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Improvement of the Benefits for Eco-friendly Transportation Projects

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Recently, the need to consider carbon neutrality in 2050 has been raised in various fields of Social Overhead Capital (SOC) public works. In the transport sector, eco-friendly railway projects that consider carbon neutrality are being promoted. Railway projects are more environmentally friendly than road projects. In general transport projects, only evaluation indicators based on benefit/cost (B/C) analysis are considered, so there are limitations in the methodology. In situations where real income per capita may increase even after accounting for inflation, such as the recent COVID-19 outbreak, calculating future monetary values at a constant value may underestimate benefits. This problem is even more pronounced for large-scale green transport projects such as railways. In this study, we propose to use the nominal Gross Domestic Product (GDP) per capita methodology to find the indicator that best represents the change in the value of travel time and apply it as a price index as a reference point for the analysis. The case analysed is the Great Train eXpress (GTX) project under construction in South Korea, and because of updating the realistic benefit value using the future time value of money methodology reflecting nominal GDP per capita, the project's B/C increased by 0.07, turning it into a project with a B/C of over 1, making it economically viable. Methodologies such as the above can contribute to the environment by increasing investment in green projects that are currently stagnant.

1. Introduction

The South Korean government has continuously invested in the SOC sector to strengthen national competitiveness and promote carbon neutrality in 2050 (Ku et al., 2022). As a result, the level of transportation facilities in South Korea has advanced to the upper level of the Organization for Economic cooperation and development (OCED). Although railroad projects are eco-friendly transportation projects compared to road projects (Pain et al., 2008), the railroad project has underperformed in SOC investment over the past decade (Van Wee et al., 2003). Road and Railways benefit evaluation items are calculated as travel time savings, vehicle operating cost savings, traffic accident reduction benefits, and environmental cost savings benefits. In terms of benefits, railroads compare favourably to roads in terms of travel time savings and environmental cost savings. Here, the environmental cost saving benefit is the value of quantifying some items such as air pollution greenhouse gas noise and converting them into costs. In Korea, when implementing transportation projects, B/C analysis is conducted according to the preliminary feasibility guidelines for road and rail (Bencekri et al., 2021). The benefits of implementing road and rail projects are an important factor in determining whether to invest, and while regional balanced development and policy necessity are considered when deciding whether to invest, the cost-benefit ratio (B/C) is generally the most important variable. In general, when conducting B/C analysis, costs are adjusted using the GDP deflator, and benefits are adjusted using the CPI (Consumer Price Index). when conducting B/C analysis, in principle, future benefits and costs are converted using price indices to match the base year of the analysis. During the recent inflation caused by COVID-19, it does not properly reflect the actual increase in value of time, causing problems in SOC project evaluation (Harrison, 2010). This study proposes a future value of time calculation method that reflects per capita income. The goal is to revitalize

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eco-friendly transportation projects such as railroads, which are currently stagnant, through a realistic benefits correction. The framework of this study is shown in Figure 1.

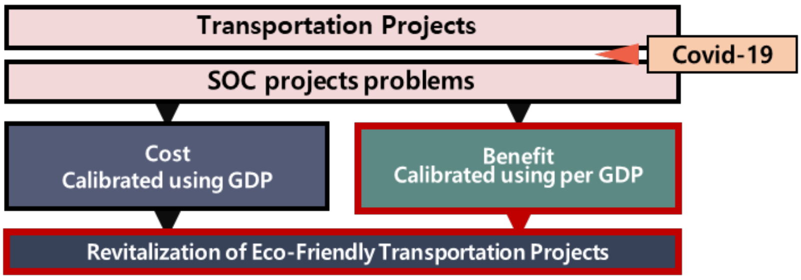

Figure 1: Framework of the study

2. Literature review

When estimating the costs and benefits of large-scale projects, such as railroads, value calibrations are made using GDP deflators and Consumer Price Index (CPI). It is important to correct for future monetary values if the costs and benefits are long-term and continuous (Boccia and Gresazler, 2013). In Korea, when analyzing transportation projects, future price conversion is based on the CPI, which is published annually, but it is necessary to check whether it properly reflects the actual economic growth rate. Therefore, the consumption growth rate per capita should be considered as a long-term consumption growth rate, and the preliminary feasibility guidelines the consumption growth rate per capita as a long-term forecast of the GDP growth rate per capita. In the KDI guidelines, the consumption growth rate per capita was selected at 4.5% using the potential growth rate over the next 20 y. The latest data on the per capita GDP growth forecast is a study by the Korea Development Institute (2013), which is estimated to be 2.6% over 30 y since 2011 and 2.45% over 40 y, reflecting consumption growth in the range of 2.45-2.60%.In the recent 3 y of abnormal inflation, the calculation of future value of time is inaccurate, and calculating with existing prices runs the risk of underestimating benefits (Eiswerth and Shaw, 1997). In Korea, changes in travel time value are estimated to be constant, but in foreign countries, long-term changes in travel time value are discussed focusing on GDP growth per capita, which is usually based on more than 30 y after the opening of the transportation facility project. Gwilliam (1997) conducted on the relationship between the increase in value of travel time and GDP per capita. Mackie, P. J., et al (2001) analyzed the change in the value of travel time over time while estimating the change in the value of business and non-business travel time, and the change in the value was found to follow GDP per capita. A study by J.D. Shires (2009) presented the travel time value of 25 European countries in 2003 and analyzed that the relationship between per capita GDP and travel time value was the highest. In the United States, the elasticity of income growth and time value increase is assumed to be 1 in the Congregational Budget Office, and the average real household income increase over the next 30 y is estimated to be 1.2% in consideration of real GDP, tax rates, and interest rates The UK's road project feasibility study manual, COBA (2002), estimates changes in future travel time value through real GDP growth rate per capita based on the per capita GDP elasticity of travel time value as 1, which is currently provided in WebTAG. WebTAG provides a separate sheet of future travel time value updates along with real GDP per capita and updates the standards through continuous future real GDP forecasts every quarter. As a result of the review, if there is an indicator that can reflect the increase in time value due to an increase in income, it is reasonable to use it as an indicator of future time value renewal.

2.1 Update future time value of money with GDP

Railroads are a more efficient and low carbon means of transportation than roadways and airways. Railroads' economic viability can be secured if environmental benefits are considered in addition to other benefit categories (Yang et al., 2019). Generally, in the case of transportation projects in South Korea, costs are calibrated using GDP and benefits are calibrated using CPI. This process distorts B/C, the ratio of costs and benefits, in inflation when there is a discrepancy between price indices (Seiler and Zurich, 2020). Economic changes can be analyzed using the CPI and GDP, which are representative price indices, but each index has different characteristics. The CPI measures economic change by weighting specific goods and measuring the change in the price of the goods. It has been criticized for being inconsistent and subjective because it is calculated on a specific goods-by-goods basis (Church, 2016). GDP is more consistent than CPI because it includes price changes across the national economy (Litra, 2009). There are problems with using the CPI to calculate future value of time in an inflation. Janson et al (2020) analysed past inflationary episodes in the United States in terms of CPI and Personal Consumption Expenditure Price Index (PCEPI). The study shows that inaccurate weighting of CPI overestimates the impact of inflation. Cavallo (2020) addressed inaccurate CPI calculations caused by basket weights in the context of inflation brought on by the impact of COVID-19. In the current situation when environmental benefits are not concretely specified and the calculation method is not established, underestimation of benefits is a major obstacle to the progress of eco-friendly transportation projects (Bencekri et al., 2021). It is necessary to accurately calculate other benefits such as travel time saving benefits. This study aims to improve the accuracy of the benefit category in which value of time is used. The economics of the railroad project, which was relatively low, can be consistent with the actual economic situation through this research. Shires and De Jong (2009) conducted a study on travel time saving benefits for 25 European countries and concluded that travel time value of money is strongly related to GDP. The study finds significant elasticity values between travel time benefits and GDP changes. This suggests that it is more appropriate to use GDP change rather than CPI change when calculating benefits. In fact, the UK and US use GDP per capita changes to calculate costs and benefits when planning and analyzing large-scale construction.

Annual Parameters

Year	GDP deflator[1] (2010=100)	Real GDP[2]			Population[3]			Households[4]			Average GDP per person			Average GDP per household		
		Historic Value	Annual Growth (%pa)	Index 1990 = 100	Historic Value	Annual Growth (%pa)	Index 1990 = 100	Historic Value	Annual Growth (%pa)	Index 1996 = 100	Historic Value	Annual Growth (%pa)	Index 1990 = 100	Historic Value	Annual Growth (%pa)	Index 1996 = 100
2010	100.00	1,884,515	2.13	147.41	62,760	0.80	109.65	26,240	0.76	110.54	30,028	1.32	134.44	71,818	1.36	120.66
2011	102.07	1,911,983	1.46	149.56	63,285	0.84	110.57	26,409	0.64	111.25	30,212	0.61	135.27	72,399	0.81	121.63
2012	103.71	1,940,087	1.47	151.76	63,705	0.66	111.30	26,620	0.80	112.14	30,454	0.80	136.35	72,881	0.67	122.44
2013	106.03	1,976,755	1.89	154.63	64,106	0.63	112.00	26,663	0.16	112.32	30,836	1.25	138.06	74,139	1.73	124.56
2014	107.72	2,035,883	2.99	159.25	64,597	0.77	112.86	26,734	0.27	112.62	31,517	2.21	141.11	76,153	2.72	127.94
2015	108.27	2,089,276	2.62	163.43	65,110	0.79	113.75	27,046	1.17	113.94	32,088	1.81	143.67	77,249	1.44	129.78
2016	110.33	2,136,566	2.26	167.13	65,648	0.83	114.69	27,109	0.23	114.20	32,546	1.43	145.71	78,814	2.03	132.41
2017	112.34	2,182,170	2.13	170.69	66,040	0.60	115.38	27,226	0.43	114.69	33,043	1.53	147.94	80,150	1.70	134.66
2018	114.58	2,218,196	1.65	173.51	66,436	0.60	116.07	27,576	1.29	116.17	33,389	1.05	149.49	80,439	0.36	135.14
2019	116.89	2,255,283	1.67	176.41	66,797	0.54	116.70	27,824	0.90	117.21	33,763	1.12	151.17	81,055	0.77	136.18
2020	123.41	2,043,373	-9.40	159.84	67,081	0.43	117.20	27,921	0.35	117.62	30,461	-9.78	136.38	73,184	-9.71	122.95
2021	123.40	2,195,717	7.46	171.75	-	0.55	117.84	28,081	0.57	118.30	-	6.87	145.75	78,192	6.84	131.37
2022	128.84	-	4.21	178.99	-	0.18	118.05	-	1.64	120.23	-	4.02	151.62	-	2.54	134.70
2023	133.39	-	-1.43	176.44	-	0.35	118.46	-	0.67	121.04	-	-1.77	148.93	-	-2.09	131.89
2024	135.60	-	1.31	178.74	-	0.35	118.88	-	0.67	121.86	-	0.96	150.36	-	0.63	132.72
2025	136.64	-	2.64	183.46	-	0.32	119.26	-	0.63	122.62	-	2.31	153.83	-	2.00	135.37
2026	137.83	-	2.65	188.33	-	0.30	119.62	-	0.62	123.38	-	2.35	157.44	-	2.02	138.11
2027	140.23	-	2.24	192.54	-	0.28	119.95	-	0.63	124.15	-	1.95	160.52	-	1.60	140.32
2028	143.46	-	1.83	196.05	-	0.14	120.11	-	0.49	124.76	-	1.69	163.22	-	1.33	142.18
2029	146.76	-	1.78	199.54	-	0.12	120.26	-	0.46	125.34	-	1.66	165.93	-	1.31	144.04

Figure2: UK Web Tag's GDP Per Capita Fact Sheet

3. Methodology

The price conversion to the base point of the current analysis applies the annual consumer price index. An analysis of the change in time value in previous studies showed that nominal GDP per capita best reflects the increase in time value. The economic analysis of public investment projects utilizes the concept of real without considering inflation, the future value of time can be updated through an increase in real GDP per capita. Renewing future time values through real GDP growth per capita has also been discussed at the Korea Development Institute (2006), and despite its applicability, uncertainty in the outlook for GDP per capita is cited as the biggest limit. If there is a forecast for future GDP growth per capita, it will be applied as in the case of the UK or US possibility. Recently, the Korea Development Institute and the National Assembly Budget Office showed real GDP per capita. The long-term financial outlook, including that, is announced through analysis reports every two to five years, and in the future. If there is a need for future time value renewal, it is possible to renew periodically enough.

In this study, the future value of travel time can be calculated from the growth rate of real GDP per capita. The universally calculated formula for real GDP per capita growth is as Eq (1).

$$\text{Real GDP Growth Rate} = \left(\frac{\text{GDP}_{present} - \text{GDP}_{past}}{\text{GDP}_{past}}\right) \times 100 \tag{1}$$

The equation for the value of time for the future year is shown in Eq (2) (KDI, 2017).

$$\text{Value Of Time for the future year} = \text{Base year Value Of Travel time} \times \frac{Real\ GDP\ per\ capita\ in\ the\ future}{Real\ GDP\ per\ capita\ in\ the\ base\ year} \tag{2}$$

In Eq (3), Value of Time (VOT) is calculated by dividing the marginal utility of travel time (α) by the marginal utility of travel cost (β) (Lam T. C. et al., 2001). VOT is the sensitivity to travel time, and the higher the value of time, the more sensitive the user is to travel time. In other words, users are willing to pay more for a shorter travel time.

$$VOT = \frac{\partial U}{\partial Time} / \frac{\partial U}{\partial Cost} = \frac{\alpha}{\beta} \tag{3}$$

Where, α is parameter for travel time, β is parameter for travel cost. $\frac{\partial U}{\partial Time}$ is marginal utility for travel time. $\frac{\partial U}{\partial Cost}$ is marginal utility for travel cost.

This study aims to actualize the benefit value of increasing eco-friendly SOC projects by using the value of travel time calculation methodology presented in the 6 th edition of the preliminary feasibility guidelines for road and rail. According to Gwilliam (1997), the increase in nominal GDP per capita is the indicator that best reflects the change in value of travel time. Therefore, the increase in nominal GDP per capita can be estimated as an increase in income, like the case of the United Kingdom and the United States. This paper determined that Korea's value of travel time is distorted because it is calibrated through CPI. This study recalculates it using a nominal GDP change.

4. Results

To evaluate the effectiveness of the improved economic analysis proposed, this study analyze Great Train eXpress (GTX) project under construction in South Korea. GTX is an express train that connects the outer suburbs of the Seoul metropolitan area to the center of the city. Its speed is more than three times faster than the existing subway. Line B, the case study for this research, is 80.1 km long. When it opens, the travel time from Songdo Station to Seoul Station will be reduced from 82 min to 27 min. This part aims to prove the economic feasibility of the GTX project and suggest the feasibility of introducing eco-friendly means.
The simulation uses the B/C analysis of the existing project and is reanalyzed to reflect changes in per capita GDP. Before the benefit analysis, the average value of travel time was recalibrated. Previously, the average value of travel time was adjusted using CPI, but in this study, it was adjusted using GDP. Finally, this study compares the economics of the traditional CPI adjustment with the economics of the GDP per capita adjustment. The case study of this research is shown in Figure 2.

Figure 3: Route Map for GTX-B

This study shows the average value of travel time using GDP per capita based on case studies. The CPI adjustment value is underestimated due to the weight effect of each product. The per capita GDP adjustment applied in this study is higher than the CPI adjustment because it reflects the impact of the overall economy. Estimated per GDP time value of time GTX-B project shown in Table 1.

Table 1: Estimated per GDP time value of time GTX-B project (KRW /unit)

Sortation	Passenger car	Bus	Truck	Rail (per capita)
Average value of travel time in 2013	14,954	88,944	16,374	5,920
Average value of travel time in 2016 (Calibrated with CPI)	15,406	91,612	16,865	6,098
Average value of travel time in 2016 (Calibrated with per GDP)	17,077	101,574	18,699	6,761

* 1) The number of people in the car is based on the number of people distributed by KOTI.
* 2) 2016 values are 2013 values multiplied by the nominal GDP growth rate. value of 2016/value of 2013 =1.142

The case study was analyzed by reflecting per GDP. In Table 2, the travel time saving benefit and traffic accident saving benefit are calibrated to reflect changes in per GDP because these are containing per capita economic values. The average value of travel time is determined by the value of one hour of labour, and the traffic accident saving benefit is the monetary value of future labour costs at the time of traffic accident death. Shires and De Jong (2009) show that nominal GDP per capita best reflects the increase in monetary value of time. This study uses nominal GDP per capita instead of CPI for value of time related benefits. Benefits index after adjusting the per GDP shown in Table 2.

Table 2: Benefits index after adjusting the per GDP (1,000,000 KRW)

Year	Travel time savings			Operating costs savings	Traffic accidents savings	Environmental cost savings	Parking cost savings	Total
	Road	Railroad	Total					
2026	529,110	-189,976	339,134	130,777	14,768	11,202	11,203	507,084
2030	507,248	-183,273	323,975	126,990	14,374	10,473	10,135	485,947
2035	491,446	-174,307	317,139	124,787	14,221	10,286	10,212	476,645
2040	468,811	-166,915	301,896	120,239	13,721	9,836	9,990	455,682
2045	433,924	-153,779	280,145	112,497	12,934	9,296	9,304	424,176

* 1) Discount rate of 4.5 % for 30 y from the base year and 3.5 % for the last 10 y

The total benefits and total costs using GDP-adjusted and CPI-adjusted values. The total benefits increased by KRW 1,346,884 million, an increase of about 7.5 % point. The discounted present value increased by KRW 233,173 million, an increase of about 4 %. Comparison of results CPI and per GDP benefit shown in Table 3.

Table 3: Comparison of results (CPI and per GDP benefit) (1,000,000 KRW)

	Gross benefit	Total cost	Total discount benefit	Total discount cost	B/C
This study (per GDP)	19,219,039	11,211,000	6,127,767	5,894,595	1.04
Case study (CPI)	17,872,155	11,211,000	5,894,595	5,728,458	0.97
Difference	+ 1,346,884	0	+ 233,172	0	+ 0.07 (+ 7 %)

Figure 4 shown the B/C ratio was calculated using the formula in Eq (4). The B/C ratio in this study is 1.04, which is about 7 % point higher than the method using the existing CPI. The Comparison of results CPI and GDP benefit of this study is shown in Figure 4.
The B/C ratio is used as an economic analysis technique (see Eq (4)) and is considered economical if the benefit/cost ratio is greater than 1 as a ratio of total cost to total benefit (KDI, 2017). The analysis period of the railroad was applied to 40 y of operation. The social discount rate changes from 4 % to 3.5 % in 30 y depending on the domestic situation.

$$B/C \text{ Ratio} = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} / \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} \quad (4)$$

where B_t is the benefit during year t, C_t is the cost during year t, r is the social discounted rate and n is the analysis period.

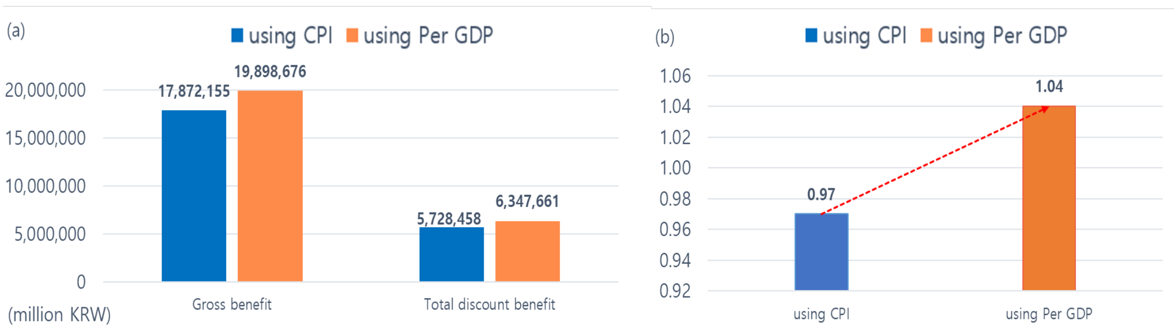

Figure 4: (a) Comparison of results using CPI and GDP (b) Comparison of B/C by GDP method

5. Conclusion

Although railroads are more eco-friendly than roads, railroads have been unfavourably evaluated because their benefit value is not properly reflected. In the current situation in which environmental benefits are presented in fragments and the calculation method is incomplete, accurate calculation of travel time-related benefits is essential. The existing transportation project evaluation method is not suitable for expanding eco-friendly

transportation projects such as railroads. In the process of calibrating the value of travel time to future prices, price indices such as CPI and GDP are utilized, but CPI does not properly reflect the actual economic situation. To revitalize the eco-friendly transportation projects, this study used nominal GDP per capita to calibrate the benefit value to match the reality, and the projects analysis showed an increase in B/C of 0.07. This study aims to contribute to eco-friendly transportation projects by expanding investment in environmental projects such as railroads, which are currently stagnant, through the realization of benefit value. This is expected to help the carbon neutrality policy in 2050.
This research uses different price indexes for each benefit category, which may cause inconsistencies in the economic analysis. In the case of foreign countries, GDP per capita is used to adjust both costs and benefits, but there is no clear reason for this. Therefore, it is necessary to develop specific reasons and guidelines for the adjustment of each benefit category both at domestic and foreign levels to improve the accuracy and consistency of the analysis.

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References

Bencekri M., Ku D., Kwak J., Kim J., Lee S., 2021, Review of eco-friendly guidance of transport infrastructure: Korea and the World, Chemical Engineering Transactions, 89, 235-240.
Boccia R., Greszler R., 2013, Social security benefits and the impact of the chained CPI, Heritage Foundation Backgrounder, 2799.
Cavallo A., 2020, Inflation with Covid consumption baskets (No. w27352), National Bureau of Economic Research, DOI 10.3386/w27352, accessed 09.06.2020.
Church J. D., 2016, Comparing the Consumer Price Index with the gross domestic product price index and gross domestic product implicit price deflator, Monthly Lab, Rev., 139, 1. <https://doi.org/10.21916/mlr.2016.13> accessed March. 2016.
Eiswerth M. E., Shaw W. D., 1997, Adjusting benefits transfer values for inflation, Water Resources Research, 33(10), 2381-2385.
Gwilliam K. M., 1997, The value of time in economic evaluation of transport projects: Lessons from recent research, World Bank, Washington DC.
Harrison M., 2010, Valuing the Future: the social discount rate in cost-benefit analysis, Available at SSRN 1599963, 71-82.
Janson W., Verbrugge R. J., Binder, C. C., 2020, The CPI–PCEPI Inflation Differential: Causes and Prospects, Economic Commentary, 2020-06.
KDI, 2017, A study on standard guidelines for pre-feasibility study on road and railway projects (6th edition), Korea Development Institute, Sejong, Korea.
Ku D., Kweon S., Kim J., Lee S., 2022, Wider Benefits of Eco-Friendly Transportation Projects with Contingent Valuation Method, Chemical Engineering Transactions, 97, 133-138.
Lam T. C., Small K. A., 2001, The value of time and reliability: measurement from a value pricing experiment, Transportation Research Part E: Logistics and Transportation Review, 37(2-3), 231-251.
Litra A., 2009, The inflation rate determined as a change in the GDP deflator and in CPI, Bulletin of the Transilvania University of Brasov, Economic Sciences, Series V, 2, 207.
Macki P.J., Jara-Diaz S., Fowkes A. S., 2001, The value of travel time savings in evaluation, Transportation Research Part E: Logistics and Transportation Review, 37, 91-106.
Pain N., Koske I., Sollie M., 2008, Globalisation and OECD consumer price inflation, OECD Journal: Economic Studies, 2008(1), 1-32.
Seiler P., 2020, Weighting bias and inflation in the time of COVID-19: evidence from Swiss transaction data, Swiss Journal of Economics and Statistics, 156(1), 1-11.
Shires J. D., De Jong G. C., 2009, An international meta-analysis of values of travel time savings, Evaluation and program planning, 32(4), 315-325.
Van Wee B., Van Den Brink R., Nijland H., 2003, Environmental impacts of high-speed rail links in cost–benefit analyses: a case study of the Dutch Zuider Zee line, Transportation Research Part D: Transport and Environment, 8(4), 299-314.
Yang X., Lin S., Li Y., He M., 2019, Can high-speed rail reduce environmental pollution? Evidence from China, Journal of Cleaner Production, 239, 118135.