The International Journal of
TRANSPORT & LOGISTICS
Međunarodni časopis
TRANSPORT I LOGISTIKA

UDC: 65.012.23:355.4

LOCATION OF THE PLANT FOR ELV TIRES TREATMENT

LOCIRANJE OBJEKATA ZA TRETMAN GUMA IZ ELV VOZILA

Svetlana DABIĆ, Momčilo MILJUŠ
Faculty of Transport and Traffic Engineering, Belgrade, Serbia

Abstract: *After numerous demands during the 1980's on cleanness of air and water, as well as other demands on ecology, the most important forthcoming topic is the reduction and economical use of resources or the reduction of waste. The cycle of resources is the motto; the aim is to produce, use for some time and at the end, with eventual interventions, put in usage with the almost original characteristics of original resources. Therefore, initiation of recycling in industrial production is a directive. In modern business, industrial manufacture, as well as any other economy, could not exist without logistics. The role of logistics in industrial manufacture becomes more important every day. Considering the presence of logistics in all parts of modern industry and services, logistics in industry was reasonably given specific treatment and is known as industrial logistics.*

The emphasis of this thesis is the part of industrial logistics that treats used products. Industrial logistics of used products is a complex topic, provided that products don't end like waste, is still insufficient researched area, with numerous solutions and possibilities for proposals of new and rationalization of existing solutions. The aim of the work is to describe present state and analyze the possibilities to reuse old vehicles and its parts at the end of their lifetime, from the logistical point of view (tires). Special attention was given to the possibility of using models to solve the problem of optimal locations for treating particular parts of ELV vehicles, including route definition of vehicles collecting the parts.

Key words: *logistics, industrial logistics, treatment of used vehicles, ELV vehicles*

Apstrakt: *Posle brojnih zahteva 80-ih godina prošlog veka o čistoći vode i vazduha, kao i drugih zahteva iz oblasti ekologije, danas najvažnija tema postaje smanjenje korišćenja sirovina i njihova štednja, odnosno redukcija otpadnih materijala. Moto je kruženje materijala, odnosno cilj je usmeren na to da se ono što se proizvede i određeno vreme koristi, na kraju svog životnog veka, uz eventualne intervencije, ponovo vrati u upotrebu i to sa osobinama koje se gotovo ni malo ne razlikuju od karakteristika originalnih, izvornih sirovina. Iz tog razloga, direktiva je uvođenje reciklaže u proces industrijske proizvodnje. U savremenom poslovanju, sama industrijska proizvodnja, kao ni bilo koja druga privredna delatnost, ne bi se ni mogla zamisliti bez odgovarajuće logističke podrške. Mesto i uloga logistike u industrijskoj proizvodnji iz dana u dan su sve značajniji i veći. Imajući u vidu sveprisutnost logistike u savremenom poslovanju u svim granama privrednih i uslužnih delatnosti, logistika u industriji sasvim opravdano je dobila specifičan tretman i kao takva poznata je pod nazivom industrijska logistika.*

U ovom radu akcenat je stavljen na onaj deo industrijske logistike koji se odnosi na tretman korišćenih proizvoda. Sam pristup industrijskoj logistici korišćenih proizvoda, pod uslovom da isti ne završavaju na deponijama, je veoma kompleksan i još uvek je nedovoljno istraženo područje, sa velikim brojem problema i mogućnosti za predlog novih i racionalizaciju postojećih rešenja. Cilj ovog rada je usmeren na to da se, sa logističkog aspekta, opišu postojeće i analiziraju mogućnosti za ponovnu upotrebu korišćenih vozila i njihovih delova koji su na kraju svog životnog ciklusa (gume). Pri tome, posebna pažnja je posvećena mogućnostima primene modela za rešavanje problema optimizacije izbora lokacije objekta za tretman određenih vrsta delova iz ELV vozila, uključujući i rutiranje vozila koja sakupljaju navedenu vrstu otpada.

Ključne reči: *logistika, industrijska logistika, tretman korišćenih vozila, ELV vozila*

1 INTRODUCTION

When the treatment of used products is analyzed, it is obvious that logistics is the base of success and profitability of this process. Also it is proved, that as much higher the value of the product is, so is the higher role of logistics. Also having in the mind the development of technologies of industrial production, different analyzes shows that the highest development is achieved in automotive manufacturing (End of Life Vehicles).

Nowadays, the very known fact is that the road vehicles have really great share of undesirable influence on environment. There are more than 600 million of vehicles "circling" in the world, presuming that at the end of decade should be over 1.000 millions of them. More developed countries are accepting serious concept for solving the problem at the end of their exploitation *(Suterland, (8))*. The vehicles must be produced, exploited, what has influence on the environment. Expectations that all what should be produced has to be accepted on environmental aspects demands that the use of new materials should be analyzed from the initial developing phase of any product. The most important characteristics of new materials are durability and reliability, but also the possibility of their recycling and involving in the new (raw) materials cycle, as it is shown on the Figure 1 *(Maslarić, Cakić, (4))*.

1 UVOD

Kada je u pitanju tretman korišćenih proizvoda, logistika predstavlja osnov uspešnosti i profitabilnosti. Pokazalo se da je njen značaj utoliko veći, što je veća vrednost proizvoda na kraju radnog veka. Imajući u vidu i brzinu ekspanzije u oblasti industrijske proizvodnje, na osnovu iskustvenih analiza, može se uočiti da je na tom području najveći razvoj ostvaren u automobilskoj industriji (End of Life Vehicle).

Danas je u javnosti raširena predstava o značajnom udelu vozila u ekološkom opterećenju životne sredine. Trenutno u svetu „kruži" više od 600 miliona putničkih vozila, a do kraja decenije predviđa se da će ih biti preko milijardu. Razvijene zemlje usvajaju ozbiljan koncept za rešavanje problema koji nastaju po završetku životnog veka vozila *(Suterland, (8))*. Vozila se moraju proizvoditi, koristiti, što se dobrim delom tiče i okruženja. Očekivanja da sve što se napravi bude i ekološki prihvatljivo, zahteva da se u početnoj fazi razvoja proizvoda razmotri korišćenje novih materijala. Odlučujući faktori su trajnost i pouzdanost (novih) materijala, kao i mogućnost njihovog ponovnog ulaska u proces kruženja materije (sirovina), što je prikazano na slici 1. *(Maslarić, Cakić, (4))*.

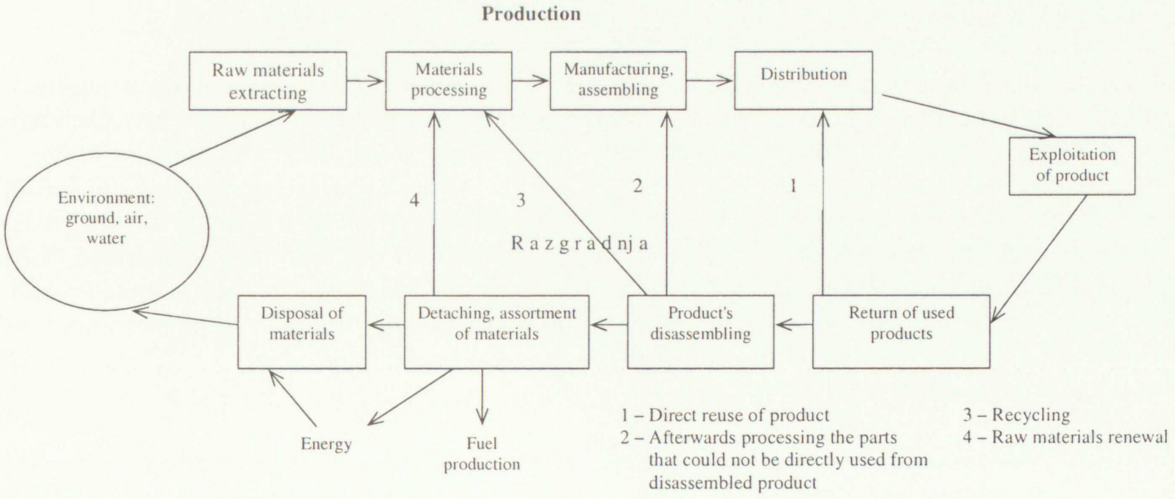

Figure 1 Raw materials cycle in supply chain (Maslarić, Cakić, (4))
slika 1 Kruženje sirovina u lancu snabdevanja (Maslarić, Cakić, (4))

The motive to be engaged in this field of researching and development is that every year around 15 millions of vehicles of different kinds (automobiles, trucks...) are going to be out of exploitation. Over 80% of materials of those vehicles are reused or recycled, where in those processing some companies, with specialized technologies, are involved. This business is, as time is passing, more and more successful and profitable, and according to some investigations of treated materials, vehicle tires are one of the most "popular" materials for recycling. Previous researches in area of treatment of used vehicles show that it is very complex topic. Also we can see that there are two group of problems in this area: activities done on vehicles at the end of exploration (influence of those vehicles on environment, industry of dissembling of used vehicles, technical-technological treatment of these vehicles' parts) and location-routing problem (location objects for treatment of used vehicles, routing of vehicles collecting these parts). None of these two groups of problems is still not researched enough, not even where car industry is very developed. The aim of solving these problems is to increase efficiency level of treatment of used vehicles' parts. That is the reason why this paper shows the treatment of exploited tires from ELV, as well as the proposal of the models to solve the problem where the old tires treatment plant in Belgrade area could be located.

Motiv za bavljenje ovom problematikom dolazi od činjenice da svake godine približno 15 miliona automobila i kamiona u svetu izlaze iz upotrebe. Više od 80% materijala istrošenih vozila se obnovi i reciklira od strane u tu svrhu posebno oformljenih tehnološki zaokruženih celina. To iz godine u godinu postaje sve uspešniji i unosniji posao, a kako istraživanja pokazuju, među „najpopularnijim" materijalima koji se recikliraju su gume. Dosadašnja istraživanja iz oblasti tretmana korišćenih vozila ukazuju da se radi o veoma složenoj problematici, koja svakodnevno postaje sve komplikovanija. Takođe se uočava da u ovoj oblasti postoje dve grupe problema: aktivnosti koje se primenjuju nad vozilima koja završe svoj radni vek (uticaj koji ta vozila imaju na okruženje, industrija rastavljanja korišćenih vozila, tehničko-tehnološki tretman delova tih vozila...) i lokacijsko-ruting problematika (lociranje objekata za tretman delova otpisanih vozila, rutiranje vozila koja sakupljaju te delove). Ni jedna od ove dve grupe problema još uvek nije dovoljno istražena, čak i tamo gde je automobilska industrija na visokom stepenu razvoja. Cilj rešavanja ovih problema je usmeren na povećanje stepena efikasnosti tretmana korišćenih delova vozila. Iz tog razloga je u ovom radu dat prikaz tretmana korišćenih guma iz ELV-a, kao i predlog modela za rešavanje problema lociranja objekata za tretman korišćenih guma na teritoriji Beograda.

2 TREATMENT OF VEHICLES' EXPLOITED TIRES

The tires of road vehicles, at the end of their exploitation, generate the problem of their further treatment. Typically, the tires of road vehicles 'generate' problem after 30-70.000 km of exploitation, depending on the type of the tires, composition of structure materials, as well on maintenance of the vehicle, characteristics of exploitation, technical condition of the vehicle and so on. The main processes and influences in life cycle of road vehicle tires are shown on the figure 2 *(Marasova, D., Husakova, N., (5)).*

Like such, tires demand special treatment when out of use and when become waste. Namely, their decomposition lasts for hundreds of years and that's why they are big danger for environment. The ambition is to lower the percentage of tires

2 TRETMAN GUMA IZ KORIŠĆENIH VOZILA

Gume drumskih vozila predstavlaju problem u smislu tretmana kada se „potroše". Generalno, pohabanost guma se javlja nakon 30 do 70 hiljada kilometara vožnje, a brzina habanja tokom veka upotrebe, zavisi od vrste i sastava materijala, kao i od redovnog servisiranja, načina korišćenja i tehničkog stanja vozila. Procesi i uticaji u životnom ciklusu guma motornih vozila su predstavljeni na slici 2. *(Marasova, D., Husakova, N., (5)).*

Kao takve, gume zahtevaju poseban tretman kada izađu iz upotrebe i postanu otpad. Naime, njihovo razlaganje traje čak i nekoliko stotina godina, pa zbog toga one predstavljaju veliku opasnost za okruženje. Težnja je da se smanji procenat guma koje trajno završe kao otpad, a da se poveća

that end like waste and to increase level of their reusing in those industrial areas that provides real possibilities for that.

External tires makes about 3,5% of total weight of cards. According to available data from 2001, 22% of them were recycled, 8,3% were used to gain energy, 9,9% were retired (from the reason that some pneumatics are in condition that doesn't allow reparation after end of working life), 16% were reused, and 3,3% were sent on dumps. The remaining part, around 40%, were on the dumps on regularly provided supplies or illegally distributed (sold) *(Dabić, (3))*.

stepen njihovog ponovnog korišćenja u onim oblastima industrije gde god za to postoje realne mogućnosti.

Spoljne gume predstavljaju oko 3,5% od ukupne težine vozila. Prema raspoloživim podacima iz 2001. godine, 22% od toga je reciklirano, 8,3% je iskorišćeno u svrhe izvora energije, 9,9% je bilo povučeno iz upotrebe (iz razloga što su neki pneumatici, posle izlaska iz upotrebe, u stanju koje ne dozvoljava reparaciju), 16% je ponovo iskorišćeno, a 3,3% je upućeno na deponije. Preostali deo, oko 40%, bio je na deponijama na regularno predviđenim zalihama, odnosno nelegalno raspoređen (prodat) *(Dabić, (3))*.

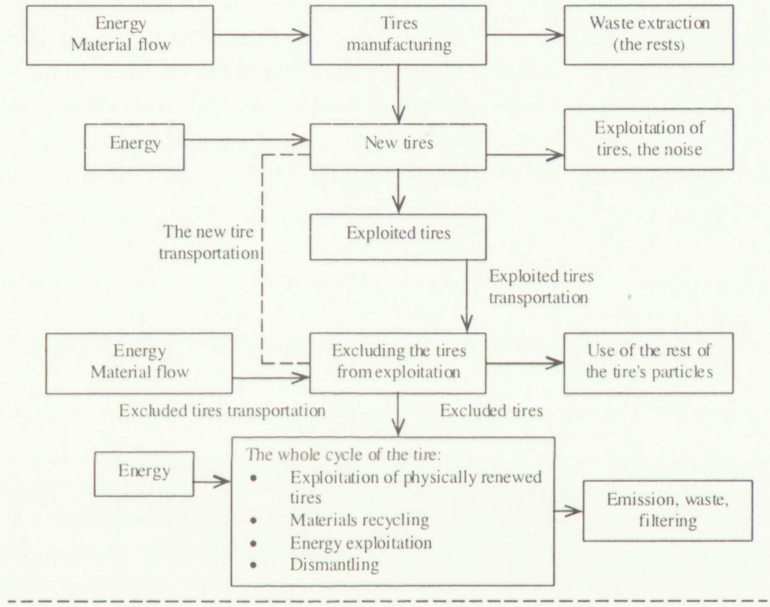

Figure 2 The life cycle of road vehicle tires (Marasova, D., Husakova, N., (5))
slika 2 Vek upotrebe guma (Marasova, D., Husakova, N., (5))

According to the source figure from *Marasova* and *Husakova,* the Figure shown here is rearranged and some additions are made, so that flows of the tires are clearly defined, from the new tires phase to the phase where the tires are dismantled.

U odnosu na izvornu sliku *Marasove* i *Husakove,* slika 2. je prerađena i dopunjena u smislu da su jasno naznačeni tokovi guma u svakoj fazi, počev od novih, pa do onih koje se nađu u fazi otpisa.

3 THE LOCATION MODEL OF EXPLOITED TIRES TREATMENT PLANT

According to the aim of this paper, here is briefly shown a location problem of exploited tires treatment. The model for this problem type is tested to Belgrade area. Two approaches are used: at the first, the 'pure' location model, and in the second, combined location routing problem.

3 MODEL ZA IZBOR LOKACIJE OBJEKTA ZA TRETMAN KORIŠĆENIH GUMA

Shodno cilju rada, u ovoj tački je dat kratak opis modela za rešavanje problema lociranja (jednog i/ili više) objekata za tretman otpisanih, odnosno (is)korišćenih guma. Primena modela vezanih za izbor lokacije ove vrste objektata je testirana za teritoriju Beograda. Primenjena su dva pristupa, od kojih se prvi odnosi na rešavanje lokacijskog, a drugi na rešavanje lokacijsko-ruting problema.

Location model that is used for the proposed problem, has further input values and assumptions: (1) the exploited tires are collected into 8 existing dismantling companies (car wrest companies), with known locations into Belgrade area; (2) four alternative locations are proposed as alternative for exploited tires treatment plant location; (3) transport of collected tires is realized with truck of 2 t capacity; (4) at each dismantling point are average 4 ELV per day delivered what is app. 0,20-0,25 t/day (where the passenger and also commercial vehicles, with greater number of tires with higher weights are also dismantled). Each dismantler generates average 1,6 t of exploited tires per week, and for Belgrade area, with 8 dismantlers, the quantity of exploited tires is average app. 13 t per week; (5) the maximal distance per one cycle of presumed collecting vehicle of exploited tires from dismantlers is 120 km (supposed average vehicle speed in the town area is 25 km/h, where are respected planned stops as well as unpredicted delays according traffic congestions.

Respecting defined dismantler's locations and proposed 4 locations of exploited tires treatment plant (assigned as A, B, C and D), OD distances matrix between them is defined as follows (Table 1). Those distances (matrix elements, expresses km) should be used as input values of Location model, defining the optimal location of the plant *(Dabić, Miljuš (2))*.

Lokacijski problem je, za model koji se predlaže za rešavanje, imao sledeće ulazne kvantitativne parametre: 1) u proces sakupljanja guma uključeno je 8 postojećih dismantlera (auto otpada) na teritoriji grada Beograda, sa poznatim lokacijama u gradu; 2) pretpostavljene su 4 potencijalne lokacije objekata za tretman otpisanih guma; 3) za transport guma od auto otpada do lokacije prerade koriste se dostavna vozila nosivosti 2 tone; 4) u svaki dismantler dolazi dnevno u proseku 4 ELV; putničko vozilo ima 4+1 gumu, a količina guma koje zahtevaju dalji tretman je oko 200-250 kg/dismantler-danu (u dismantlerima se rastavljaju putnička, ali i teža vozila - koja imaju ugrađen veći broj većih i težih guma); sledi da jedan dismantler zahteva otpremu nedeljno oko 1,6 tona otpisanih guma u objekat za dalji tretman; budući da je angažovano 8 dismantlera, procenjena količina pneumatika koja zahteva dalji tretman nakon izdvajanja iz ELV vozila na teritoriji Beograda iznosi oko 13 t nedeljno; 5) maksimalna dužine jedne rute vozila za sakupljanje pneumatika iz dismantlera (auto otpada) je do 120 km (pretpostavljeno je da se vozila kreću kroz grad prosečnom brzinom od 25 km/h, gde su uračunata planirana i zaustavljanja usled smetnji i zastoja u saobraćaju.

Na osnovu definisanih lokacija na kojima se nalaze dismantleri (koji su označeni brojevima od 1 do 8) i potencijalnih lokacija za postavljanje jednog objekta za tretman guma (koje su označene slovima A, B, C, D), utvrđena je matrica rastojanja između svih dismantlera i potencijalnih lokacija (tabela 1). Elementi matrice će poslužiti kao ulazni podaci modela za izbor optimalne lokacije, pri čemu su rastojanja data u matrici izražena u kilometrima *(Dabić, Miljuš (2))*.

Table 1 OD Matrix (km) between dismantlers and alternative exploited tires treatment plant location on Belgrade area
Tabela 1 Matrica rastojanja između dismantlera i potencijalnih lokacija objekata za tretman guma na području Beograda

	Alternative plant location points			
Dismantler	***A***	***B***	***C***	***D***
1	3.8	14.4	16.6	24.8
2	9.3	3.4	15.3	25
3	13	2.8	11.4	24.2
4	14.2	12.2	6.3	20.6
5	14.4	12.8	13.1	11.7
6	14	14.8	13.1	11.5
7	16.5	17.1	15	15.1
8	7.3	15	13.3	21.5

In the model used variables express:

- i 1,2,..., m - alternative exploited ELV tires treatment plant (m=4),
- j 1,2,..., n - dismantler, where exploited ELV tires for treatment are collected (n=8),
- c_{ij} transport cost per quantity unit that is transferred from dismantler j to tires treatment plant i,
- F_i fixed investments for constructing and processing of ELV tires treatment plant i,
- D_i load capacity of vehicle for tires collecting in dismantling points and transfer to the tires treatment plant i (capacity of the vehicle is 2 t),
- x_{ij} quantity of dismantled tires that is transferred from dismantling point j to plant i where should be treated (1,6 t).

$$y_i = \begin{cases} 1 \text{ when plant is located on point } i \\ \text{or} \\ 0 \text{ otherwise} \end{cases}$$

Function that should be minimized is:

$$F = \sum_{i=1}^{m} Fi \cdot y_i + \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} \cdot x_{ij}, \qquad (1)$$

respecting following constrains:

$$\sum_{j=1}^{n} x_{ij} = D_i \quad j = 1, 2, \ldots, n \qquad (2)$$

$$\sum_{j=1}^{n} x_{ij} \le y_i \cdot \sum_{i=1}^{m} D_i \quad i = 1, 2, \ldots, m \qquad (3)$$

$$x_{ij} \ge 0 \quad i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n \qquad (4)$$

The solution, resulting from the model, is based on the objective function (1), mentioned constrains (2), (3) i (4) as well as shown inputs above, presents that the optimal exploited ELV tires treatment plant location is on the point defined as ***A***, with resulting minimal objective function value (F = 96, while the values of F, for the other points, are much over 100).

U modelu figurišu sledeće varijable:

- i 1,2,..., m - broj potencijalnih lokacija za postavljanje objekta za tretman guma iz ELV (m=4),
- j 1,2,..., n - broj dismantlera iz kojih se prikupljaju gume ELV koji zahtevaju dalji tretman (n=8),
- c_{ij} troškovi transporta po jedinici količine koja se preveze iz auto otpada i do objekta za tretman guma j,
- F_i fiksni troškovi otvaranja i rada objekta i za tretman guma ELV,
- D_i količina tereta koju može da preuzme teretno vozilo iz auto otpada i uputi ga u objekat za tretman gumama i (nosivost vozila 2 tone),
- x_{ij} količina otpisanih pneumatika koja se iz otpada i upućuje objekat j za njihov dalji tretman (1,6 tona).

$$y_i = \begin{cases} \textbf{1 za objekat lociran na lokaciji } i \\ \textbf{ili} \\ \textbf{0 za ne} \end{cases}$$

Funkcija cilja koju treba minimizirati, glasi:

$$F = \sum_{i=1}^{m} Fi \cdot y_i + \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} \cdot x_{ij}, \qquad (1)$$

Uz ograničenja:

$$\sum_{j=1}^{n} x_{ij} = D_i \quad \text{za } j = 1, 2, \ldots, n \qquad (2)$$

$$\sum_{j=1}^{n} x_{ij} \le y_i \cdot \sum_{i=1}^{m} D_i \quad \text{za } i = 1, 2, \ldots, m \qquad (3)$$

$$x_{ij} \ge 0 \text{ za } i = 1, 2, \ldots, m \text{ i } j = 1, 2, \ldots, n \qquad (4)$$

Rezultati modela, dobijeni na osnovu funkcije cilja (1) i ograničenja (2), (3) i (4), i predstavljenih ulaznih veličina pokazuju da je objekat za preradu najbolje postaviti na lokaciji ***A***, jer tu funkcija cilja ima najmanju vrednost (F=96, za sve ostale lokacije ova vrednost je preko 100).

Location routing problem solution is based on idea presented in papers of *(Benton, W.C., Srikar, B., (1))*, where procedures for multiple vehicle routing problem are solved - there the Clark - Wright heuristic is involved, than on idea of *Sirvastava, R., (7)*, where location routing problem is solved using three heuristics approach, and partially on *Tuzun and Bruke, (10).*, where two - phase approach based on "taboo search" algorithm was used, what was necessary for the great dimension problem *(Schultmann, Zumkeller, Rentz, (6))*. Location-routing problems are very present in modern business and numerous tools and methods are used for their solving. Generally, various heuristics are used, and the main reason for their usage is that fact that the problem has big dimensions (numerous knots). Substance of this type of problem (very known and used shortcut LRP) is that that choice of optimal object location (of any kind) must include routes made by vehicles that tour the knots. Many authors dealt and deal with LRP problems and their solving, among them most important Von Boventer (1961), Maranzana (1965), Webb (1968), Lawrence and Pengilly (1969), Christofides and Eilon (1969), and Higgins (1972). Even most complicated problems were solved through their researches, and one of them is combination of choice of optimal location and so called *transport deciding*. For example Later and Coper (1972, 1976) their researches on LRP base on generalization of classic transport-location problem that include choice of optimal object location with reducing transport costs between potential location and knots toured by vehicles that service them (*Min, H., Sirvastava, R., 1998.*).

In this scenario, using mentioned idea(s) above, the location routing problem has been solved, which, in a way, represents the "extension" of the first scenario problem. Difference is in usage of an vehicle of 5 t capacity for collecting exploited tires, so (according collected quantities of tires from ELV) those vehicle are enabled to load tires form three dismantlers during one cycle passed. The other input variables and values are the same, so the problem is to find out one of four alternative locations on Belgrade area. It is also assumed, that cost of longer trips per vehicle cycles is much lower than constructing two or more new exploited tires treatment plants, where that solutions are enabling a shorter cycles

Lokacijski-ruting problem koristi ideju prisutnu u radovima *(Benton, W.C., Srikar, B., (1))*, koji su se bavili osmišljavanjem procedura za rešavanje višestrukog rutiranja vozila (multiple vehicle routing problem) - oni su svoje istraživanje sproveli korišćenjem Clark-Wright-ove heuristike; zatim na ideji koju je imao *Sirvastava, R., (7)*, koji je lokacijski-ruting problem rešavao primenom tri heuristike; delom i *Tuzun and Bruke, (10).*, koji su predložili primenu dvofaznog pristupa zasnovanog na „tabu search"-u, kako bi se omogućilo rešavanje problema velikih dimenzija *(Schultmann, Zumkeller, Rentz, (6))*. Lokacijsko-ruting problemi su u današnje vreme veoma prisutni u savremenom poslovanju i za njihovo rešavanje koriste se mnogobrojni alati i metode. Generalno posmatrano, najčešće se za to koriste razne heuristike, a osnovi razlog za njihovo korišćenje leži u činjenici da se radi o problemima velikih dimenzija (veliki broj čvorova). Suština ove vrste problema (poznata i često upotrebljavana skraćenica LRP) je u tome da su izbor optimalne lokacije objekta (bilo koje vrste) uključene i razmatrane rute koje prave vozila koja obilaze čvorove. LRP problemima i njihovim rešavanjem se bavio i bavi veliki broj autora, među kojima su najznačajniji Von Boventer (1961), Maranzana (1965), Webb (1968), Lawrence and Pengilly (1969), Christofides and Eilon (1969), and Higgins (1972). Kroz njihova istraživanja, rešavani su i najsloženiji problemi, a jedan od njih je zapravo ništa drugo do kombinacija izbora optimalne lokacije i takozvanog *transportnog odlučivanja.* Na primer, Later and Coper (1972, 1976) svoja istraživanja vezana za LRP baziraju na uopštavanju klasičnog transportno-lokacijskog problema koji uključuje izbor optimalne lokacije objekta uz minimizaciju troškova transporta između potencijalne lokacije i čvorova koji obilaze vozila koja pri tom rade opsluživanje istih (*Min, H., Sirvastava, R., 1998.*).

U ovom scenariju, korišćenjem ideje(a) navedenih autora, rešavan je lokacijski ruting problem, koji na neki način, predstavlja „proširenje" problema iz prvog scenarija. Razlika je što se ovde za dopremu pneumatika ELV koriste vozila nosivosti 5 tona, tako da (na osnovu sakupljenih kolličina guma) u jednoj ruti ona mogu da prođu (opsluže) tri korisnika. Ostale ulazne veličine su identične, a problem se svodi na lociranje objekta za tretman otpisanih guma na jednoj o 4 pretpostavljene moguće lokacije na teritoriji Beograda. Usvojena je pretpostavka da je mnog manji trošak većih dužina ruta sa jednim, nego izradnja, dva i/ili više objekata, sa manjim dužinama ruta. Ova pretpostavka značajno

distances. This assumption also much relaxes the problem and then the solving using modified "cleaning" algorithm *(Teodorović, D., (9))* is enabled. With this approach for each route the new node distribution is made, and based on that results is examined the case when the shortest path of the vehicle is achieved. On the Figure 3 is explained the case when the routes are developed from the beginning in the node A, but the steps are the same when other nodes are used.

pojednostavljuje problem i omogućava njegovo rešavanje korišćenjem modifikovanog algoritma „čišćenja" *(Teodorović, D., (8))*, u kome se za svaku rutu pravi poseban raspored čvorova, kako bi se odredilo po kome od njih vozilo prelazi najkraći put. Slika 3 objašnjava postupak, i to za slučaj kada se rute formiraju iz čvora A, ali je isto i kada se radi o ostalim čvorovima *(Dabić, (3))*.

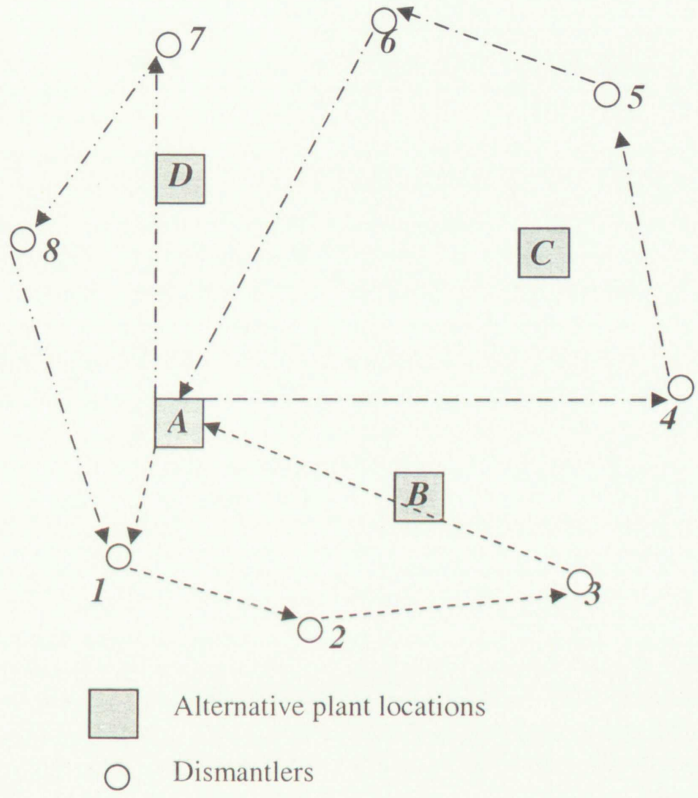

Figure 3 Route distribution resulting from "cleansing" algorithm approach, when the treatment plant is located in point A
slika 3 Raspored ruta dobijenih algoritmom „čišćenja" (objekat je na lokaciji A)

Using distances matrix between all dismantlers and alternative exploited tires treatment plant locations, respecting above mentioned assumptions, results of model are shown in Table 2. There each vehicle routes (km) could be seen from each alternative treatment plant location. The "cleansing" algorithm is made on the rule of "starting' from the node that is closest to chosen location.

Na bazi matrice rastojanja između svih dismantlera i potencijalnih lokacija objekata za tretman guma iz ELV-s, respektujući prethodno iznete pretpostavke, napravljena je tabela 2., iz koje se mogu sagledati dužine ruta vozila (u km) iz svake od potencijalnih lokacija ponaosob. Algoritam „čišćenja" je napravljen po principu „polaska" iz čvora koji je izabranoj lokaciji najbliži *(Dabić, (3))*.

Table 2 Node's distribution and route distances (plant in the A, B, C, or D)
Tabela 2 Raspored čvorova u rutama i dužine ruta (objekat u A, B, C, ili D)

Location	Route 1 - l1	Route 2 - l2	Route 3 - l3	l1+ l2+ l3 - min
A	A-1-2-3-A (35.2)	A-4-5-6-A (45.7)	A-7-8-A (36.4)	117.3
	A-1-3-2-A (35.2)	A-4-6-5-A (52.9)		
B	B-2-3-4-B (32.2)	B-5-6-7-B (45.3)	B-8-1-B (33.0)	***108.1***
	B-2-4-3-B (30.2)	B-5-7-6-B (44.9)		
C	C-5-6-7-C (32.1)	C-8-1-2-C (44.0)	C-3-4-C (35.8)	111.9
	C-5-7-6-C (32.1)	C-8-2-1-C (56.7)		
D	D-7-8-1-D (56.1)	D-2-3-4-D (62.2)	D-5-6-D (44.8)	163.1
	D-7-1-8-D (56.2)	D-2-4-3-D (73.2)		

Results in Table 2 show that vehicle, engaged on collecting tires, makes the shortest distances (and lowest costs) when the treatment plant is located in point B. To make decision which of two points to choose for constructing the plant, it should be necessary to investigate and some other factors/parameters, as they are: cost of the land on each location, available infrastructure (energy, supply,...), environment conditions, transportation infrastructure and connections with dismantlers *(Dabić, Miljuš (3))*.

Iz tabele 2 se uočava da vozilo koje sakuplja otpisane gume najkraće puteve (i najmanje troškove) pravi ukoliko se objekat locira na potencijalnoj lokaciji B. Da bi se donela konačna odluka o tome na kojoj od ove dve lokacije izgraditi objekat za tretman gumama iz ELV vozila, trebalo bi razmatrati i neke druge parametre, kao što su, na primer, troškovi kupovine zemljišta na pomenutim lokacijama, položaj u odnosu na gradsku infrastrukturu, ekološke faktore, kakva je saobraćajna povezanost sa gradom (koja od ove dve lokacije ima prednost kada je u pitanju saobraćajna infrastruktura za vezu sa dismantlerima) i sl *(Dabić, (3))*.

The modeled problem solved by using „cleaning" algorithm can be solver by using enumeration method. This method considers all possible combinations of knots when forming vehicle's route (not only "departures" from knots closest to potential object location, but from all knots). This gives realistic solution, because all possible combinations for forming vehicle's route are searched. Given problem is so huge that it allows usage of this method. So, we can say that analysis of route made by vehicles collecting pneumatics from dismantler (knots, 1,2...8i) is in certain way expanded regarding the previous, by considering all other combinations including ones when vehicles is starting from any 8 given dismantlers, and not only analysis and comparing route made when vehicles departures from dismantler closest to the tested location. By this the problem got big dimension, but the result is consider realistic because all detached situation in service system defined like this are covered. The function of aim is, like in the previous algorithm, that the vehicle travels the least while serving. The distances between knots in route (distances are real, having in mind that the coordinates of dismantlers and potential object location for treatment of charged tires are given

Međutim, modeliran problem koji je rešavan primenom algoritma „čićenja", može se rešiti i primenom metode enumeracije. Ova metoda u razmatranje uzima sve moguće kombinacije čvorova prilikom formiranja ruta vozila (ne samo „polaske" iz čvorova najbližeg potencijalnoj lokaciji objekta, već iz svih pretpostavljenih čvorova). Na taj način se dobija realno rešenje, jer su ispitane sve moguće kombinacije za formiranje ruta vozila. Postavljeni problem je takvih dimenzija, da omogućava primenu ove metode. Dakle, može se konstatovati da je analiza pređenih puteva vozila koji sakupljaju pneumatike iz dismantlera (čvorovi 1, 2,..., 8) na neki način proširena u odnosu na prethodnu, tako što se, pored analize i upoređivanja pređenog puta kada vozilo polazi iz dismantlera najbližeg analiziranoj lokaciji, razmatraju i sve druge kombinacije, odnosno i one kada vozilo polazi iz bilo kog od 8 pretpostavljenih dismantlera. Na taj način je problem dobio mnogo veću dimenziju, ali se i rezultat smatra realnim, jer su pokrivene sve objektivno moguće situacije u ovako definisanom sistemu opsluge. Funkcija cilja je, kao i u prethodnom algoritmu ista, a to je da vozilo prilikom opsluge pređe što kraći put. Kao polazni podatak korišćena su rastojanja između čvorova u ruti (rastojanja su realna, imajući u vidu da su pre pravljenja tabele predočene koordinate

before making tables, and for measuring distances is used "plan plus") are used as starting data. From figure 4 we can see that industrial facility is best to be built on ***location C (node)***, because this location makes the least vehicle's route distance of 77,5 with all car-wrecks served. If the problem had higher dimension, it would require usage some of heuristic or metaheuristic methods, which would give acceptable, but not optimal solution.

So the enumeration method is considered relevant for solving given problem, and final results are shown on figure 4. On this figure is given comparative view of results given by using "cleaning" algorithm and using of enumeration.

lociranih dismentlera i potencijalnih lokacija za objekte za tretman otpisanih guma, a da se za izračunavanje tih rastojanja koristio «plan plus»). Sa slike 4. može se uočiti da je industrijsko postrojenje najbolje izgraditi na pretpostavljenoj ***lokaciji C***, jer ova lokacija daje najmanju dužinu rute vozila od 77,5 km, pri čemu su opsluženi svi auto-otpadi. Ako bi problem bio većih dimenzija, zahtevao bi korišćenje neke od heurističkih ili metaheurističkih metoda, kojima bi se dobilo prihvatljivo, ali ne zasigurno i optimalno rešenje.

Stoga se postupak enumeracije relevantnim za rešavanje postavljene problematike, a konačni rezultati prikazani su slikom 4. Na ovoj slici dat je uporedni prikaz rezultata dobijenih algoritmom «čišćenja», kao i primenom enumeracije.

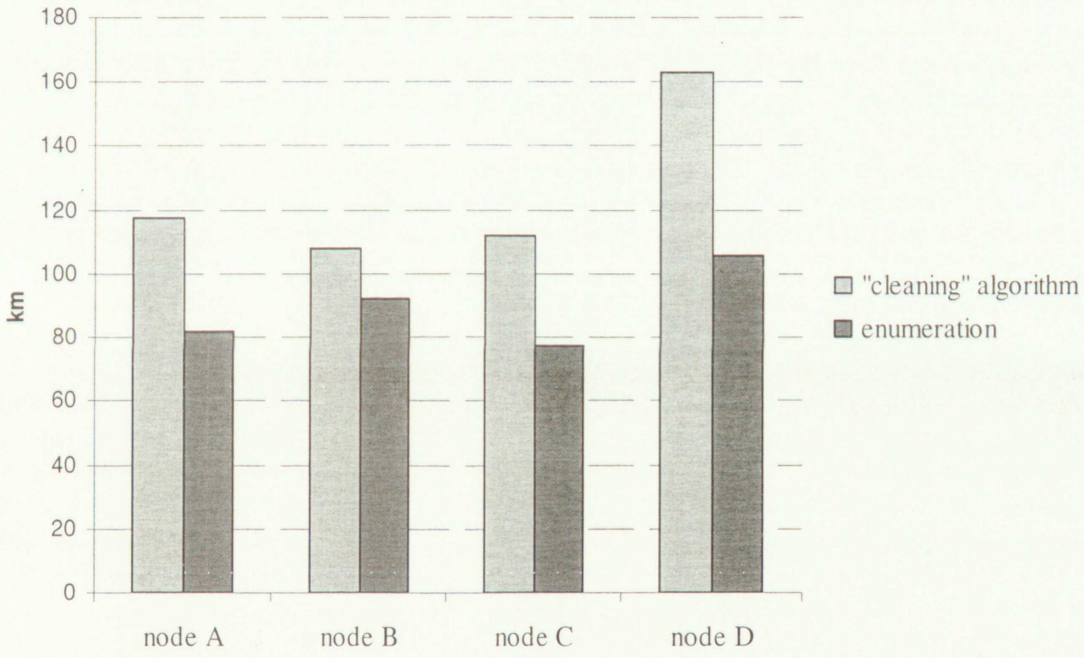

Figure 4 Comparative view of vehicle's route distances using enumeration and "cleaning" algorithm
slika 4 Uporedni prikaz dužina ruta vozila dobijenih primenom enumeracije i algoritma «ćišćenja»

From figure we can se that enumeration gives exact and financially most suitable results, because the vehicle's route distance, no matter which knots is starting point, is significantly shorter with using of enumeration and considering all possibilities for forming vehicle's route, comparing to results given by using "cleaning" algorithm when vehicle starts from dismantler closest to the potential location.

Sa slike se uočava da, kao što je već naglašeno, enumeracija daje tačne i ekonomski povoljnije rezultate iz razloga što je dužina ruta vozila, nezavisno od toga iz kog se čvora polazi, značajno kraća u slučaju kada se primenjuje enumeracija, odnosno ispituju sve mogućnosti za formiranje rute vozila, u poređenju sa rezultatima dobijenim primenom algoritma «čišćenja», kada vozilo polazi iz dismantlera najbližeg analiziranoj

This other approach to location-routing scenario is considered more important, more usable in real life and closer to realistic situation, since it considers all possible combination for vehicle's route. One very important thing for solving this type of problem is that enumeration gives exact results, since all possible combinations are tested. Comparing to „cleaning" algorithm (Figure 4) we can see that route distances are significantly shorter when using method in which all possible combinations of vehicle's route and their distances are considered.

4 CONCLUSION

With development of science and technology, man has created numerous materials with complex chemical juncture for his needs. There materials, due to its complexity, can hardly or can't at all retrogress natural way or the time of their retrogression is considered unlimited. Storing of such materials, whether on wild or arranged dumps is potential danger for pollution of environment. By recycling these materials, beside financial gain, man protects environment, which has healthier way of life for man as consequence.

Due to complex juncture of vehicles, their recycling is possible only by defined treatment of all components that they are made of. The refining technologies of these materials are complex, but economy and saving the environment makes the funds and efforts worthy. Considering all given factors, they will be expansions of such companies in the world and here in the future.

Tires, like other parts of used ELV, looked from logistic aspect, are gaining on importance when talking about their treatment and possibility of reusing. Location of installment for modification of ELV parts has special importance, because remarkable growth of quantity of recycling materials is expected. Regarding that, in this paper is analyzed usage of some models for solving one class of problems in this area, when recycling tires. Usage of models is tested for entry values expected for area of Belgrade. With expected growth of quantity and assortment of these materials, it is clear that problems of locating installment for their recycling will have growing importance, but also will become more and more complex.

potencijalnoj lokaciji. Ovaj drugi pristup lokacijsko-ruting scenarija, smatra se značajnijim, u praksi primenljivijim i bližim realnoj situaciji, budući da ispituje sve moguće kombinacije ruta vozila. Ono što je izuzetno značajno za rešavanje ove vrste problema jestečinjenica da enumeracija daje tačne rezultate, budući da su ispitane sve moguće kombinacije. U poređenju sa „algoritmom čišćenja" (slika 4) može se uočiti da su dužine ruta znatno kraće kada se primenjuje postupak u kome se ispituju sve moguće kombinacija ruta vozila i njihove dužine.

4 ZAKLJUČAK

Razvojem nauke i tehnologije, čovek je za svoje potrebe stvorio veliki broj materijala složenih hemijskih sastava. Takvi materijali se zbog svoje složenosti teško ili čak uopšte ne mogu razgraditi prirodnim putem ili se vreme njihove razgradnje može smatrati beskonačnim. Deponovanje takvih materijala, bez obzira da li na uređenim ili divljim deponijama predstavlja potencijalnu opasnost zagađenja životne sredine. Reciklažom ovakvih materijala, pored ekonomske dobiti čovek štiti životnu sredinu, što ima za posledicu i kvalitetniji i zdraviji život samog čoveka.

Zbog složenog sastava vozila, reciklaža istih je uspešno moguća samo uz odgovarajući tretman svih sastavnih komponenti koje ga sačinjavaju. Same tehnologije prerade ovakvih materijala su složene, ali ekonomija i zaštita životne sredine opravdavaju uložena sredstva i trud. Zbog svih navedenih faktora u budućnosti će doći do ekspanzije ovakvih preduzeća kako u svetu tako i kod nas.

Gume, kao i ostali delovi korišćenih ELV-a, posmatrano sa aspekata logistike, sve više dobijaju na značaju kada je u pitanju njihov tretman i mogućnost ponovnog korišćenja. Lokacija postrojenja za preradu delova ELV zbog toga ima poseban značaj, jer realno je očekivati značajan porast količina materijala koji se recikliraju. U tom cilju, u ovom je radu analizirana primena nekih od modela za rešavanje jedne klase problema u ovoj oblasti, pri tretmanu guma. Primena modela je testirana za ulazne veličine koje su pretpostavljene za teritoriju Beograda. S obzirom na realno čekivane sve veće količine i asortiman ovih materija, jasno je da će problemi lociranja postrojenja za njhovu preradu u gradovima sve više dobijati na značaju, ali i postajati sve kompleksniji.

REFERENCES / LITERATURA

[1] Benton, W., C., Sikar, B.: *Experimental study of environmental factors that affect the vehicle routing problem.* Journal of Business Logistics 6, USA, 1985., pp. 66-78.

[2] Dabić, S., Miljuš, M.: *Logistics Aspects in ELV Treatment.* microCAD 2007, 22-23 March 2007, Miskolc, Hungary, pp. 13-18.

[3] Dabić, S.: *Addition to the development of industrial logistics for used products in car-industry.* master thesis, Faculty for Transport and Traffic Engieenering, Belgrade University, 2008.

[4] Maslarić, M., Cakić, R.: *Six sigma concept in supply chain.* National conference of quality, Serbia, 2006.

[5] Marasova, D., Husakova, N.: *Tire recycling.* Transport and Logistics, Belgrad, 2006.

[6] Schultmann, F., Zumkeller, M., Rentz, O.: *Integrating Spent Products of Material into Supply Chains: The recycling of End of life Vehicles as an example.* Institute for industrial product, University of Karlsruhe, Germany, 2005., pp. 36-58.

[7] Sirvastava, R.: *Alternate solution procedures for the location-routing problem.* Omega, Vol. 21, No 4, pp. 497-506, 1993

[8] Suterland, J.: *Automotive industry.* Michigan Techn. University, USA, 2000.

[9] Teodorović, D.: *Transportation Networks.* Faculty of Transport and Traffic Engineering, University of Belgrade, Belgrade, 1996.

[10] Tuzun, D., Burke, L.: *A two-phase taboo search approach to the location routing problems.* EJOR 116, pp. 87-99, 1999.

Reviewal/Recenzija: prof. dr Gordana Radivojević