

## Modeliranje ponavljajoče se prevozne poti cestnega vozila

### Modelling of the Repeated Transport Route of a Road Vehicle

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*V prevoznem prometu se uporabljajo različni modeli organizacije gibanja cestnih tovornih vozil po prevozni poti. Ti modeli so predvsem odvisni od karakteristik blagovnih tokov, prevoznih razdalj, karakteristik tovora, lokacije avtomobilske baze, uporabljenih cestnih vozil idr.*

*Učinkovito organiziranje gibanja cestnih tovornih vozil pri opravljanju prevoznih storitev zagotavlja največji prevozni učinek z najmanjšimi prevoznimi stroški. Pri zagotavljanju največjega prevoznega učinka med pomembnejše postopke spada izbira optimalne prevozne poti.*

*Glede na različne modele prevoznih poti v praksi kakršne so: ponavljajoče se prevozne poti, radialne, ciklične, zbirne in razvozne, se bodo v tem delu analizirali, kot najaktualnejši modeli ponavljajoče se prevozne poti z različnimi variantami lokacije avtomobilske baze.*

*Modeliranje ponavljajoče se prevozne poti omogoča ugotavljanje potrebnih kazalcev za optimiranje načrtovanja in organizacije gibanja cestnega tovornega vozila pri opravljanju prevozne storitve, analizo prevoznega učinka in na splošno učinkovitejše gospodarjenje na področju njihove uporabe.*

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**(Ključne besede: modeliranje, poti transportne, modeli poti, vozila cestna)**

*In the transporting process different models for the organisation of movement of road cargo vehicles are used on the transportation route. These models depend on the route, transportation distances, the characteristics of the cargo, autobase location, transportation means used, etc.*

*The efficient organisation of the movement of road cargo vehicles in transporting goods ensures the maximum transportation efficiency with the minimum transport costs and demands the selection of the best transportation route.*

*There are different models for the transportation route, these include the repeated transportation route, radial, cyclic, collective or distributive. In this paper the repeated transportation route with different variants of autobase location will be analysed*

*The modelling of the repeated transportation route ensures the necessary parameters for optimising the planning and movement of a road cargo vehicle in the transportation process, an analysis of transportation efficiency and more efficiency in general.*

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**(Keywords: modelling, transportation routes, route models, road vehicles)**

#### 0 UVOD

Ponavljajoča se prevozna pot vsebuje tako gibanje cestnega vozila pri opravljanju prevoznega prometa, da se posamezne vožnje ponavljajo po isti prevozni poti med dvema točkama. Pri tem imamo lahko naslednji dve osnovni obliki:

- s prevozom tovora samo v eni smeri,
- s prevozom tovora v obeh smereh.

Ti obliki prevoznih poti se najpogosteje pojavljata na krajših razdaljah do 100 km pri opravljanju prevoznih storitev s cestnimi vozili na področju gradbeništva, gozdarstva, kmetijstva, razvozu

#### 0 INTRODUCTION

The repeated transportation route is the repeated movement of a road vehicle which is transporting goods over the same route between two points.

There are two forms:

- transportation of goods in one direction only,
- transportation of goods in both directions.

These models of transportation routes are often used for distances up to 100 km for road vehicles involved in civil engineering, forestry, farming, and supplying people with goods. Transportation in

različnega blaga pri oskrbovanju prebivalcev ipd. Oblika prevozne poti s prevozom tovora samo v eni smeri, čeprav se pri nas še dosti uporablja, lahko zagotovi samo najmanjše in tudi negativne gospodarne učinke [1].

V praksi se zelo pogosto opravlja tudi ponavljajoča se prevozna pot z delno izkoriščenostjo kilometrine, ki se zaradi zapletenosti modeliranja velikega števila različic v tem prispevku ne bo obravnavala.

Za določanje kazalcev prevozne storitve cestnega vozila, odvisno od oblike ponavljajoče se prevozne poti, je posebej pomembna lokacija avtomobilske baze, iz katere vozilo odpelje na opravljanje prevozne naloge in v katero se vrača po opravljeni nalogi, kar je posebej pomembno pri obliki prevozne poti s prevozom tovora samo v eni smeri.

Glede na prevozno pot razlikujemo naslednje tri značilne lokacije avtomobilskih baz:

- zunaj prevozne poti med dvema terminaloma,
- zunaj prevozne poti in ni med dvema terminaloma,
- nekje na prevozni poti.

Od lege avtomobilske baze glede na prevozno pot je odvisno, ali bo cestno vozilo porabilo ničti čas za ničto kilometrino, ali pa bo ta vključen v vozni krog.

Optimiranje gibanja cestnega vozila pri opravljanju prevozne storitve z modeliranjem ponavljajoče se prevozne poti zagotavlja največji prevozni učinek z najmanjšimi prevoznimi stroški.

## 1 MODEL PONAVLJAJOČE SE PREVOZNE POTI S PREVOZOM BLAGA SAMO V ENI SMERI

Ponavljajoča se prevozna pot s prevozom tovora samo v eni smeri se bo v tem delu analizirala predvsem z vidika lokacije avtomobilske baze.

### 1.1 Model prevozne poti s povratno prazno vožnjo in avtobazo zunaj prevozne poti med dvema terminaloma

Ponavljajoča se prevozna pot s povratno prazno vožnjo z avtomobilsko bazo zunaj prevozne poti med terminaloma A in B je najmanj sprejemljiva prevozna pot, saj je med delom cestnega vozila v enem ciklu samo ena vožnja s tovorom (sl. 1) [7].

V tem primeru veljajo obrazci za [1]:

- čas kroženja cestnega vozila:

$$t_c = \frac{2 \cdot L_{stx}}{V_p} + t_{nr} = \frac{2 \cdot L_{stx} + t_{nr} \cdot V_p}{V_p} \quad (1).$$

Možno število krogov cestnega vozila je odvisno od časa dela vozila na prevozni poti oziroma od časa za opravljanje kroga:

one direction, although common in Slovenia, results in low or negative economic effects [1].

The repeated transportation route, with partial utilisation of kilometrage will not be analysed in this paper because of the modelling complexity resulting from a large number of variants.

In defining the work parameters of the transportation process of a road vehicle, depending on the form of repeated transportation route, the location of the autobase is relevant. In other words, where the vehicle begins its travel and where it returns after the completion of the operation. This is especially important for the transportation of cargo in one direction only.

There are three typical locations for an autobase:

- outside the transportation route, between the two terminal stations;
- outside the transportation route, but not between the two terminal stations;
- somewhere on the transportation route.

The location of the autobase determines whether the vehicle will spend zero time for zero kilometrage, or this will be included in the cycle of the vehicle.

The optimisation of road vehicle movement with the help of modelling of the repeated transportation route ensures the maximum transportation efficiency with minimum transportation costs.

## 1 MODELS OF THE REPEATED TRANSPORTATION ROUTE WITH THE TRANSPORTATION OF GOODS IN ONLY ONE DIRECTION

The repeated transportation route with the transportation of goods in only one direction can be analysed with respect to the location of the autobase.

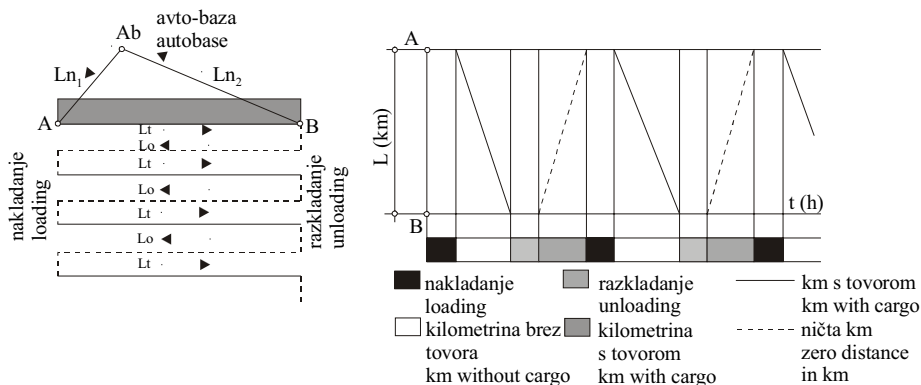
### 1.1 A model of the transportation route with the returning vehicle empty and with the autobase outside the transportation route, between two terminal stations

The repeated transportation route with the returning vehicle empty and the location of the autobase outside the transportation route, between the terminal stations A and B, is the least acceptable because the work of the road vehicle in one cycle is one journey with cargo (Fig. 1) [7].

Follows the formula for [1]:

- the time of the vehicle cycle:

The number of cycles depends on the time of the vehicle's work completed on the transportation route or on the time of carrying out the cycle:



Sl. 1. Shematski model ponavljajoče se prevozne poti s povratno prazno vožnjo in avtomobilsko bazo med dvema terminaloma

Fig. 1. Schematic model of the repeated transportation route with the returning vehicle empty and the autobase between the two terminal stations.

- čas za vožnjo po ničti prevozni poti:

- travel time at zero distance travelled:

$$H_0 = \frac{L_n}{V_p} = \frac{L_{n1} + L_{n2}}{V_p} \quad (2),$$

kjer so:

where:

- čas cikla vozila,
- srednja razdalja ene vožnje s tovorom,
- prometna hitrost cestnega vozila,
- čas nakladanja in razkladanja cestnega vozila,
- čas vožnje po ničti prevozni poti,
- ničta prevozna pot v enem dnevu,
- ničta prevozna pot od avtomobilske baze do nakladalnega mesta,
- ničta prevozna pot od razkladalnega mesta do avtomobilske baze.

- $t_c$  h the time of the vehicle cycle,
- $L_{stx}$  km average distance of one loaded vehicle journey,
- $V_p$  km/h traffic speed,
- $t_{nr}$  h time of loading and unloading,
- $H_n$  h travel time at zero distance travelled,
- $L_n$  km zero distance travelled per day,
- $L_{n1}$  km zero distance travelled from autobase to loading point,
- $L_{n2}$  km zero distance travelled from unloading point to autobase.

- čas dela cestnega vozila na prevozni poti:

- the time of vehicle's work performed on the transportation route:

$$H_n = H_d - \frac{L_n}{V_p} \quad \text{and} \quad (3),$$

ter je

$$H_n = Z_0 \cdot t_c + \left( \frac{L_{stx}}{V_p} + t_{nr} \right)$$

kjer so:

where:

- $H_d$  - čas dela cestnega vozila na prevozni poti,
- $Z_0$  - število voženj vozila v enem dnevu,
- $\left( \frac{L_{stx}}{V_p} + t_{nr} \right)$  prosta vožnja po krogih, opravljenih na koncu delovnega časa vozila,

- $H_d$  - the time of vehicle's work performed on the transportation route,
- $Z_0$  - number of vehicle journeys in one working day,
- $\left( \frac{L_{stx}}{V_p} + t_{nr} \right)$  light travel per cycle carried out at the end of the vehicle's operating time

$$H_n = Z_0 \cdot t_c + \left( \frac{L_{stx} + t_{nr} \cdot V_p}{V_p} \right) = \frac{Z_0 \cdot t_c \cdot V_p + (L_{stx} + t_{nr} \cdot V_p)}{V_p} \quad (4),$$

ker je

because

$$H_n \cdot V_p = Z_0 \cdot t_c \cdot V_p + (L_{stx} + t_{nr} \cdot V_p)$$

iz tega izhaja, da je:

it follows that:

- mogoče število krogov vozila v delovnem dnevu:

- possible number of vehicle cycles in one working day:

$$Z_0 = \frac{H_n \cdot V_p - (L_{stx} + t_{nr} \cdot V_p)}{t_c \cdot V_p} = \frac{H_n \cdot V_p - (L_{stx} + t_{nr} \cdot V_p)}{\left( \frac{2L_{stx} + t_{nr} \cdot V_p}{V_p} \right) \cdot V_p} = \frac{H_n \cdot V_p - (L_{stx} + t_{nr} \cdot V_p)}{2L_{stx} + t_{nr} \cdot V_p} \quad (5),$$

- skupna kilometrina prevozne poti v enem delovnem dnevu vozila: - the total kilometrage of the transportation route in one working day:

$$L = 2L_{stx} \cdot Z_0 + L_{stx} + L_{n1} + L_{n2} = L_{stx}(2Z_0 + 1) + L_{n1} + L_{n2} = L_{stx}(2Z_0 + 1) + L_n \quad (6),$$

- kilometrina s tovorom v enem delovnem dnevu: - kilometrage of a loaded vehicle in one working day:

$$L_t = L_{stx} \cdot Z_x = L_{stx} \cdot Z_0 + L_{stx} = L_{stx}(Z_0 + 1) \quad (7),$$

- kilometrina brez tovora v enem delovnem dnevu: - kilometrage of a light vehicle in one working day:

$$L_p = L_{stx} \cdot Z_0 \quad (8),$$

- količina prevoženega blaga in prevozna storitev v enem delovnem dnevu: - the quantity of goods carried and the transportation work completed in one working day:

$$Q = q \cdot \gamma \cdot Z_x \quad (9),$$

ter and

$$S = q \cdot \gamma \cdot Z_x \cdot L_{stx} \quad (10),$$

- koeficient izkoriščenosti kilometrine: - coefficient of the kilometrage utilisation:

$$\beta = \frac{L_t}{L} = \frac{L_{stx}(Z_0 + 1)}{L_{stx}(2Z_0 + 1) + L_n} \quad (11),$$

- koeficient ničte kilometrine: - coefficient at zero kilometrage:

$$\omega = \frac{L_p}{L} = \frac{L_n}{L_{stx}(2Z_0 + 1) + L_n} \quad (12),$$

kjer so:

količina prevoženega blaga,  
prevozna storitev v enem delovnem dnevu,

koristna nosilnost cestnega vozila,  
koeficient statične izkoriščenosti nosilnosti  
cestnega vozila,

število voženj s tovorom,  
koeficient izkoriščenosti kilometrine,

koeficient ničte kilometrine,  
kilometrino prevozne poti brez tovora v enem  
delovnem dnevu vozila,

skupna kilometrina prevozne poti v enem  
delovnem dnevu vozila,

kilometrino prevozne poti s tovorom v enem  
delovnem dnevu vozila.

where:

Q t the quantity of goods carried,  
S tkm transportation work completed in one working day,

q t useful carrying capacity of a vehicle,  
 $\gamma$  coefficient of the static utilisation of the vehicle's carrying capacity,

$Z_x$  number of journeys with cargo,  
 $\beta$  coefficient of kilometrage utilisation,

$\omega$  coefficient of zero kilometrage,

$L_p$  km kilometrage of transportation route without cargo in one working day of the vehicle,

L km the total kilometrage of transportation route in one working day,

$L_t$  km kilometrage of loaded vehicle in one working day.

## 1.2 Model ponavljajoče se prevozne poti s povratno prazno vožnjo in avtomobilsko bazo zunaj prevozne poti in terminalov

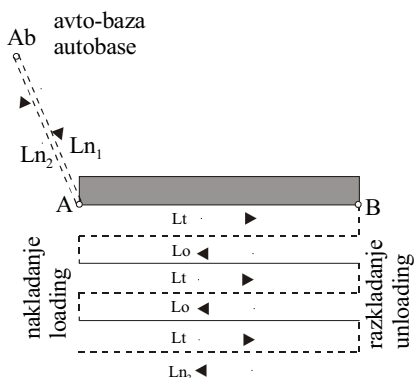
Ponavljajoča se prevozna pot s povratno vožnjo in avtomobilsko bazo zunaj prevozne poti in terminalov, kakor v prejšnjem primeru, v zadnji vožnji

## 1.2 A model of the repeated transportation route with the returning vehicle empty and the autobase outside the transportation route and terminal stations

A repeated transportation route with the returning vehicle empty and the autobase outside the transportation route and terminal stations, as in the previous case,

s tovorom ob koncu delovnega časa vozilo ne opravi polnega kroga, saj pri vračanju iz točke nakladanja (B) opravi ničto kilometrino na razdalji B-A-Ab (sl. 2)[2].

during the last loaded travel at the end of the working time the vehicle does not complete the whole cycle because returning from the loading point (B) it performs zero kilometrage in the distance B-A-Ab (figure 2.) [2].



Sl. 2. Shematski model ponavljajoče se prevozne poti s povratno prazno vožnjo in avtomobilsko bazo zunaj prevozne poti in terminov

Fig. 2. Schematic model of the repeated transportation route with the returning vehicle empty and the autobase outside the transportation route and terminal stations

Po tem modelu so naslednji obrazci za [7]:

- čas kroga vozila: po obrazcu (1),
- mogoče število krogov vozila v delovnem dnevu: po obrazcu (5),
- ničto kilometrino vozila v delovnem dnevu:

Here the formulae are as follows [7]:

- Time of a vehicle's cycle: according to formula (1),
- Possible number of cycles per working day: according to formula (5),
- Zero kilometrage per working day:

$$L_n = L_{n1} + L_{n2} = L_{n1} + (L_{n1} + L_{stx}) = 2L_{n1} + L_{stx} \quad (13),$$

- kilometrino vozila s tovorom v delovnem dnevu: po obrazcu (7),
- kilometrino brez tovara v delovnem dnevu: po obrazcu (8),
- skupno kilometrino vozila v delovnem dnevu:

- Loaded kilometrage per working day: according to formula (7),
- Light kilometrage per working day: according to formula (8),
- Total kilometrage per working day:

$$L = 2L_{stx} \cdot Z_0 + L_{stx} + 2L_{n1} + L_{stx} = 2L_{stx} \cdot Z_0 + 2L_{stx} + 2L_{n1} = 2[L_{stx}(Z_0 + 1) + L_{n1}] = 2(L_{stx} \cdot Z_x + L_{n1}) \quad (14),$$

- dnevno količino prepeljanega tovara Q po obrazcu (9) in prevozne storitve cestnega vozila v enem dnevu S po obrazcu (10),
- koeficient izkoriščenosti kilometrine v delovnem dnevu vozila:

- Daily quantity of cargo carried Q is acquired from formula (9) and transportation work completed S from formula (10):
- Coefficient of kilometrage utilisation per working day:

$$\beta = \frac{L_t}{L} = \frac{L_{stx} \cdot Z_x}{2(L_{stx} \cdot Z_x + L_{n1})} \quad (15),$$

- koeficient ničte kilometrine v delovnem dnevu vozila:

- Coefficient of zero kilometrage per working day:

$$\omega = \frac{L_n}{L} = \frac{2L_{n1} + L_{stx}}{2(L_{stx} \cdot Z_x + L_{n1})} \quad (16).$$

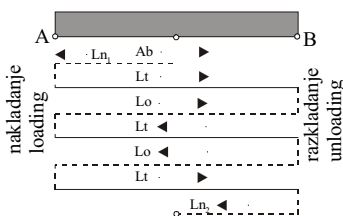
### 1.3. Model prevozne poti s povratno prazno vožnjo in avtomobilsko bazo na prevozni poti med terminali

### 1.3 A model of the transportation route with the returning vehicle empty and with the autobase on the transportation route, between terminals

V primeru, ko je avtomobilska baza na prevozni poti med terminoma A in B (sl. 3), se prevozni proces lahko opravlja na dva glavna načina, in sicer ko je:

In the case in which the autobase is on the transportation route, between two terminal stations, A and B (figure 3), the transportation process may be performed in two ways, i.e.:

ter  $Z_0 = Z_x$  and  $Z_x = Z_0 + 1$



Sl. 3. Shematski model ponavljajoče se prevozne poti s povratno prazno vožnjo in avtomobilsko bazo na prevozni poti med terminali  
 Fig. 3. Schematic model of the transportation route with the returning vehicle empty and with the autobase on the transportation route, between terminals

V prvem primeru se za opravljanje ničte kilometrine (Ab-A) na začetku delovnega časa vozila in (B-Ab) na koncu delovnega časa od delovnega časa ne odšteje ničti čas, saj je ničta kilometrina na prevozni poti ter se ničti čas šteje v čas kroga vozila.

Tu veljajo obrazci za:

- čas dela cestnega vozila za opravljanje kroga:

$$H_n = H_d \quad (17),$$

- čas trajanja kroga vozila: po obrazcu (1),  
 - mogoče število ciklov vozila v delovnem dnevu: po obrazcu (5),  
 - ničto kilometrino vozila v delovnem dnevu:

$$L_n = L_{n1} + L_{n2} = L_{stx} \quad (18),$$

- kilometrino vozila s tovorom v delovnem dnevu:

$$L_t = L_{stx} \cdot Z_0 = L_{stx} \cdot Z_x \quad (19),$$

- kilometrino vozila bez tovora v delovnem dnevu:

$$L_p = L_{stx} (Z_0 - 1) \quad (20),$$

- skupno kilometrino v delovnem dnevu:

$$L = L_{stx} \cdot Z_0 + L_{stx} (Z_0 - 1) + L_{stx} = 2L_{stx} \cdot Z_0 = 2L_{stx} \cdot Z_x \quad (21),$$

- koeficient izkoriščenosti kilometrine v delovnem dnevu:

$$\beta = \frac{L_t}{L} = \frac{L_{stx} \cdot Z_x}{2L_{stx} \cdot Z_x} = 0,5 \quad (22),$$

- koeficient ničte kilometrine v delovnem dnevu:

$$\omega = \frac{L_n}{L} = \frac{L_{stx}}{2L_{stx} \cdot Z_x} = \frac{1}{2Z_x} \quad (23),$$

In the first case the zero kilometrage performed (Ab-A) at the beginning of the vehicle's operation time and (B-Ab) at the end of the vehicle's operation time is not subtracted from the operation time as the zero kilometrage takes place on the transportation route and the zero time is included in the vehicle' cycle.

Here are the formulas for:

- vehicle's operation time for the performance of a cycle:

- duration of a vehicle's cycle: according to formula (1),  
 - number of cycles possible per working day: according to formula (5),  
 - vehicle's zero kilometrage per working day:

- loaded vehicle's kilometrage per working day:

- light vehicle's kilometrage per working day:

- total kilometrage per working day:

- coefficient of kilometrage utilisation per working day:

- coefficient of zero kilometrage per working day:

- dnevno količino prepeljanega tovora Q po obrazcu (9) in prevozne storitve cestnega vozila v enem dnevu S po obrazcu (10).

V primeru, ko je  $Z_x = Z_0 + 1$ , se ničti čas za opravljanje ničte kilometrine odšteje od delovnega časa vozila, saj ta ne opravlja polnega kroga, temveč poleg določenega števila krogov obstaja tudi ena prosta vožnja samo v eni smeri.

V tem primeru veljajo obrazci za:

- čas za opravljanje kroga vozila oziroma delo na prevoznih poti:

$$H_n = H_d - \frac{L_{n1} + L_{n2}}{V_p} = H_d - \frac{L_{stx}}{V_p} \quad (24),$$

- čas trajanja kroga: po obrazcu (1),
- mogoče število krogov v delovnem dnevu: po obrazcu (5),
- ničta kilometrina vozila v delovnem dnevu: po obrazcu (18),
- kilometrina vozila s tovorom v delovnem dnevu: po obrazcu (19),
- kilometrina vozila brez tovora v delovnem dnevu: po obrazcu (8),
- skupna kilometrina v delovnem dnevu:

- amount of cargo carried per working day in Q[t] is acquired from formula (9) and transportation work completed S[tkm] from formula (10).

For the case when  $Z_x = Z_0 + 1$  the zero time for the performance of zero kilometrage is subtracted from the vehicle's operation time as the latter does not complete the full cycle but in addition to the number of cycles there is one empty journey.

For this case there is a formula for:

- time for the completion of the vehicle's cycle or work performed on the transportation route:

- duration of cycle: according to formula (1),
- number of cycles per working day: according to formula (5),
- zero kilometrage per working day: according to formula (18),
- loaded vehicle's kilometrage per working day: according to formula (19),
- light vehicle's kilometrage per working day: according to formula (8),
- total kilometrage per working day:

$$L = L_{stx}(Z_0 + 1) + L_{stx} \cdot Z_0 + L_{stx} = 2L_{stx}(Z_0 + 1) = 2L_{stx} \cdot Z_x \quad (25).$$

Koeficient izkoriščenosti kilometrine v delovnem dnevu se dobi po obrazcu (22), koeficient ničte kilometrine v delovnem dnevu po obrazcu (23), dnevna količina prevoženega blaga po obrazcu (9) in dnevne transportne storitve po obrazcu (10).

The formula for the coefficient of the kilometrage utilisation per working day is (22), the formula for the coefficient of zero kilometrage per working day is (23), the formula for the amount of cargo carried per working day is (9) and the formula for the transportation work is (10).

## 2 MODEL PONAVLJAJOČE SE PREVOZNE POTI S PREVOZOM V OBEH SMEREH

Pri ponavljajoči se prevoznih poti s prevozom tovora v obeh smereh bo cestno vozilo v vsakem krogu opravilo dve vožnji s tovorom. V tem primeru za število voženj v krogu ni pomembno, ali se prevoz začne v terminalu A ali B.

Ne glede na lokacijo avtomobilske baze bo ničta kilometrina enaka dvojni razdalji od avtobaze do mesta, kjer se opravlja prvo nakladanje vozila (sl. 4)[1].

V tem primeru veljajo obrazci za:

- čas trajanja kroga vozila:

$$t_c = \frac{2L_{stx}}{V_p} + 2t_{nr} = \frac{2L_{stx} + 2t_{nr} \cdot V_p}{V_p} = \frac{2(L_{stx} + t_{nr} \cdot V_p)}{V_p} \quad (26),$$

- mogoče število krogov vozila v delovnem dnevu:

- Number of cycles possible per working day:

$$Z_0 = \frac{H_d - H_n}{t_c} = \frac{H_d - \frac{2L_{n1}}{V_p}}{t_c} = \frac{H_d \cdot V_p - 2L_{n1}}{t_c \cdot V_p} = \frac{H_d \cdot V_p - 2L_{n1}}{2(L_{stx} + t_{nr} \cdot V_p)} = \frac{\frac{H_d \cdot V_p}{2} - L_{n1}}{L_{stx} + t_{nr} \cdot V_p} \quad (27),$$

- ničta kilometrina v delovnem dnevu:

- zero kilometrage per working day:

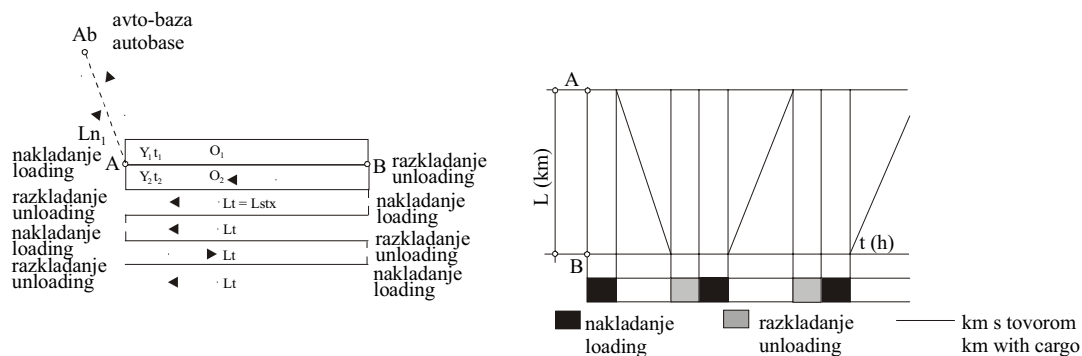
## 2 MODEL OF THE REPEATED TRANSPORTATION ROUTE WITH LOADED RUNNING IN BOTH DIRECTIONS

According to the model of the repeated transportation route with loaded running in both directions the road vehicle will make two journeys with cargo in one cycle. In this case it is irrelevant if the travel begins at terminal station A or B.

Regarding the location of the autobase the zero kilometrage will be equal to double the distance from the autobase to the first loading point (figure 4) [1].

Here the formulas are for:

- The duration of a vehicle's cycle:



Sl. 4. Shematski model ponavljajoče se prevozne poti s prevozom v obeh smereh  
 Fig. 4. Schematic model of the repeated transportation route and the loaded travel in both directions

$$L_n = 2L_{n1} \quad (28),$$

- kilometrina s tovorom v delovnem dnevu: - loaded vehicle's kilometrage per working day:

$$L_t = L_{stx} \cdot Z_x = 2L_{stx} \cdot Z_0 \quad (29),$$

- kilometrina bez tovora v delovnem dnevu: - light vehicle's kilometrage per working day:

$$L_p = 0 \quad (30),$$

- skupna kilometrina v delovnem dnevu: - total kilometrage per working day:

$$AL = 2L_{stx} \cdot Z_0 + L_n = L_{stx} \cdot Z_x + 2L_{n1} \quad (31),$$

- koeficient izkoriščenosti kilometrine: - coefficient of the kilometrage utilisation:

$$\beta = \frac{L_t}{L} = \frac{L_{stx} \cdot Z_x}{L_{stx} \cdot Z_x + 2L_{n1}} \quad (32),$$

- koeficient ničte kilometrine: - coefficient of the zero kilometrage:

$$\omega = \frac{L_n}{L} = \frac{2L_{n1}}{2L_{stx} \cdot Z_0 + 2L_{n1}} = \frac{L_n}{L_{stx} \cdot Z_0 + L_n} \quad (33),$$

- količina prepeljanega tovora v delovnem dnevu Q in transportnega dela v dnevu S: - the amount of cargo carried per working day Q and the transportation work performed in S:

$$Q = q(\gamma_1 + \gamma_2)Z_0 = \frac{q \cdot Z_x(\gamma_1 + \gamma_2)}{2} \quad (34),$$

ter and

$$S = \frac{q \cdot L_{stx} \cdot Z_x(\gamma_1 + \gamma_2)}{2} \quad (35),$$

kjer sta:

$\gamma_1$  - koeficient statične izkoriščenosti nosilnosti cestnega vozila v prvi polovici kroga,  
 $\gamma_2$  - koeficient statične izkoriščenosti nosilnosti cestnega vozila v drugi polovici kroga.

where:

$\gamma_1$ , coefficient of static utilisation capacity of the road vehicle in the first half of the cycle,  
 $\gamma_2$ , coefficient of static utilisation capacity of the road vehicle in the second half of the cycle.

### 3 SKLEPI

### 3 CONCLUSIONS

Modeliranje prevozne poti v prometu opravljeno s poudarkom na ponavljajoči se prevozni poti s prevozom tovora samo v eni smeri in s prevozom tovora v obeh smereh.

Transportation route modelling in the process of goods transportation is carried out with the stress on the repeated transportation route with cargo transportation in one direction and in both directions.



Glede na očitne probleme v praksi se modelirane različice prevozne poti za primere, ko je avtomobilska baza zunaj prevozne poti in terminalov, zunaj prevozne poti med terminali ter na prevozni poti med terminali.

Analizirani modeli omogočajo optimiranje, načrtovanje in organiziranje gibanja cestnih tovornih vozil pri opravljanju prevozne storitve, analizo prevoznega učinka posameznih cestnih tovornih vozil in na splošno učinkoviteje gospodarjenje na področju njihove uporabe.

Praktična vrednost tega prispevka je predvsem v matematičnih modelih, ki omogočajo ugotavljanje in analizo:

- časa trajanja kroga vožnje cestnega vozila,
- števila krogov cestnega vozila v delovnem dnevu vozila,
- potrebnega časa za vožnjo po t.i. niči prevozni poti,
- časa dela cestnega vozila na prevozni poti,
- skupne kilometrine prevozne poti v delovnem dnevu vozila,
- ničte kilometrine cestnega vozila v delovnem dnevu,
- kilometrine s tovorom v delovnem dnevu vozila,
- kilometrine brez tovora v delovnem dnevu vozila,
- količine prevoženega tovora,
- prevozno storitev cestnega vozila v delovnem dnevu,
- koeficient izkoriščenosti kilometrine v delovnem dnevu vozila,
- koeficient ničte kilometrine v delovnem dnevu vozila itn.

Taking into account the problems in practice, modelling variants of the transportation route are for cases like autobase outside the transportation route and terminal stations, autobase outside the transportation route between the terminal stations and autobase on the transportation route between the terminal stations.

The analysed models enable the optimising, planning and movement organisation of road cargo vehicles in the transportation process, the analysis of the transportation efficiency of the individual road cargo vehicles and in general more efficient exploitation.

The practical value of this paper is the mathematical models that enable us to establish and analyse:

- the time of road vehicle cycle,
- number of road vehicle cycles per working day,
- travel time on the zero transportation route,
- operation time of road vehicle on the transportation route,
- total kilometrage on the transportation route per working day,
- zero kilometrage of road vehicle per working day,
- loaded kilometrage per working day,
- light kilometrage per working day,
- amount of goods transported,
- transportation work of road vehicle completed in one working day,
- coefficient of kilometrage utilisation per working day of the road vehicle,
- coefficient of zero kilometrage per working day of the road vehicle etc.

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