Future of Aluminium Demand in India - A System Dynamics Approach

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ABSTRACT

Although there are more than 3000 end uses of aluminium in the world and more than 300 in India, yet there are five sectors viz. power,consumer durables, transport, building consturction canning and packaging which account for more than 90% of aluminium consumption. To study the dynamics of demand of aluminium in these sectors, system dynamics model having various sectors viz. Population, economy, power, consumer durables, construction, packaging and canning, transport and aluminium consumption model has been simulated from 1970´to 2000 A.D. using dynamo.

INTRODUCTION

Demand for aluminium and for that matter, the same for any consumer or capital product, in a given region is intimately related to the overall economic conditions prevailing in the said region. In a crude way, it is possible to project the national income and per capita income on the basis of expected growth rate, and consequently, a rough estimate of aluminium demand can be made. End use method have also been used for predicting the demand for aluminium in India. Such a static model though useful for making checks of estimates, has no value for understanding the dynamics of interaction among various sectors dynamically influencing the demand. As economic change is the result of dynamic interaction of a large number of economic and social variables, an accurate projection of demand can only be made by deriving the demand, for different items of aluminium from the important economic indicators dynamically changing due to cause and effect relationship of change between them. Thus system dynamics is a powerful methodology based on feed-back control theory which helps in understanding the dynamics of demand. Authors' earlier experience in formulating steel demand model (Gupta and Garga 1981,pp C 169-174) and a general consumer demand model (Gupta and Garga 1983, pp 824-829) based on system dynamics encouraged to use system dynamics for aluminium demand model. System dynamics has been used in a modest way as a first application to keep the technique understandable to the planners.

It may be pointed out that more than the predictive function of the model, its usefulness lies as an instrument for understanding the mechanism involved in the changes in the various sectors and consequently knowing the demand for a product, it is aluminium, in this case.

HISTORIC PERSEPECTIVE OF ALUMINIUM DEMAND

Among the non ferrous metals, aluminium occupies a place of pride. It has wide range of applications in industries like power, transport, building and consumer durables such as utensils and packaging. The properties that make aluminium such a versatile metal are lightness, favourable strength to weight ratio, corrosion resistance, high reflectively and thermal conductivity. In view of its wide range of applications, aluminium has come to play an important role in the development of industrial economies all over the world. In view of its high reserves compared to copper, aluminium is expected to maintain its place as an important non ferrous metal in the future too (commerce 1982, pp. 12-19).

Since the inception of aluminium industry in India from 1943, when the production capacity was 3 thousand tonnes per year, capacity has been increased more than three lac tonnes by 1980. Although the capacity utilization of the aluminium industry has been declining from 108 percent in 1970-71 to 64 percent in 1981-82 due to power shortage and fluctuations in its demand. India has to import aluminium depending upon the variations in its local supply and demand.

Although there are more than 3000 end uses of aluminium in the world and more than 300 in India, yet there are five areas which account for more than 90 percent of aluminium demand. In the Indian context, these in the order of their importance:-

1.	Power	52%
2.	Consumer Durables	17%
3.	Transport	12%
4.	Packaging	6%
5.	Construction	4%

The 91 percent of aluminium demand in India is accounted for by the above five sectors of consumption, while all other uses put together need only 9 percent of aluminium. Accordingly the above mentioned sectors have been modeled in somewhat detail as shown in the Fig.1. Their consumption factors have been developed separately . All other have been aggregated.

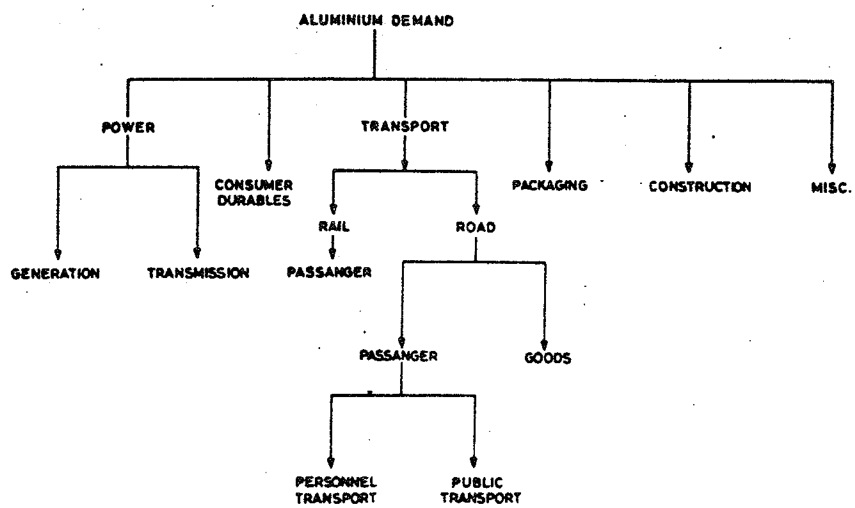

FIG.1 ITEMS TO BE CONSIDERED FOR ALUMINIUM DEMAND

As per the available statistics the per capita aluminium consumption in India is only .4 kgs whereas the world average is placed at 5.18 kgs. per capita. For developed countries like U.K., U.S.A. and Japan; per capita aluminium consumption is as high as 17 kgs. Thus one can infer that the scope of aluminium demand in India is still very large. But the share of aluminium consumption in various sectors in India is vastly different from that, in other countries. Whereas 52 percent of the aluminium consumed in India is in power sector only, the corresponding figure for U.S.A. and U.K. is only 13 percent. Again whereas packaging and canning consumes 6 percent of total aluminium consumption in India the corresponding figures for U.S.A. and U.K. are 18 percent and 28 percent respectively, forming most important sector of consumption in these countries. This underlines the hazard of model making in the Indian context. The norms of consumption in each sector have to be developed exclusively from the Indian data of recent past only. However the model should be used judiciously to account for the random changes in prices and availability of aluminium.

THE MODEL

The system dynamics model has been formulated on the basis of following sectors. A simplified causal loop diagram is shown in the Fig.2.

1) Population,2) Economy, 3) Power, 4) Consumerdurables, 5) Transport, 6)Building consturction, 7) Canning and Packaging and 8) aluminium consumption.

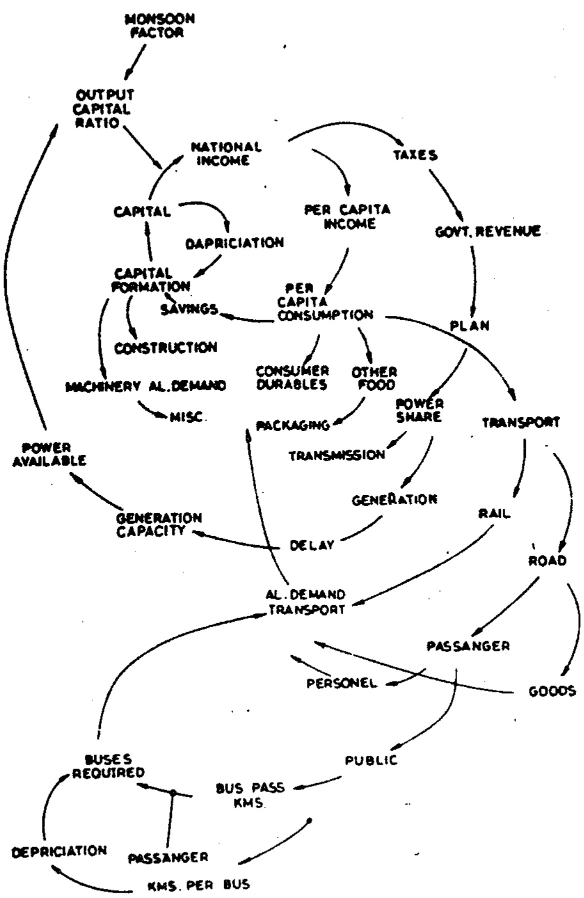

FIG. 2 CAUSAL LOOP DIAGRAM

Population sector has been developed in a simple way for this model. Population is a level which is increased by the incoming births and decreased by the deaths.Birth rates for the positve loop and death rates for the negative loop have been based on the birth rates and death rates developed by (Srinivasan 1979, pp. 105-108). Population is fed to economy sector for calculating the per capita income.

Economy model generates national income from capital. National income is broken up in savings, consumption and taxes. Savings are fed back to the capital to give the growth oriented positive feedback to the economy. Dapriciation accounts for the negative feed back loop for the capital. Population fed back to this sector computes per capita income. Thus this sector makes available data for consumption, savings and capital formation on the annual basis, which forms inputs to other sectors for estimation of intermediate variables for estimation of aluminium demand.

Power sector is the most crucial sector for aluminium demand. Half of the aluminium is being consumed in power sector for various types of conductors viz. all aluminium conductors (AAC), aluminium conductors steel reinforced (ACSR), all alloy aluminium conductors (AAAC) for transmission and wires for manufacturing of electrical equipment. To compute the demand for aluminium in power sector, Govt.revenue is generated from taxes which in turn decides the plan for power (causal loop diag. 2) and money spent on generation and transmission. Power is a level in megawatts which is increased by power inrate and power in pipeline, and is decreased by power depriciation outrate. Power inrate is dependent upon money spent on power from the power plan and gestation period for getting the money converted into power installed capacity, depending upon power generation cost i.e. Rs. 30,000/- per megawatt at 1970-71 prices.

Alongwith generation there has to be commensurate investment in transmission and distribution to evacuate power from generating stations and deliver it to the point of consumption. Expenditure on transmission and distribution is very important for consumption of aluminium in power sector. It has been found that expenditure on transmission and distribution should normally be between 66 percent to 100 percent of the expenditure on generation. The national average of investment in Transmission and distribution in U.S.A. is about 70 percent of the investment in generation. In India however the investment on Transmission and distribution needs to be much higher although it has been much less(energy policy 1979, pp.67). Therefore money spent on generation is assumed to be 70 percent of the total expenditure on power plan upto 1986 and thereafter it goes down to 60 percent by 2000 AD.

Thus aluminium demand for power sector is being calculated form the money spent on transmission and power installed capacity. Power installed is also fed back to the economy sector for affecting the output capital ratio depending upon the power demand forecast given by (Energy Policy 1979, pp. 64-65). This factor varies from .5 to 1.1 when ratio of power available to power demand increases from 0 to 1.4.

Transport sector is divided into two main sectors i.e. Passanger transport and goods transport. Passanger transport is again divided into personnel and public transport. Public transport is further divided into rail and road. A part of the per capita consumption is on transport. Per capital expenditure on transport is a function of per capita consumption. As per capital consumption increases expenditure on transport increases much more as compared to expenditure on other items. This has been represented by a table function. Using these subheads of expenditure, the norms of aluminium consumption is each are developed to find consumption of aluminium in transport sector. Road passanger public transport is the most sensitive sector for consumption of aluminium in transport. So the other way of aluminium consumption is for buses and has been based on the number of buses required each year. Buses required are function of Bus-Passanger-Kms. which depends upon the expenditure on public road transport and passanger kms per bus as shown in the causal loop diag. 2. Replacement of Buses is a function of passanger kms. per bus. Passanger kms. per bus increases with time as the public transport requirement increases with rise in population and diverseeconomic activity.

consumer durables forms the next important sector for consumption of aluminium. With rise in per capita income per capital consumption increases, as basic needs are fulfilled, more and more money is spent on consumer durables. Expenditure on consumer durables and semi durables increased from 10.4 percent of private final consumption expenditure to 15.6 percent while per capita income rises from Rs. 551.5 to Rs. 589 at 1970-71 prices (National Accounts Statistics 1983 pp.XXXV). Expenditure on consumer durables computes the aluminium demand for this sector.

For packaging and canning toothpaste, shaving creams, facial creams, pharmaceutical preparations, cigarettes, tea etc, aluminium is used in the form of aluminium foil and aluminium collapsible cubes. Part of the consumption accounted for foods other than the basic foods, which include beverages, milk, cigarettes, tea, drugs, have been separated, to be used as the economic indicator for aluminium demand in packaging and canning sector.

Demand for aluminium in building and construction has been based on the share of construction in capital formation. Share of construction sector decreases with time as more and more conventional machinery is replaced by Capital intensive machinery. Share of construction in capital formation has been assumed to be decreasing with time from 55 percent in 1970-71 to 40% in 2000 AD. So the capital formation in construction sector decides the requirement of aluminium in construction sector. Demand for aluminium in miscellaneous sector has been based on the capital formation in machinery sector.

Aluminium consumption sector develops the norms of the aluminium consumption vis-a-vis expenditure in transmission, consumer durables, packaging, transport sectors and megawatts in generation sector and No.of buses for public transport. For this purpose norms have been developed analysing the consumption norms for various items in each sector and production for each item, and expected variations in consumption norms for future.

RESULTS

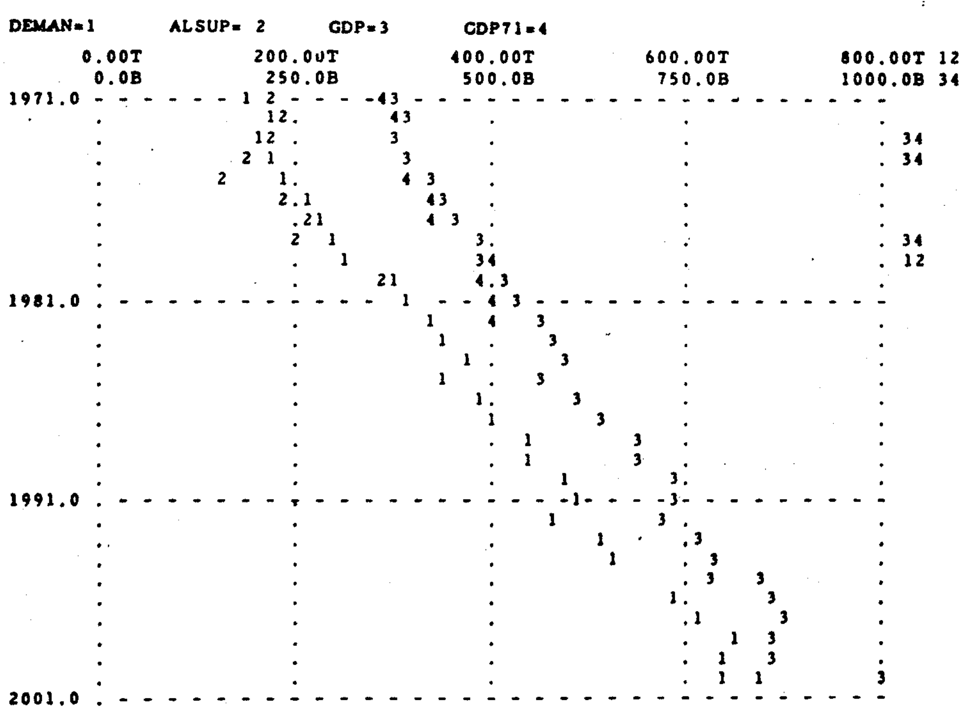

Fig. 3.

The demand model has been validated by running it from 1971 onwards by comparing the graphical results for aluminium demand and Gross domestic product upto 1981 with the actual figures (Fig.3). The model results shows that the demand pattern as generated by the model are very near to be actual demand figures. Fig.3 based on computer graph gives the projected figures for the following items upto Year 2000. Model aluminium demand (DEMAN)=1,aluminium actual demand(Alsup=2), Model Gross Domestic product(GDP)=3,GDP actual at 1970-71 prices(GDP 71)=4.

TABLE - 1
ALUMINIUM DEMAND FOR VARIOUS SECTORS

TIME E 00	DEMAND E 03	POWER E 03	TRANS-PORT E 03	CONS. DURABLES E 03	CONSTRUC-TION E 03	PACKAGING E 03	MISC. E 03
1971.0	156.03	72.52	20.684	29.37	6.579	10.625	16.250
1972.0	168.89	78.36	22.987	31.41	7.129	11.470	17.538
1973.0	162.82	78.77	19.276	30.01	6.773	11.390	16.608
1974.0	176.09	84.34	21.757	32.25	7.376	12.326	18.042
1975.0	191.59	91.17	24.636	34.75	8.044	13.352	19.639
1976.0	207.36	99.21	27.068	37.02	8.647	14.332	21.084
1977.0	225.05	107.92	29.919	39.76	9.429	15.380	22.642
1978.0	240.38	117.00	31.285	42.19	10.001	16.216	23.689
1979.0	245.76	124.13	29.841	41.29	10.142	16.621	23.729
1980.0	286.06	140.29	36.880	51.95	11.623	18.422	26.892
1981.0	294.84	148.49	36.382	51.58	11.948	19.061	27.374
1982.0	327.04	160.41	41.486	61.25	13.123	20.965	29.802
1983.0	341.42	167.78	42.485	64.21	13.724	22.286	30.927
1984.0	358.91	175.50	44.273	68.69	14.407	23.794	32.249
1985.0	338.60	174.30	37.512	57.85	13.992	23.813	31.141
1986.0	377.91	186.59	44.086	71.20	15.461	26.329	34.243
1987.0	399.91	194.28	47.500	77.79	16.26	28.364	35.755
1988.0	437.58	205.14	54.328	90.99	17.539	31.110	38.471
1989.0	437.22	207.66	52.688	88.34	17.639	32.363	38.529
1990.0	478.48	219.96	59.925	101.13	19.547	35.378	42.537
1991.0	483.22	223.66	58.946	101.57	19.609	36.904	42.530
1992.0	463.98	222.37	52.777	90.81	19.024	37.596	41.403
1993.0	516.20	237.13	61.750	109.18	20.892	41.618	45.634
1994.0	527.98	242.88	61.926	111.59	21.220	43.831	46.527
1995.0	586.43	260.62	72.424	127.26	24.270	48.435	53.428
1996.0	609.26	269.18	74.836	132.89	25.217	51.394	55.748
1997.0	646.92	281.52	80.374	142.89	26.999	55.192	59.949
1998.0	638.10	282.50	75.377	139.24	26.095	56.674	58.209
1999.0	640.39	286.44	72.867	138.76	25.793	58.722	57.810
2000.0	708.17	306.65	84.275	157.44	29,328	64.412	66.061

Above table shows the aluminium demand for various sectors upto year 2000. Power sector remains the most important sector for aluminium demand. Share of power plan expenditure on transmission varies the demand in power sector considerably and thus affecting the power installed capacity due to the variation in the money spent in generation sector which in turn will influence the output capital ratio for covering capital to Gross Domestic Product.Secondly buses in transport sector consumes the maximum aluminium as compared to other subsectors of transport.Thus three more scenarious have been generated based on the variations in transport and power sector.

TABLE - 2

TIME	DEMAN	DEMAN2	DEMAN3	DEMAN4
1971.0	156.03	151.89	156.03	156.03
1972.0	168.89	163.37	168.89	168.89
1973.0	162.82	161.43	162.82	162.82
1974.0	176.09	168.11	176.09	176.09
1975.0	191.59	182.14	191.59	191.59
1976.0	207.36	200.94	207.36	207.36
1977.0	225.05	218.28	225.05	225.05
1978.0	240.38	235.03	240.38	240.38
1979.0	245.76	240.43	245.76	245.76
1980.0	286.06	272.34	286.06	286.06
1981.0	294.84	292.37	294.84	294.84
1982.0	327.04	315.65	330.72	330.72
1983.0	341.42	336.01	349.02	349.02
1984.0	358.91	349.59	370.69	370.69
1985.0	338.60	334.06	353.59	353.59
1986.0	377.91	361.31	397.84	397.84
1987.0	399.91	390.20	424.27	424.27
1988.0	437.58	427.63	467.17	467.17
1989.0	437.22	437.18	469.90	469.90
1990.0	478.48	466.12	517.16	517.16
1991.0	483.22	482.57	524.51	524.51
1992.0	463.98	459.91	500.82	505.74
1993.0	516.20	497.43	554.01	564.59
1994.0	527.98	527.13	562.43	578.46
1995.0	586.43	574.61	622.24	645.22
1996.0	609.26	612.06	642.91	671.91
1997.0	646.92	642.15	679.19	714.76
1998.0	638.10	642.17	666.67	706.22
1999.0	640.39	632.66	666.04	708.21
2000.0	708.17	693.29	733.86	782.20

Table 2 shows the demand of all the secenarios upto 2000 AD in thousand tons.Deman is the base run. Deman2 is the demand based on number of buses required in transport sector while all other sectors remain the same as in the base run. Deman3 is the rerun by changing the expenditure on transmission upto 40% of power plan in the year 2000. This increased the aluminium demand from 708 to 733 thousand tons while increasing the aluminium for transmission from 206 to 266 thoudsand tons and depresses the power installed capacity in rate which in turn reduces the demand for generation from 100 thousand tons to 83 thousand tons. Thus by increasing the share of transmission money invested in power generation is reduced thus power installed capacity reduced from 112 thousand Megawatts to 103 thousand megawatts. Deman4 shows the resutls as the money in further increased in transmission. Thus the demand increases from 708 thousand tons to 782 thousand tons while the aluminium in genration decreases from 100 to 77 thousand tons and in transmission it rises from 206 thousand tons to 324 thousand tons thus raising the demand from 708 thousand tons to 782 thousand tons.

CONCLUSION

It seems that model has been able to capure the basic structure for projecting the alminium demand. Results show that the money invested in transmission is most important for power sector aluminium demand which is the major consumer in India.

As the model was not able to capture the sudden depression in aluminium demand in some years, so further investigation of literature showed that suddenly in some years money is diverted from transmission to generation to achieve the the generation capacity target in some particular year when the projects are delayed more than the expected time.

The study shows that the system dynamics models can be gainfully used to project the demand of any industrial product or consumer product. This model helps in understanding the causal relationship in the related sectors which helps in understanding the dynamics of change among various sectors.

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