Estimating the level of rail- and road-based passenger mobility in India*

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ABSTRACT

The main aim of this paper is to forecast the level of rail- as well as road-based passenger mobility in India up to the year 2015-16. Forecasting is based on estimation of *S*-shaped growth curves using annual data of the level of passenger mobility from the year 1950-51 to 1995-96. It is found that road transport will play an extremely dominant role in India in providing passenger mobility to the people in forthcoming years. By the end of the year 2015-16, road share in passenger movement will touch the mark of 95 percent as against the 5 percent for the rail. In such circumstances, the expected greater reliance on road will pose a challenge to the policy makers. Energy availability and environmental concerns will be areas of grave concern.

JEL Classification: C53, L90, R40

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1. Introduction

The passenger mobility in India is heavily relying on rail and road. Passenger travel by air and water is negligible in comparison to rail and road. On an average, an Indian travelled 287 kms in a year in 1950-51; out of which 187 kms was by rail and 100 kms by road. In a span of four and a half decades their annual travel figure jumped to 2987 kms – 372 by rail and 2615 by road. In the period 1950-51 to 1995-96, passenger travel (i.e., pass.-kms) by road and rail taken together increased at 5.34 percent annually against the GDP rate of 4.23 percent. The growth of road-based passenger movement during these 45 years has been around 9.79 percent per annum against the corresponding annual growth rate of 3.69 percent by railways. Although, National Transport Policy Committee (NTPC) had estimated road share at only 48 percent by the end of the 20th century, but it is well known that this estimate is quite far from the truth. In fact, even five years back to the end of the 20th century, road share had crossed the mark of 85 percent. This only shows how the committee was off the mark in its assessment about the modal split of passenger transport system in India. The risk inherent in such faulty projections is not that they can go wildly wrong, but in fact, they can dangerously distort the government policies related with transport sector.

The main aim of this study is to forecast the level of rail- and road-based passenger mobility for the next twenty years. *S*-shaped growth curves have been used to model the development in passenger mobility in India. Annual data from 1950-51 to 1995-96 are used for the purpose of estimation. The statistical program LIMDEP Version 7.0 is used for this.

We find that road has to play extremely dominant role in future. By the end of the year 2015-16, road share in passenger movement will touch the mark of 95 percent as against the 5 percent for the rail. It is expected that the divergence between rail share and road share will slow down and stability will be achieved around 2020-21.

2. Rail- and road-based passenger mobility; 1950-51 to 1995-96

The importance of time-series and growth curves models for transport demand forecasting is obvious. To get precise estimates of such models, we need to have long annual series of the level of rail- as well as road-based passenger mobility. The annual series of the level of rail-based passenger mobility from 1950-51 to 1995-96 is readily available (e.g., Statistical Abstract India; CSO, GOI). The similar series for road-based passenger traffic is not available. Although, there are few estimates regarding the level of the road-based passenger mobility (e.g., CMIE, Mumbai and TEDDY, New Delhi), but they are not only incomplete but also their reliability is very much questionable.[1] Therefore, we decided to estimate the level of road-based passenger traffic from 1950-51 to 1995-96 on the basis of services provided by different motor vehicle category. The estimates are based on the following passenger vehicles:

(1) Cars, jeeps, and taxis,

(2) Two-wheelers,

(3) Auto-rickshaws, and

(4) Buses

India's passenger transport for short and medium distances is essentially bus oriented. Buses even compete with railways on certain long-distance routes by offering night services. Buses enjoy a distinct edge over railway for short and medium distances because of their flexibility and accessibility to a large number of towns and villages. Compared to personal modes of transport like cars and two-wheelers, buses per passenger yield noticeable economy in the use of road space, incur lower fuel consumption and lower cost of operation. From the very beginning, buses have dominated the road-based passenger movement. Bus travel currently represents around 80 percent of the road-based passenger travel. Table 1 presents growth of Indian bus industry over the years with some indicators of its productivity performance. The bus population went up from a meagre 34411 in 1950-51 to 448970 in 1995-96 representing an average annual growth rate of 5.87 percent. Also, there is noticeable change in productivity of bus operation. Annual utilization, for instance, jumped up from 36400 kms in 1950-51 to 98800 kms in 1995-96. This was brought about by various factors, important among them being road improvements, better buses and their maintenance, and superior managerial effort. The

[1] For example, CMIE provides estimates of road-based passenger-kms from 1950-51 to 1988-89 in 11 data points. It does not present annual complete series from 1950-51 to 1995-96 for which motor vehicle population data is readily available. TEDDY provides similar series and seems to be based on CMIE estimates.

occupancy ratio (ratio of number of passengers to the seats offered) has also been gradually rising from around 45 percent in 1950-51 to 85 percent in 1995-96. To calculate the level of mobility provided by the buses, average seating capacity is assumed to be 52.

TABLE 1 IS HERE

Cars, jeeps, taxis, auto-rickshaws, and two-wheelers are other modes of passenger transportation. Table 2 reports population of these vehicles at different points in time. The vehicle population is growing faster in the category of two-wheelers and three-wheelers (auto-rickshaws). During 1950-51 to 1995-96, the two-wheelers and three-wheelers population grew at an average annual rate of 16.37 and 15.32 percent respectively. The growth in population of cars, jeeps, and taxis is relatively modest. In the last four and half decades, car (including jeep and taxi) ownership is increasing at the rate of 7.54 percent per annum.

TABLE 2 IS HERE

The passenger-kilometers accounted for by these modes of transport is calculated after making reasonable assumptions regarding their average annual utilization and average occupancy.[2] Annual utilization of cars (include jeeps and taxis), two-wheelers, and auto-rickshaws are assumed to be 12600, 6300, and 33500 kms respectively. Average occupancy of a car, two-wheeler, and auto-rickshaw are assumed to be 3.18, 1.5, and 1.76 respectively. Accordingly, we compute the level of passenger mobility provided by the different modes of road transport from the period 1950-51 to 1995-96. Table 3 presents the level of road-based passenger mobility according to the vehicle category.

TABLE 3 IS HERE

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[2] Assumptions regarding annual utilization and average occupancy of different modes of passenger transport is based on studies like National Transport Policy Committee Report (1980), Planning Commission, New Delhi; Road Development Plan 1981-2000 (1984), Indian Road Congress, New Delhi; Estimation of Road Transport Passenger and Freight Demand (1986), Study Report of Ministry of Surface Transport, New Delhi; and Report of Steering Group on Transport Planning (1987), Planning Commission, New Delhi.

Surface-based long-distance passenger mobility mainly depends on rail. The Indian railway system is the second largest in the world under a single management. It had played a dominant role in providing passenger mobility from second half of the nineteenth century to the early 1950s. Rail-system started loosing its ground from the late 1950s, which never stopped afterwards. The upward sloping curve of road share and downward sloping curve for rail share tells the same story (Figure 1). In the period 1950-51 to 1995-96, rail-based passenger mobility has increased at the rate of just 3.69 percent per annum against the corresponding annual growth rate of 9.79 percent by roads. Table 4 presents the level of rail-based passenger mobility along with its share in total surface-based passenger movement from 1950-51 to 1995-96.

FIGURE 1 IS HERE

TABLE 4 IS HERE

3. Rail- and road-based passenger mobility; 1995-96 to 2015-16

The medium and long-term forecasts of the level of passenger mobility are essential to plan the required infrastructure facility. In a practical forecasting problem, the statistical nature of the data-generating process is unknown, and the forecaster's task is to select a model that best approximates the 'real life' data generating process. For a time series like the level of passenger mobility, it is conceivable that the time series converge to a certain maximum as time passes by. If we plot the level of passenger mobility against time, it is expected that it will look like an *S*-shaped curve (Figure 2). Therefore, growth curves can very well be used to model and forecast the development of passenger mobility.[3] Among the growth curves, logistic curves are very widely used curves in the literature. The *basic* logistic curve is *simple logistic curve* which was initially formulated by Verhulst in 1838 (see, Tanner J. C. (1978)).[4] It is an *S*-shaped curve, symmetric about its point of inflection (i.e., at the half of the saturation level). Its equation is

$$Y_t = \frac{\alpha}{1 + \gamma \exp(-\beta t)} + \varepsilon_t \qquad \textbf{(1)}$$

[3] An overview of so-called growth curves is given in Meade N. and Islam T. (1998), see also Meade N. and Islam T. (1995).

where Y_t is the level of passenger mobility (measured as pass.-kms in billions) at time t, α is the saturation level, β is called the coefficient of imitation or the coefficient of internal influence, and ε_t is an error term. All the parameters – α, β, and γ are positive.

FIGURE 2 IS HERE

Differentiation of the global logistic curve (ignoring the error term), **(1)**, yields the following differential equation:

$$\frac{dY(t)}{dt} = \frac{\beta}{\alpha} Y(t)(\alpha - Y(t)) \quad \textbf{(2)}$$

Equation **(2)** can be written in a discrete form as follows (which can be econometrically estimated):

$$Y_t - Y_{t-1} = \frac{\beta}{\alpha} Y_{t-1}(\alpha - Y_{t-1}) + \varepsilon_t \quad \textbf{(3)}$$

The growth curve based on equation **(3)** is popularly known as *local logistic curve*. The philosophy underlying the local logistic curve is that the forecasts of market development (here, it is passenger mobility) should be extrapolated from the last known observation. It is argued that this is preferable to extrapolating the simple or global logistic, **(1)**, which may not fit the most recent observations well.

The basic model has been extended in several different ways. Bass (1969) proposed *extended logistic curve* growth model in a form convenient for fitting by linear regression:[5]

$$Y_t - Y_{t-1} = (\lambda + \mu Y_{t-1})(\alpha - Y_{t-1}) + \varepsilon_t \quad \textbf{(4)}$$

where α is the saturation level, and ε_t is error term.

There are many different estimation methods for growth curves, see Meade N. and Islam T. (1995), but here we use the non-linear least square routine in LIMDEP Version 7.0 to estimate the parameters of models **(1)**, **(3)**, and **(4)**. We estimate all the three models separately for both rail- as well as road-based passenger mobility indicator. Annual data of

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[4] The word *basic* is used to imply that the models from a basis from which other models may be developed.

[5] The *extended logistic curve* is also called *generalized logistic curve*. Its shape is determined by both λ and μ.

rail- and road-based passenger-kilometers (in billions) from 1950-51 to 1995-96 is used for this. Estimation results are reported in Table 5.

TABLE 5 IS HERE

Figure 3 and 5 reveal the goodness of fit of logistic models for the road- and rail-based passenger-kms respectively. We projected the road- and rail-based passenger movement up to 2015-16 on the basis of fitted logistic models and depicted in Figure 4 and 6 respectively. According to adj. R^2 value, simple logistic model seems to have better predictive power than local and extended logistic models.

FIGURE 3 IS HERE

FIGURE 4 IS HERE

FIGURE 5 IS HERE

FIGURE 6 IS HERE

Estimation result of simple logistic model reveals that surface-based passenger movement demand will saturate at 19956.53 billion passenger-kms, out of which 96 percent will be served by roads against to 4 percent by rails. The level of road-based passenger mobility will be very near to the 10000 billion passenger-kms marks by the end of year 2015-16 whereas corresponding rail-based figure will be just around 530 billion passenger-kms (Table 6). Result shows that by that time, around 95 percent of surface-based passenger movement will be road-based. It is expected that continued divergence between road and rail share will slow down by the year 2020-21 and stability will be achieved when road and rail share is around 96 and 4 percent respectively. The average annual growth rates during 1995-96 to 2015-16 are expected to be 7.35 percent for road-based passenger movement and 2.28 percent for rail-based passenger movement. This may be compared with actual growth rates during 1950-51 to 1995-96 (9.79 percent for road-based passenger movement and 3.69 percent for rail-based passenger movement).

TABLE 6 IS HERE

4. Concluding remarks

In this study, we estimated the level of rail- and road-based passenger mobility from the period 1995-96 to 2015-16 using logistic curve models. The level of road-based passenger traffic is expected to be between 7763 to 9960 billion passenger-kms during the year 2015-16 whereas corresponding rail-based figure is between 405 to 532 billion passenger-kms. This shows that road has to play a more dominant role in future.

The gap between percentage share of rail and road in passenger movement will widen further. By the end of year 2015-16, around 95 percent of surface-based passenger traffic will be handled by road. The respective saturation levels reveal that stability will be achieved when road share touches 96 percent mark.

We know that the transport sector is major contributor to environmental degradation. In addition to its contribution to air pollution, the transport sector is the largest single source of noise pollution. Transportation is a major contributor to solid waste accumulation in the form of abandoned vehicles, non-recyclable materials such as automobile and truck tires. The number of deaths and injuries and the property damage of automobile accidents are enormous. In fact, land-based transport, especially the automobile, is the biggest single contributor to the environmental damage caused by the sector. In such circumstances, the expected greater reliance on road will pose a challenge to the policy makers. Energy availability and environmental concerns will be areas of grave concern.

Table 1.
Growth of Indian bus industry; 1950-51 to 1995-96. Source: data compiled and analysed by the author from various sources such as: (1) Singh M. and Kadiyali L. R. (1990), "Crisis in Road Transport" *Konark Publishers Pvt. Ltd., New Delhi*; (2) Performance Statistics of STUs, 1990-91/1991-92 to 1995-96/1996-97 published by CIRT, Pune and (3) TEDDY, New Delhi; various issues.

Year	Bus population (thousand)	Average annual utilization (kms)	Occupancy ratio (percent)	Pass.-kms (billion PKm)
1950-51	34.411	36400	45	29.310
1955-56	46.461	41200	51	50.764
1960-61	56.792	46700	59	81.369
1965-66	73.175	54300	60	123.970
1970-71	91.406	58800	73	204.023
1975-76	114.193	67800	76	305.975
1980-81	153.909	79000	80	505.807
1985-86	227.608	80100	85	805.828
1990-91	331.100	87000	85	1273.212
1995-96	448.970	98800	85	1960.634

Table 2.
Passenger vehicle population ('000) and its compound annual growth rate (%age) since previous period (in parentheses). Source: Statistical Abstract India, Various issues; Published by CSO, GOI.

Year	Cars, Jeeps, and Taxis	Two Wheelers	Auto-rickshaws	Buses
1950-51	159.26 (-)	25.21 (-)	1.65 (-)	34.41 (-)
1955-56	203.18 (4.99)	38.44 (8.80)	2.52 (8.84)	46.46 (6.19)
1960-61	309.58 (8.79)	88.36 (18.11)	6.24 (19.88)	56.79 (4.10)
1965-66	455.91 (8.05)	225.63 (20.62)	16.07 (20.83)	73.18 (5.20)
1970-71	674.31 (8.14)	572.11 (20.45)	36.66 (17.93)	91.41 (4.55)
1975-76	776.38 (2.86)	1045.43 (12.81)	59.45 (10.15)	114.19 (4.55)
1980-81	1121.54 (7.63)	2530.44 (19.34)	142.07 (19.03)	153.91 (6.15)
1985-86	1709.86 (8.80)	6264.35 (19.88)	336.91 (18.85)	227.61 (8.14)
1990-91	2953.99 (11.56)	14199.86 (17.78)	617.37 (12.88)	331.10 (7.78)
1995-96	4189.37 (7.24)	23111.39 (10.23)	1008.97 (10.32)	448.97 (6.28)

Table 3.

The level of passenger mobility (passenger-kilometers in billions) provided by different modes of road transport. Source: values estimated by the author.

Year	Cars, jeeps, and taxis	Two-wheelers	Auto-rickshaws	Buses	Road transport
1950-51	6.381	0.238	0.097	29.310	36.027
1951-52	6.475	0.238	0.097	31.009	37.820
1952-53	6.749	0.259	0.106	36.442	43.557
1953-54	6.968	0.268	0.110	39.834	47.180
1954-55	7.454	0.296	0.121	42.608	50.478
1955-56	8.141	0.363	0.149	50.764	59.417
1956-57	8.796	0.407	0.166	44.311	53.681
1957-58	9.742	0.525	0.215	43.345	53.828
1958-59	10.722	0.593	0.247	61.740	73.302
1959-60	10.977	0.638	0.284	67.346	79.245
1960-61	12.404	0.835	0.367	81.369	94.976
1961-62	13.609	1.027	0.461	88.244	103.341
1962-63	15.041	1.238	0.515	95.848	112.642
1963-64	15.564	1.483	0.640	105.378	123.065
1964-65	17.151	1.779	0.803	115.452	135.186
1965-66	18.267	2.132	0.947	123.970	145.317
1966-67	19.311	2.532	1.057	136.115	159.015
1967-68	20.930	3.145	1.355	156.499	181.929
1968-69	23.165	3.712	1.568	174.781	203.226
1969-70	25.129	4.463	1.822	193.448	224.862
1970-71	27.018	5.406	2.161	204.023	238.608
1971-72	29.487	6.287	2.464	223.716	261.954
1972-73	28.392	6.970	3.339	236.854	275.555
1973-74	30.756	7.924	3.963	261.200	303.842
1974-75	30.484	8.848	4.408	291.760	335.501
1975-76	31.108	9.879	3.504	305.975	350.466
1976-77	32.407	11.672	4.915	320.021	369.015
1977-78	34.412	13.529	5.533	347.382	400.857
1978-79	37.060	15.858	6.503	383.644	443.065
1979-80	39.086	17.840	7.175	418.270	482.372
1980-81	44.938	23.913	8.374	505.807	583.031
1981-82	48.376	27.997	9.533	547.098	633.004
1982-83	54.140	33.187	10.724	602.144	700.195
1983-84	57.069	40.010	14.085	673.194	784.358
1984-85	61.937	48.389	16.268	744.610	871.204
1985-86	68.511	59.198	19.858	805.828	953.394
1986-87	75.933	72.371	22.746	888.509	1059.559
1987-88	91.301	87.475	25.082	972.682	1176.540
1988-89	99.621	103.617	28.084	1033.725	1265.046
1989-90	109.627	118.417	31.934	1182.154	1442.132
1990-91	118.360	134.189	36.388	1273.212	1562.149
1991-92	128.409	147.995	39.463	1412.772	1728.639
1992-93	134.662	162.381	42.458	1472.627	1812.128
1993-94	143.038	178.593	45.450	1627.549	1994.630
1994-95	153.883	196.857	52.892	1802.458	2206.090
1995-96	167.860	218.403	59.469	1960.634	2406.365

Table 4.
Trends in rail and road share in passenger movement; 1950-51 to 1996-97

Year	Rail passenger service (pass.-kms in billions)	Road passenger service (pass.-kms in billions)	Rail share (in percentage)	Road share (in percentage)
1950-51	67.065	36.027	65.05	34.95
1955-56	62.898	59.417	51.42	48.58
1960-61	78.061	94.976	45.11	54.89
1965-66	96.756	145.317	39.97	60.03
1970-71	118.120	238.608	33.11	66.89
1975-76	148.761	350.466	29.80	70.20
1980-81	208.558	583.031	26.35	73.65
1985-86	240.623	953.394	20.15	79.85
1990-91	295.790	1562.149	15.92	84.08
1995-96	342.359	2406.365	12.46	87.54

Table 5.
Parameter estimates of different logistic models (with t-statistic in parentheses)

Model	Estimate
Road-based passenger mobility	
Simple logistic (1)	α = 19221.97 (3.26), β = 0.1007 (48.00), γ = 715.936 (3.89); Adj. R^2 = 0.999
Local logistic (3)	α = 12471.29 (1.50), β = 0.10934 (9.96); Adj. R^2 = 0.898
Extended logistic (4)	α = 10443.37 (1.53), μ = 0.0000109 (1.27), λ = -0.0001881 (0.34); Adj. R^2 = 0.898
Rail-based passenger mobility	
Simple logistic (1)	α = 734.56 (5.87), β = 0.05628 (15.68), γ = 15.571 (7.02); Adj. R^2 = 0.989
Local logistic (3)	α = 682.70 (1.39), β = 0.05771 (2.53); Adj. R^2 = 0.146
Extended logistic (4)	α = 413.82 (4.22), μ = 0.0003069 (1.44), λ = -0.0159245 (0.94); Adj. R^2 = 0.171

Table 6.
Logistic curves based forecasts of passenger mobility (pass.-kms in billions). Source: values estimated by the author.

	1995-96	2000-01	2005-06	2010-11	2015-16
Road					
Simple logistic	2412	3688	5421	7572	9960
Local logistic	2405	3606	5119	6805	8433
Extended logistic	2403	3577	4987	6456	7763
Rail					
Simple logistic	339	390	441	489	532
Local logistic	329	391	438	482	521
Extended logistic	327	370	388	399	405

Figure 1.
Rail and road share in passenger movement

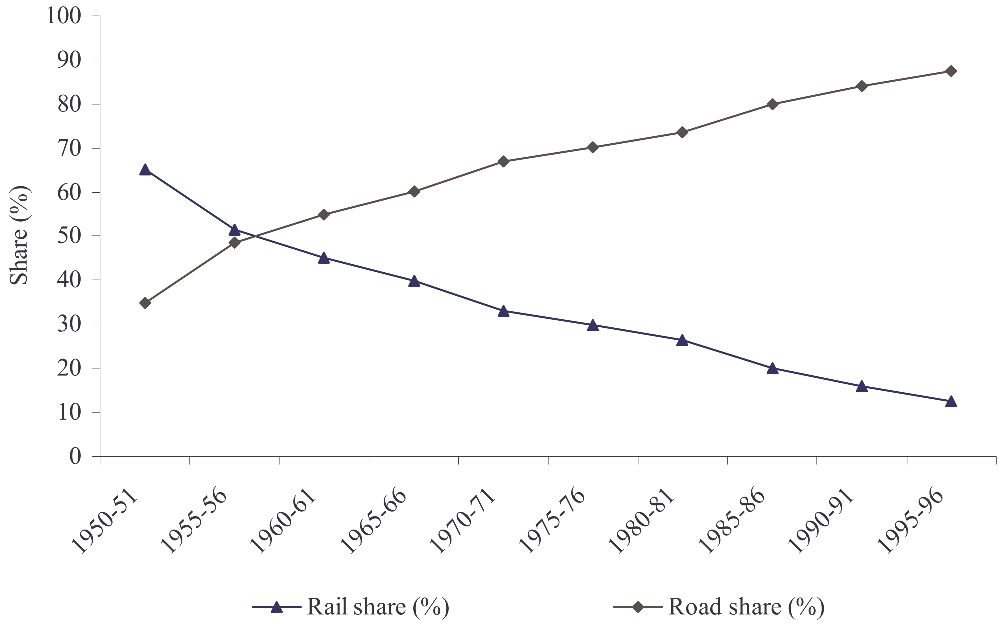


Figure 2.
An example of a logistic curve

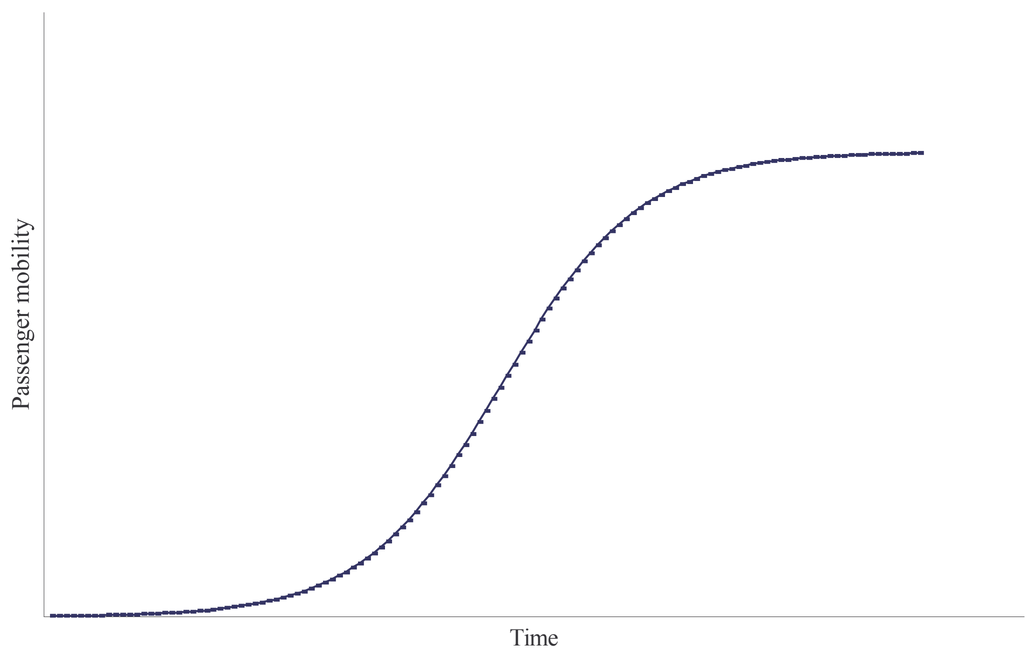


Figure 3.
Predicting power of logistic models (road-based passenger mobility)

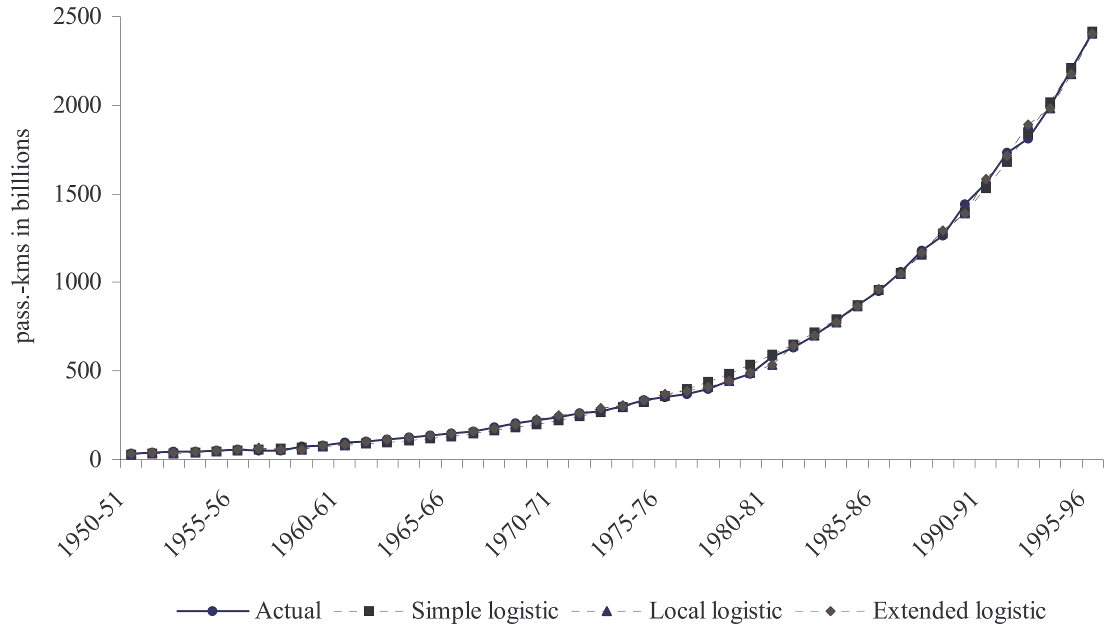


Figure 4.
Projection of road-based passenger mobility

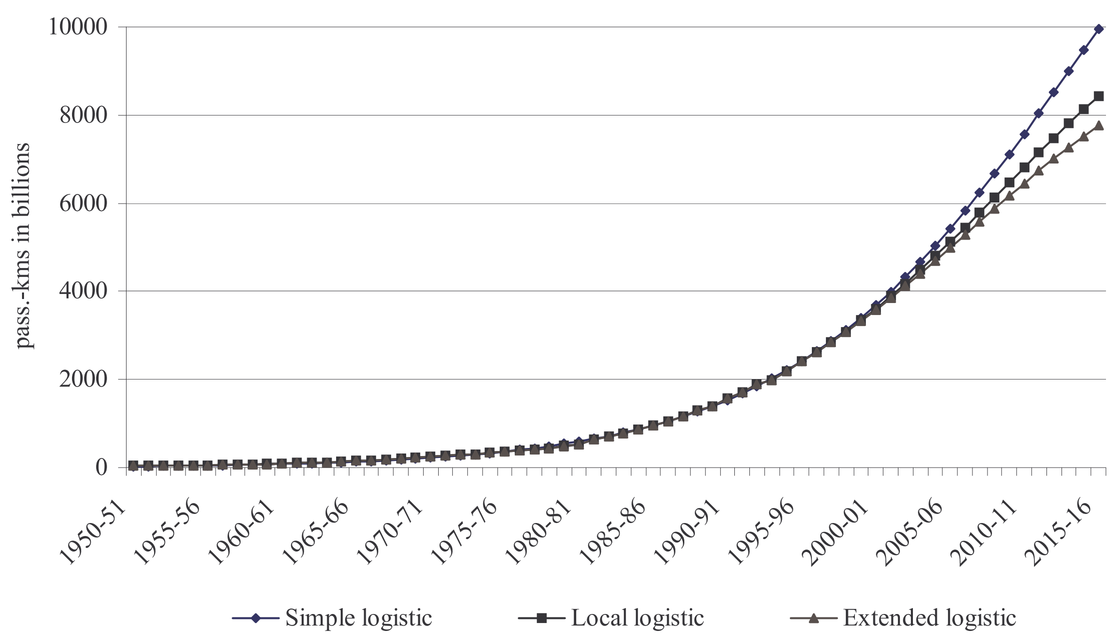


Figure 5.
Predicting power of logistic models (rail-based passenger mobility)

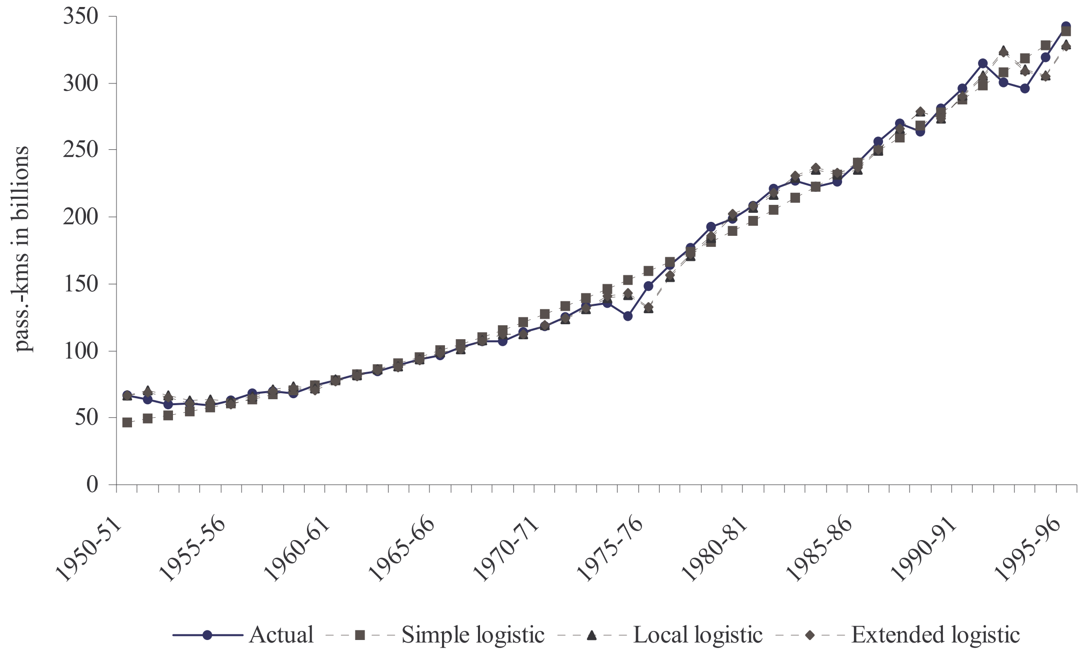
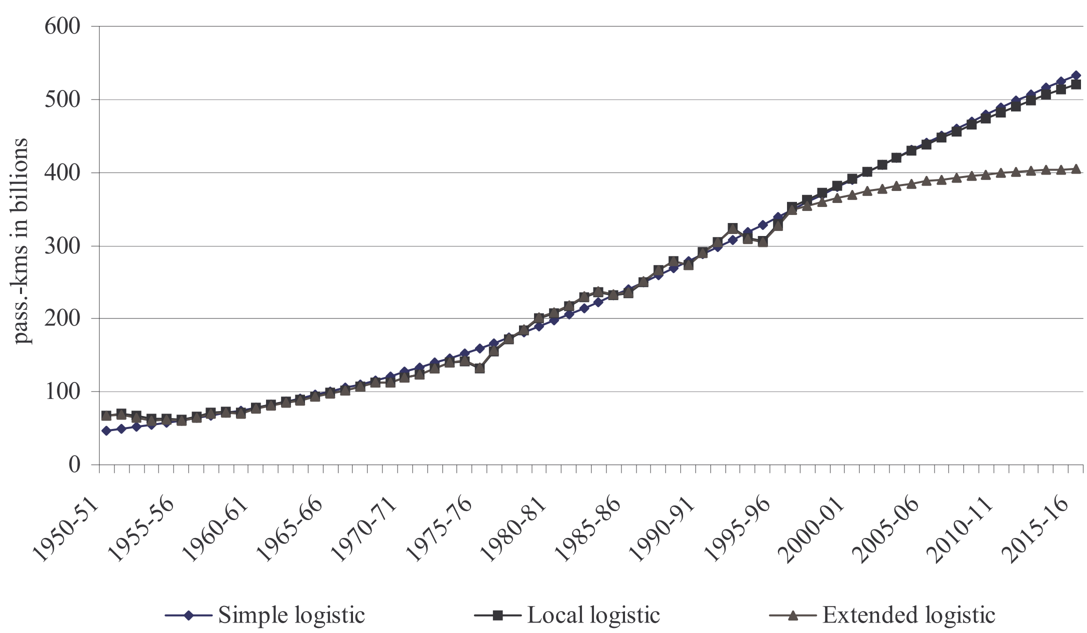


Figure 6.
Projection of rail-based passenger mobility



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