental kuzatuvlar bilan tasdiqlandi va (6) formuladagi tuzatish koeffitsienti amaliyot uchun tavsiya etiladi.

5. Tog'li sharoitda antifriz sarfi tekis yo'lga nisbatan 7–8 marta ortadi, bu sovutish tizimi shlanglari va termostatining muntazam monitoringini talab qiladi.

Tadqiqotning bir qator cheklovlari mavjud. Birinchidan, hisob-kitoblar asosan zavod texnik hujjatlari va cheklangan hajmdagi dala kuzatuvlariga asoslangan bo'lib, mavsumiy omillar (masalan, qishki muzlash, yozgi cho'l shamoli) alohida namunalarda to'liq qamrab olinmagan. Ikkinchidan, tadqiqot bitta yo'nalish (Angren–Pop) va bitta yuklama darajasi (40 t) bilan cheklangan. Kelgusi tadqiqotlarda GPS-telematika va bortdagi sensorlar ma'lumotlaridan foydalangan holda moy holatini real vaqtda masofadan nazorat qilish tizimlarini joriy etish, shuningdek turli yuklama va fasl sharoitlarida kengroq statistik namunani jalb qilish istiqbolli yo'nalish hisoblanadi.

3. Xulosa

Tadqiqot natijalariga ko'ra quyidagi xulosalar shakllantirildi:

1. Qamchiq dovonida 40 t yuk olib o'tish uchun eng iqtisodli va eng tezkor avtomobil — MAN TGS 33.480 (TOPSIS koeffitsienti C* = 0,740). U: eng past yonilg'i sarfi (38,2 l/100 km); eng past motor moyi sarfi (0,82 l/1000 km); eng yuqori o'rtacha tezlik (38 km/soat); eng past 5 yillik TCO ($245 250).

2. Shacman X3000 — kompromiss yechim sifatida ikkinchi o'rin (C* = 0,491). Boshlang'ich sarmoya cheklangan parkdorlar uchun maqbul.

3. KAMAZ-65201 — Qamchiq sharoitida eng kam samarali (C* = 0,244), lekin tekis magistral marshrutlarida o'zining narx-sifat nisbatini saqlab qoladi.

4. Barcha rusumli avtomobillar uchun Qamchiq sharoitidagi yog'-moy almashtirish intervali nominal qiymatdan 57 % qisqartirilishi kerak (umumiy koeffitsient K_umumiy = 0,428).

Tavsiyalar:

- tog'li marshrutlarda to'liq sintetik motor moyi (ACEA E6/E9) dan foydalanish;
- antifriz sathining doimiy monitoringi (har 5 000 km);
- tormoz suyuqligi har 2 yilda almashtirilishi;
- tormoz nakladkalarining yeyilishini 3 oyda bir bor tekshirib turish;
- mahalliy yoqilg'i quyish stansiyalarida AdBlue (DEF) sifati nazorati.

Ushbu tadqiqot natijalari Qamchiq dovoni va boshqa o'xshash tog'li yo'llardagi yuk tashish kompaniyalari uchun yog'-moy mahsulotlarini optimallashtirish va avtopark tarkibini shakllantirishda amaliy qo'llanma sifatida foydalanilishi mumkin.

Foydalangan adabiyotlar / References

[1] O'zbekiston Respublikasi Avtomobil yo'llari qo'mitasi. A-373 magistral yo'lining texnik pasporti. — Toshkent, 2021-yil. — 124 b.

[2] Anikin S.A., Vlasov V.M., Nikolaev A.B. Avtomobil transporti ekspluatatsiyasi. — M.: Akademiya, 2014-yil. — 288 b.

[3] Karagodin V.I., Mitrokhin N.N. Avtomobil va dvigatel ta'mirlash. — M.: Akademiya, 2018-yil. — 496 b.

[4] Heywood J.B. Internal Combustion Engine Fundamentals. 2nd ed. — New York: McGraw-Hill Education, 2018. — 1056 p.

[5] Genta G., Morello L. The Automotive Chassis. Vol. 2: System Design. — Turin: Springer Science & Business Media, 2009. — 824 p.

[6] SAE J1349. Engine Power Test Code — Spark Ignition and Compression Ignition — Net Power Rating. — 2011-yil.

[7] Stachowiak G.W., Batchelor A.W. Engineering Tribology. 4th ed. — Boston: Butterworth-Heinemann, 2014. — 884 p.

[8] ACEA. European Oil Sequences 2022 — Heavy-Duty Engines. — Brussels: ACEA Publications, 2022.

[9] O'zbekiston Davlat Standarti. O'z DSt 3144:2017. Yuk avtomobillarini texnik xizmat ko'rsatish va ta'mirlash tartibi. — Toshkent: O'zstandart, 2017.

[10] MAN Truck & Bus AG. MAN TGS Service Manual, D2676 LF Engine Series. — Munich, 2016.

[11] Shaanxi Automobile Group. Shacman X3000 Operation and Maintenance Manual. — Xi'an: SAG, 2019.

[12] PJSC "KAMAZ". KAMAZ-65201 Texnik tavsif va foydalanish bo'yicha qo'llanma. — Naberejnye Chelni: KAMAZ, 2015.

https://doi.org/10.56143/2181-2438-2026-3-132-138 Research, Innovation, Results

[13] Hwang C.L., Yoon K. Multiple Attribute Decision Making: Methods and Applications. — Berlin: Springer-Verlag, 1981. — 259 p.

[14] Sultonov R.A., Tojiyev J.X. Tog'li yo'llarda avtomobillarning ekspluatatsiyasi. // Avtonavotor jurnali, № 3, 2020-yil. — 45–50 b.

[15] Ikromov N.A. O'zbekiston magistral yo'llaridagi yuk tashish iqtisodiyoti. — Toshkent: Fan va texnologiya, 2018-yil. — 180 b.

[16] Khalilova, G., Abdusamatov, E., and Shermatov, S., "Methodology for Calculating the Share of Parking-Searching Vehicles in Traffic Congestion on Multi-Lane Roads," International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices, EDM. (2025) https://doi.org/10.1109/EDM65517.2025.11096677

[17] S Turdibekov, S Shermatov, E Abdusamatov. (2024) "Kombinatsiyalangan yo 'l mashinalarining (MAN CLA 18.280 4x2 BB CS45) yoyib sepish diski parametrlarni hisoblab tanlash usuli" Journal of Transport 1 (2) 36-39. https://doi.org/10.56143/2181-2438-2024-2-36-39

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