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THE COST OF TIME AND THE DEMAND FOR PASSENGER TRANSPORTATION

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1.AIM OF THIS STUDY

In the present study two aims can be distinguished. On the one hand an attempt was made to measure the value of the time spent in private passenger transportation in Belgium, in order to obtain an approximation of the economic cost of the alternative means of passenger transportation.

On the other hand the determinants of modal choice in private passenger transportation in Belgium were investigated.

The demand for passenger transportation has been subject to a number of investigations, some of which are included in the bibliography. These studies reveal that the important variables in the determination of passenger modal choice are: (1) price, (2) parking facilities, (3) disposable income, (4) economic value of time gained, (5) the notions "security" and "comfort". In this study special emphasis will rest upon the factors (1), (3) and (4).

The study of the impact of the time cost, next to the impact of the material transportation price on the demand for transportation, may yield some useful insights for the appraisal of the Belgian passenger transport policy. The controversy between a price (or say, a taxation, or a subsidization) policy and a policy which entails an improvement of the driving or waiting times in transportation, can for example, be better understood in the light of this work.

(*) The authors are indebted to Drs. G. Blauwens for valuable comments. Evidently, the authors are responsible for the use that has been made thereof.

Both aims, i.e., both parts of the study involve the valuation of time. A relatively recent development on this domain was made by Becker /1/. The main new idea in his article was to consider the consumer as a producing unit of consumption activities which require two types of inputs: goods (or services) and time. On the assumption that the consumer tends to maximize his production of activities under budget and time constraints, one obtains the classical result, that, for each activity the ratio between the marginal utility of one input, A say, and the marginal utility of time must equal the ratio between the price of A and the price or marginal value of time. This ratio must also equal the technical substitution ratio between time and the good A, in the production of an activity.

Some authors tried to deduce on this theoretical ground, the marginal value of time in given activities, from empirical observations (see for instance Quarmby /16/ and Stopher /18/). Although this kind of research is very promising, it cannot be used for an analysis based on time series.

In this study, the value of time was taken simply to be the net rate of pay. The argument is, that this variable represents the opportunity cost of leisure. This argument, allows us to measure approximately the value that a large group of individuals attaches to travelling time. F.X. de Donnea /3/, points out that the valuation of travel time differs according to the circumstances in which time is spent. This kind of differentiation was neglected in the present study.

The next section of this study will be entirely devoted to the measurement and the evaluation of the time cost for alternative means of transportation. The study of the determinants of modal choice in Belgian transportation modes is presented in section three. Some conclusions follow in section four. Two appendices are attached to this document, as well as a selected bibliography.

The analysis was executed for two inter-city means of transportation: railways and private cars, as well as for three urban modes, notably, busses, tramway and private cars. With "inter-city transportation" we indicate the mutual transport between regional centres and major centres, while urban transportation is considered as the transport within major centres only.

A final preliminary remark concerns the coefficient estimates. Theoretically, one would expect the coefficients of the money cost and of the time cost to be equal, on the condition that the capital market were perfect. But it should also be kept in mind, that travelling has a recreational value, even on one's way to or from work, and may not be considered entirely as an input.

2. MEASUREMENT OF THE TIME ELEMENT

2.1. Preliminary remarks

In the present subsection it is outlined in which manner the variable of time spent in various sorts of passenger transportation can be approximated.

There are a number of main difficulties which are encountered in this respect. A traveller from a point x in city A to a point y in city B may possibly make use of a number of different modes. Consequently, all the features of the whole network, as well as the interactions between various modes in this network will be important to his choice of mode. For example, waiting times for busses should be coupled to waiting and connection times for trains in order to evaluate properly the total transportation time spent. At present it was impossible to follow this line of approach. Instead, the time spent in each of the transport modes was investigated separately.

Obviously, the total time in a particular form of transportation falls apart in driving times and waiting times.

Driving times for each of the modes considered, were calculated on a sample basis. This implied essentially that the problem was studied for main connections only.

The network which was considered for inter-city transportation, consisted of some 20 lines (see fig.1). Approximately the same lines were chosen for railway and for car transportation. The annual average driving times per line could be read from the official time-tables in the case of the railways. In the case of car transportation, driving times could be approximated through the relationship between number of lanes and average speed. The results of the investigations of the Highway Research Board (1) as well as the data concerning the evolution of the number of lanes for each road in the sample were used for this purpose. In both transport modes, the annual average driving times on each particular line were weighted with the traffic volume on that line, in order to obtain a synthetic series of the average driving time for each of the inter-city transport modes. The series consists of 19 observations (1952-1970) in the case of the railways, and of 20 observations (1952-1971) in the case of car transportation.

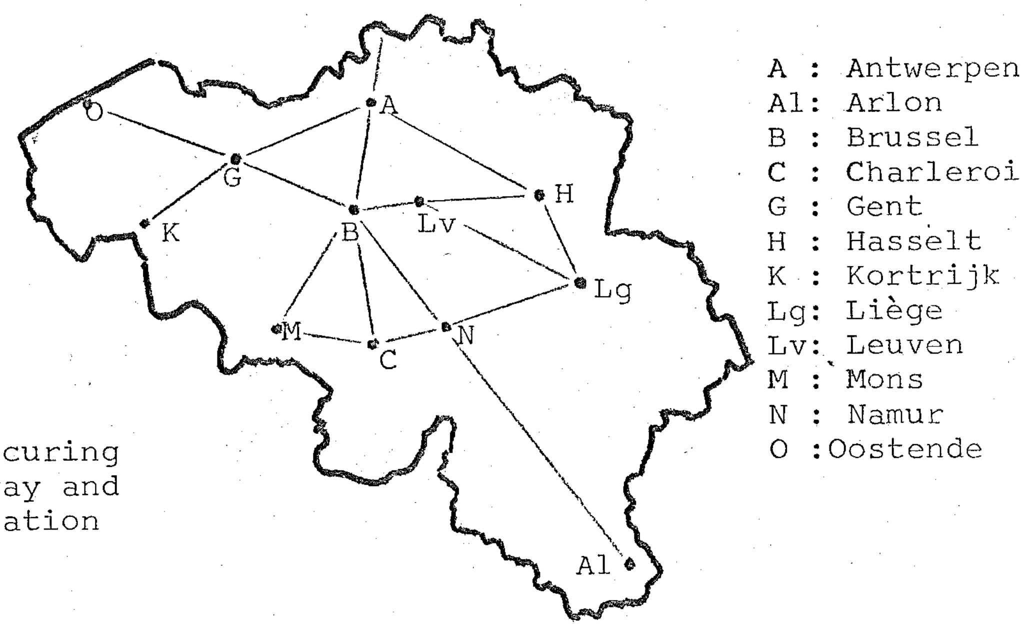


Fig.1.

Sketch of the lines, occuring in the sample for Railway and Intercity Car Transportation

The sample for urban transportation modes was taken in the city of Antwerp. It was assumed that the driving time of cars in this town runs parallel to the driving time of busses. Allowance was made

(1) See: - Capacité des Routes, Editions Janio, Bruxelles, 1954, pp.31, 33, 48; - Highway Capacity Manual, Highway Research Board, Washington, 1966, p. 63.

for the fact that cars do not lose time on account of the stepping in of passengers - nor on the stop-and-go sequence which belongs to it - as busses do.

The calculations of driving times in the urban public transport modes are executed by the same method as in the case of the railways. Five lines were selected for both busses and tramways. The annual average driving times could be read from the offical time schedule, and these driving times per line were then weighted with the annual traffic volumes on each line. However, there is a difference, referring to the length of the series. In the case of public urban transportation (and therefore also in the case of car transportation), the driving times were not available before 1962, so that only 10 observations (1962-1971) are available here.

In Appendix A, the reader will-find more details as to the measurement of the cost of driving times for the various modes.

As to waiting times, only those which are due to the discontinuity of departures in main stations are considered here. This kind of waiting times are inversely proportionate to the frequency of departures in e.g. the final stations of a line. The passenger car is the only transport mode which is not subject to such kind of waiting times.

There is however another source of delay, which is very important with respect to all urban transportation modes, notably: congestion, traffic lights etc. This kind of waiting time is incorporated in the driving time for these modes, since they are derived from the time-schedules that are actually followed.

In order to approximate the average cost of time, the average time spent for one kilometer in the various transport modes was weighted with the net wage per unit of time earned in the industry.(1).

The results of these calculations allow us to investigate the relative importance of the "material" price and of the total economic cost of the alternative modes of transportation. Even allowing for the fact that the estimates give but a broad picture, it should nevertheless be pointed out that the conclusions offer striking information. In section 2.2 these factors are compared for the various modes.

2.2. Money cost, time cost, total cost

An investigation of the figures in the accompanying tables and graphs shows that time cost is the principal part of total cost, except in the case of intercity car transportation (2).

Table 1. Share of the money cost and time cost in the total cost in 1971 (*)

TRANSPORT MODE	Absolute figures (in BF per km(**)		Relative figures Total = 100.0	
	MONEY COST	TIME COST	MONEY COST	TIME COST
Railways	0.7133	0.8609	45.3	54.7
Car (intercity)	1.3367	0.5558	70.6	29.4
Bus	1.7532	6.2872	21.8	78.2
Tramway	1.7532	5.2267	25.1	74.9
Car (urban)	1.4384	2.6744	35.0	65.0

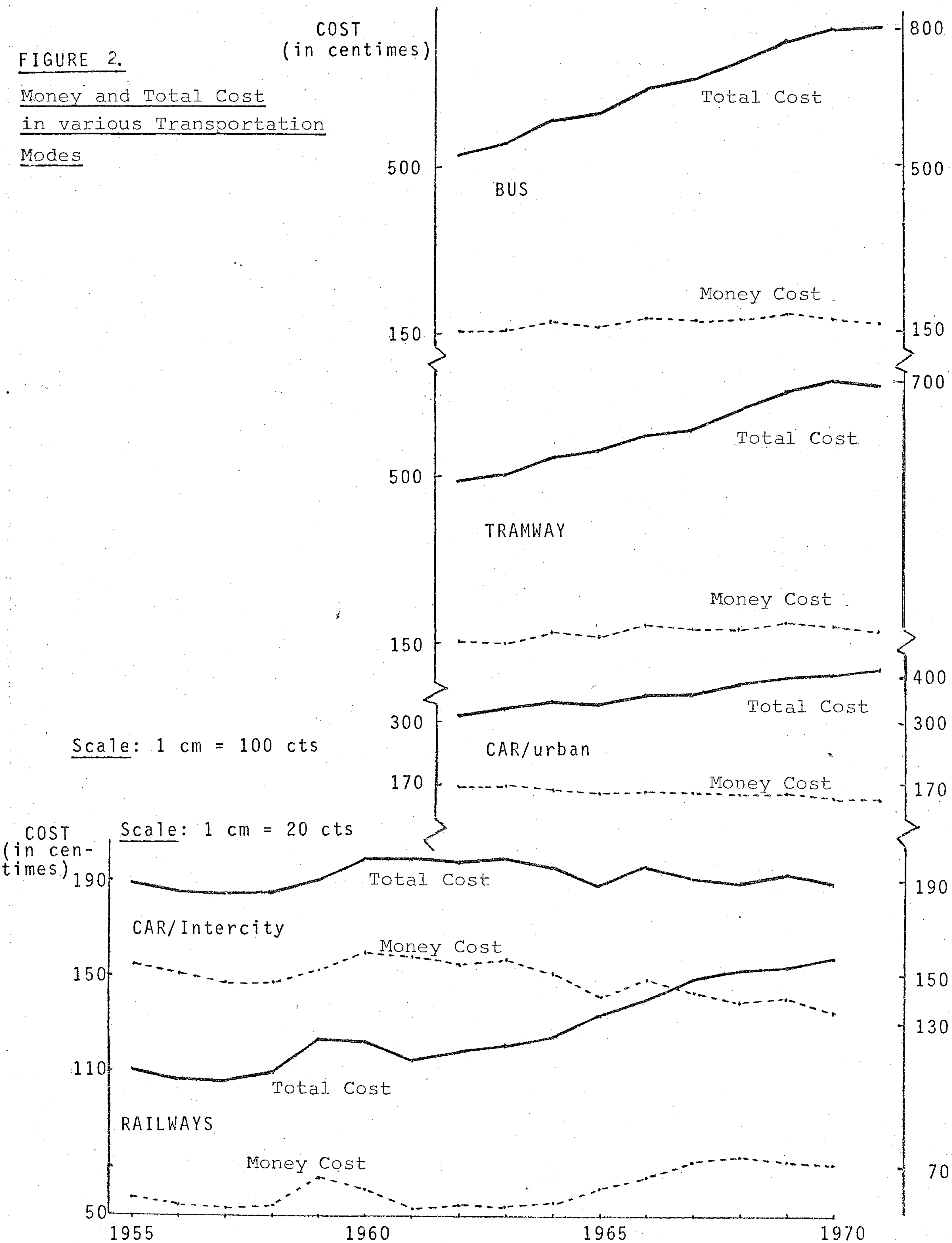
(*) The figures for 1971 were not available in the case of railway transportation. The 1970 figures were used there.
(**) Car-km in the case of both intercity and urban car transportation, passenger-km in all other cases.

(1) Source: An index of the net wage per unit of time, earned in the industry was found in the Recherches Economiques de Louvain, Supplement Statistique, série II,B, Rénumérations,Appointements, Coûts, Industries par heure. This index was transformed in a series of absolute figures,by means of the absolute figure for 1966 found in Statistisch Tijdschrift, december 1971, "Lonen in de nijverheid", Algemeen gemiddelde (alle bedrijfstakken, mannen en vrouwen).

(2) The price (cost) series, are deflated. The price index of GNP was used for this purpose.

FIGURE 2.

Money and Total Cost in various Transportation Modes



In all cases the growth rate of the time cost is greater than that of private cost, which may mean that the discrepancy between private and total cost will increase in the future.

Table 2. Average annual growth rate of money cost, time cost and total cost in the various modes (*)

TRANSPORT MODE	Average rate over 1962-1971 (%)			Average rate over 1952-1962 (%)		
	MONEY C.	TIME C.	TOTAL C.	MONEY C.	TIME C.	TOTAL C.
Railways	3.2	3.3	3.3	0.4	0.5	0.4
Car (intercity)	-1.5	2.8	-0.4	0.0	2.5	0.3
Bus	1.0	5.5	4.3	3.4	(**)	(**)
Tramway	1.0	4.6	3.5	3.4	(**)	(**)
Car(urban)	-1.5	6.0	2.6	0.0	(**)	(**)

(*) The average was calculated over 9 years only, since the 1971 figure was not available.
(**) No observations available.

The figures also reveal, that total cost is increasing at a much higher rate in public transportation than it is in private transportation, mainly on account of the decrease (by 1.5% a year) of the latter's money cost or material price. The competitive position of the public transportation modes, is in other words deteriorating.

3. REGRESSION RESULTS

In this section regression experiments regarding the determinants of passenger transportation are reported upon.

Several experiments were performed. First, the separate effects of money (p_{1i}) and of the time cost (p_{2i}) on the demand for transportation in each mode i were studied. The second and third exeriments were arranged in order to measure the cross effects of both the material price and the time cost as to the level of demand in the main competing service. For the railways, the main alternative is intercity car transportation and vice versa. For the urban modes, the cross effects that were considered important are those between the bus and tramway on the one side and the car on the other. So, it appears that cross effects are studied between public modes on the one hand and private ones on the other.

A final group of experiments should allow an investigation of the impact of lagged variables.

Apart from the time cost and the material cost, we retained as important explanatory variables, the level of disposable income (y_d), and time (t). The latter was added in order to account for the gradual shift in demand, due to technological progress. Further it was necessary to introduce a dummy variable, for the explanation of the quantity demanded of urban car transportation. In Antwerp there has been a shift of through-traffic from city lanes to a newly built belt-highway around the city, during the period of observation.

All the demand equations were specified in double logarithmic form, so that constant elasticities were obtained.

In order to estimate the parameters, ordinary least squares were used in most of the cases (after taking procentual changes of the original variables). The interactions of supply and demand have not been investigated for those cases. The case of urban car transportation forms an exception, in that the driving time in this transportation mode (and therefore also the time cost), is dependent on the number of cars in the city. So that next to the relation

$$x_{CA} = f(p_{2CA}, \text{etc....})$$

there exists a second relation, stating that:

$$p_{2CA} = f(x_{CA}, \text{etc...})$$

The original demand equation would read

$$x_{CA} = b.(p_{1CA})^{a_1}.(p_{2CA})^{a_2}.(y_d)^{a_3}.(d)^{a_4}.e^{\lambda t}.e^{\mu} \qquad (3.1)$$

where p_1, p_2, y_d and t are as explained earlier in this section and where d = the dummy
= error term.

Equation (3.1) is not identifiable since x_{CA} and p_{2CA} are interdependent. On the other hand, equation (3.1) belongs to a system of equations, and the equation may be identified by the application of a 2SLS technique on the condition that the second equation of the system contains at least one variable that does not accur in equation (3.1). This condition is satisfied, since we can write:

$$p_{2CA} = b'(x_{CA})^{a'_1}.(D_T)^{a'_2}.(D_B)^{a'_3}.e^{\lambda' t}.e^{\mu'} \qquad (3.2)$$

where D_T = total number of tramway departures per day (main tramway lines only)
D_B = total number of bus departures per day (main bus lines only).

The driving time of cars in urban areas will generally be affected to some extent by the relative frequency of busses and tramways per unit of time.

The data, that were used for the computations, are presented in table B.2 of appendix B. Some comments are attached to that table.

The regression results are presented in tables 3 to 7. A word should be devoted first to the subscripts, used with the symbols. Essentially, each mode is referred to by its initial letter. This rule was violated in the case of intercity car transportation, where the subscript "c" was used, and in the case of urban car transportation, where the subscript "CA" was used. Further one must know that p, the total price, is the sum of p_1 and p_2.

In most of the following tables, a number of dynamic relations are included. An additional subscript was used to indicate whether the immediate effect (t) or the one period lagged effect (t-1) of the variable is meant.

Table 3. Regression results: the Railways (*)

		R^2
1	$x_R = \underset{(0.10)}{-0.19p_1} \quad \underset{(0.19)}{-0.26p_2} \quad \underset{(0.34)}{+0.55y_d} \quad \underset{(2.89)}{-3.97}$	0.51
2	$x_R = \underset{(0.21)}{-0.43p} \quad \underset{(0.21)}{-0.04p_{1C}} \quad \underset{(0.34)}{+0.55y_d} \quad \underset{(3.30)}{-4.25}$	0.51
3	$x_R = \underset{(0.24)}{-0.37p} \quad \underset{(0.29)}{+0.45p_{2C}} \quad \underset{(0.34)}{+0.77y_d} \quad \underset{(2.65)}{-4.69}$	0.61
4	$x_{R_t} = \underset{(0.09)}{-0.04p_{1t}} \quad \underset{(0.17)}{-0.34p_{1t-1}} \quad \underset{(0.18)}{-0.23p_{2t}} \quad \underset{(0.21)}{+0.10y_{dt}} \quad \underset{(0.40)}{+0.49}$	0.85
5	$x_{R_t} = \underset{(0.13)}{-0.12p_{1t}} \quad \underset{(0.35)}{-0.38p_{2t}} \quad \underset{(0.51)}{+0.40p_{2t-1}} \quad \underset{(0.43)}{+0.68y_{dt}} \quad \underset{(3.19)}{-6.64}$	0.73
6	$x_{R_t} = \underset{(0.13)}{-0.12p_{1t}} \quad \underset{(0.42)}{-0.50p_{2t}} \quad \underset{(0.46)}{+0.77y_{dt}} \quad \underset{(0.27)}{+0.11y_{d_{t-1}}} \quad \underset{(3.60)}{-6.52}$	0.68
(*) 19 observations		

In railway transportation, the elasticities of the material price, the time cost and the total cost are well below unity, whereas disposable income has a larger impact. In the second row of table 3, one reads that the material price of intercity car transportation has only a very small impact on the quantity demanded in railway transportation. An augmentation of p_x (e.g. through the price of gas, whether or not an account of taxation), does not lead to an increase of the demand for railway services. On the other hand an improvement of the travel speed in car transportation (e.g. through the construction of a highway), does affect the railways' demand appreciably: the cross elasticity of p_{2C} amounts to 0.45.

The effect of the material price of one period before on demand is far more important than its instantaneous effect, but the coefficient of the time cost, one periode before (p_{2t-1}) is not clear.

Table 4. Regression results: Intercity Car Transportation (*)

		R^2
1	$x_c = \underset{(0.46)}{0.14p_1} \underset{(0.26)}{-0.43p_2} \underset{(0.31)}{+0.45y_d} +6.55$	0.32
2	$x_c = \underset{(0.14)}{-0.24p} \underset{(0.31)}{-0.36p_{1R}} \underset{(0.72)}{=0.86y_d} \underset{(2.53)}{+6.87}$	0.30
3	$x_c = \underset{(0.14)}{-0.23p} \underset{(1.08)}{+1.10p_{2R}} \underset{(0.78)}{+0.92y_d} \underset{(2.23)}{+5.81}$	0.27
4	$x_{ct} = \underset{(0.40)}{0.09p_{1t}} \underset{(0.37)}{+0.06p_{1t-1}} \underset{(0.29)}{-0.46p_{2t}} \underset{(0.34)}{+0.35y_{dt}} \underset{(4.60)}{+8.90}$	0.32
5	$x_{ct} = \underset{(0.09)}{0.37p_{1t}} \underset{(0.19)}{+0.23p_{2t}} \underset{(0.22)}{-1.34p_{2t-1}} \underset{(0.23)}{+0.63y_{dt}} \underset{(1.25)}{+6.74}$	0.49
6	$x_{ct} = \underset{(0.28)}{0.32p_1} \underset{(0.07)}{-0.15p_2} \underset{(0.72)}{+0.57y_d} \underset{(0.62)}{+1.00y_{dt-1}} \underset{(3.22)}{+3.84}$	0.58
(*) 20 observations		

The most striking results in this table are, that an increase in the material price does not bring about a decrease of the demand for car transportation, whereas the time cost has an appreciable impact on demand, especially in the long run (see rows 1 and 5). The income elasticity is larger here than in the case of railway transportation, and it appears to become well over unity in the long run (see row 6).

Another remarkable result is, that the cross effect of the railway's time cost on car transportation demand is over unity, although the statistical precision as to this result does not allow us to draw final conclusions (row 3).

On the other hand of the material price of the railways (p_{1R}) on car transportation is negative (second row), which would lead us to the rather unexpected statement that, in consumption the railway is a complement of the car for intercity traffic. Again, the statistical precision was low.

Table 5. Regression results: Bus transportation (*)

		R^2
1	$x_B = \underset{(0.23)}{0.44p_1} \underset{(0.82)}{-0.02p_2} \underset{(0.67)}{+1.46y_d} \underset{(8.08)}{-18.27}$	0.63
2	$x_B = \underset{(0.48)}{1.05p} \underset{(0.45)}{-0.25p_{1CA}} \underset{(0.74)}{+1.28y_d} \underset{(6.98)}{-21.47}$	0.62
3	$x_{Bt} = \underset{(0.35)}{0.13p_{1t}} \underset{(0.18)}{-0.22p_{1t-1}} \underset{(1.06)}{+0.79p_{2t}} +1.10y_{dt} \underset{(8.51)}{-18.23}$	0.65
4	$x_{Bt} = \underset{(0.29)}{0.33p_{1t}} \underset{(1.03)}{+0.42p_{2t}} \underset{(0.14)}{-0.44p_{2t-1}} \underset{(0.90)}{+1.32y_{dt}} \underset{(10.85)}{-15.85}$	0.60
5	$x_{Bt} = \underset{(0.18)}{0.52p_{1t}} \underset{(0.58)}{-1.09p_{2t}} \underset{(0.56)}{+1.94y_{dt}} \underset{(0.72)}{-1.82y_{dt-1}} \underset{(0.86)}{-0.44}$	0.86

(*) 10 observations

For this first urban mode, only five experiments were made. This comes from the fact that the time cost of urban car transportation was derived from the time cost of the bus. This means that the third experiment, where the time cost of the car is inserted, next to the total price of the bus, would have broken down on account of almost perfect multicollinearity. On the other hand, the ommission of the third experiment doesn't imply a loss of information, since we could establish the relationship between the time cost of the bus on one side and the time cost of the car, on the other. The regression coefficient amounted to 0.94.

In the first row of table 5, one will find that the time cost elasticity in bus transportation cannot be distinguished from zero (first row). Equally so, the cross effect of the time cost of transportation by car on x_B will be undifferent from zero. In contrast to the first row, row 5 indicates an important instantaneous effect of the time cost. As yet, there is not enough evidence to believe either one of the different results.

According to row 4, changes in the time cost, occuring one period before, affect x_B appreciably (-0.44). Equally so, the retarded cross effect of p_{2CA} on demand for bus transportation, will be appreciable.

Bus transportation is further strongly affected by income. Income tends to increase in the course of time, so that a positive trend might be expected as to x_B. However, the separate effect of time is negative , and much larger in absolute value, than the effect of a change in income.

The last remark is about the impact of a change in the material price. Here, a distinction must be made between the long and the short run effect. Considering only the latter, one would label the bus service to be an inferior good, whereas the long run effect is negative.

Table 6. Regression Results: the Tramway (*)

		R^2
1	$x_T = \underset{(0.09)}{-0.19p_1} \underset{(0.27)}{+0.29p_2} \underset{(0.34)}{-0.45y_d} \underset{(0.38)}{-0.74}$	0.60
2	$x_T = \underset{(0.24)}{-0.29p} \underset{(0.22)}{-0.39p_{1CA}} \underset{(0.38)}{-0.89y_d} \underset{(3.70)}{+4.72}$	0.56
3	$x_T = \underset{(0.42)}{-0.80p} \underset{(0.32)}{+0.52p_{2CA}} \underset{(0.37)}{-0.70y_d} \underset{(3.69)}{+2.27}$	0.53
4	$x_{Tt} = \underset{(0.13)}{-0.13p_{1t}} \underset{(0.14)}{+0.06p_{1t-1}} \underset{(0.35)}{+0.24p_{2t}} \underset{(0.24)}{-0.34y_{dt}} \underset{(4.70)}{-1.95}$	0.56
5	$x_{Tt} = \underset{(0.11)}{-0.15p_{1t}} \underset{(0.31)}{+0.30p_{2t}} \underset{(0.16)}{-0.28p_{2t-1}} \underset{(0.25)}{-0.25y_{dt}} \underset{(4.91)}{-1.27}$	0.58
6	$x_{Tt} = \underset{(0.11)}{-0.16p_{1t}} \underset{(0.56)}{+0.36p_{2t}} \underset{(0.43)}{-0.34y_{dt}} \underset{(0.74)}{+0.11y_{dt-1}} \underset{(9.31)}{-3.34}$	0.61
(*) 10 observations		

Tramway transportation is not very responsive as to changes in the material price. A decrease of the latter with 1% would bring about an increase of demand of about 0.20%.

The time cost elasticity on the other hand is positive, but this is only so in the short run (compare rows 1 and 5).

When only the material price would have been considered, the car and the tramway would have been labelled to be "complementary in consumption", since the cross effect of p_{1CA} is negative (row 2). When the cross effect of the time cost is considered, both urban transportation modes would apparently be substitutes, since a decrease in the time cost of the car with 1%, would bring about a 0.50% loss of sales for the tramway.

The last important effect is the income effect. The increase of net disposable income goes hand in hand with a decrease of the demand for tramway transportation. As to the trend, it is not clear whether it is positive or negative.

Table 7. Urban car transportation.
Coefficient estimates of Ay+Bx=v (*)

	x_{CA}	p_2	p_1	y_d	x_T	x_B	d	constant	R^2
1	/	-0.82 (0.57)	-0.48 (1.00)	1.31 (0.93)	/	/	-22.50 (15.38)	1.71 (2.86)	0.43
2	0.34 (0.20)	/	/	/	0.62 (0.45)	0.008 (0.007)	/	7.63 (1.86)	0.27

(*) 10 observations

The demand equation is presented in the first row of table 7. One notices that the response to changes in the time cost (p_2) is much larger than the response to changes in the material price. As to the latter, the hypothesis that the coefficiënt differs significantly from zero, would be rejected on the classical standards of statistical tests.

The impact of changes in disposable income on the demand level is very important. An increase of this variable with 1% gives rise to an increase in the demand for urban car transportation of about 1.32%.

The second row in table 7 may not be interpreted as a supply equation, on the contrary it is a technical relation, stating to what extent the outputs of three urban transportation modes affect the driving time of one of them. This may be interesting in itself, but it falls outside the scope of this study, and is therefore given for granted.

4. CONCLUSIONS

(1) In this study, the determinants of the demand for passenger transportation were studied. Special attention was given to the impact of the time cost, as compared with the impact of the material price. The comparison of the time cost for various transportation modes, was a second aim of this study.

(2) An investigation of the total cost structure reveals the importance of the time cost element, especially in the urban transport modes, and, though to a smaller extent, in railway transportation. In this context, one may ask oneself, under what conditions social welfare would be improved if policy efforts were shifted e.g. from a subsidization of the material price towards an improvement of the speed of the transport means.

(3) The regression results throw some light on the above mentioned issue, although for some of them allowance must be made for the fact that the statistical precision is small. The results that were obtained are:

a) The material price elasticity is in some cases positive. In the cases where it was negative it was very low. The modes where positive elasticities were found are the bus and intercity car transportation. In tramway and railway transportation we found an elasticity of about -0.20, while the price elasticity in urban car transportation was somewhat higher (-0.48).

b) The impact of the time cost on demand was, in general, appreciably higher than the impact of the price. This was so in railway transportation (-0.26 versus -0.19), in intercity car transportation (-0.43 versus positive), in bus transport (-0.02 versus positive) and in urban car transportation (-0.82 versus -0.48). Tramway transportation formed an exception: its time cost elasticity was positive, whereas the money cost elasticity of -0.20.

c) The elasticity of the total cost was relatively high in most of the cases. It ranged between -0.30 and -0.80.

d) Only in bus and urban car transportation, the income elasticity was over unity. In both cases it was as high as 1.30. For the two intercity transportation modes the elasticity was under unity. For railway transportation it ranged from 0.10 to 0.77, while for car transportation it was between 0.35 and 1.00.

e) The investigations about the time shape reactions yielded a few important results. So, it appears from the tables that, in bus transportation, a change in the material price does have a negative effect on demand in the long run, whereas the short run elasticity was positive. In several cases, the impact of the time cost, which was only small in the short run, appears to be very important as to the demand of the next period. This phenomenon was established in intercity car transportation, where the coefficient of p_{2t-1} amounted to -1.34, To a smaller extent it was also established in bus transportation and in tramway transportation.

(4) The results, admittedly imperfect, when taken at face value would indicate, that an infrastructure policy meant to reduce the time cost, would have an effect in the long run, that is especially high for both intercity and urban car transportation. In general it was found that demand is more responsive to changes in the time cost than to changes in the material price. So,we reach the conclusion, that a policy which would entail an augmentation of the material price on one side and an improvement of the quality (like waiting and/or driving times) on the other, might well benefit the consumer.

APPENDIX A. THE MEASUREMENT OF THE TIME COST

A.1. The time cost in rural private car transportation

With regard to the evolution of the driving time in rural car transportation the results of the investigations of the Highway Research Board were used. The editions of 1954 (a translation in French) and of 1966 supplied the necessary figures.

These important studies deal (among other things) with the relationship between average speed on a road on the one side, and traffic volume, number of lanes, sight conditions on the other. For the purpose of our calculations only the relationship between average speed and number of lanes is important. The traffic volume was arbitrarily fixed at 800 vehicles per hour per lane, which is a rather moderate rate, while sight conditions were assumed to be perfect. The accompanying table shows how average speed varies with the number of lanes under the conditions that were just mentioned.

Table A.1. Average speed and number of lanes

Number of lanes	Average speed
1 x 2	58 km/h
1 x 3	70 km/h
1 x 4	72 km/h
2 x 2	90 km/h
2 x 3	100 km/h

Source: - Capacité des Routes, Editions Janio, Bruxelles, 1954, pp.31, 33, 48.
- Highway Capacity Manual, Highway Research Board, Washington, 1966, p. 63.

The crucial step in the calculation of driving time was the construction of a matrix, which represents the partitioning of a particular road in five classes of width for each of the 19 years in the period considered. The underlined notions are further explained. It should be remarked that each element x_{ij} in the matrix is a percentage, and that $\sum_j x_{ij} = 100\%$ for all years i.

1. A particular road: in fact the matrix just described was constructed for a number of main roads of the Belgian network. The selection of roads was based mainly on traffic volumes: essentially only roads with a medium frequency of 10.000 vehicles per day (1) and over were considered. The figures of 1971 (2) were used for this selection. In order to obtain a more even spatial spread over the Belgian territory, the threshold of 10.000 vehicles was removed in a few cases.

The accompanying table presents the list of the roads that were finally chosen.

Table A.2. The selected sample roads, their official number and length

	Road number	Distance
1. Brussel-Boom-Antwerpen (Wolvertem)(*)	weg nr.177	45 km
2. Brussel-Antwerpen (Eppegem)	weg nr.1	45
3. Brussel-Leuven (Kortenberg)	weg nr.2	27
4. Brussel-Namur (Hoeilaart)	A4	62
5. Brussel-Charleroi (Gosselies)	weg nr.5	53
6. Brussel-Mons (Soignies)	weg nr.7	57
7. Brussel-Gent (Erpe)	A10	55
8. Antwerpen-Gent (Beveren)	weg nr.14	58
9. Antwerpen-Hasselt (Oevel)	A13	78

(1) From 6 a.m. to 10 p.m.

(2) Source: "Studie der Verkeersvolumes met Automatische Telapparaten", Ministerie van Openbare Werken, Bestuur der Wegen, Verkeerstechnische Dienst.

	Road Number	Distance
10. Hasselt-Liège (Millen)	A13	39 km
11. Leuven-Liège (Boutersem)	weg nr.3	70 km
12. Liège-Namur (Ben-Ahin)	weg nr.17	66
13. Namur-Charleroi (Fosses-La-Ville)	weg nr.22	40
14. Charleroi-Mons (Leval-Trahegnies)	weg nr.22	38
15. Gent-Kortrijk (Zulte)	weg nr.14	45
16. Gent-Oostende (Jabbeke)	A10	64
17. Leuven-Hasselt (Assent)	weg nr.2	51
18. Namur-Marche (Emptinne)	weg nr.4	47
19. Marche-Bastogne (Harsin)	weg nr.4	43
20. Antwerpen-Breda 5(Wuustwezel) till borderline	weg nr.1	22

(*) The place names between brackets indicate the location of the automatic counting device.

2. Classes of width. The five classes mentioned in the first table are ment here., namely: 1x2, 1x3, 1x4, 2x2 and 2x3.

3. The period considered. Although figures were available the postwar years before 1952 werd not included in the sample: too close to the war-period as they are they might obscure the relationships which the present study wants to reveal. The last observation as to most series at the time the calculations were executed, was 1971.

Each of the matrices constructed in the manner which was outlined above was then postmultiplied by a columnvector. Each element of this vector represents the time (in seconds) which is required to cover one kilometer of a road with 1x2 lanes, 1x3, ..., 2x3 lanes. Each of the five elements of this vector is thus the inverse of the average speeds that were presented in table A.1.

The result of this postmultiplications is, for each of the 20 roads, a 19x1 column vector, which represents the evolution of driving time of 19 years.

In order to reach the final solution, that is, a synthetic index of driving time for the country, the results for the single roads must be brought together by means of proper weights. Traffic volumes on each road were used for this purpose. Unfortunately these data are only available since 1962. Accordingly we had to calculate the mean values of the traffic volumes over the nine years that were available (1962-1970), and use these means as weights for the period that was not covered by original data (1952-1961). The result of these last computations can now be interpreted as the time (in seconds) it takes to cover an "average kilometer of the Belgian network at a certain point in time". The time cost is calculated simply as the multiplication of the time spent on one kilometer by the amount which can be earned on the average in the industry in one second. The latter was derived from the net wage earned in the industry (1).

A.2. The time cost in railway transportation

The calculations of the time cost in railway transportation were quite similar to those that are described in the previous item A.1.). Main differences were:

1. Driving times didn't have to be calculated. They were provided by the official time-table of the Railways. The calculations of driving times was based here on the direct connections. This was done in order to imitate the ideal conditions that were assumed with respect to the relationship between speed and number of lanes in road traffic.

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(1) Source: An index of the net wage par unit of time, earned in the industry was found in the Recherches Economique
(1) See footnote (1) on page 7.

2. The relative traffic volumes per line (as percentage of total traffic volume of all lines considered), which were used as weights for the driving times per line were practically fixed during the whole period. Since this was an important time-saving element in the calculations, the minor differences were not taken into account, and fixed weights were used.

3. In addition to driving times, waiting times had to be calculated. First the average time that elapses between consecutive departures was calculated for main lines and for each of the 19 years. These results per line were weighted with the relative traffic volumes per line that were mentioned in point 2. above. We reckoned that halving these results would be a good approximation of the time that passengers spend on waiting for their train, or in arriving too early.

Since waiting times had to be added to driving times, the former were divided in the end by the average length of a journey, which is a figure ranging between 32.09 and 47.38 kilometers over the period that we consider here.

Similar to the calculations of the time cost for private car transportation were the next two steps:

1. The information about dirving times and waiting times was only accumulated for main lines. The selection of these lines was again based on the average traffic volume: only lines with a medium frequency of 10.000 passengers a day and over were considered. In order to improve the spatial spread of the sample the connections Namur-Arlon (line 162), Antwerpen-Hasselt (line 16 or 35) and Gent-Kortrijk (75) were added to the sample. On the other side, line 50bis (which is a second connection between Brussel and Ghent, next to line 50) as well as line 94(Doornik-Brussel) were dropped.

The accompanying table presents those lines that were used for data accumulation.

Table A.3. The selected sample lines, their official line numbers and distances (*)

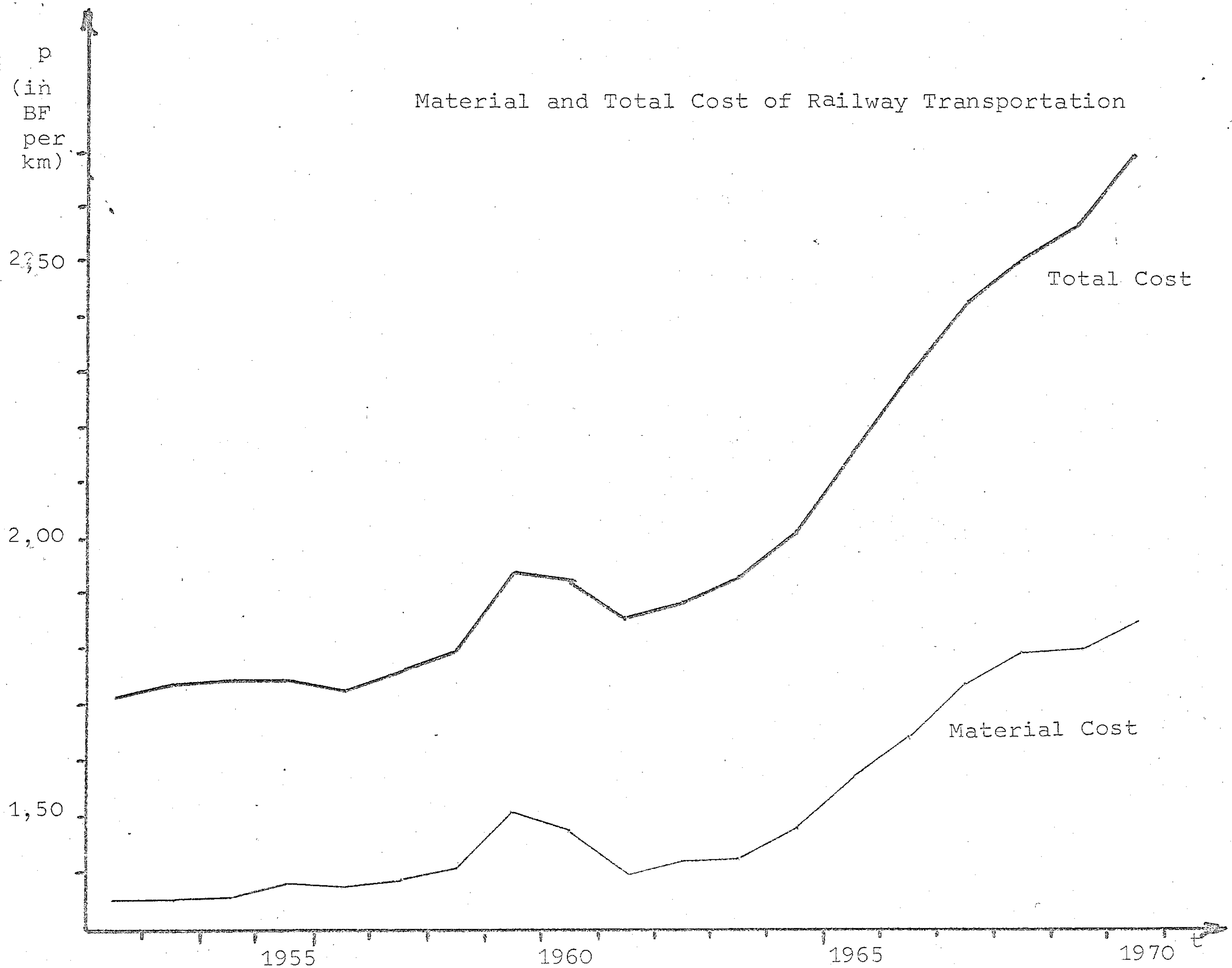
Line	Distance	Number
Brussel-Antwerpen	46 km	25
Brussel-Leuven	33	36
Leuven-Liège	71	36
Leuven-Landen-Hasselt (**)	59	36
Leuven-Aarschot-Hasselt (**)	54	35
Brussel-Gent	61	50
Gent-Oostende	63	50
Brussel-Mons	64	96
Brussel-Charleroi	59	124
Brussel-Namur	65	161
Namur-Arlon	75	162
Gent-Kortrijk	42	75
Antwerpen-Aarschot-Hasselt	78	16 and 35
Antwerpen-Roosendaal	42	12
Charleroi-Mons	45	118
Liège-Namur	60	125
Namur-Charleroi	37	130

(*) The distances were supplied by the Exploitation Service of the Belgian Railroad Company, the NMBS.

(**) The connection Leuven-Landen-Hasselt was achieved in 1964. The driving time per kilometer was shorter than for the original connection (line 35). For this reason the calculation of driving times were bases on the new line since 1964.

2. The time cost was dervied from driving time (inclusive waiting time), simply through multiplication of driving time by the wage per second which is earned in the industry.

The time cost, as well as the driving time (inclusive of waiting) time) are presented in the accompanying figure.


Material and Total Cost of Railway Transportation
p
(in
BF
per
km)
2,50
2,00
1,50
Total Cost
Material Cost
1955
1960
1965
1970
t

A.3. The time cost in urban public transportation

The demand for urban transportation was studied for the case of Antwerp.

The calculations of the time cost in the present case basically proceed along the same lines as in the case of the railways, which will be explained further in this appendix. However, there is one difference, referring to the length of the series. In the case of urban transportation (public and private) the data for some variables were only available for the period of 1962-1971. Driving time in public transportation was one of those variables.

As in the former items, the calculation of the time cost are based on driving times for main lines which are than weighted by means of the relative traffic volumes. In the case of the tramway the line numbers 2, 7, 10, 12 and 24 were selected, whereas the line numbers 5, 25, 17 and 27 were selected in the case of bus transportation.

Driving times for the main tramway and bus lines were supplied by the traffic control of the urban transportation company (1).

With respect to waiting times, the average time elapsing between consecutive departures in one terminal station of the main lines was calculated. Again we assumed that the best approach of the real time that an average passenger spends on waiting for a tramway or a bus and in arriving too early is obtained by halving the calculated average time between departures. In order to obtain the average waiting time per kilometer, waiting times were devided by the mean distance of a journey, which amounts to 3.250 meters. Waiting times were then added to driving times per kilometer. The calculation of the time cost which has been explained already in the two preceding items, was based on the driving plus waiting time.

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(1) This company is called: "Maatschappij voor Intercommunaal Vervoer te Antwerpen."

A.4. The time cost in urban car transportation

Essentially, the driving time of urban car transportation is parallel to the driving time of urban bus transportation. The difference refers to the manoeuvre of allowing travellers to step in and out.

MIVA investigated that during peak-hours seven passengers are waiting per halting-place. It takes about 18 seconds for these seven persons to step in and take a ticket. Next, it is known that there is one bus halting place every 375 meters. So, each kilometer a bus loses $\frac{18x1000}{375}$ = 48 second on account of the stepping in of passengers. However, there is another source of time-loss, notably the stop-and-go sequence. A few simple observations revealed that the normal speed of a bus is about 50 km per hour. Next, it appeared to take 8 seconds (or 30 meters) to bring the vehicle from this speed to stoppage, and about 14 seconds (or 100 meters) seemed to be needed in order to bring the bus from standstill to its normal speed again. If the bus skipped this stop-and-go process, the 130 meters would be covered in 9 seconds. Since the manoeuvre itself lasts 22 seconds, we can evaluate the time-loss on account of this manoeuvre at 13 seconds, which amounts to $\frac{13x1000}{375}$ = 34 seconds per kilometer.

The final conclusion is, that 1 minute and 22 seconds more are needed for a bus to cover 1 kilometer than for a private car.

APPENDIX B. THE DATA

The time cost series for each of the transportation modes have been commented in appendix A. In this appendix, some comments will be offered, regarding the outputs and the material prices for each of the modes, as well as disposable income. Apart from these comments, the data will be presented.

As to the dimension of the data, we remark that some series are represented in physical units, whereas some other series are in money terms. The latter series were deflated with the price index of GNP.

B.1. The output in the various transport modes

The most adequate measure of output in passenger transportation is the passenger-kilometer. Only the railways provide a series in this dimension (1). With respect to the output of urban public transportation, only figures in "number of passengers" are provided (2). And the only available measure for urban and rural car transportation is the number of cars passing certain observation points.

An alternative measure for the output in private car transportation would be the annuel sales of petrol stations. However, it was only possible to dispose of the purchases by the dealers, and it is common knowledge that the petrol dealer's demand is also determined by speculative considerations.

However the data on which we based our estimations can be criticised too. Even if we combine two sources, it was impossible to derive

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(1) The data were borrowed from the "Statistisch Jaarboek van de NMBS", 1952/1970.

(2) Cfr. the "Jaarverslagen van de MIVA", 1962/1971.

a complete series for the period 1952-1970 (1). There were no countings available for the years 1953, 1954, 1956, 1957, 1958, 1959 and 1961. We reckoned that we might well approximate the missing figures in a simple way. First we calculated the ratio $\frac{\text{average daily frequency per counter}}{\text{number of cars in the fleet}}$. As it was expected, the evolution of this ratio has a downward tendency:

1952 : 11,23
1955 : 10,80
1960 : 10;19
1962 : 8,54
1963 : 8,75
1964 : 8,33
1965 : 7,55
1966 : 7,20
1967 : 7,04
1968 : 6,95
1969 : 7,04
1970 : 6,84.

Next, the ratio values were linearly intrapolated for the years 1953, 1954, 1956, 1957, 1958, 1959, 1961 which results in:

1953 : 11,08
1954 : 10,96
1956 : 10,68
1957 : 10,56
1958 : 10,44
1959 : 10,32
1961 : 9,37

Finally these intrapolated values were multiplied by the number of cars in the fleet for the corresponding years.

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(1) The "Ministerie van Openbare Werken, Verkeerstechnische Dienst", organised "de visu" countings of traffic intensity in the years 1949, 1952, 1955, 1960, 1965, 1970. Since 1962 it also organises countings with automatic device.

The accompanying table summarizes the calculations, and presents the output series that was used in the regression analysis.

Table B.1. The observed and calculated output of rural car transportation

Year	Number of cars in the fleet x 10^3	Ratio: daily frequency per counter / fleet x 10^3 — Directly calculated	Ratio: daily frequency per counter / fleet x 10^3 — Intrapolated	Observed and calculated daily average frequency per counter
1952	320	11,23		3.593
1953	368		11,08	4.077
1954	450		10,96	4.932
1955	500	10,80		5.398
1956	539		10,68	5.757
1957	583		10,56	6.156
1958	633		10,44	6.609
1959	684		10,32	7.059
1960	753	10,19		7.670
1961	843		9,37	7.899
1962	915	8,54		7.818
1963	1.022	8,75		8.945
1964	1.151	8,33		9.584
1965	1.340	7,55		10.121
1966	1.503	7,20		10.817
1967	1.653	7,04		11.642
1968	1.813	6,95		12.600
1969	1.921	7,04		13.518
1970	1.060	6,84		14.085

With respect to the urban car transportation, the data were provided by the Traffic Control of the Antwerp Police Force.

Traffic volumes are recoredered on some twenty points in town, during several working days in winter and in summer. A daily average of traffic is than calculated for each observation point. For our purpose the sum of these daily averages is a fair approximation of the output in town.

B.2. The material price

In the case of the railways the average revenue or price per passenger kilometer was calculated (1). In the case of urban bus and tramway transportation, there exists a uniform tariff which is independent of the length of the passenger's trip. Over 90% of the passengers buy at this uniform tariff, and therefore we assumed, it approximated the real market price (2).

On the analogy of the railways, a per kilometer price was calculated. Therefore, the average length of a passenger's trip ,which amounts to 3.250 meters, was used.

In the case of car transportation there was no cut-and-dried solution available to approximate the market price. If one accepts a few hypotheses with respect to the use that is made of cars, input-prices might be combined in a way to approximate the real price.

INPUT PRICES

Only data with respect to main inputs were gathered. These are:

- the car, inclusive of taxes;
- the petrol;
- maintenance and repair.

Prices of a typical car, which was in our case the volkswagen 1200, were borrowed from the magazine "Auto-Motor Revue", edited by the Belgian Automobile Association: Comaubel. Data on the transfer tax were provided by the Department of Finance. The consecutive tax rates were as follows:

2 oktober 1950: 12%
16 juli 1955 : 13%
5 may 1961 : 16%
1 january 1966: 18%
1 january 1971: 25%.

(1) The series of total revenue and total passenger kilometers were borrowed from the "Statistisch Jaarboek van de NMBS".

(2) Consecutive tariff rates were supplied by the MIVA operations devision.

The evolution of the petrol price was provided by the Belgian Petrol Institution, and with respect to the maintenance and repair-cost, results of an enquiry, set up by the Dutch Consumer Association: "De consumentenbond", were used (1). In this enquiry, 2.000 car-owners were interrogated about their maintenance and repair expenses within the first 40.000km.

HYPOTHESES

1. The car is depreciated in 5 years.
2. The car's annuel performance amounts to 20.000 kilometers.
3. From the above mentioned enquiry we know that owners of a Volkswagen 1200 spend an average of 8.400BF on maintenance and repair of their car, within the first 40.000km. We now assume that this amount will be spent two more times in the remaining 60.000km of the car's life.
4. Further it is assumed that the variation in maintenance and repair expenses is proportionate to the wages in garages (2).

Finally, data were combined as follows. The price of a new car, inclusive of taxes, was devided by 100.000 for each year, in order to obtain the per kilometer price of this input under given assumptions. To this figure the maintenance and repair cost per km was added. The petrol cost per km is derived from the car's petrol consumption, which amounts in the present case to 9 liters per 100km for rural transport and to 10,5 liters per 100km for urban transport. The addition of the petrol cost per km to the other components, leads consequently to a slightly different material price for urban car transportation on one side and rural car transportation on the other.

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(1) See a detailed discussion of the iqenquiry in "Text-Achats", mai 1972, p.12/15.

(2) Data were provided by the federation of Belgian garage-keepers ("Fegarbel") and the government social insurance service ("Rijksdienst voor Maatschappelijke Zekerheid").

B.3. Disposable income

Disposable income in real prices was calculated through summing the topics 3.1 and 3.5 of the third of the Belgian National Accounts (1). These topics correspond with private consumption, and the households'savings.

The 1952 figures are not available in the national accounts. Therefore we extrapolated the series from 1953 to 1952 by means of a sidisposable income series which was constructed by DULBEA.

From the original data, the per capita income was calculated. For this purpose the population figure of the NIS (2) was used.

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(1) NIS, Statistische Studiën, n°21, 1970 and n°22, 1971.

(2) NIS, Statistisch Jaarboek .

Table B.2. The data

Year	Disposable Income (BF x 10^9)	RAILWAYS Material price (in BF per kilometer)	Time Cost	Total Cost	output in 10^6 pass.kilometers
1952	368,8	0,4335	0,3823	0,8158	7.546
1953	374,9	0,4540	0,3858	0,8408	7.528
1954	390,7	0,4596	0,3865	0,8461	7.562
1955	402,2	0,4866	0,3566	0,8432	7.846
1956	410,2	0,4787	0,3521	0,8308	8.333
1957	418,4	0,4910	0,3691	0,8601	8.555
1958	426,7	0,5101	0,3920	0,9021	9.057
1959	435,8	0,6183	0,4131	1,0314	8.519
1960	459,3	0,5841	0,4408	1,0249	8.578
1961	475,3	0,5089	0,4510	0,9599	8.693
1962	502,0	0,5202	0,4679	0,9881	8.958
1963	521,0	0,5326	0,4999	1,0325	9.009
1964	547,1	0,5777	0,5390	1,1167	9.041
1965	577,5	0,6700	0,5924	1,2624	8.975
1966	591,3	0,7476	0,6425	1,3901	8.708
1967	605,0	0,8561	0,6658	1,5219	8.534
1968	630,4	0,8982	0,7025	1,6007	8.177
1969	658,5	0,9078	0,7656	1,6734	8.238
1970	699,1	0,9466	0,8482	0,7948	8.260
1971	760,0	-	-	-	-

Year	CAR (INTERCITY) Material price (in BF per kilometer)	Time Cost	Total Cost	output average number of cars per hour
1952	1,3406	0,2828	1,6234	3.593
1953	1,3508	0,2875	1,6383	4.077
1954	1,3363	0,2967	1,1633	4.932
1955	1,3299	0,3043	1,6342	5.398
1956	1,3452	0,3144	1,6596	5.757
1957	1,3704	0,3375	1,7079	6.156
1958	1,3853	0,3459	1,7312	6.609
1959	1,4436	0,3584	1,8020	7.059
1960	1,5231	0,3795	1,9026	7.670
1961	1,5228	0,3956	1,9184	7.899
1962	1,5108	0,4162	1,9270	7.818
1963	1,5692	0,4324	2,0016	8.945
1964	1,5805	0,4700	2,0505	9.584
1965	1,5549	0,5145	2,0694	10.121
1966	1,7053	0,5489	2,2542	10.817
1967	1,6930	0,5719	2,2649	11.642
1968	1,6923	0,6071	2,2994	12.600
1969	1,7764	0,6649	2,4413	13.518
1970	1,7738	0,7375	2,5113	14.085

Table B.2. The data (continued)

Year	BUS			
	Material price (in BF per kilometer)	Time Cost	Total Cost	Output in 10^3 passengers
1962	1,5827	3,7006	5,2833	16.050
1963	1,5384	3,9758	5,5142	14.040
1964	1,7515	4,3384	6,0899	14.873
1965	1,6798	4,5950	6,2720	13.828
1966	1,8745	4,8784	6,7429	12.730
1967	1,8176	5,1200	6,9375	11.623
1968	1,8330	5,5069	7,3399	11.130
1969	1,9443	5,8137	7,7581	10.878
1970	1,8549	6,1757	8,0307	10.404
1971	1,7532	6,2872	8,0404	10.041

Year	TRAM			
	Material price (in BF per kilometer	Time Cost	Total Cost	Output in 10^3 passengers
1962	1,5827	3,3384	4,9212	46.571
1963	1,5384	3,5323	5,0707	46.510
1964	1,7515	3,7164	5,4679	43.889
1965	1,6798	3,8871	5,5670	43.398
1966	1,8745	7,0263	5,9000	41.091
1967	1,8176	4,2809	6,0985	40.239
1968	1,8330	4,6573	6,4903	39.919
1969	1,9443	4,9182	6,8625	37.612
1970	1,8549	5,2488	7,1037	35.674
1971	1,7532	5,2267	6,9799	33.867

Year	CAR (URBAN)			
	Material price (in BF per kilometer	Time Cost	Total Cost	Output in 10^3 cars per day
1962	1,6778	1,4938	3,1716	149,6
1963	1,6907	1,6210	3,3117	165,6
1964	1,6255	1,8216	3,4472	183,4
1965	1,5254	1,8992	3,4243	188,4
1966	1,6043	2,0252	3,6294	198,9
1967	1,5464	2,0904	3,6368	206,9
1968	1,5039	2,3410	3,8458	216,1
1969	1,5122	2,4697	3,9818	164,2
1970	1,4407	2,6260	4,0667	179,5
1971	1,4384	2,6744	4,1128	171,1

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