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The journal is published 4 times a year and contains publications in the following main areas:

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Development of a mathematical model for linking wagons to a schedule thread on railway sections

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Abstract: In this article, an analysis was carried out on the development of a mathematical model of attachment of rail cars to graphic times and experiments on minimizing the time of their stay at stations. Work has also been done to determine the number of walkway variants of a particular part of the group of wagons to be added up to a specified station using Gauss's method of "solving a system of linear algebraic equations". The functional possibilities of integrating the group of cars into commuter trains and optimizing their withdrawal from the overtaking stations on the railway site have been researched on the basis of the creation of a mathematical model.

Keywords: railway section, graphic times, train formatting plan, matrix element, transient train, section train, reserve locomotive, pick-up train.

Temir yo‘l uchastkalaridagi vagonlarni grafik vaqtlariga biriktirishning matematik modelini ishlab chiqish

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Annotatsiya: Mazkur maqolada temir yo‘l uchastkalaridagi vagonlarni grafik vaqtlariga biriktirishning matematik modelini ishlab chiqish va ularni stansiyalarda turib qolish vaqtlarini minimallashtirishga doir tajribalar tahlili olib borilgan. Shuningdek, belgilangan stansiyagacha qo‘shib yuboriladigan vagonlar guruhining ma’lum qismining yurish yo‘li variantlari sonini Gaussning “Chiziqli algebraik tenglamalar sistemasini yechish” usuli yordamida aniqlash ishlari amalga oshirilgan. Vagonlar guruhini yo‘l-yo‘lakay poyezdlarga qo‘shib yuborish va temir yo‘l uchastkasidagi ortish-tushirish stansiyalaridan ularni olib chiqish bo‘yicha optimallashtirish masalasining funksional imkoniyatlari matematik model yaratish asosida tadqiq etilgan.

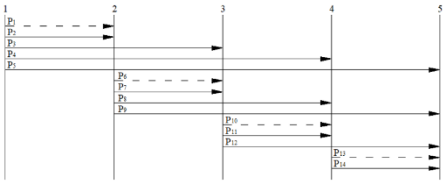
Kalit so‘zlar: temir yo‘l uchastkasi, grafik vaqtlari, poyezdlar tuzish rejasi, matritsa elementi, o‘tkinchi poyezd, uchastka poyezdi, zaxira lokomotivi, terma poyezd.

1. Kirish

Bozor iqtisodiyoti va temir yo‘l transportini qayta qurish sharoitida iqtisodiy ko‘rsatkichlarni yaxshilashga, tashish sifati, temir yo‘l transportining nufuzi va jozibadorligini oshirishga va uni amalga oshirish usullarini izlashga qaratilgan tashish jarayonining samarali texnologiyasidan foydalanish hozirgi zamon dolzarb masalalaridan biridir. Tashish sifatiga qo‘yilgan zamonaviy talablar butun temir yo‘l yo‘nalishlarida foydalanish ishlarining muntazamliligini, aniqligini va ritmini oshirish zarurligini taqozo etmoqda. Shu bilan birga, yuk tashish tannarxini pasaytirish va ularning rentabelligini oshirish ko‘p jihatdan bir qator tizimlarni ishlab chiqish va joriy etishga bog‘liq bo‘lib, ular ishlashini optimallashtirish temir yo‘l transporti ishini yaxshilashga ta’sir qiladi. Shulardan biri stansiyalarda vagonlarning ortiqcha turib qolish vaqtlarini minimallashtirishning kompleks tizimini yaratishdir.

2. Tadqiqot metodikasi

Texnik stansiyalar (tadqiqot ishida beshta texnik stansiya qabul qilingan) misolida uzoq yo‘nalishlardagi poyezdlardan nisbatan yaqin yo‘nalishlardagi poyezd tarkibiga vagonlar guruhining ma’lum qismini qo‘shib yuborish mumkin bo‘lgan variantlar sonini ko‘rib chiqamiz (1-rasm).



1-rasm. Beshta texnik stansiya sharoitida poyezdlar tuzish rejasining mumkin bo‘lgan variantlari

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1-rasmdan ko‘rish mumkinki, agar vagonlar guruhining ma’lum qismini P_2 yo‘nalishidan nisbatan yaqin bo‘lgan boshqa yo‘nalishga ulash zarur bo‘lsa, vagonlarni yetkazib berish varianti faqat bitta bo‘ladi (P_1 yo‘nalish), ya’ni terma poyezd bilan olib chiqiladi.

Vagonlarning ma’lum qismini belgilangan yo‘nalishdan boshqa nisbatan yaqin manzilga qo‘shish zarur bo‘lgan hollarda, vagonlar guruhini yetkazib berish variantlarini quyidagi jadvallardan ko‘rish mumkin (1 – 3-jadvallar).

1-jadval

Vagonlar guruhining ma’lum qismini P_3 yo‘nalishidan boshqa nisbatan yaqin manzilgacha qo‘shib yetkazib berish variantlari

Variant raqami	Yurish yo‘li
1.	$P_1 \rightarrow P_6$
2.	$P_1 \rightarrow P_7$
3.	$P_2 \rightarrow P_6$
4.	$P_2 \rightarrow P_7$

2-jadval

Vagonlar guruhining ma’lum qismini P_4 yo‘nalishidan boshqa nisbatan yaqin manzilga qo‘shib yetkazib berish variantlari

Variant raqami	Yurish yo‘li	Variant raqami	Yurish yo‘li
1.	$P_1 \rightarrow P_5 \rightarrow P_8$	7.	$P_2 \rightarrow P_5 \rightarrow P_9$
2.	$P_1 \rightarrow P_5 \rightarrow P_9$	8.	$P_2 \rightarrow P_6 \rightarrow P_8$
3.	$P_1 \rightarrow P_6 \rightarrow P_8$	9.	$P_2 \rightarrow P_6 \rightarrow P_9$
4.	$P_1 \rightarrow P_6 \rightarrow P_9$	10.	$P_2 \rightarrow P_7$
5.	$P_1 \rightarrow P_7$	11.	$P_3 \rightarrow P_8$
6.	$P_2 \rightarrow P_5 \rightarrow P_8$	12.	$P_3 \rightarrow P_9$

3-jadval

Vagonlar guruhining ma’lum qismini P_5 yo‘nalishidan boshqa nisbatan yaqin manzilgacha qo‘shib yetkazib berish variantlari

Variant raqami	Yurish yo‘li	Variant raqami	Yurish yo‘li
1.	$P_1 \rightarrow P_5 \rightarrow P_8$	18.	$P_2 \rightarrow P_6 \rightarrow P_{12}$
2.	$P_1 \rightarrow P_5 \rightarrow P_9$	19.	$P_2 \rightarrow P_7 \rightarrow P_{10} \rightarrow P_{13}$
3.	$P_1 \rightarrow P_6$	20.	$P_2 \rightarrow P_7 \rightarrow P_{10} \rightarrow P_{14}$
4.	$P_1 \rightarrow P_6 \rightarrow P_9$	21.	$P_2 \rightarrow P_7 \rightarrow P_{11} \rightarrow P_{13}$
5.	$P_1 \rightarrow P_7$	22.	$P_2 \rightarrow P_7 \rightarrow P_{11} \rightarrow P_{14}$
6.	$P_2 \rightarrow P_5 \rightarrow P_8$	23.	$P_2 \rightarrow P_7 \rightarrow P_{12}$
7.	$P_1 \rightarrow P_7 \rightarrow P_{10} \rightarrow P_{14}$	24.	$P_2 \rightarrow P_8 \rightarrow P_{13}$
8.	$P_1 \rightarrow P_7 \rightarrow P_{11} \rightarrow P_{13}$	25.	$P_2 \rightarrow P_8 \rightarrow P_{14}$
9.	$P_1 \rightarrow P_7 \rightarrow P_{11} \rightarrow P_{14}$	26.	$P_2 \rightarrow P_9$
10.	$P_1 \rightarrow P_7 \rightarrow P_{12}$	27.	$P_3 \rightarrow P_{10} \rightarrow P_{13}$
11.	$P_1 \rightarrow P_8 \rightarrow P_{13}$	28.	$P_3 \rightarrow P_{10} \rightarrow P_{14}$
12.	$P_1 \rightarrow P_8 \rightarrow P_{14}$	29.	$P_3 \rightarrow P_{11} \rightarrow P_{13}$
13.	$P_1 \rightarrow P_9$	30.	$P_3 \rightarrow P_{11} \rightarrow P_{14}$
14.	$P_2 \rightarrow P_6 \rightarrow P_{10} \rightarrow P_{13}$	31.	$P_3 \rightarrow P_{12}$
15.	$P_2 \rightarrow P_6 \rightarrow P_{10} \rightarrow P_{14}$	32.	$P_4 \rightarrow P_{13}$
16.	$P_2 \rightarrow P_6 \rightarrow P_{11} \rightarrow P_{13}$	33.	$P_4 \rightarrow P_{14}$
17.	$P_2 \rightarrow P_6 \rightarrow P_{11} \rightarrow P_{14}$		

Shunday qilib, belgilangan stansiyagacha qo‘shib yuboriladigan vagonlar guruhining ma’lum qismining yurish yo‘li variantlari sonini Gaussning “Chiziqli algebraik tenglamalar sistemasini yechish” usuli yordamida aniqlash mumkin. Sistemani kengaytirilgan matritsa ko‘rinishida quyidagicha ifodalash mumkin:

$$\begin{pmatrix} 2^n & 2^{n-1} & 2^{n-2}\ldots. & 2^0 \\ 3^n & 3^{n-1} & 3^{n-2}\ldots. & 3^0 \\ 4^n & 4^{n-1} & 4^{n-2}\ldots. & 4^0 \\ 5^n & 5^{n-1} & 5^{n-2}\ldots. & 5^0 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots & & & \end{pmatrix} \begin{pmatrix} 1 \\ 4 \\ 12 \\ 33 \\ \ldots. \end{pmatrix} \quad (1)$$

Istalgancha stansiyalar soni uchun etib borish stansiyagacha vagonlar guruhining ma’lum qismini qo‘shib yuborish mumkin bo‘lgan variantlar sonini quyidagicha aniqlash mumkin:

$$\sum P = \frac{4}{3} \cdot K^n - \frac{19}{2} \cdot K^{n-1} + \frac{151}{6} \cdot K^{n-2} - 22 \quad (2)$$

bunda$K$ – poyezd qayta ishlanadigan stansiyalar soni;

n – matritsa elementining tartib o‘rni.

4-jadvalda poyezdlar tuzish rejasidagi ma’lum bir yo‘nalish bo‘yicha vagonlarning yurish yo‘lidagi temir yo‘l uchastkasida 10 tadan ko‘p texnik stansiya mavjud bo‘lmasligini inobatga olgan holda, etib borish stansiyagacha vagonlar guruhining ma’lum qismini qo‘shib yuborish mumkin bo‘lgan variantlar soni keltirilgan [1].

4-jadval

Vagonlar guruhining ma’lum qismini qo‘shib yuborishning mumkin bo‘lgan variantlari soni

Stansiyalar soni (K)	Yetib borish stansiyagacha belgilangan yurish yo‘li variantlari soni ($\sum R$)
2	1
3	4
4	12
5	33
6	75
7	146
8	254
9	407
10	613

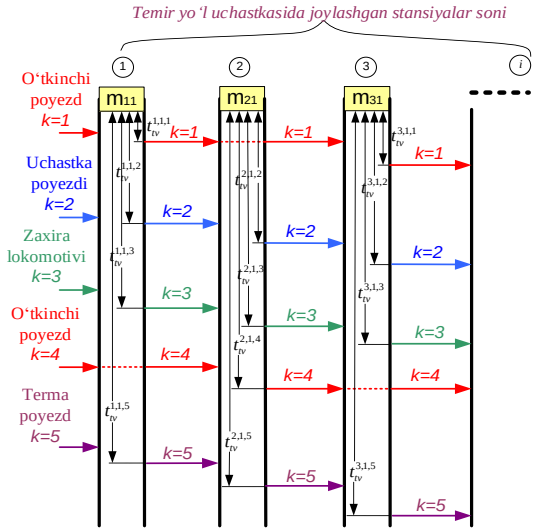
Belgilangan stansiyagacha qo‘shib yuboriladigan vagonlar guruhining ma’lum qismini yurish yo‘lidagi variantlarining samaradorlik sohasi kompleks texnik-iqtisodiy hisoblar asosida aniqlanadi.

4-jadvaldan ko‘rish mumkinki, yurish yo‘lida texnik stansiyalar soni qancha ko‘p bo‘lsa, belgilangan stansiyagacha qo‘shib yuboriladigan vagonlar guruhi ma’lum qismining yurish yo‘lidagi variantlari soni shunchalik ko‘p bo‘ladi.

Yo‘l-yo‘lakay poyezdlarga vagonlar guruhini biriktib jo‘natish barcha hollarda ham o‘zini oqlamaydi. Buning uchun avvalo, vagonlar guruhini biriktirishning maqsadga muvofiqligini, unga matematik yondashuv va modellar asosida aniqlash zarurdir.

Ishlab chiqarish sohasida vagonlarni poyezdlarga ulashgacha bo‘lgan davrda ularning turib qolish vaqti muhim ahamiyat kasb etadi. Turib qolish vaqtining me’yordan ortib ketishi vagon aylanmasining sekinlashishiga, yuklarni yetkazib berish vaqtining cho‘zilishiga sabab bo‘ladi. 2-rasmda vagonlar guruhini yo‘l-yo‘lakay poyezdlarga ulashgacha bo‘lgan davrda ularning turib qolish vaqtini aniqlash sxemasi keltirilgan.

Yuqorida keltirilgan chora-tadbirlar ilmiy-texnik adabiyotlarda [2 – 5] temir yo‘l yo‘nalishlari ishi ishonchliligini oshirishda muhim omil sifatida belgilangan. Biroq hozirgi vaqtda, ularni “O‘TY” AJ amaliyotda qo‘llash samaradorligini har tomonlama baholashning matematik modeli ishlab chiqilmagan.



2-rasm. Vagonlar guruhini yo'l-yo'lakay poyezdlarga ulashgacha bo'lgan davrda ularning turib qolish vaqtini aniqlash sxemasi

Muammoga qat'iy matematik yechimlar kiritish, tortuv turlaridan yanada samarali foydalanishga, oraliq stansiyalarda vagonlarning turib qolish vaqtini kamaytirishga va mahalliy vagonlarni yetkazib berishni tezlashtirishga imkon beradi.

Vagonlarni grafik vaqtlariga biriktirishning matematik modelini yaratishda vagonlar guruhini yo'l-yo'lakay poyezdlarga qo'shib yuborish va temir yo'l uchastkasidagi ortish-tushirish stansiyalaridan ularni olib chiqishning optimallashtirish masalasini funksional imkoniyatlarni minimallashtirish asosida hal etish mumkin:

$$\sum_i \sum_j \left[\sum_k x_{ijk} \cdot t_{tv}^{ijk} \cdot m_{ij} \cdot e_{v-s} + y_{ik} \cdot \delta_{ik} \cdot (t_{tv.kj}^{ik} \cdot C_{bts} + C_{pt})\right] \rightarrow min \quad (3)$$

bunda i – vagonlar qo'shilayotgan stansiyaning tartib raqami;

j – i-stansiyaga qo'shib yuborishga tayyor bo'lgan vagonlar guruhining raqami;

k – i-stansiyasida vagonlarni qo'shib yuborish uchun to'xtatilishi ko'zda tutilgan poyezdning "grafik vaqti" raqami;

x_{ijk} – i-stansiyasida tuzilgan j-vagonlar guruhini k-poyezd "grafik vaqti"ga qo'shib yuborish imkoniyatini aks ettiruvchi mantiqiy o'zgaruvchi;

t_{tv}^{ijk} – i-stansiyadagi vagonlarning j-guruhini k-poyezdga qo'shishdan oldin vagonlarning turib qolish vaqti davomiyligi, soat;

m_{ij} – vagonlar j-guruhining i-stansiyadagi soni, vag.;

e_{v-s} – bir vagon-soat xarajat stavkasi, so'm;

y_{ik} – i- ctansiyadagi k-"grafik vaqti"ga vagonlar guruhini qo'shib yuborish imkoniyatini aks ettiruvchi mantiqiy o'zgaruvchi;

$$y_{ik} = \begin{cases} 0, \sum_i x_{ijk} = 0; \\ 1, \sum_j x_{ijk} > 0; \end{cases} \forall(i,k) \quad (4)$$

Ushbu chegarani quyidagicha yozish mumkin

$$\sum_i^n x_{ijk} \leq n \cdot y_{ik}, j = 1,2,3,\ldots,n \quad (5)$$

δ_{ik} – i- stansiyadagi k-poyezdga vagonlar guruhini qo'shib yuborish uchun to'xtatish imkoniyatini aks ettiruvchi mantiqiy o'zgaruvchi;

$$\delta_{ik} = \begin{cases} 0, \text{agar } k - \text{poyezdning } i - \text{stansiya bo'yicha} \\ \text{texnik to'xtashi ko'zda tutilgan bo'lsa;} \\ 1, \text{aks holda.} \end{cases} \quad (6)$$

$t_{tv.kj}^{ik}$ – i-stansiyada k-poyezdning vagonlarni qo'shib yuborish bo'yicha texnologik amallar ostida turish vaqti, soat;

C_{bts} – uchastkadagi poyezdlarning turib qolish vaqti bilan bog'liq umumiy xarajatlar, so'm;

C_{pt} – vagonlar qo'shib yuborilishi ko'zda tutilgan stansiyalarda poyezdning to'xtab-yurishi bilan bog'liq umumiy xarajatlar, so'm;

Vagonlar guruhini temir yo'l uchastkasining ortish-tushirish stansiyalaridan poyezdlar qayta ishlanadigan stansiyalarga tashish shartini quyidagicha ifodalash mumkin:

$$\sum_k x_{ijk} = 1, \forall(i,j) \quad (7)$$

Qo'shib yuborilishi ko'zda tutilgan vagonlar guruhi uzunligining k-poyezd tarkibiga sig'ishi shartini quyidagicha ifodalash mumkin:

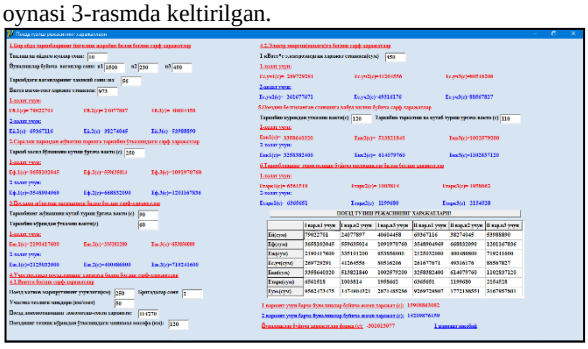
$$\sum_i \sum_j x_{ijk} \cdot m_{ij} \leq \Delta m_k, \forall(k) \quad (8)$$

bunda Δm_k –k-poyezdga sig'ishi mumkin bo'lgan vagonlarning uzunligi, m.

Tadqiqot ishi davomida vagonlarni grafik vaqtlariga biriktirishning matematik modelini ishlab chiqish asosida vagonlar guruhini yo'l-yo'lakay poyezdlarga qo'shib yuborishning mumkin bo'lgan variantlarini texnik-iqtisodiy baholash bo'yicha dasturiy ta'minotni yaratishga ehtiyoj sezildi.

3. Xulosa

Vagonlar oqimining nomutanosibligini inobatga olgan holda, vagonlar guruhini yo'l-yo'lakay poyezdlarga qo'shib yuborishning amaliy natijalari joriy etilishi mumkin, lekin ularni qo'shib yuborishda texnik-iqtisodiy ko'rsatkichlariga alohida e'tibor qaratish lozim. Yuqoridagilarni inobatga olgan holda, vagonlar oqimini tashkil etishning iqtisodiy samaradorligini aniqlash uchun *Delphi* dasturlash tilida "O'zgaruvchan grafik sharoitida vagon oqimlarini tashkil etishning samarali variantini tanlash" nomli dasturiy ta'minot ishlab chiqildi. Ushbu dasturiy ta'minotning ishchi oynasi 3-rasmda keltirilgan.



3-rasm. "O'zgaruvchan grafik sharoitida vagon oqimlarini tashkil etishning samarali variantini tanlash" nomli EHM uchun dasturining ishchi oynasi

Mazkur dasturiy ta'minot poyezdlarni jo'natishda vagon oqimlari harakatining samarali variantini poyezdlar harakati bilan bog'liq bo'lgan quyidagi sarf-xarajatlarni hisobga olgan holda tanlash uchun mo'ljallangan:

- tarkiblarning yig'ilish jarayoni bilan bog'liq sarf-xarajatlar, so'm;

❖ saralash parkidan jo‘natish parkiga tarkibni o‘tkazish amallari hamda tuzish bo‘yicha amallar bilan bog‘liq sarf-xarajatlar, so‘m;

❖ poyezdni jo‘natish (ko‘rikdan o‘tkazish, jo‘natishdagi kutish) amallari bilan bog‘liq sarf-xarajatlar, so‘m;

❖ uchastkalarda poyezdlarning harakati bilan bog‘liq sarf-xarajatlar, so‘m;

❖ poyezdni belgilangan stansiyaga qabul qilish bo‘yicha amallar bilan bog‘liq xarajatlar, so‘m;

❖ tarkiblarning tarqatilishi bo‘yicha amallar bilan bog‘liq sarf-xarajatlar, so‘m.

Ishlab chiqilgan matematik model va dasturiy ta’minot temir yo‘llar ishida samarasiz yo‘nalishlarni o‘z vaqtida bekor qilinishini ta’minlash, samaralilarini esa tezkor aniqlash va ularni joriy etish imkonini beradi.

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