

Analyses of Construction and Maintenance Costs of Forest Transportation System in Croatian State Forests between 2004 and 2011

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Abstract:

Forests and forest lands in the Republic of Croatia can be generally divided into four relief categories: lowland area, foothill and hilly area, mountain area and karst area. Each relief category is related to construction technologies of primary (truck forest road - TFR) and secondary (skid road - SR) forest roads. Because of the specific features of the dominant influence factors in each relief area, primarily habitat factors (slope, geology and soil foundation and its related construction category materials and soil bearing capacity, the presence of various landforms, hydrography, etc.), building costs of individual forest road categories and subcategories, depending on area, differ significantly.

This research covers the whole territory of Croatia and all 16 Forest Administrations (FA), where the company "Croatian Forests" Ltd. Zagreb manages the land area of 2,018,987 hectares of state forests and forest land (36% of Croatia). The analyzed costs of construction and maintenance of forest roads are divided into four groups: the construction of the lower-layer of truck forest roads, construction of the upper-layer of truck forest roads, truck forest road maintenance and construction of skid roads. All costs are shown for each relief category and each FA for the period 2004 - 2011. All components are grouped according to the contractors; construction works were carried out either by the "Croatian Forests" Ltd. Zagreb, or by private contractors.

Research results indicate that the total costs, associated with forest civil engineering (construction costs of lower and upper layer of forest roads at the level of the entire study area), exceeded 52.02%, maintenance of truck forest roads were 32.59% and construction costs of skid roads amounted to 15.39%. In the future, with getting closer to the existing primary classical optimal openness, the construction of truck forest roads will be reduced. Within the increasing number of truck forest roads the share of their maintenance costs will rise. Therefore, in future research, among other issues, the focus should be placed on planning, monitoring (control) and rationalization of truck forest roads maintenance costs.

Keywords: relief category, truck forest roads, skid trails, construction costs, maintenance costs

1 Introduction

The total area of forests and forest land in Republic of Croatia is 2 688 687 ha, which is 47% of the continental area of the country. Out of this area, 2 106 917 ha is owned by Republic of Croatia, and 581 770 ha is owned by private forest owners. Most of state-owned forests are managed by the company "Croatian Forests", Ltd. Zagreb (2 018 987 ha), and the managed area is divided into 16 Forest Administrations.

The basic principle of the Croatian forestry is sustainable management with the preservation of natural structure and diversity of forests, and continuous increase of stability and quality of economic and generally beneficial forest functions. According to the Forest Act (Official Gazette "NN" 140/05, 82/06, 129/08, 80/10, 124/10, 25/12, 68/12), forest management involves silviculture, protection and use of forests and forest land, as well as construction and maintenance of forest infrastructure, in accordance with the European criteria for a sustainable forest management.

According to the Forest Act, forest roads are (Hodi and Juruši 2011), as well as the remaining forest transportation infrastructure, a constituent part of forests and forest land and they are not the property of the company “Croatian Forests”, Ltd. Zagreb. The state (owner) provided the source of funding aimed at investing into designing, construction and maintenance of forest roads, and these financial resources come from the Non-Wood Forest Functions Fund or from the state investment funds.

The Republic of Croatia has invested, especially after gaining independence, considerable financial resources into primary opening of forests, and however there are still many inaccessible forest areas that will be the object of further investments aimed at achieving the target accessibility (Pentek et al. 2006). Target accessibility has been the subject of many research studies (Anon 1997, Pentek et al. 2005, Pentek et al. 2006, Pentek et al. 2011, Hodi and Juruši 2011) and it provides the possibility of projecting the required investments into primary forest road infrastructure.

2 Scope of research, material and methods

2.1 Scope of research

By the application of nowadays techniques and technologies, the use of forest resources without forest roads is unthinkable and economically unfeasible (Nevećrel 2010). Technological development and new transport possibilities provide economically feasible use of forests and transport of wood at higher distances. In this way, distant forest complexes have become attractive and interesting for all forest owners as a permanent source of income. The aim of opening forests by forest roads (Pentek 2009), is to establish an optimal network of forest roads. In doing so, it is necessary to determine the phases of the whole process of construction of the primary forest road infrastructure.

Planning, design, construction with surveillance and maintenance are the basic and closely connected phases for the establishment of a forest road network. Apart from these mandatory phases, there are also two occasional phases, and these are reconstruction performed to increase the standard of the existing forest roads and putting the forest road out of order when it becomes unnecessary.

According to Ryan et al. (2004.) the establishment of an optimal forest road network is carried out through the following phases: planning, development of design, routing (on specific terrain), construction, building of underground and aboveground drainage facilities and maintenance.

Construction of forest roads is the most expensive, the most time-consuming and the most demanding task of all forest operations. It is very difficult to estimate the costs of construction of forest roads (Koger 1978, Kochenderfer et al. 1984, Ou and Swarthout 1984, Layton 1990) due to terrain variability, different types of soil and rocks, used mechanization, special design solutions, etc.

Terrain variability is a very significant component in the construction phase of forest roads, and therefore for the area of the Republic of Croatia (Šikić et al. 1989) four categories of relief have been determined: lowland area, foothill-hilly area, mountain area and karst area. Each relief area has some specific characteristics that affect the cost of construction of individual forest roads, and the application of different technologies of construction of primary forest road infrastructure is conditioned by the type of soil and rocks. The construction can be performed by dozers in lowland areas and dredges in foothill-hilly and mountain areas (sloped terrain) (Pentek 2010).

Pentek (2010) outlines the most significant problems met in construction of forest roads in lowland areas:

- ✗ no soil strength or low strength,
- ✗ lack of stone material on forest road routes,
- ✗ distance between the quarry and construction site (high transport costs),
- ✗ developed hydrographical network – permanent waters with high flow (necessary construction of bridges),

- ✘ high level of underground water (construction of dams for raising the level of forest roads, construction of drainage ditches),
- ✘ considerable fluctuation of water level in the stand (construction of spillway dams),
- ✘ avoiding “closing“ of forest areas (necessary construction of culverts).

The most significant problems (Pentek 2010) met in construction of forest roads in hilly and mountain areas are as follows:

- ✘ heavy categories of construction material (sometimes the use of explosives required),
- ✘ highside slopes,
- ✘ deep notches and high dams (construction of supporting and coating walls),
- ✘ risk of enhancing erosion processes,
- ✘ necessary use of higher longitudinal slopes of roadways,
- ✘ risk of sudden rushing of water on the route of forest roads (construction of drainage ditches, culverts and soaka ways).

Maintenance of forest roads involves a series of civil-engineering procedures that must be regularly performed so as to maintain the roads in their original state, in which they can fulfill all their tasks. The costs of construction and maintenance of a forest road in the period of its amortization (25 – 40 years depending on the author and method of calculation) are the total costs of a forest road management.

2.2 Material and methods

In this paper, data were used obtained from the company “Croatian Forests”, Ltd. Zagreb, related to the construction and maintenance of primary forest roads and construction of secondary forest roads, which have been systematically monitored for years independently and with the help of the Faculty of Forestry in Zagreb. These data are the bases for the analyses of the actual costs in the investigated periods, interrelation of cost trends and for planning future costs related to forest transportation infrastructure.

3 Results

This paper presents the analysis of all data on costs related to primary and secondary forest transportation infrastructure in the period 2004 to 2011. Construction costs of primary forest roads were analyzed separately for the upper and lower layer. Analysis was made of data grouped in two groups of costs. The first group represents the costs of construction of forest roads and skid roads, and the second group the maintenance costs of forest roads.

All the data were analyzed, for the period in question, by type of contractor, and difference was analyzed in the price of individual groups of work between the operating units of the company Croatian Forests, Ltd. Zagreb and private contractors.

3.1 Construction costs of primary and secondary forest roads

For the period 2004 to 2011, the construction costs were analyzed for an average construction cost of both forest roads and skid roads. If considering the total average costs of construction per kilometer, certain trends can be observed within each analyzed year. With the construction of forest roads, an increase can be observed of the average construction cost from 2004 to 2011, and the situation is quite the opposite with skid roads in the period in question – construction costs show a decreasing trend.

If the obtained results are analyzed by type of contractor, construction costs by operating units of the Croatian Forests, Ltd. Zagreb, show an increasing trend in both cases, with the construction of forest roads as well as with the construction of skid roads. On the other hand, when considering the costs of construction performed by private contractors, the construction costs of forest roads increase, while the construction costs of skid roads show a slight decrease.

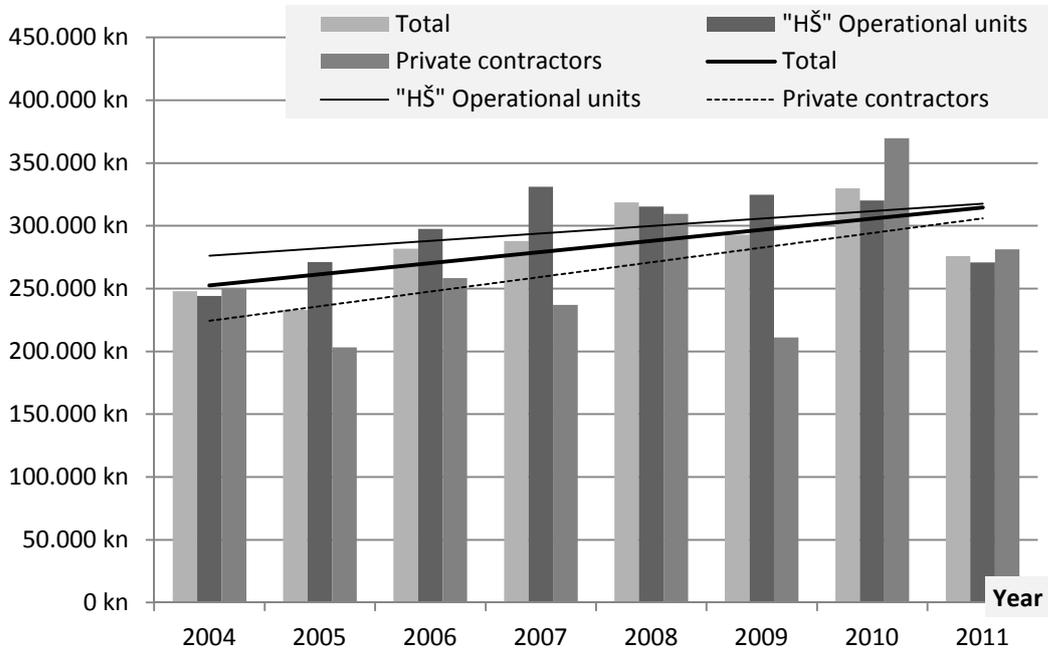


Figure 1: Average cost of construction of forest roads for the period 2004 to 2011 by contractors and in total

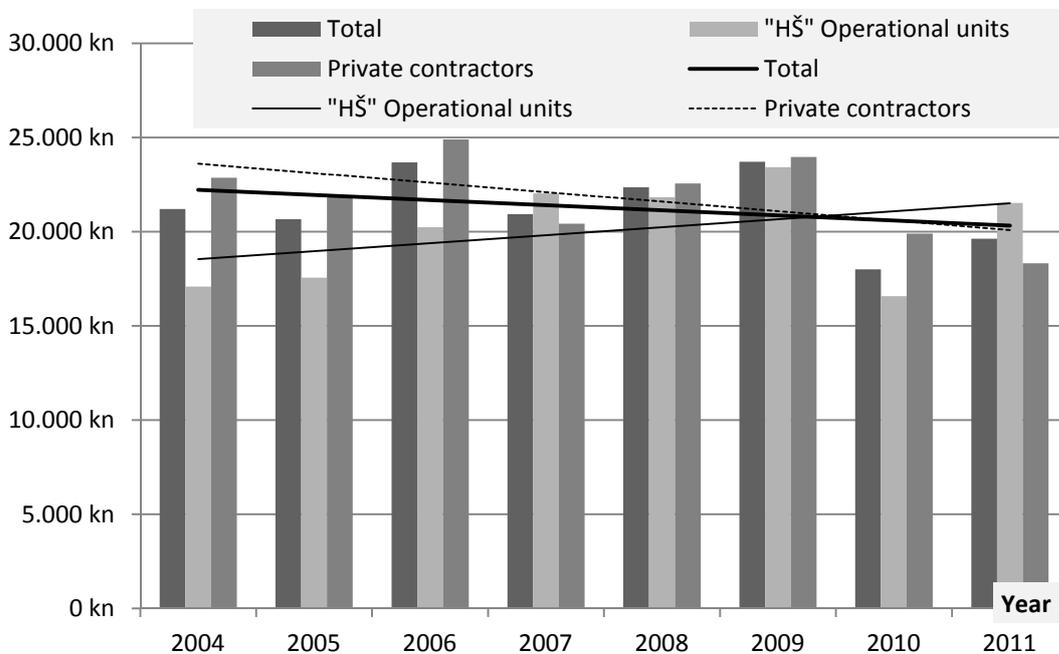


Figure 2: Average cost of construction of skid roads for the period 2004 to 2011 by contractors and in total

In the observed period, a total of 1 883.85 kilometers of the lower layer of forest roads were constructed and 2 087.77 kilometers of the upper layer of forest roads. No difference should be expected in the total quantity of the constructed lower and upper layer, if the construction of forest roads were carried out after winning a tender. The reason for the difference in the quantity between the upper and lower layer lies in several significant factors. The construction of the required amount of kilometers is determined by the annual plan of each forest office of the Croatian Forests, Ltd. Zagreb, and the necessary financial resources are allocated accordingly. Financial resources are distributed to forest offices in accordance with the funds obtained from the Non-Wood Forest Functions Fund and from the company's income. In accordance with the requirements of implementation of the Forest Management Plan, each individual forest office decides on the dynamics of investments into the necessary components of primary or secondary forest road infrastructure and accordingly decides whether to invest most financial resources into construction and establishment of the lower layer of a new forest road or to finish the forest road with an already existing lowerlayer.

3.2 Comparison of construction costs with respect to the type of contractor

Costs related to forest roads, both primary and secondary, are also analyzed with respect to the type of contractor. The company Croatian Forests, Ltd. Zagreb has some operating units qualified for all kinds of construction and maintenance of forest road infrastructure. On the other hand, tenders are invited for all the works that the company Croatian Forests, Ltd. Zagreb is not able to carry out by its own capacities. Analysis was made of costs of construction and maintenance of forest roads and construction of skid roads. The presented data for all cases (construction of lower and upper layer, construction of skid roads and maintenance of forest roads) show an increasing trend of works within the total costs of the operating units of Croatian Forests compared to private contractors. The presented analyses were made based on costs, and not based on the volume of work performed.

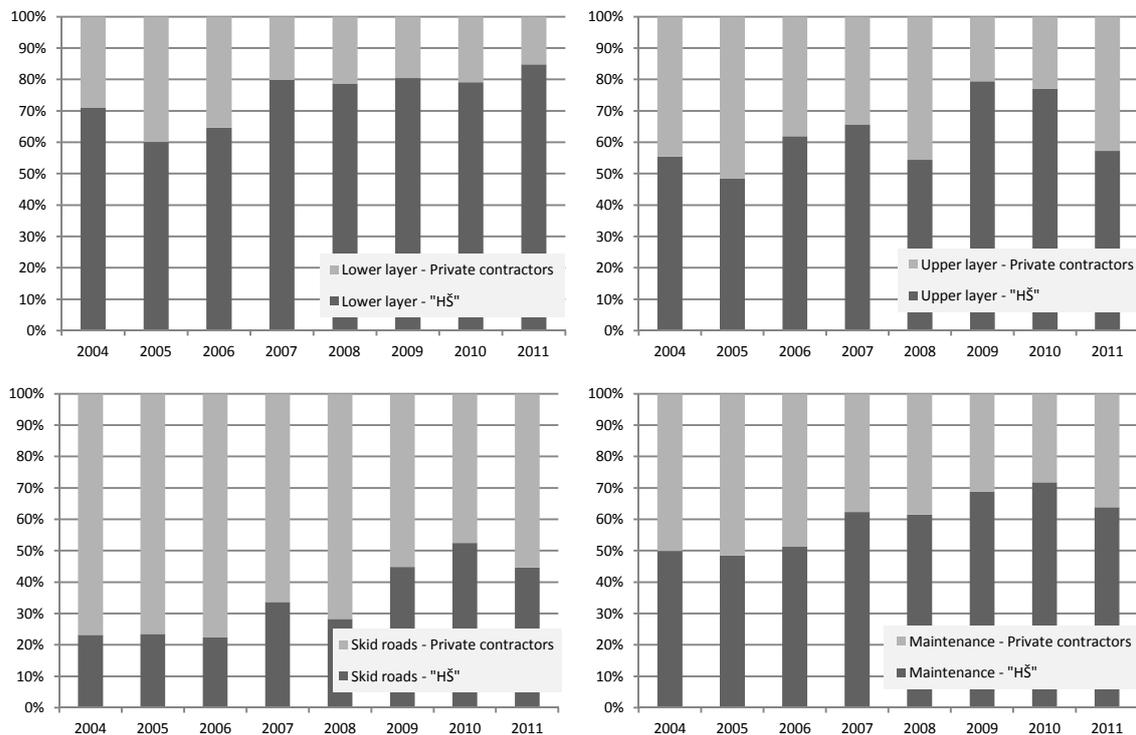


Figure 3: Relation of construction costs of lower layer, upper layer, skid roads and maintenance costs by type of contractor for the period 2004 - 2011

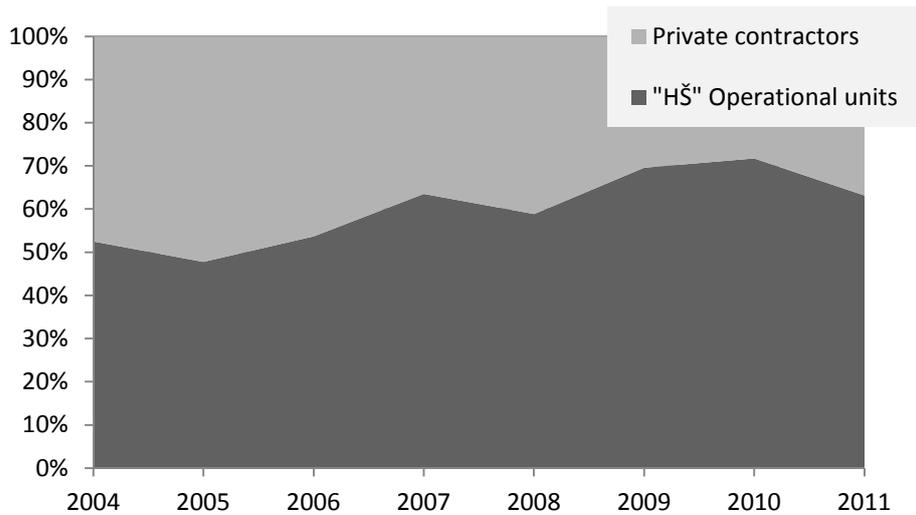


Figure 4: Relation of total costs vs. contractor for the period 2004 to 2011

3.3 Costs of maintenance of forest roads

Continuous (on annual basis) construction of the network of primary forest roads results in increasing demands regarding their systematic and timely maintenance. The share of maintenance of forest roads in the total annual costs increases and hence a detailed analysis of data on costs is required. Therefore, the costs of forest road maintenance were first divided by Forest Administrations. The presented data show great difference in the average maintenance costs, which is closely related to the relief areas within individual Forest Administrations. It can be noticed that data vary considerably from the average maintenance costs, so that, in developing the methodology for analyzing the maintenance, each individual Forest Administration should be analyzed individually.

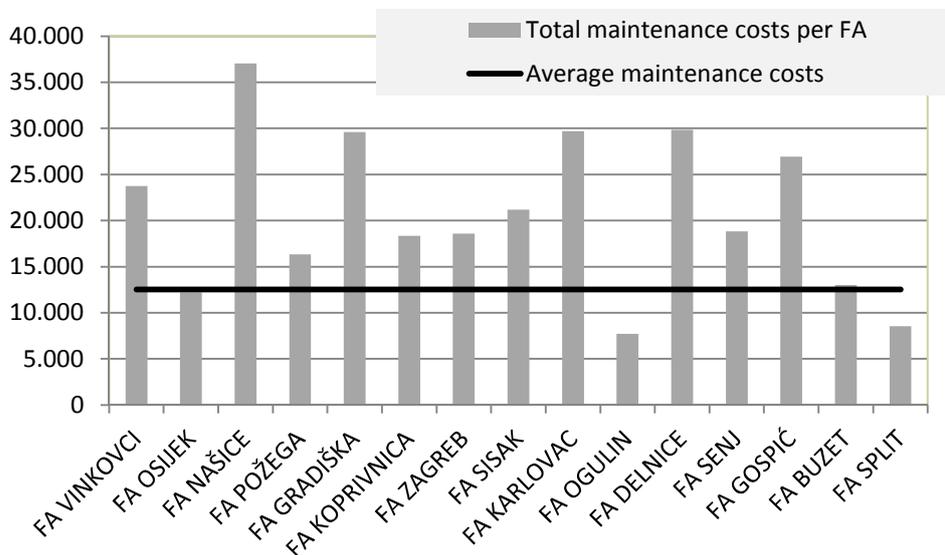


Figure 5: Comparison of average maintenance costs within individual Forest Administrations in the period 2004 – 2011

3.4 Comparison of construction and maintenance costs of forest roads

The analysis of cost structure is shown for the construction costs of lower and upper layer and for the maintenance costs of forest roads. No data are presented of the construction costs of skid roads in order to get a clearer picture of the relation between construction and maintenance of forest roads. It could be said for the shown trend that it was expected, because due to the increase of the total amount of forest roads, the need for maintenance also increases, while the intensity of construction does not change considerably, i.e. a decreasing trend can be observed – decrease of the relative share in the total costs. When the target primary forest accessibility (density of truck forest roads) is approached, the intensity of forest road construction decreases. Due to the lack of financial resources available for investing into primary forest road infrastructure and in order to provide functioning of already built forest roads, the funds for the construction of the new forest roads are first reduced (or in some extreme situations completely cancelled), i.e. reallocated to the maintenance of the existing primary forest road network.

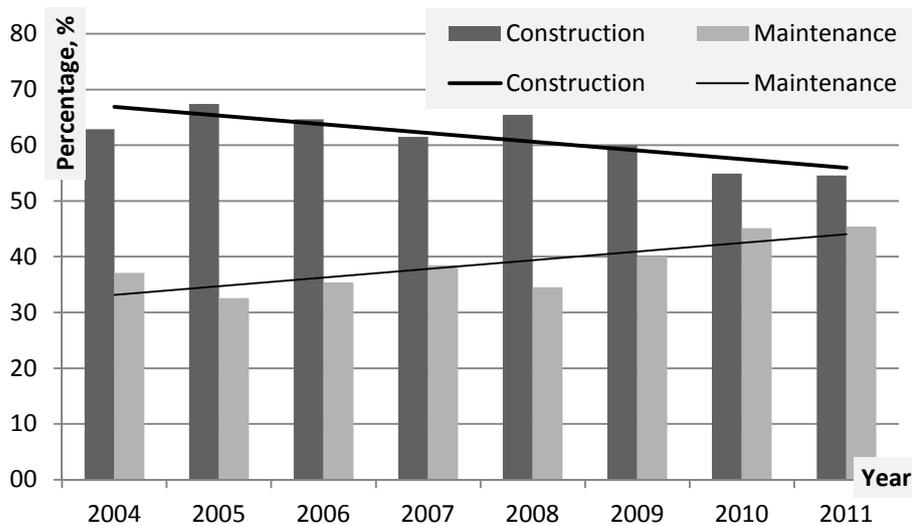


Figure 6: Survey of relation of total construction and maintenance costs for forest roads in the period 2004 – 2011

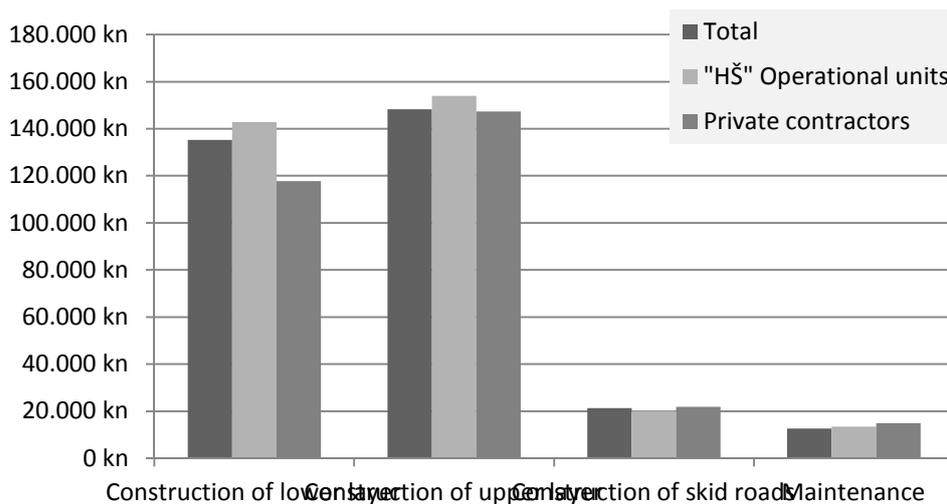


Figure 7: Average costs of construction and maintenance of forest roads and construction costs of skid roads

4 Discussion and conclusions

Construction and maintenance of primary forest roads and construction and repair of secondary forest roads represent a significant item in the costs of the company “Croatian forests”, Ltd. Zagreb. Construction of forest roads is provided by limited financial resources and a detailed analysis of costs and monitoring of trends can contribute to the rationalization of development and preservation of the whole primary and secondary forest road network.

The analysis of data for the period 2004 to 2011 provided the following pieces of information: the average cost of construction of upper and lower layer, construction of skid roads and maintenance of truck forest roads. Considering the overall costs of construction of lower and upper layer, as the cost of construction of individual forest roads, the presented data show a deviation from the planned costs (Anon 2011), which make part of the annual plans or are the object of planning the need of constructing new forest roads (Hodi and Juruši 2011).

For the observed period, the average construction cost shows an increasing trend – increase of cost, which can be explained by the increase of price of oil products (in the period in question) on one hand, and by increasingly demanding routs of new forest roads, on the other. In the recent past, the first forest roads were made in easily accessible terrains suitable for construction, and the used mechanization was then expensive, the duration of works was longer and the construction of forest roads on such terrains was not feasible. The intensity of construction of forest roads was increased as a result of continuous need for getting closer to wood assortments by forest roads, i.e. reducing the mean skidding distance, making accessible far away areas, very often, of demanding relief characteristics, as well as the result of change of construction technologies and machines. Closer construction cost of lower and upper layer is the consequence of the increased transportation distance of stone material required for the construction of the upper layer. In the past, it was possible to open borrow pits when constructing forest roads and then the material was used on the spot for the lower and upper layer, which reduced the transportation distance of stone material, and consequently also the cost of individual forest roads. In the observed period, the cost of stone material was also accompanied by the increase of oil products, and however it had no a significant effect on the increase of overall costs.

The actual cadastral office of primary forest roads should be upgraded and updated by a large number of data on the state of individual roads and the pertaining road facilities, and this would highly contribute to timely maintenance. Within the cadastral office of primary forest roads, new categorization should be applied, as new researches (Pentek et al. 2007, Neve erel 2010) show that the current Technical Conditions for forest roads are obsolete and that a detailed analysis of the actual primary forest road infrastructure is required.

The analysis made for the observed period by types of contractor showed that the share of the operating units of the Croatian Forests, Ltd. Zagreb in the total sum of costs of construction and maintenance of forest roads is higher than the share of private contractors and this relationship shows an increasing trend. The reason lies in higher investments in civil-engineering mechanization necessary for the construction and maintenance of forest roads and better qualification and efficiency of the operating units of the company “Croatian Forests”, Ltd. Zagreb. Furthermore, saving of financial resources through optimization of expenses is a condition for retaining work within the company’s operating units, which contributes to preserving the company’s property and retaining the current jobs or providing new jobs. All components of construction and maintenance of primary and secondary forest roads carried out in accordance with the annual plans show an increase of the share in total costs in favor of the operating units of the company „Croatian Forests“, Ltd. Zagreb. For the observed period, the average costs show no large deviations with respect to the type of contractor.

In accordance with the Forest Act (Official Gazette “NN” 140/05, 82/06, 129/08, 80/10, 124/10, 25/12, 68/12), forest infrastructure is primarily intended for the purpose of forest management and it makes an integral part of the forest. In case of use of forest road for acquiring income (Anon 2009), the users have to pay a fee for their use to the company (Croatian Forests, Ltd. Zagreb). The amount of the fee for forests owned by the Republic of Croatia is determined by a general act of the company. Maintenance of forest roads is the obligation of the company “Croatian forests“, Ltd. Zagreb, whose task is to enable each user

to drive his vehicle in all weather conditions. The total maintenance costs, in the observed period 2004 to 2011, are approaching more and more the total construction cost of forest roads (Fig. 6). The increase of maintenance costs is accompanied by the increase of oil product prices and by an ever increasing need for maintenance of the existing (larger all the time) forest road network. The maintenance cost of forest roads, considered by Forest Administrations, shows considerable deviations from the total average maintenance costs in the observed period. The reason lies in different relief factors. Maintenance cost is directly related to the quantity of the stone material built in the upper layer. Transport distance has a considerable impact on maintenance cost in individual Forest Administrations and right in these areas the methodology of preserving the upper layer should be developed and new methods of maintenance applied. The lowest maintenance cost was recorded in Split Forest Administration, which can be explained by a lower maintenance volume (lower thickness of pavement construction), conditioned by geological, pedological and climate factors and small transport distances of stone material (use of mobile crushers).

5 References

- Anon, 1997: Izvješ e o problematici gradnje i održavanja šumskih i protupožarnih prometnica i stanju otvorenosti šuma J. P. „Hrvatske šume“ p. o. Zagreb, p. 11.
- Anon, 2009: Pravilnik o korištenju šumske infrastrukture “Hrvatske šume”, d.o.o. Zagreb.
- Anon, 2011: Izvješ e o izgradnji donjeg i gornjeg ustroja šumskih cesta za razdoblje 2004-2011. “Hrvatske šume”, d.o.o. Zagreb.
- British Columbia Ministry of Forests, 2001: Forest Practices Code, Forest Road Engineering Guidebook, 2nd edition, Government of British Columbia, Victoria.
- Erichson, A., 2005: Helping Forest Landowners Manage Their Roads. *Journal of Western Forester*, 12-14.
- FAO, 1998: Manual for the planning, design and construction of forest roads in steep terrain, Food and Agriculture Organisation of the United Nations, Rome, p. 188.
- Hodi , I., Juruši , Z., 2011: Analysis of primary openness of forest managed by “Hrvatske šume” ltd. as basis for designing of future policy forest roads construction. [Analiza primarne otvorenosti šuma kojima gospodare HŠ d.o.o. Zagreb kao podloga za kreiranje budu e politike izgradnje šumskih cesta], Šumarski list br. 9-10, 2011, 487-499.
- Devlin, G. J., McDonnell, K., Ward, S., 2008: Timber haulage routing in Ireland: an analysis using GIS and GPS. *Journal of Transport Geography* 16(1), 63-72.
- Kochenderfer, J.N., Wendel, G.W., Smith, H.C., 1984: Cost of and soil loss on „minimum-standard“ forest truck roads constructed in Appalachians. Res. Pap. NE-544. Broomall, PS: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.
- Koger, J.L., 1978: Factors affecting the construction cost of logging roads. Tech. Note B27, Norris, TN: Tennessee Valley Authority, Division of Forestry, Fisheries, and Wildlife Development.
- Kramer, B.W., 2001: Forest road contracting, construction, and maintenance for small forest woodland owners. Oregon State University, Forest Research Laboratory, Research Contribution 35, p. 79.
- Layton, D.A., 1990: Forest road construction cost equations for the central Appalachians. Morgantown, WV: West Virginia University. M.S. thesis.
- Neve erel, H., Pentek, T., Pi man, D., Stanki , I., 2007: Traffic load of forest roads as a criterion for their categorization-GIS analysis, *Croatian Journal of Forest Engineering*, vol. 28 (1), p. 27-38.

Ou, F.L., Swarthout, C.D., 1984: Cost estimating model for forest roads. In: Proceedings, 64th annual meeting of the Transportation Research Board, 1984; Washington, DC.

Pentek, T., Pi man, D., Neve erel, H., 2005: Planiranje šumskih prometnica – postoje e stanje, odre ivanje problema i smjernice budu eg djelovanja. Nova mehanizacija šumarstva, Vol. 26 No. 1., 55-63.

Pentek, T., Neve erel, H., Pi man, D., Poršinsky, T., 2007: Forest road Network in the Republic of Croatia - Position and Perspectives, Croatian Journal of Forest Engineering, vol. 28 (1), p. 93-106.

Pentek, T., Neve erel, H., Poršinsky, T., Pi man, D., Lepoglavec, K., Poto nik, I., 2008: Methodology for Development of Secondary Forest Traffic Infrastructure Cadastre. Croatian Journal of Forest Engineering. 29 (2008), 1; p. 75-83.

Pentek, T., Pi man, D., Neve erel, H., Lepoglavec, K., Papa, I., Poto nik, I., 2011: Primarno otvaranje šuma razli itih reljefnih podru ja Republike Hrvatske. Croatian Journal of Forest Engineering, Volume 32, 401-416.

Pentek, T., Neve erel, H., Pi man, D., Poršinsky, T., 2007: Forest road network in the Republic of Croatia – Status and perspectives. Croatian Journal of Forest Engineering, Volume 28, 93-106.

Pi man, D., Pentek, T., Neve erel, H., Papa, I., Lepoglavec, K., 2011: Mogu nost i primjene relativne otvorenosti pri sekundarnom otvaranju šuma nagnutih terena Republike Hrvatske. Croatian journal of forest engineering 32 (2011), 1; 417-430.

Poto nik, I., Yoshioka, T., Miyamoto, Y., Igarashi, H., Sakai, H., 2005: Maintenance of forest road network by natural forest management in Tokyo University Forest in Hokkaido, Croatian Journal of Forest Engineering 26(2): p. 71-78.