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IMPACTS OF DIFFERENT JUNCTION TYPES ON HEAVY DUTY VEHICLES

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ABSTRACT

The paper includes the impacts which four different junction types cause on heavy duty vehicles. In order to indicate this clearly the light vehicles are surveyed, too. The impacts are estimated in quantitative units and in money terms. The junction alternatives are: an intersection, a roundabout, an interchange with one loop ramp and three rhombic ones and an interchange with four rhombic ramps. The type vehicles are a coach, a single unit truck, a truck + semi-trailer combination and a truck + trailer combination and two light vehicles; it is the passenger car and the van. The impacts are estimated by using a vehicle motion simulator based on dynamics. It is called VEMOSIM and developed in Finland.

The VEMOSIM outputs directly the data needed for quantifying the impacts, when vehicles move through the junctions. The impacts are: the fuel amount (and thus the variable vehicle operating costs), the emission amounts by components (NO_x, CO, HC, PM and CO_2), the time consumed, gear changes, etc.

Based on these output data the following cost items are calculated: the variable vehicle operating costs, the time costs and the emission costs and, additionally, the gear changes and information about the benefit distribution between the vehicle categories. The case study concerns a 4-leg junction of the main roads no. 5 and no. 14 in Finland (ADT ca 8500; 89 % of light vehicles and 11 % of HDVs).

The results and the conclusions are: the best alternative is the interchange with four rhombic ramps. However, its benefit/cost ratio is not high enough, because the construction costs are high and the traffic volume low. The roundabout is the worst. It causes extra costs compared with the present intersection, because of decelerations and accelerations, when the vehicles move through the roundabout. Among the different vehicle categories the greatest impact concerns the truck + trailer combination. Especially, the fuel consumption and emissions increase remarkably in the case of the roundabout. The VEMOSIM system is an effective tool for analyzing impacts of different junction types.

INTRODUCTION

The origin of the study is based on the traffic growth at a junction of two main roads (highways 5 and 14) in Eastern Finland. This is a normal junction with four legs, of which three are highways and one is a secondary road. The highway no 5 is locating in the direction South-North-South. The Eastern leg is highway no 14, and, especially, this has caused congestion during summer weekends. Because the present junction is of the type of the intersection, plans have been made in order to improve the traffic situation. The junction alternatives to be studied are: an intersection (current), a roundabout (abbreviated RA), an interchange with one loop ramp and three rhombic ones (IC L), and an interchange with all rhombic ramps (IC D).

The paper includes the impacts which four different junction types cause on different vehicle categories. These impacts are estimated in quantitative units and in money terms. The type vehicles are a passenger car, a van, a coach, a single unit truck, a truck + semi-trailer combination and a truck + trailer combination. The impacts are estimated by using a vehicle motion simulator based on dynamics. It is called VEMOSIM and developed in Finland.

STUDY METHOD

As a method we have used a vehicle motion simulator, VEMOSIM, based on dynamics.
The VEMOSIM simulates a motion of any vehicle. It is based on the technical characteristics of the vehicle (engine, powertrain and gear ratios, drive resistances etc.), the road vertical and horizontal geometry and the driving technique. In this case the time resolution for the simulation is 0.1 seconds. At the rate of this data updating frequency the VEMOSIM calculates the instantaneous power need and regulates the accelerator or brake pedal positions and gear locations according to these requirements, in other words simulates the real engine operating state ten times per a second.

The VEMOSIM outputs directly the data needed for quantifying the impacts, when vehicles move through the junctions. The impacts are: the fuel amount (and thus the variable vehicle operating costs), the emission amounts by components (NO_x, CO, HC, PM and CO_2), the time consumed, gear changes, etc.

Because all individual vehicles passing through the junctions cannot be simulated, a representative sample of different vehicles are selected for the vehicles categories. In this context they are called the type vehicles.

INPUT DATA

For the simulation concerning each type vehicle three different types of input data are needed: 1) the technical characteristics of the type vehicles, 2) the vertical and horizontal alignment of the different routes (continuously) and 3) the driving technique that is mainly composed of the goal speed pattern (meter by meter).

In order to calculate the total impacts (all vehicles passing the junctions), the traffic volumes by the vehicle categories and traffic routes (4 * 3 = 12) must be known, see table 1. The cross section traffic volumes by road leg and vehicle categories are seen in table 2.

The goal speed pattern is in general an array of the instantaneous speed that the driver tries to maintain at any part of the route to be driven. The current speed limit values naturally determine the most of the patterns, but for example at turns (left and right) as well as at roundabouts those speed limit values (80, 60 and 50 km/h) cannot be maintained. In those cases the goal speed is 20...30 km/h unless the vehicle stops. But sometimes the vehicles are obliged to stop when swerving the priority traffic. Then the goal speed is instantaneously 0 km/h. In the goal speed patterns the share of stopping vehicles has been taken into account. For each route and junction type alternative two patterns have been determined, the one for the non-stopping vehicles and the other for the stopping vehicles, see table 3.

The traffic is composed of six vehicle categories, which are represented by the respective type vehicles. These are:

Vehicle category	*Abbreviation*	*Average mass*
		kg
Passenger car	P	1200
Van	V	2300
Bus & coach	C	15000
Single unit truck	T	20000
Truck + semi-trailer	TS	35000
Truck + trailer	TT	50000

The detailed vehicle technical data are not presented here.

IMPACTS STUDIED

The impacts caused by the different junction alternatives are surveyed both as quantitative and as economical. The results are presented as differences compared to the present junction type (intersection). An example of a drive simulation through a roundabout is shown in figure 1.

The most important quantity is the fuel consumption. On the basis of the fuel consumption the all variable vehicle operating costs are determined, too.

The variable operating costs are composed of the following items:
- fuel costs
- lubricant costs
- repair and maintenance costs
- tyre costs

In this study the lubricant, repair & maintenance and tyre costs are assumed to change in the same ratio as the fuel consumption (Wehner's principle). These costs are presented both at the market price (including indirect taxes) and at the production cost price (excluding indirect taxes).

The used time is surveyed, too. The time has also shadow unit prices for the different vehicle categories. In this respect there is no difference between the market price and production cost price.

The pollutant emissions to be surveyed are:
- nitrogen oxides (NO_x)
- carbon monoxide (CO)
- hydro carbons (HC)
- particulate matters (PM)
- carbon dioxide (CO_2)

These pollutants also have shadow unit prices, by which the emission amounts have been converted to monetary values.

RESULTS

Fuel amount

The changes in the fuel amount are shown in figures 2 - 3. Concerning the different vehicle types in this respect the truck + trailer plays a dominant role. Concerning the junction alternatives the roundabout increases remarkably fuel consumption while the both interchange types decrease it.

Nitrogen oxides

The changes in the NO_x amount are shown in figures 4 - 5. As regards the nitrogen oxides the same conclusions as the ones regarding fuel consumption can be made. However, the truck + trailer seems to have an emphasized role.

Time

The time changes are shown in figures 6 - 7. In this respect the passenger car is dominant because of its high traffic volume and, in addition, to the highway 5 (South - North - South) the highway 14 (East - South) has some significance.

Variable vehicle operating costs

The variable vehicle operating costs at cost production price are shown in figure 8 and the ones at market price in figure 9. According to the definition of the variable vehicle operating costs (Wehner's principle) the impacts on them are in the same relationship as the impacts on fuel consumption.

Total costs

The changes in the total costs are shown in figures 10 and 11. Concerning the different vehicle types in this respect both the passenger car and the truck + trailer play a dominant role. Concerning the junction alternatives the roundabout increase total costs of both the passenger car and the truck + trailer. The interchange with four rhombic ramps is the best solution and decreases the total costs for all vehicle categories.

CONCLUSIONS

The best junction type is an interchange in general, because it causes savings in the vehicle operating, time and emission costs for all vehicles.
In this case the interchange with the four rhombic ramps brings the most benefits to the traffic.

On the contrary, the roundabout is the worst because it only increases vehicle operating, time and emission costs for all vehicles. In general, the roundabout should be avoided as junctions of main roads.

The VEMOSIM system is an effective tool for analysing impacts of different junction types.

TABLES & FIGURES

Table 1- **Traffic volumes ADT [veh/d] at the junction**

	DIRECTION	*P*	*V*	*C*	*T*	*TS*	*TT*	*TOT*
1	SOUTH-WEST	131	15	3	4	0	4	157
2	SOUTH-NORTH	1060	118	24	32	40	168	1440
3	SOUTH-EAST	1710	190	41	38	6	43	2027
4	WEST-NORTH	126	14	3	4	0	4	151
5	WEST-EAST	124	14	3	4	0	4	149
6	WEST-SOUTH	131	15	3	4	0	4	157
7	NORTH-EAST	226	25	7	8	3	19	287
8	NORTH-SOUTH	1060	118	24	32	40	168	1440
9	NORTH-WEST	126	14	3	4	0	4	151
10	EAST-SOUTH	1710	190	41	38	6	43	2027
11	EAST-WEST	124	14	3	4	0	4	149
12	EAST-NORTH	226	25	7	8	3	19	287

Table 2- Cross section volumes ADT [veh/d] at the junction

	L E G	*P*	*V*	*C*	*T*	*TS*	*TT*	*TOT*
1	SOUTH	5802	645	134	146	91	428	7246
2	WEST	761	85	18	24	0	24	912
3	NORTH	2822	314	67	87	84	381	3755
4	EAST	4119	458	101	99	17	131	4925

Table 3- Proportion of stopping flows and average waiting time at the junction

	ALTERNATIVE		*1*		*2*		*3*		*4*
		STOP	*TIME*	*STOP*	*TIME*	*STOP*	*TIME*	*STOP*	*TIME*
		%	*s*	*%*	*s*	*%*	*s*	*%*	*s*
1	SOUTH-WEST	22	6	8	4	45	6	35	6
2	SOUTH-NORTH	0	0	8	4	0	0	0	0
3	SOUTH-EAST	0	0	8	4	24	2	20	2
4	WEST-NORTH	100	2	8	4	65	10	30	10
5	WEST-EAST	100	2	8	4	30	0	0	0
6	WEST-SOUTH	100	2	8	4	30	4	0	0
7	NORTH-EAST	35	6	8	4	20	2	25	10
8	NORTH-SOUTH	0	0	8	4	0	0	0	0
9	NORTH-WEST	0	0	8	4	20	1	25	1
10	EAST-SOUTH	100	2	8	4	0	0	20	2
11	EAST-WEST	100	2	8	4	0	0	0	0
12	EAST-NORTH	100	2	8	4	0	0	0	0

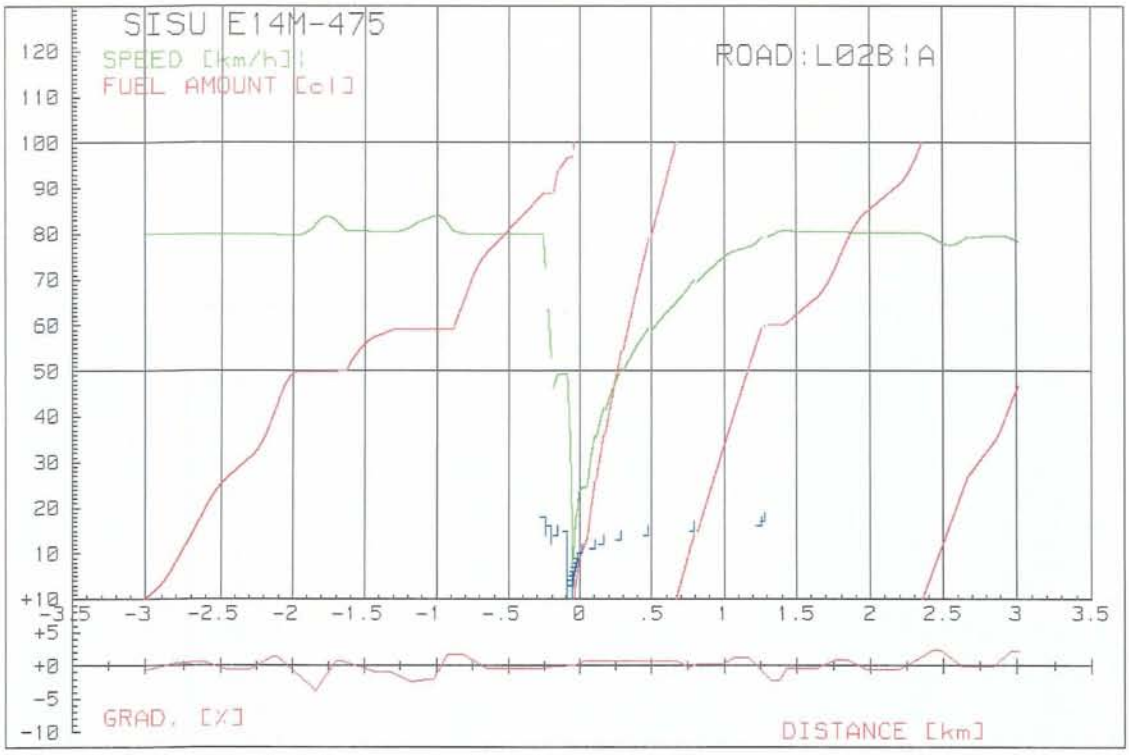

Figure 1 - An example of a drive simulation through a roundabout

Type vehicle: truck + trailer

Route: South - North

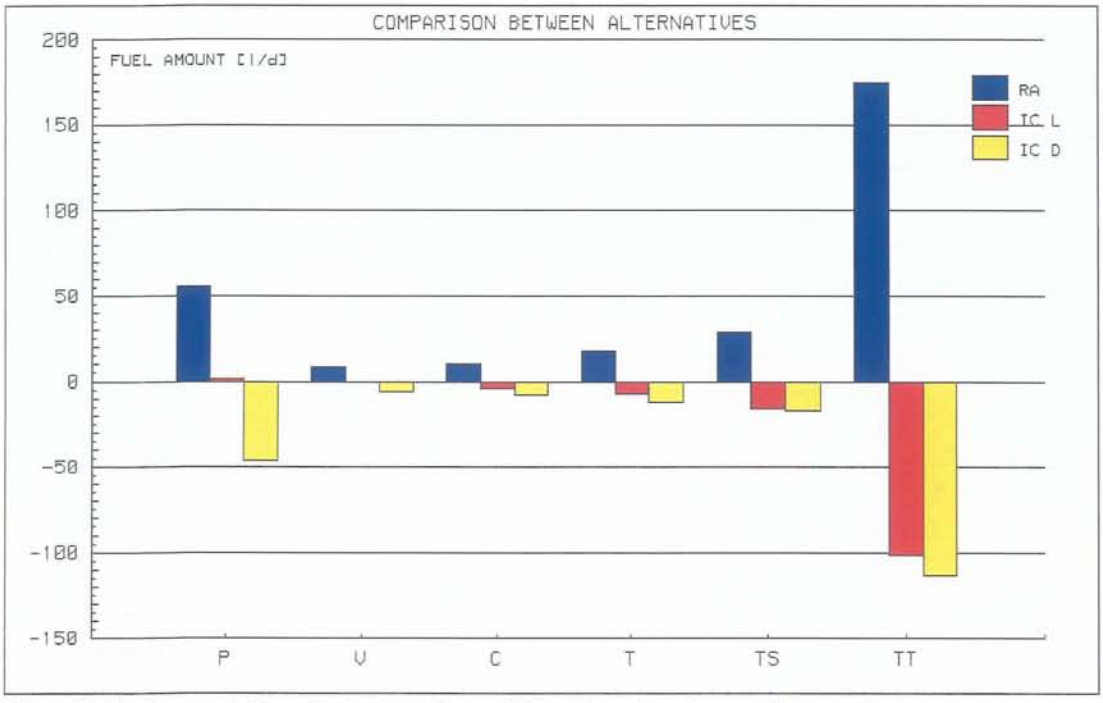

Figure 2 - Fuel amounts by vehicle categories at different junction types vs intersection

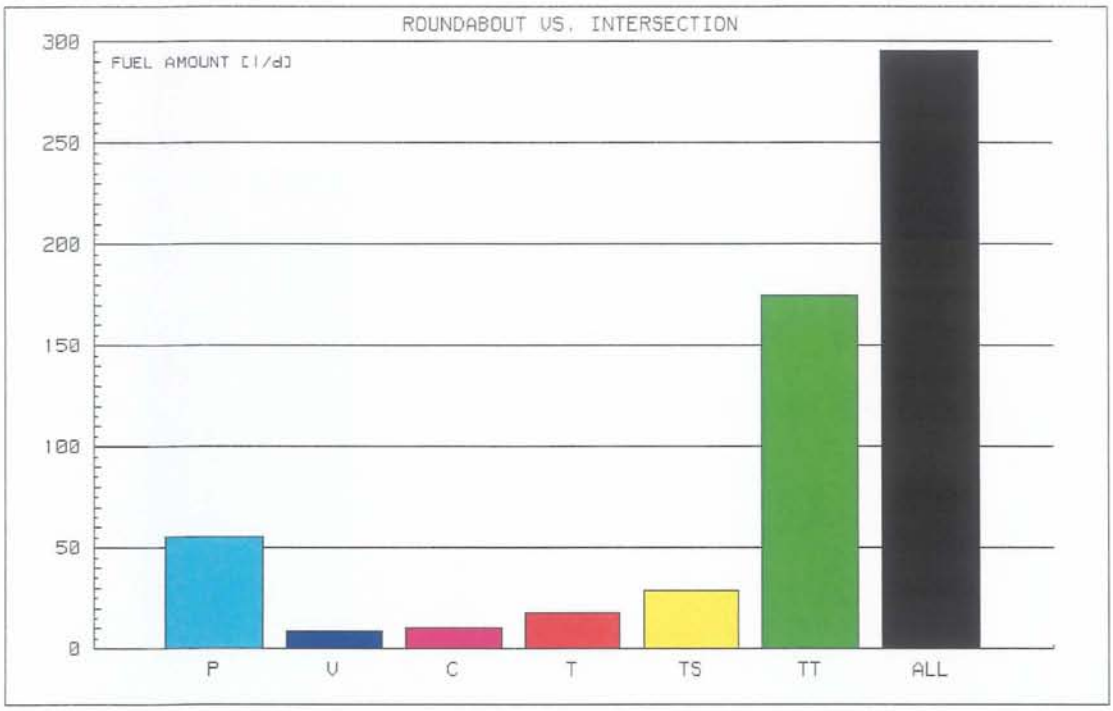

Figure 3 - Fuel amounts by vehicle categories at roundabout vs intersection

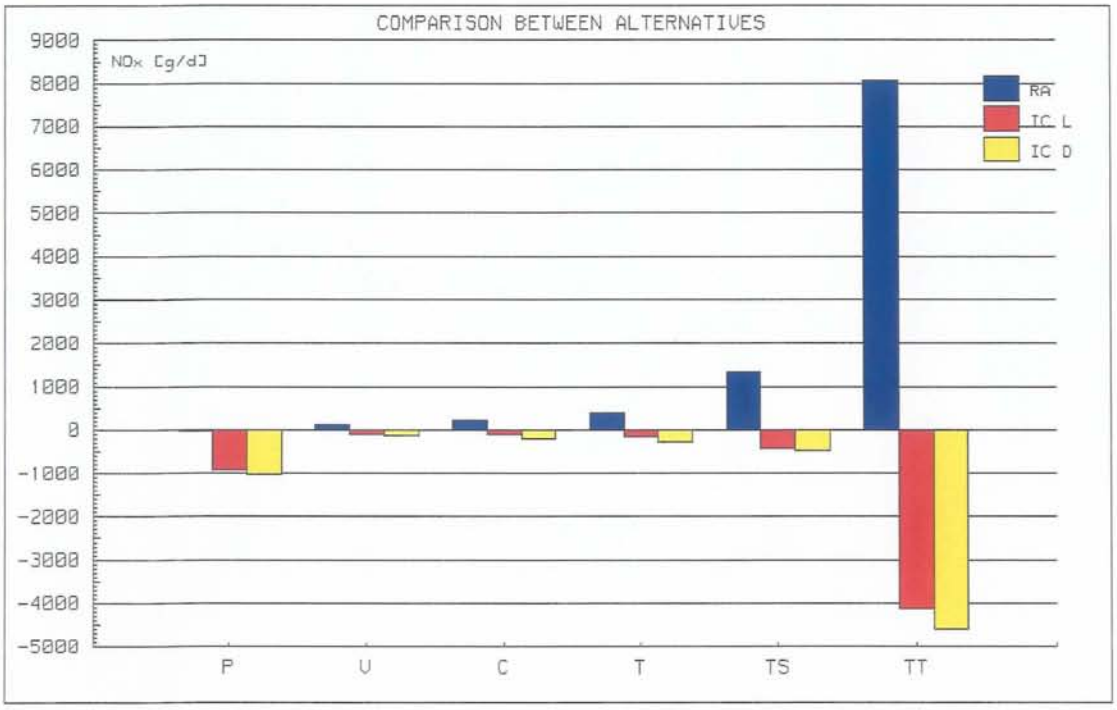

Figure 4 - NO_x amounts by vehicle categories at different junction types vs intersection

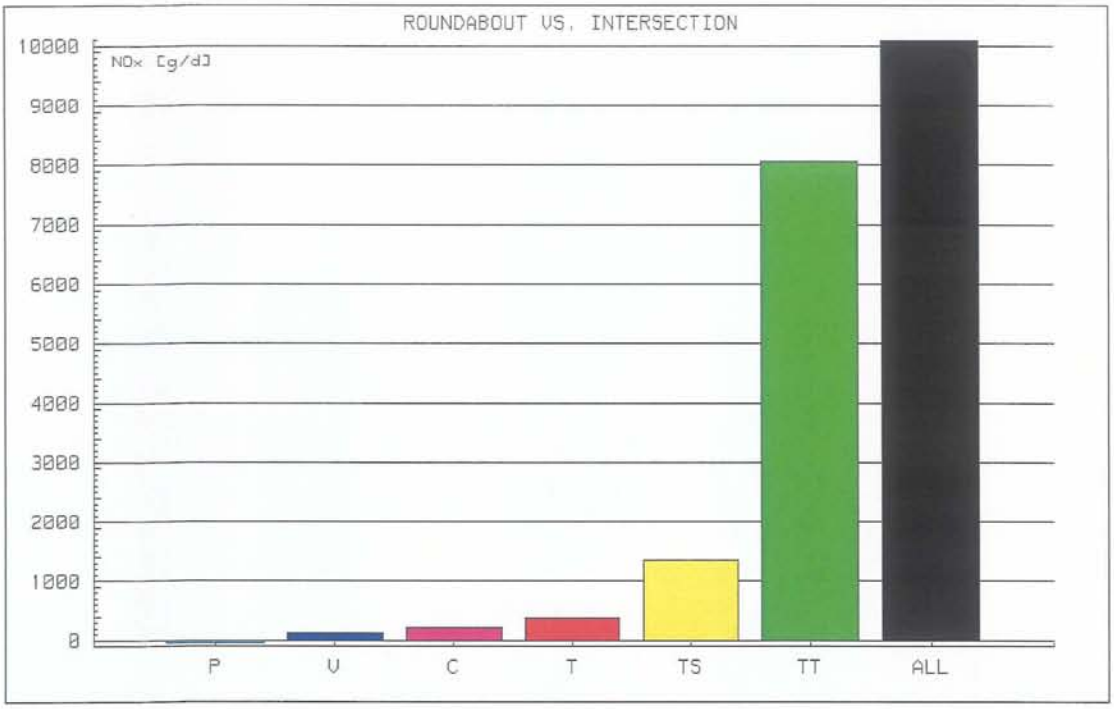

Figure 5 - NO_x amounts by vehicle categories at roundabout vs intersection

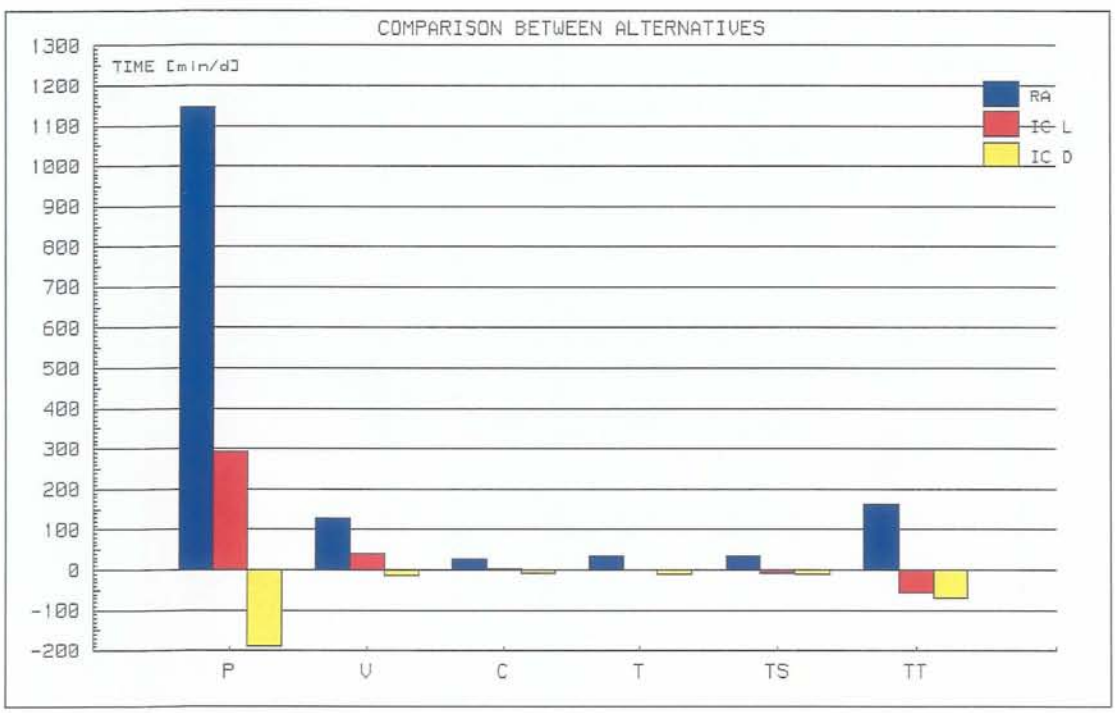

Figure 6 – Time consumed by vehicle categories at different junction types vs intersection

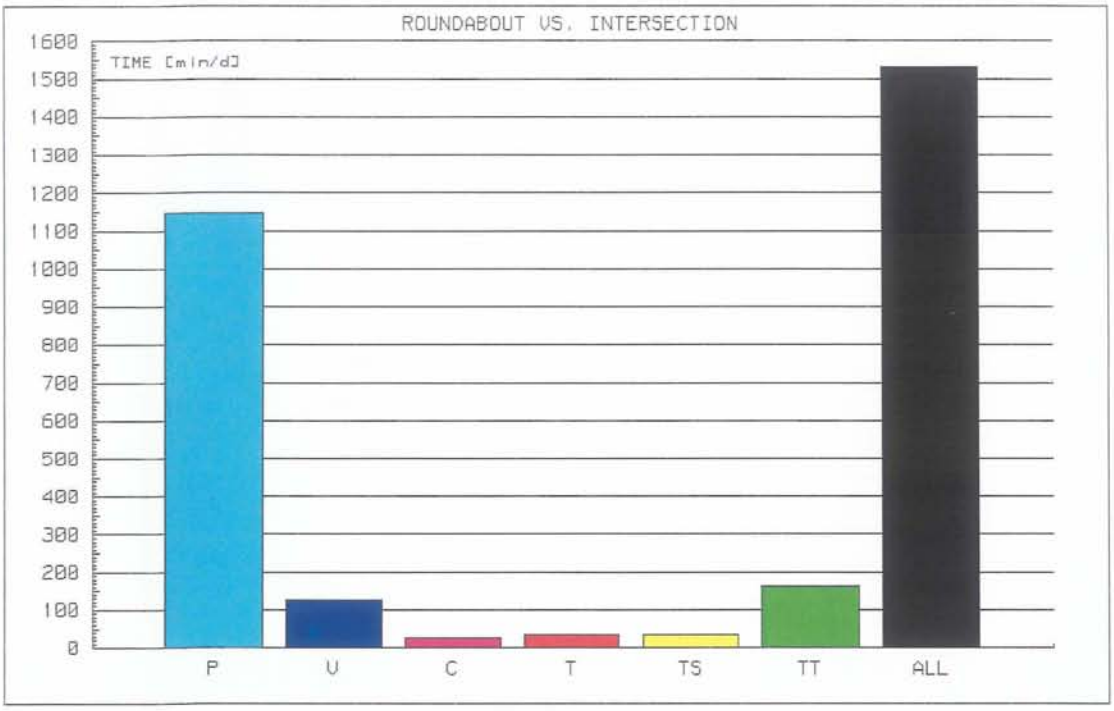

Figure 7 –Time consumed by vehicle categories and their sum at roundabout vs intersection

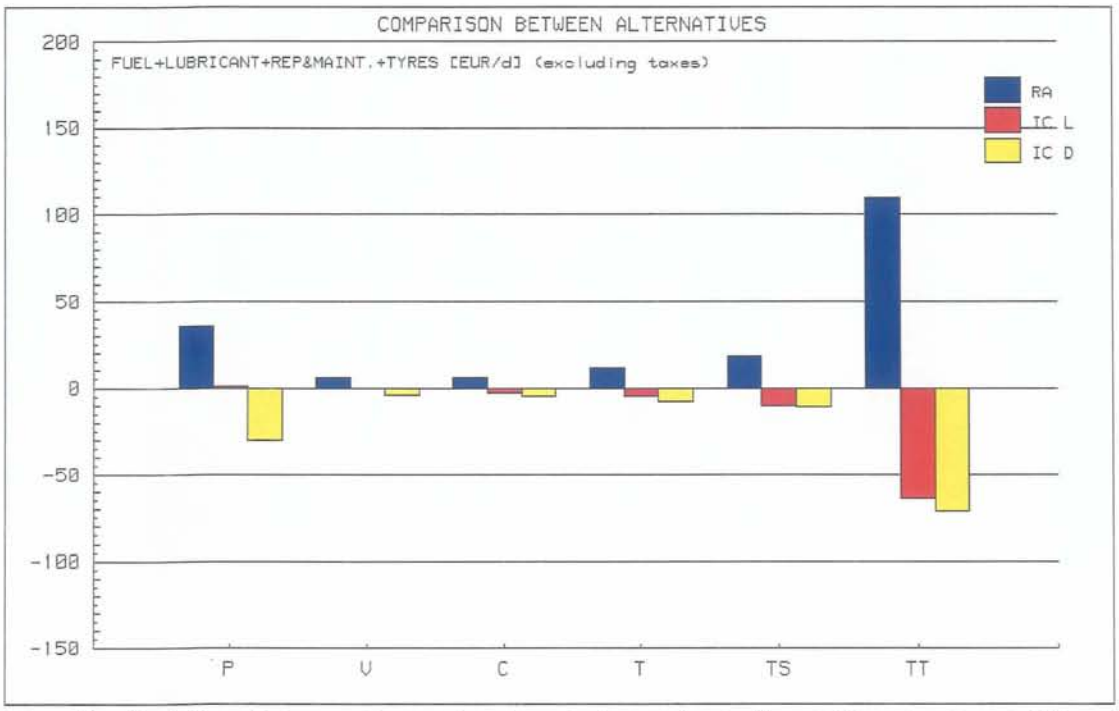

Figure 8 – Variable vehicle operating costs at production cost price by vehicle categories at different junction types vs intersection

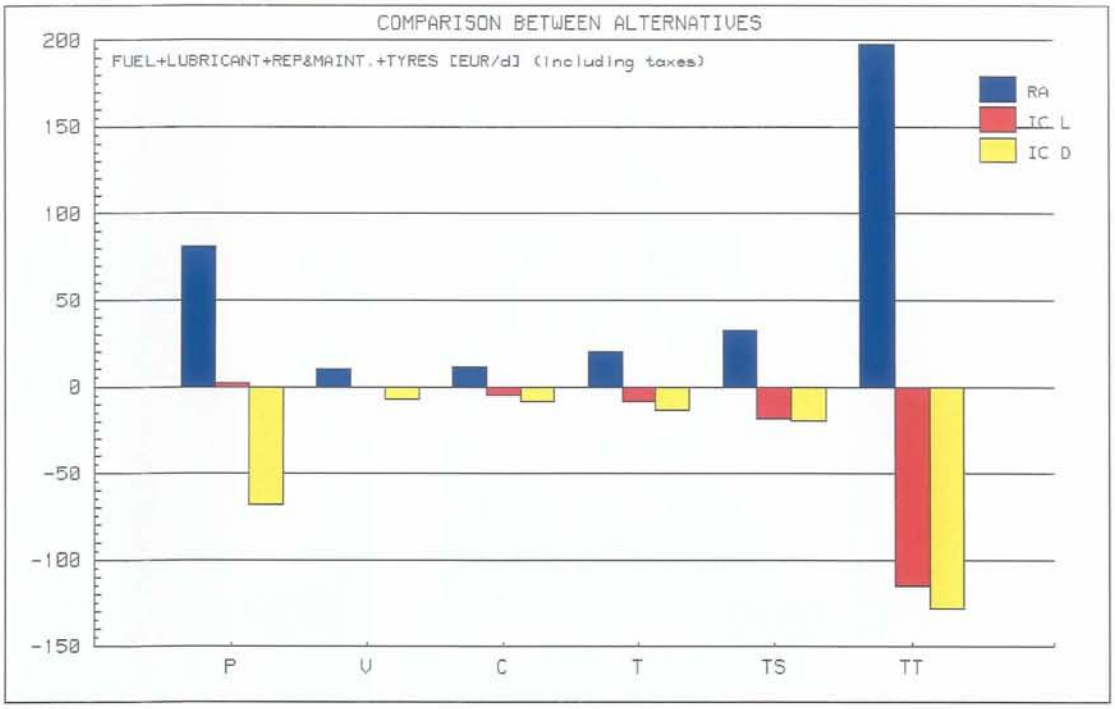

Figure 9 – Variable vehicle operating costs at market price by vehicle categories at different junction types vs intersection

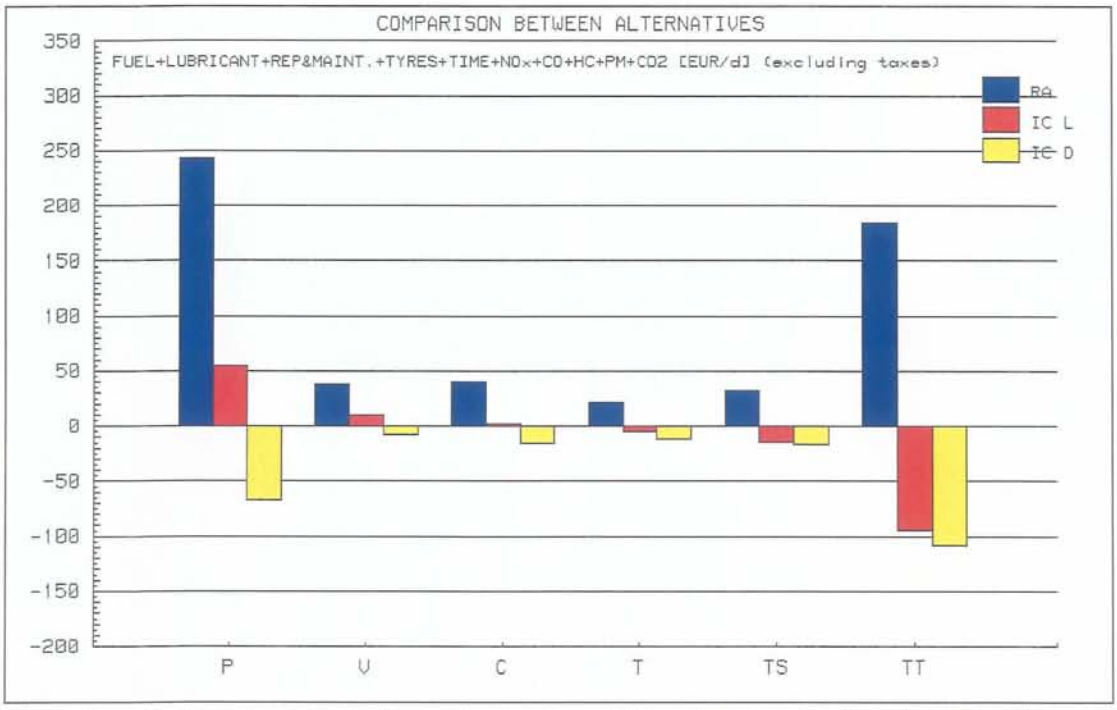

Figure 10 – Total costs at production cost price by vehicle categories at different junction types vs intersection

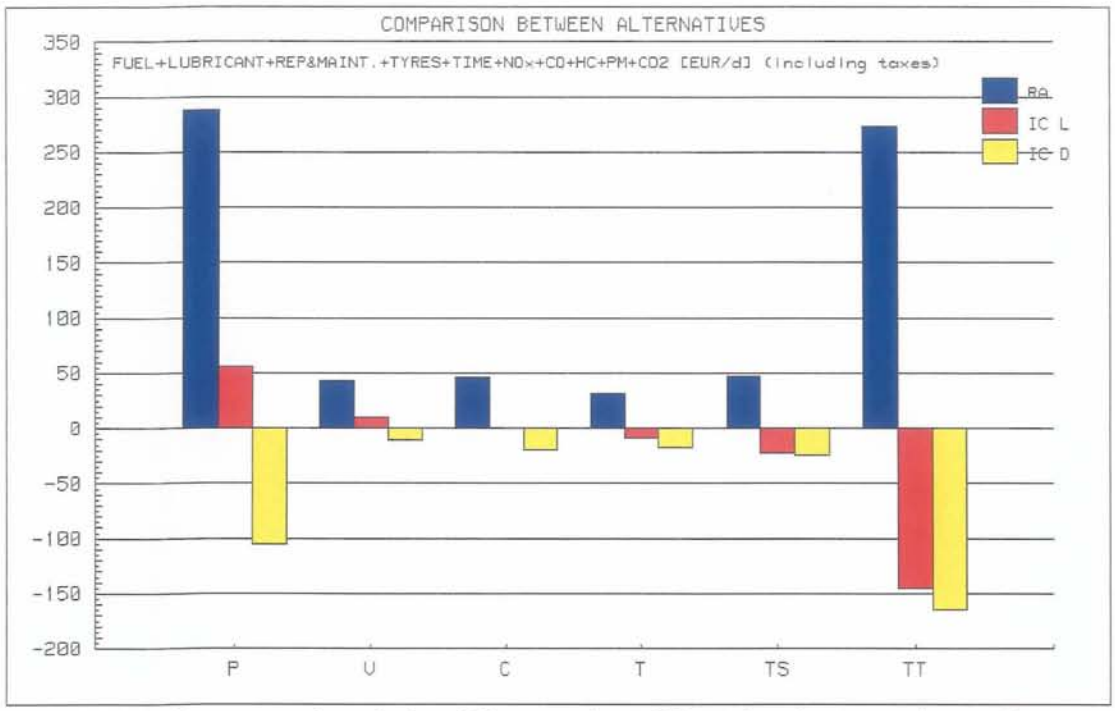

Figure 11 – Total costs at market price by vehicle categories at different junction types vs intersection