A Study of the Number of Distribution Channel Levels for the Road Transportation Systems

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Abstract

Generally, the tons lifted and ton-kilometers are widely used to analyze the road freight transport. However, these two indicators are simply to show the road freight transport statistics rather than to explain the road freight transportation systems. In this study, the variables such as the number of distribution channel levels, the integral distance, tons in transport and the average transport distance are defined and estimated to investigate the road freight transport system of Korea. In order to compare the road transport system of Korea to other countries, the comparative study was conducted including USA, Japan, Holland and Taiwan. The major findings of this study are as follows; i) The number of distribution channel levels and integral distance of Korea and Taiwan have been increased, but the average transport distance decreased from 1971 to 1996 period. ii) On the contrary to Korea case, the number of distribution channel levels and integral distance of US, Japan and Holland have been decreased, but the average transport distance increased. iii) In the time-series model analysis shows that the number of distribution channel levels are statistically positively closely related to the logistics costs and the costs of transportation as a percentage of GDP.

1. Introduction

In Korea, the road transportation accounts over 90% of all freight movements in 1996 in terms of tons moved in domestic and accounts over 50% for total logistics costs. The share of the total logistics cost to gross domestic products (GDP) has been continuously increased during the 1990's and reached at the level of almost 17% in 1997. Also, these heavily road oriented freight movement trends will continues in next decade which is most critical issues in the Korea freight transportation systems for international competitiveness.

Usually, the analysis of the road freight transports focus on the ton-kilometers (ton-km). The ton-km themselves are explained by the tons lifted and the average distance per lift. And the ton-km together with the average load per lift explains the vehicle kilometers. So, with the ton-km at the core of analysis, there is great interest in finding reliable forecasts of it. In principle one would like such forecasts to fit in with the structural determinants of the variable. However, it turns out that tons lifted and average distance is rather unreliable variables. They are influenced in uncertain ways by the distribution channel levels[1]. In other words, analysis of road freight transport is hindered by lack of reliable data on the number of distribution channel levels.

The number of distribution channel levels is the frequency of lifts of the tons in the supply chain. It hence is the frequency, by which the same goods are handled from origin to destination, and thus it is, if statistical measurement is correct, also the number of times that the same tons are reported. Algebraically, the distribution channel level is the ratio of the *tons lifted* to the actual tons passing through the supply chain. For clarity of terms, the latter tons in the supply chain will be called the *tons in transport*. It can be deduced - as will be done below - that the number of distribution channel level is the ratio of the integral distance over all the lifts to the average distance of each lift. The integral distance is

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[1] Cool(1997) defines the number of distribution channel levels as "handling factor" and Ballou(1992) defines as the "Channel Design".

the distance from producer to the final customer.

The statistics of the freight transportation reported by the Ministry of Construction and Transportation (MOCT) of Korea annually published the tons and the ton-km. These data, however, do not provide a full summary of freight transport system, and neither is it possible to derive the distribution channel levels by applying a fixed accounting rule or formula to the two kinds of data that are given. Also, the data on tons and ton-km are affected in uncertain ways by changes in distribution (here: production and logistics), and by influences of these changes on the whole economic progresses. For example, if the number of distributors doubles and the average transport distance halves, and all else such as the integral distance remains the same, then these distributors would report twice as many tons though the number of tons in transport would not actually change.

One approach to tackle this data problem is the use of econometrics, and notably to devise structural equations with hidden variables and then to estimate what has not been measured statistically. One of the main assumptions below will be to relate the tons in transport to the national product (GNP or GDP). Another assumption is that the integral distance will depend upon income and on developments within the distribution system. It may be noted here that the present analysis concerns unimodal transport of road freight only. Thus we do not regard intermodal or multimodal chain transport where the integral distance from origin to destination has a common meaning, as in Chen & Lenoir (1995). However, in our analysis, origin and destination are defined by the statistical procedures of the system of national accounts, and thus have a clear meaning.

In this paper, we propose to consider in more detail analysis for the number of distribution channel levels in the international comparison using modified model, which is outlined in the Cool's study (1997). Section two clarifies the concepts for the distribution channel level and the other freight transportation related statistics. Section three develops the modified structural model using Cool's (1997) original model for estimating "handling factors". Section four provides the simultaneous model for estimation on aggregate data for Korea, Japan, and Taiwan for Asia, United States and Holland for Europe for international comparisons. Finally, section five provides a discussion of the results as well as a few conclusions including further researches.

2. Theoretical aspects of freight transportation statistics

The subject of the statistics of the freight transportation concerned; usually the four important basic statistics are defined. Namely, the channel levels, tons in transport, total integral distance and average distance. In order to explain thesis freight related statistics following sample statistics table is useful. For simplicity, we assume that the total integral distance and tons in transport are not changed and only the number of distribution channel levels are changed from 3 to 2.

Table <2-1> A Typical Distribution Channel

Year	1990			1991		
	Tons	*Km*	*Ton-km*	*Tons*	*Km*	*Ton-km*
Origin – wholesale	10	40	400	10	40	400
Wholesale – factory	10	20	200			
Factory – Destination	10	30	300			
Wholesale – Destination				10	50	500
Total	30	90	900	20	90	900
Number of distribution channel levels	3			2		
Total integral distance	40+20+30 = 90 km			40+50 = 90 km		
Tons in transport	10 ton			10 ton		
Ton	10+10+10 = 30 ton			10+10 = 20 ton		
Average distance	90/3 = 30 km			90/2 = 45 km		

As shown above table <2-1>, let us regard a chain from origin of commodity such as factory, wholesaler, local warehouses and final destination such as shops, and this over a period of two years in this case 1990 and 1991. Let the factory produce 10 tons, and let these be transported over a distance of 90 kilometers to the shops. The wholesaler is 50 kilometers from the producer and 40 kilometers from the shops. In year 1990 there are various local warehouses before the goods actually reach the shop. In year 1991, the warehouses are skipped, and the goods are transported to the shops directly from the wholesaler. Given that there are fewer stages from factory to shop, there is a concentration in terms of the number of distribution channel levels. This example has been chosen such that, for convenience, the integral distance from the factory to the shops does not change and remains 90 kilometers in both years.

Though Table <2-1> gives the actual data on the example problem, it appears that these data are difficult to measure. To understand the difficulty in measurement, we best regard the statistical practices by which the transporting agents are obliged to report their activities to the statistical office. They will report the tons lifted and the average distance per haul, i.e. the first two columns of a year in Table <2-1>. The statistical office will determine the ton-km in the third column. Then it computes the total values of column 1 and column 3 of a year, and reports only these totals. From these, we can compute the *average* distance.

Table <2-2> Typical Government (MOCT) Freight Statistics Summary

Year	1990			1991		
	Tons	*Km*	*Ton-km*	*Tons*	*Km*	*Ton-km*
Total	30	30	900	20	45	900

We find two crucial points when comparing Tables <2-1> and <2-2>. The first is that Table <2-1> gives the integral distance (90 km) while Table <2-2> gives the average distance for 30 km in 1990 and 45 km in 1991. The second is that the totals row in Table <2-1> allows the determination of the tons in transport (10 = 900 / 90), while the totals row in Table <2-2> doesn't. These two crucial points are related. Given Table <2-2>, the tons in transport can be determined from the integral distance, and vice versa. Given the subject of this paper we ask: What are the numbers of distribution channel levels in above Table <2-2>? The numbers of distribution channel levels are given by the frequency of lifting the tons in transport. Hence in year 1990, it is the ratio 30 / 10 = 3, and in year 1991, it is 20 / 10 = 2. Thus the statistics reports a drop in tons lifted, while, paradoxically, the actual tons in transport have not changed. The paradox can be explained: changes in the amount of tons lifted have ambiguous meaning, and the numbers of distribution channel levels are needed to supplement the picture.

Above example is quite simple. It regards one flow of commodities, while transporting agents normally transport more goods in more directions (with more modes of transport). Obviously it would make for a very complex task to keep track of many movements in all kinds of directions. Precisely since that would be a very complex task, the statistical practice has been simplified to the format of Table <2-2>. The most important variable, the ton-km, has been recorded. This simplification, however, comes at a cost, namely the lack of information on the number of distribution channel levels, the integral distance and the actual tons in transport in the supply chain.

3. The Model

The government freight statistics published the tons lifted *(TL)* and the associated ton-km *(TK)*, so that we can deduce the average transport distance *(A)*:

$$TK = A \cdot TL \quad (1)$$

Unobserved are the tons in transport *(T)*, the number of distribution channel level *(h)* and the integral distance *(K)*:

$$h = TL / T \quad (2)$$
$$K = TK / T \quad (3)$$

From above it follows:

$$K = h \cdot A \quad (4)$$

The transport distance (A) depends negatively on the number of distribution channel level in two ways. Partly it is a matter of definition. When the integral distance (K) and the tons in transport (T) remain the same, and the channel levels (h) doubles, then the tons lifted (TL) double and the statistical average of the distance (A) is halved. Apart from this relationship there will be a behavioral component too. Parameters will determine the deviation from the relationship. These parameters control the growth of ton-km as a result of changes in logistics.

$$A = \eta \cdot e^{-\theta h}$$
(5)

Another behavioral assumption is that the number of tons in transport grows with both national income (y) and a trend (t) for the value added density - i.e. value added per ton (y / T):

$$T = a_T y^{b_T} e^{g_T t} \qquad (6)$$

The integral distance will change with those same variables and the number of distribution channel levels:

$$K = a_K y^{b_K} e^{g_K t} h^{d_K}$$
(7)

These assumptions derive from demand theory and, for h, on the assumption of a lognormal distribution. There is no prior information on the sign of dK. Combining these definitions and behavioral assumptions results into the following two equations for simultaneous estimation. Firstly (3) can be written as $TK = T \cdot K$, and substitution of (6), (7) and then (5) gives, changing to logarithms:

$$Log(TK) = Log(a_T) + Log(a_K) + (b_T + b_K)\,Log(y) + (g_T + g_K)t + d_K Log(Log(\eta/A)/\theta) \qquad (8)$$

The last term in equation (3) can be simplified, but has been left in this form so that one can check more easily that it is the inverse of equation (5). Secondly, taking equations (5) and (6), changing to logarithms:

$$Log(A) = Log(\eta) - \theta\, TL / (a_T y^{b_T} e^{g_T t})$$
(9)

The crucial insight is this. By proper substitutions we have eliminated the unknown the number of distribution channel levels h. We have produced two equations in known variables that allow the identification of key parameters. The estimated values of these parameters then can be applied to the right hand side of equation (6) to generate an estimate of the tons in transport. Since it suffices to know only one of the three unknown variables, we then can easily derive the remaining unknowns, i.e. the number of distribution channel levels via equation (2) and integral distance via equation (3) or (4) or (7).

It may be observed that other kinds of substitutions and combinations can generate other equations for estimation. Above selection seems most robust - while it is useful to have a simultaneous test. Finally, one can check that all parameters are identified up to aT. That means that the number of distribution channel levels or the level of the integral distance cannot be determined by above relationships. An estimator of the number of distribution channel levels, however, is useful. The least that we can do is normalization. Simple dispersion cannot be used, since when a variate x is known up to a scalar, also its average and standard deviation are unknown up to that same scalar. An estimate however can be found by assuming maximum entropy. Since h is equal or greater than unity (by definition), then $f = 1 / h$ is a fraction equal or less than unity, and the entropy measure is (assuming that it is relevant for h only):

$$Entropy = -f \cdot Log(f) = Log(h) / h \qquad (10)$$

Entropy reflects uncertainty. Choosing a maximum entropy normalization here is another way of saying that we present the estimator that best reflects our actual lack of knowledge of the true level of the number of distribution channel levels.

4. Empirical Results

4.1 Korea

Table <4-1> shows the parameter estimation results using equations (3), (5) and (8) for the 1971-1996 period for Korea.

Table <4-1> Parameter Estimation of the Number of Distribution Channel Levels (Korea)

Coefficient	*Value*	*T-value*
a_T	59.8591	entropy
a_K	60.9247	14.7513
b_T	2.1058	3.9225*
b_K	-0.3533	-0.6658
d_K	0.1365	1.2317
η	49.4970	11.7243*
θ	0.1529	3.2742*
g_T	-0.0702	-1.5800
g_K	0.4341	0.9826

Two runs appear to be necessary. In the first run a_T is not known, and auxiliary variables must be used for combinations of parameters. In the second run the level of a_T can be plugged in. The t-values are more important than the correlation, and these are encouraging. The coefficients can then be evaluated as follows:

As expected, the tons in transport have an elasticity $b_T = 2.105$ on GNP. These values are reasonable, with an appealing ratio. The integral distance has a small elasticity on GNP; i.e. the value $b_K = -.35$ is and statistically insignificant.

Below Table <4-2> are the four freight transportation statistics which is drawn from the results of Table <4-1>.

Table <4-2> Four Key Freight Statistics of Korea (1971-1996)

Year	Levels	Km	Ton (Million)	Km (average)	Year	Levels	Km	Ton (Million)	Km (average)
1971	1.65	69.24	50.75	38.43	1984	3.07	94.81	149.69	30.93
1972	1.78	71.93	52.01	37.65	1985	3.32	97.85	159.65	29.76
1973	1.78	72.01	62.26	37.68	1986	3.65	99.50	188.59	28.28
1974	1.91	73.93	68.25	36.90	1987	4.21	101.70	224.46	25.96
1975	1.98	75.95	72.07	36.54	1988	3.96	101.16	265.56	27.01
1976	2.20	77.35	85.14	35.31	1989	3.91	103.02	285.00	27.21
1977	2.22	78.15	97.19	35.23	1990	3.68	103.32	322.25	28.16
1978	2.46	80.20	109.48	33.94	1991	3.67	104.58	360.88	28.23
1979	2.94	83.83	117.22	31.55	1992	4.12	109.06	372.83	26.35
1980	3.03	89.16	100.49	31.11	1993	4.19	111.92	391.37	26.05
1981	3.15	91.86	104.86	30.54	1994	4.15	113.53	430.71	26.21
1982	3.12	93.40	113.84	30.68	1995	3.99	114.51	478.63	26.86
1983	3.15	93.75	135.23	30.57	1996	3.86	116.36	511.47	27.39

During the analyzed periods from 1971 to 1996, the number of distribution channel levels increased from 1.65 in 1971 to 3.87 in 1996 account for almost 133%. The reasons for these rather huge increases of the distribution processes require for further analysis. Also, total integral freight distance increases from 69 Km in 1971 to 116Km in 1996 results in 47Km more. And, tons in transport increases almost 9 folds from 50 million tons in 1971 to 511 million tons in 1996 which reflects the rapid economic progress made during these period in Korea. Finally, the average freight distance decreased from 38.4Km from 1971 to 27.4Km in 1996.

The decreasing average freight distances can be explained by the fact that the differences between the number of distribution channel levels increased 133% and the total integral distance increased by 68%.

4.2 Other Countries (USA, Japan, Taiwan, Holland)

In order to compare results obtained in Korea to the other important countries[2], four (USA, Japan, Taiwan and Holland) countries are selected. Because of the available data for freight statistics for each countries, the different time periods are examined, namely, the USA and Japan for 1971 to 1994, Holland for 1971 to 1993 and Taiwan for 1975 to 1994.

Below Table <4-3> shows the estimated results of the number of distribution channel level for the selected countries. The tons in transport have an elasticity on GNP are almost unity for USA, Holland and Taiwan. However, the elasticity on GNP is 2.56 for the Japan, which are quite similar results for the Korea. All countries except for the USA, this elasticity is statistically significant.

Table <4-3> Parameter Estimation of the Number of Distribution Channel Levels

	USA		Japan		Taiwan		Holland	
Coefficients	Value	T-Value	Value	T-Value	Value	T-Value	Value	T-Value
a_T	390.59	entropy	1236.91	entropy	73.50	entropy	59.61	Entropy
a_K	1281.07	4.4999**	190.47	3.0278**	80.85	17.1721**	254.40	3.6672**
b_T	0.9621	0.9625	2.5627	3.3101**	1.2385	1.9357*	1.1207	9.0880**
b_K	-1.1222	-1.3685	-0.6390	-0.5750	-0.4771	-0.8905	0.0337	0.1538
d_K	0.1523	0.9204	-0.3132	-1.3448	0.3531	3.9120**	-0.3955	-2.0658*
η	534.35	8.5893**	72.88	4.4419**	74.42	12.5981**	107.34	4.2651**
θ	0.0660	2.1436*	0.2223	4.3151**	0.1536	3.2875	0.2784	5.1523**
g_T	-0.0256	-0.3780	2.5627	3.3101**	-0.0722	-1.3938	0.0066	0.9057
g_K	0.0702	1.2334	-0.6390	-0.5750	0.0437	0.9972	-0.0145	-1.2169

The trends of the number of distribution channel levels in five countries including Korea are shown in Figure <4-1>. The number of distribution channel levels in the USA, Japan and Holland are decreased, however, the Korea and Taiwan are continuously increased during the analyzed periods. Namely, the number of distribution channel level is decreased from 4.86 to 2.68 for the USA, from 5.58 to 1.76 for the Japan and from 4.24 to 2.02 for the Holland. However, the number of distribution channel levels is increased from 2.81 to 4.96, which are quite similar results to the Korea.

As we indicated previously, the reasons for these trends of the number of distribution channel levels are quite complex. The factors influence for the distribution channel levels are various such as type of economic activities involved, structure and volume of the goods, location of the origins and destinations of the goods and shipper's and receiver's policy of stock keeping etc.

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[2] The USA and Japan have deregulated their freight industries during 1980's and Holland is one of the leading countries for innovated distribution systems. And, Taiwan has a quite similar freight transportation systems as well as government regulation to Korea.

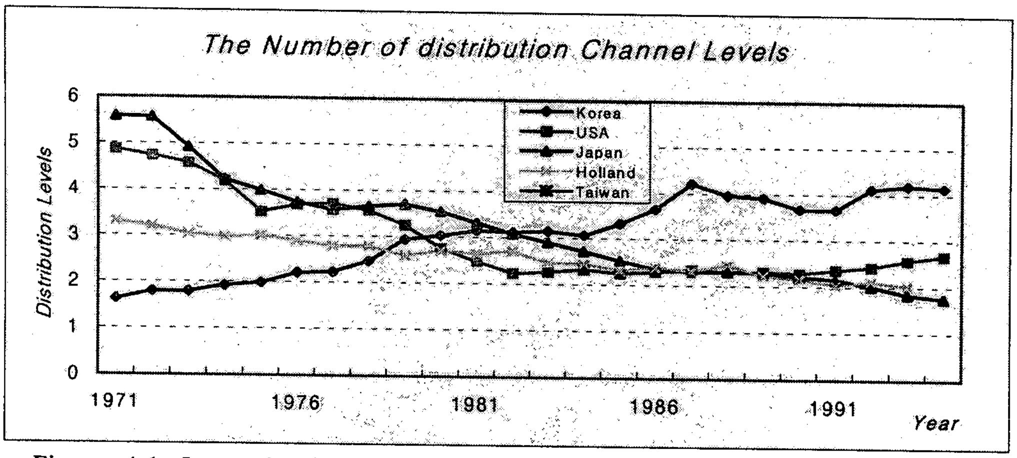


Figure <4-1> International Comparison of the Number of Distribution Channel Levels

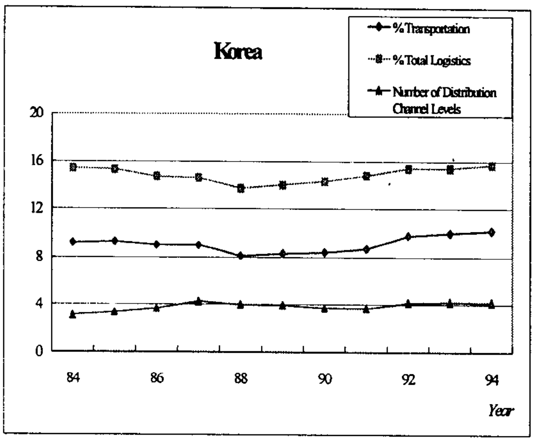
4.3 The Number of Distribution Channel Levels and The Cost of Logistics

The carrier may influence decision making on the location of the stocks where the transport system as such uses transfer points. Either the carrier may choose transfer point at the existing stock centers or the shipper, who can keep. These spatial combinations can have important logistics costs consequences, because the number of distribution channel levels may be reduced by it.[3]

In order to find the relationship between the number of distribution channel levels of the distribution systems and the costs of logistics, the time series analysis are conducted. The data used in the analysis are the number of distribution channel levels as dependent variable and the dependent variable is the costs of logistics (transportation) as percent of GDP. Also, the available data limited our analysis to Korea and USA.

Figures <4-2> and <4-3> show the number of distribution channel levels and the costs of logistics/transportation as percent of GDP in Korea and USA respectively.

Figure <4-2> The number of distribution channel levels and The Costs of Logistics (Korea)[4]



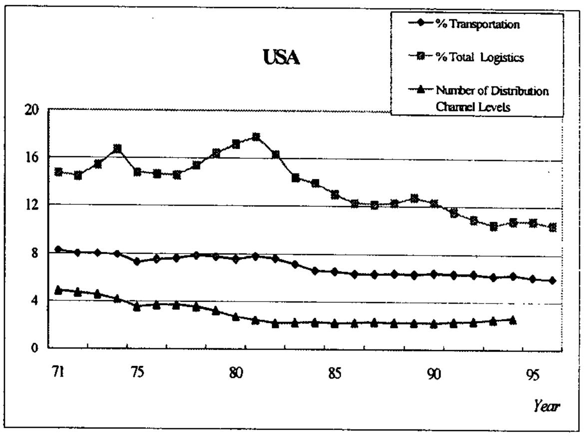


Figure <4-3> The number of distribution hannel levels and The Costs of Logistics (USA)[5]

[3] See "Goods distribution systems in urban areas", Report of the 61 Round Table on transportation economics, 1984, pp.38-39.

[4] The logistics costs and other statistics are calculated by The Korea Transport Institute, 1995.

The estimated results between the number of distribution channel levels and the costs of logistics are statistically significant as well as positive signs. As increase 1 unit of the number of distribution channel levels, the costs of logistics increase about 1.34 percent and 1.85 percent in the costs of transportation in Korea. In the case of the USA, the results are more significant, as decrease 1 unit of the number of distribution channel levels about 3.35 percent decrease the costs of logistics and 0.73 percent of transportation costs in the USA. In the case of the USA, the inventory costs are more closely related in the number of distribution channel levels which is analyzed by Delaney(1992).[6]

5. Conclusion

The findings can be summarized as follows. In Korea from 1971 to 1996 there have been a continuous increases in the number of the distribution channel levels from 1.65 to 3.86. During the same time period, total integral freight distance increased from 69Km to 116Km. And the same time, the average freight distance reduced from 38Km to 27Km.

In order to compare the Korea case to the other important countries, the countries such as the USA, Japan, Holland and Taiwan are examined. The USA, Japan and Holland show quite similar trends in the number of distribution channel levels, total integral distance and the average freight distances. Namely, as the number of distribution channel levels in the distribution systems decreased, total integral distance is decreased and the average freight distances are increased. Thus there has been a concentration in logistics without an increase of the integral distance.

In contrary to the USA, Japan and Holland, the case of Korea and Taiwan have opposite directions, namely, the number of distribution channel levels are increased continuously, the total integral distances are increased and the average freight distances are decreased. Thus there has been a de-concentration in logistics with an increase of the integral distance.

Also, the relationship between the number of distribution channel levels, which are estimated in this paper, and the costs of logistics and transportation are examined. The time series analysis revealed that the two variables are quite closely related. The reasons for increase or decrease of the number of distribution channel levels in the distribution systems are not examined in this paper, however, one possible explanation is the government regulation policy to the freight transportation industry.

Finally, this result needs to be corroborated by more information about the meso and micro level. Also, above model is very simple on logistics. We also need to take into account other modes of transport, and the influence of prices and costs. Hence, above result can be used with some confidence, but not without caution and not without continued research.

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[5] The statistics of the costs of logistics as percent of GDP obtained from "Improving Productivity Competitive Positioning", the 8th Annual State of Logistics Report, June, 1997.

[6] See Robert Delaney (1992), "The North American Scene: A Macro-Economic View", Transportation Quarterly, Vol. 46, No. 1, Eno Transportation Foundation, USA, for more detailed analysis on the impact of deregulation of the logistics costs.

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