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Feedback Approach for the Dynamic Interactions Between Urban Transportation and Air pollution

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Abstract

To solve the policy problem between transportation and environment in trade-offs, above all, it is necessary to understand the complicated relationship between transportation and environment clearly before selecting policy alternatives. From this point of view, this study will propose the logic structure to examine the complex interaction of transportation and environment and investigate theoretically what kinds of impact would appear by the air related polices.

In this research, we used 'system-dynamics' which investigates the complexity through the flow of information and materials and the interaction of elements, which constitutes systems. System Dynamics is an approach that the variables to decide structural relationship in a system affect one another not in only-way but in inter-way and the power of influence changes time by time.

This research is trying to examine the complex interaction of transportation and air pollution. For achieving this purpose, causal maps in System Dynamics approach were used. The main issues are as follows; first, to investigate the dynamic relationship between transportation and air pollution caused by exhaust emission gas. Second, to structuralize the logic of simulation to experiment the impacts of policies to relieve air pollution.

Keyword: urban transportation, air pollution, feedback structure, fuel & vehicle

I. Introduction

Nowadays, local governments are trying to achieve two aims properly; one is that they should activate economic conditions such as transportation and the other is that they should improve the quality of environment to enhance citizen's life quality. But these are in trade-offs. So that it's not easy to meet with the policies achieving two aims at the same time. The difficulties in responding this problem can be explained with the inseparable relation of transportation and air environment. For example, the investment to transport services may bring about a bad condition in the air by letting out more fumes because of more traffic. And the opposite situation may lead to shrink of economic activity.

Local governments have focused on making better their economic conditions by investing in transportation system such as roads before the recognition of the atmospheric pollution is raised in cities. This phenomenon can be seen in Seoul, which has invested 30% of its budget to the expansion and improvement of road facilities every year. Seoul local government invested 5~7 trillion won, 30~40% of the total budget including general and special accounts every year, in transportation facility from the year 1997.

But as o-zone warnings were appeared 40 cases in the year 2000, which were only 5 cases in 1995, and are threatening people's life directly and more frequently, local governments and citizens recognized the quality of atmospheric environment is not a less important factor to decide the quality of life than economic conditions (convenience) just like harmonious traffics. A series of these changes proposed policy problem to peruse the improvement of air environment and the expansion of city services (facilities) simultaneously.

Thus, to solve the policy problem between transportation and environment in trade-offs, it is necessary to understand the complicated relationship between transportation and environment clearly before choosing policy alternatives. From this point of view, this study will propose the logic structure to examine the complex interaction of transportation and environment, and will investigate theoretically what kind of impacts the air related policies would have on the two through policy causal maps.

In this research, we used 'system-dynamics' which investigates the complexity through the flow of information and materials and the interaction of factors, which constitutes systems. System Dynamics is the approach that the variables to decide structural relationship in a system affect one another not in only-way but in inter-way and the power of influence changes time by time.

This research is trying to examine the complex interaction of transportation and air pollution. For this, causal loop diagrams in System Dynamics approach were used. The main issues are as follows; first, to investigate the dynamic relationship between transportation and air pollution caused by exhaust gas.

Second, to structuralize the logic of simulation to experiment the impacts of policies to relieve air pollution.

II. System thinking about relationship between urban transportation and air pollution

1. Traditional approaches for transport and air pollution and their limits

There have been many researches to understand, analyze and solve the transportation and air pollution problems. Former studies (Lee, S. W., 1996; Lee, S. H., 1998) assumed one-way cause-effect relationship that as people's activity increases in the city traffic volume substantially increases then air condition deteriorates and finally the quality of life is lowered.

Meanwhile, the main method of the above studies (Han, S. G., 1996; Gang, H. B., 1998 etc) is to divide traffic condition and air pollution condition from the past to the present of one particular area, to investigate them separately and to analyze them only numerically. This results in the fact that traffic volume and air pollution increase continually and transportation is the main source of air pollution. So it's enough to try solving the problem only around the transportation side. So the researches proposed technical methods to lower air pollution mainly focused on problem-solution around transportation. But, we think that these studies made three mistakes.

First, they supposed transportation-air pollution relationship as one-way. But this idea is so stagnant because in reality transportation and air pollution affect each other in feedback.

Second, the means of analysis is so parametric. That is, they pulled out problems by comparing two factors numerically. But, because sub-systems are changing, and there are lots of social phenomenon not expressed in number and many kinds of situation appeared in non-linear relation, it's very hard to understand various situations with this method comprehensively.

Third, there is simplicity in policies suggested in their studies. They focused on transportation because transportation-air pollution relationship was assumed one-way, therefore suitable resolutions were not proposed according to the dynamic situations.

2. Theoretical study of transportation-air pollution relationship through system thinking

1) System thinking approach for the transportation-air pollution relationship in urban system

System thinking is considered as a frame of new thinking, which overcomes existing one-way thinking. Basic features of the complex human system are that there are so many cases in which causes and effects are not directly combined in space-time, multi-factors get mingled one another and fundamental differences between the changes for short-term and long-term exist. So the thinking may incur serious errors to understand problems exactly and prescribe the policy properly; stagnant think that independent variables affect dependents only in one-way, partial thinking that handles systems in part not in whole.

So as to overcome the limits of the linear and unidirectional thinking, system thinking emphasizes that primary factors are connected with one another in circular causal relations, their relative importance can be changed so we should pay attention to overall change patterns for a long time and it's necessary to harmonize analytical thinking with integrated one.

Urban transportation is not the self-end, but a means of satisfying demand derived by economic development. Today urban demand for transportation is increasing abruptly and this affects environment directly or indirectly. So traffic problems have been discussed linked with economic and environmental aspects. The linkage among economic development, transportation and environment can be looked at the following Figure 1.

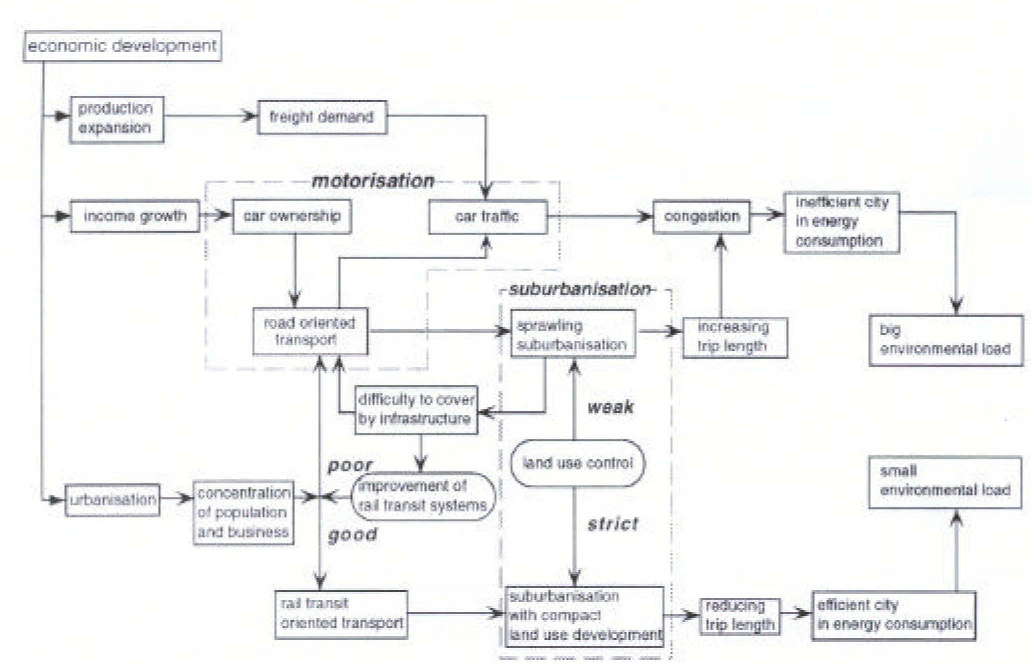

Figure 1. Interactions among urban transportation, and economic development and environment

First, economic development increases production and traffic volume. This leads to worse environmental condition due to inefficient energy consumption by traffic congestion.

Second, economic development increases urban income and this can be divided in two ways. One is that increased urban income produces more vehicles. The other is that it makes people to use cars than public ones and to expand traveling distance because of sub-urbanization. Consequently, traffic jam, ineffective energy consumption and deterioration of air are getting worse.

Third, economic development promotes urbanization. Population and industry are concentrated and traffic congestion occurs due to more traffic volume. In the end, the quality of environment gets worse.

The relationships among economic development, transportation and environment are shown in <Figure 1>. Next we will explain the relationships between economic development & transportation and transportation & environment, especially about the air pollution.

Economic development and transportation

Demand for transportations is derived by urbanization and urban sprawling, i.e. urban growth and development. Nowadays individual countries, especially developing countries are experiencing the importance of transportation in metropolitans and therefore the problems are produced by more dependency on land transportation due to urbanization. To resolve this problem, they have carried out the policies to invest in transportation part mainly but couldn't afford to catch up with urban sprawling because of growing population. Simultaneously sub-urbanization, especially sprawling sub-urbanization accelerates motorization because unprepared public transport makes suburbanites depend on their own cars. The negative feedback of sub-urbanization and motorization involves in negative synergy and incurs the gradual increase of traffic energy consumption. Today inter-urban transportation problems occupy the majority of transportation issues, so they are as seriously considered as internal-urban transport problems.

Transportation and air pollution in dynamic urban system

Transportation is the main energy-consumer and air-pollutant in cities from the producing phase of vehicles, parking lots, roads and so on, to the operating phase of vehicles and to disposal phase of waste tires and used cars.

Developing and developed countries have been experiencing serious air pollution by exhaust gas of growing number of land transport as well as population concentration due to industrialization and urbanization. That is to say, urbanization and motorization have brought about deterioration of the air in cities. In a practical circumstance that the volume of vehicle's sale is increasing rapidly especially in developing countries among OECD countries, one gallon of oil consumed by vehicles discharges 19 pounds of C02 to the air directly and NOX discharged by human activity occupies most of transportation section. NOX is discharged as a combustible of fossil fuels during internal combustion in addition to vehicle 1/3 - 1/2 of NOX discharge originates in transportation domestically(Gray Hag 1997).

There are various pollutants emitted by cars, among them CO, NOx, HC and PM are principal pollutants, 82% of the air in Seoul. The main troublemaker related to exhaust is light oil-used vehicles, which emit enormous pollutants. Large-sized buses and trucks, for instance, are observed to emit 5 to 20 or 30 times more pollutants than cars, according to emission quotient. By the way, the decrease of vehicle speed because of traffic jam causes unnecessary energy consumption. For example, the gasoline oil-used vehicles with 20km/h is efficient with 1 ½times more than ones with 10km/h and 40 to 70km/h is the most energy-efficient.

City is a huge system. Cities have a cycle of growth, transition and decay changing dynamically and urban growth is formed by interaction of economic, socio-cultural and environmental factors through feedbacks. Transportation and air pollution as a sub-system of the dynamic urban system, also involves complicated dynamics. Interacted circular causal relationship between these systems can be explained like this;

To begin with, the growing number of urban population increases traffic volume. The traffic volume makes traffic congestion, average traffic speed lowered and it brings out more serious air pollution. The air deterioration stimulates the crisis for environment. So the necessity to regulate transportation part is proposed and such policies are adopted as environmental tax-levy, affordable exhaust standard, preferential treatment for small car, efficient energy use, etc. These policies decrease traffic volume and as a result, air condition gets better. But on the contrary, when regulations get weakened, traffic volume will be larger and the air will be worse because of more exhaust produced by vehicles. The circular causal relationship will proceed repeatedly. Now the complex relationship between transportation and air pollution should be investigated to solve dynamic inter-way feedback problems.

2) Basic feedback structure of interactive relationship between transportation and air pollution

As mentioned above, transportation and air pollution are in circulating cause-effect relationship of feedback loop. The basic structure of this is shown in <Figure 2>. There are four feedback loops.

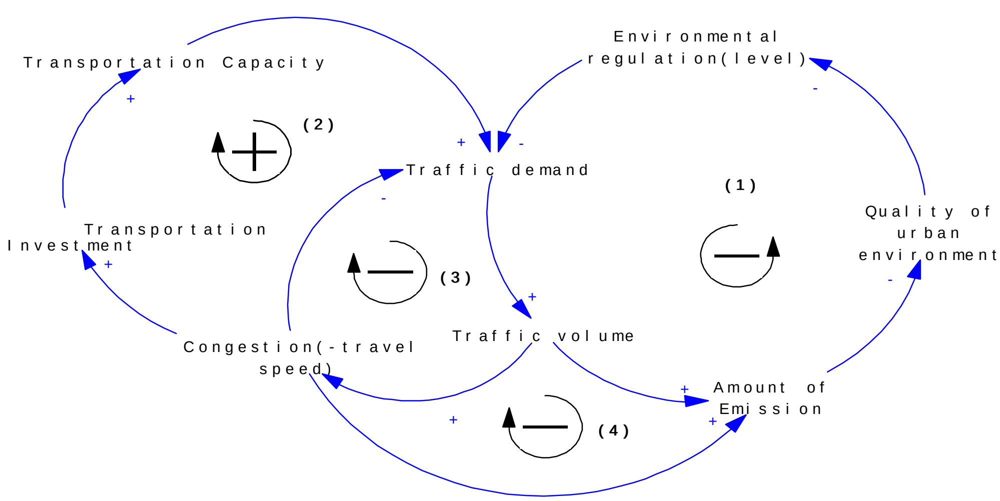

Figure 2. Basic Feedback structure between urban transportation and environment

First one is the negative feedback loop. Negative feedback loop is called self-restraining feedback or stabilizing feedback and is indicated as a sign of minus, - sign at the center of a circle. For example, negative feedback loop shows what mechanism is implied filling a cup with water to the desired line. Once the desired line is decided, it begins to fill a cup in case it's empty. When the water is enough to approach the line, it begins to slow and stops, finally achieving stabilization (Kim, D H. etc., 1999). In the case the traffic volume and congestion, when traffic volume increases congestion increases as well, but when traffic congestion increases traffic volume decreases because demand for transportation decreases due to increasing gas consumption and cost by traveling time.

Second one is the positive feedback loop. Positive feedback loop is often called self-reinforcing feedback and is indicated as the sign of plus, + sine at the center of a circle. An armament race between countries is the example showing the positive circulating relationship. It's why the armament race is increasing between country A and B; The arms of A threatens B and B expands her armaments in return but this threatens A and A expands armaments as the results. The behavior between two countries repeats the vicious circle (Kim, D H. etc., 1999).

As same as this feedback loop, when traffic volume increases, traffic congestion increases and for this, investment in transport increases i.e. traffic capacity increases. But this finally incurs growing traffic volume. The phenomenon circulates repeatedly. This is why traffic congestion is continually increasing although Seoul has invested trillions of won in roads.

Above these two loops, we can suggest that because traffic congestion by increasing traffic volume will be stabilized naturally as time goes on, imprudent supply-oriented traffic policies. Investment on SOCs has been focused on road construction and the policies of supply-oriented transportation have been implemented in Korea. But once roads are constructed, cars dominate most of them. So in fact the concentrated investment in roads operates as the same action of supplying the subsidy to cars. This distorts the desirable investment in SOCs in the end (Min, M. G., 2000) may only increase traffic volume and offset the effects of environmental policies.

Third one shows negative feedback loop of traffic speed and environmental regulation. The increasing demands for transportation exhaust more not only because traffic volume gets larger but also because the traffic congestion due to shortage of road capacity lowers the traffic speed. Accordingly, regulating policies get reinforced to reduce traffic volume and this relieves traffic congestion, finally traffic speed increase.

Fourth one is the negative feedback loop of traffic volume and environmental regulation. When traffic volume increases, exhaust gas is produced more lowering the quality of environment. This heightens the crisis for environment and the necessity of environmental regulation suppresses the demand for transportation. It lowers the exhaust gas and thanks to this, urban environment gets better. But if so, when regulations get softer, the traffic volume will be larger again.

The fundamental feedback structure of transportation and environment can be summarized simply like this: If air pollution produced by growing traffic volume gets worse, then environmental regulations are carried out and this reduces the traffic volume.

Besides simple feedback structure, it is necessary to understand fully the complex relationship between transportation and air pollution to structuralize the logic of policy simulations. So next, we'll structuralize all factors' feedback loops and observe policy leverage.

III. Analysis of causal maps of dynamic relationship between transportation and air pollution to search for policy alternatives

As a methodology of system dynamics, causal loop diagramming is a basic work to search for appropriate policy alternatives by helping to understand the complex relationships between systems.

As mentioned above, transportation and air pollution are in the interactive feedback relationship. But we can't suggest policy, which solve the problem of interrelated system simultaneously with only one feedback loop. So we will first look at feedback structure of transportation problems through a causal loops and then, we'll look at interactive causal loops of system factors.

Urban policy should be approached with the long, integrated sight and in this point, causal loops can give a great help to policy-makers because they are aggregated level of models which show the circular causal relationship of urban growth and feedback structure (Kim, D. H. etc., 1999)

1. Traffic demand and air pollution

The level of air pollution in the city is basically a function of traffic demand and traffic volume. <Table 1> shows that Seoul had 2,300,000 cars in 1999 which had only 1,375,000 in 1991 according to economic development and the increase of household income.

We can check traffic volume also increased depending of the increase of vehicles in <Table 2>. Increasing rate of in-outflow of Seoul in 1990 to 1997 is three times more than the one of gross passing volume. This means traveling distance and time get longer as home and work get divided due to new towns. Accordingly, the exhaust gas of car increases.

Table 1. Trend of total registered motor vehicles

	1981	1986	1991	1996	1999	Increase rate (%)
Capital region[a]	291,121	700,501	2,180,24	4,481,45	4,931,90	19.2
Seoul	221,644	521,521	1,374,67	2,168,18	2,227,90	15.5
Kyoung Ki	49,082	140,573	610,168	1,809,62	2,133,38	26.2
Inchon	20,395	49,407	195,395	503,645	570,610	22.9
National[b]	571,794	1,309,43	4,247,81	9,553,09	10,732,7	19.9
Ratio(%) (a)/(b)	50.9	54.3	51.3	46.9	46.0	-

Table 2. Trend of total traffic demand of Seoul

(Unit: 1,000 trip)

	1990	1997	Increase rate
Total traffic demand	2,464	2,720	10.4%
In-out Flow traffic demand	475	613	29.1%
In-out Flow traffic demand ratio	19.3	22.5	-

So pollution by cars in the air had increased 83.8% in 1998 from 60.8% in 1992, and it's necessary to understand basic interaction of the increase of traffic volume, traffic demand, and air pollution in order to decrease the growing rate of air pollution by transportation.

Table 3. Trend of total air pollutants and It’s ratio by vehicles

(Unit: 1,000 ton)

		'92	'93	'94	'95	'96	'97	'98
National	Air pollutants	4,868	4,584	4,526	4,350	4,425	4,365	3,768
	Air pollutants By vehicles (%)	1,839 (37.8)	1,664 (36.3)	1,645 (36.3)	1,710 (39.3)	1,702 (38.5)	1,795 (41.1)	1,552 (41.2)
Seoul	Air pollutants	760	534	455	422	396	388	334
	Air pollutants By vehicles (%)	462 (60.8)	383 (71.6)	351 (77.1)	341 (80.6)	326 (82.3)	331 (85.3)	280 (83.8)

The causal loops are shown below (Figure 3). It is the control of traffic demand that functions as a policy leverage, playing an important role of linkage of transportation and air pollution.

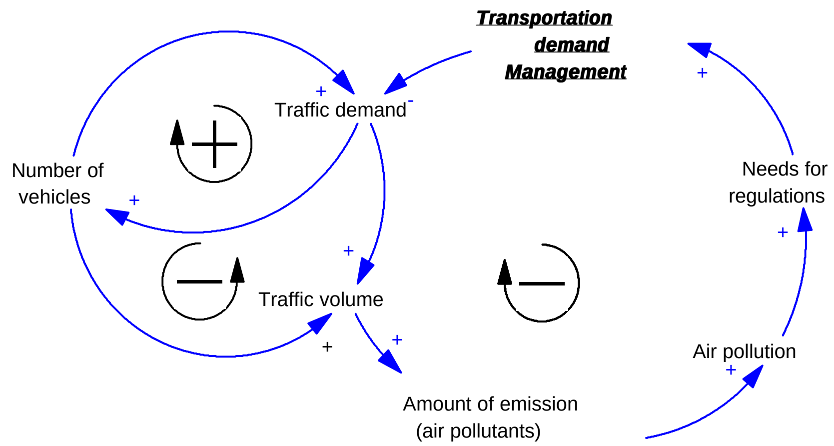

Figure 3. Feedback structure between urban transportation demand and environment

2. Transportation mode and air pollution

One of the most important things in the interaction of transportation and air pollution is the relationship among the type of vehicle, the volume of exhaust gas and the type of pollutants. When we look at the pollutants discharged by cars, mostly CO and NOX contribute to the air pollution.

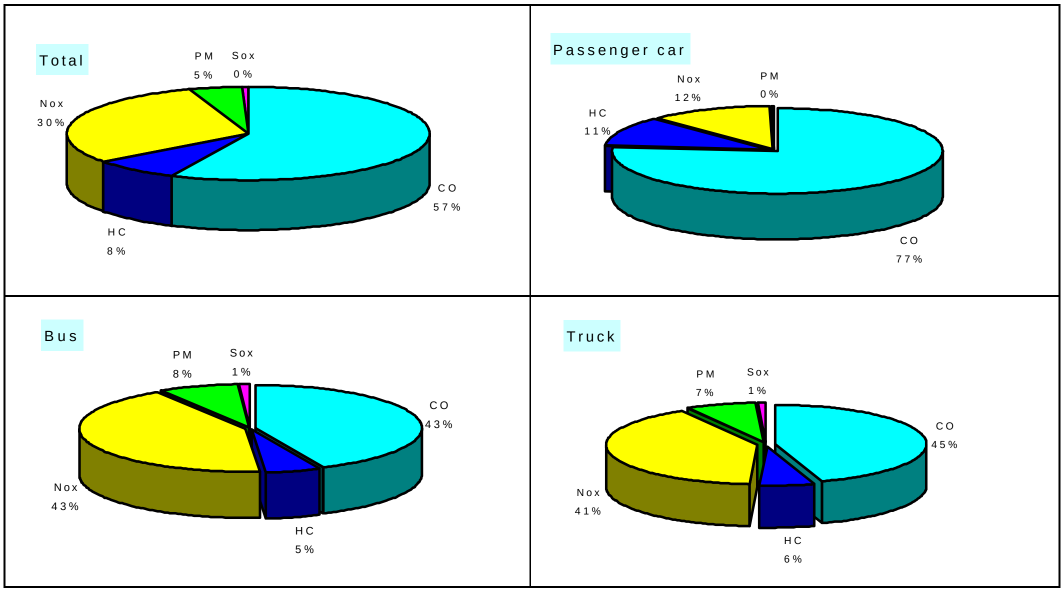

Figure 4. Air pollutants emission rate by vehicles

The relative importance of exhaust gas is different by a type of vehicle such as cars discharge more of CO, NOX and HC, NOX and CO in case of bus and CO and NOX in truck. It is shown in Figure 4 that point out CO and HC are discharged mainly by cars and NOX and PM are discharged mainly by large trucks.

Table 4. Vehicle type Dependency of emission factors

(Unit: ton/year)

			Number of Vehicles	Travel distance (km)	CO	HC	NOx	PM	SO_2
Passenger Car		Gasoline	1,634,588	36	56,546	8,996	8,996	214	34
		LPG	74,682	177	28,819	3,464	3,897	0	0
BUS	Small	Gasoline	27,410	33	2,063	166	475	3	0
		Diesel	170,636	53	4,597	397	4,795	1,158	586
	Medium		3,184	44	100	42	81	33	14
	Large		15,802	105	7,241	1,058	7,755	1,221	354
Truck	Small		244,240	56	8,839	794	7,399	1,837	861
	Medium		32,097	57	1,322	557	1,067	436	285
	Large		45,928	70	16,651	2,188	15,422	2,422	904
Total			2,248,567	630	126,178	17,663	49,888	7,325	3,039

Therefore it is needed to focus on the relationship between transportation and air pollution by the type of vehicle and to search for policy leverage to reflect the feedback. When we indicate the dynamics between a type of vehicle & air pollution and the policy leverage (control of traffic demand by a type of vehicle and pollutants), it is as follows (Figure 5). The Figure shows the policy proving is important between a type of vehicle and air pollution.

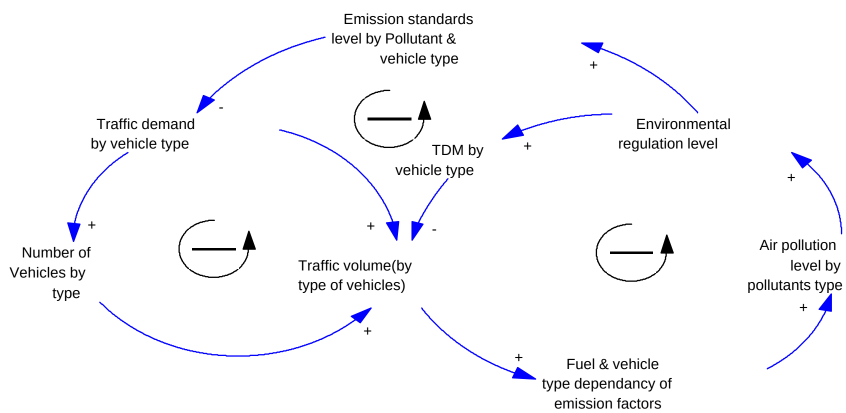

Figure 5. Feedback structure between transportation mode and environment

3. Travel speed and air pollution

The main factor of discharge increase in Korea is the increase of fuel consumption by the decrease of average traffic speed caused by traffic congestion. Specially, CO is emitted heavily by traffic congestion and the pollution degree is showed very high at an edge of downtown road where traffic jams are severe (Han, W. G., p12). While the traffic speed of car was 22.9 /h(2.49 /h decrease in contraction to 1999 year) in 2000 in Seoul, urban bus was 18.99 /h(0.22 /h decrease in contraction to 1999 year). In addition, (Table 5) showed the relationship between traffic speed of car and exhaust gas volume. Pollutant exhaust coefficient is varied according to average traffic speed regardless of a type of vehicle.

Table 5. Trend of Average travel speed of Seoul

(Unit: km/h)

Year	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘99/’00
Passenger car	23.53	23.18	21.96	20.90	21.06	25.41	25.41	22.92	-9.8%
City Bus	17.02	18.42	18.79	18.35	18.69	20.07	19.21	18.99	-1.1%

Table 6. Speed Dependency of Emission Factors for Gasoline Passenger Cars

	Pollutant type	CC	Speed range	Emission Factor
Gasoline passenger	CO	all	10-60	260.788*V^(-0.910)
			60-130	14.653-0.220*V+0.001163*V^2
	NOX	1.4<cc<2.0	10-130	1.484+0.013*v+0.000074*v^2
	VOC	all	10-60	19.079*V^-0.693
			60-130	2.608-0.037*V+0.000179*V^2
	Fuel Consume	1.4<cc<2.0	10-60	606.1*V^(-0.667)
			60-130	102.5-1,364*V+0.0086*V^2

So traffic speed is an important factor to probe the relationship between transportation and air pollution too and a causal loop between transportation and air pollution should be searched for at the level of policy leverage around these factors. The causal map is as following.

At the next Figure 6, the traffic volume decreases by a control of traffic demand is connected to exhaust gas volume decrease but an investment in the environment capacity of road releases traffic congestion and increases traffic speed. Consequently, this results in the increase of traffic volume and finally ends in growing amount of exhaust gas.

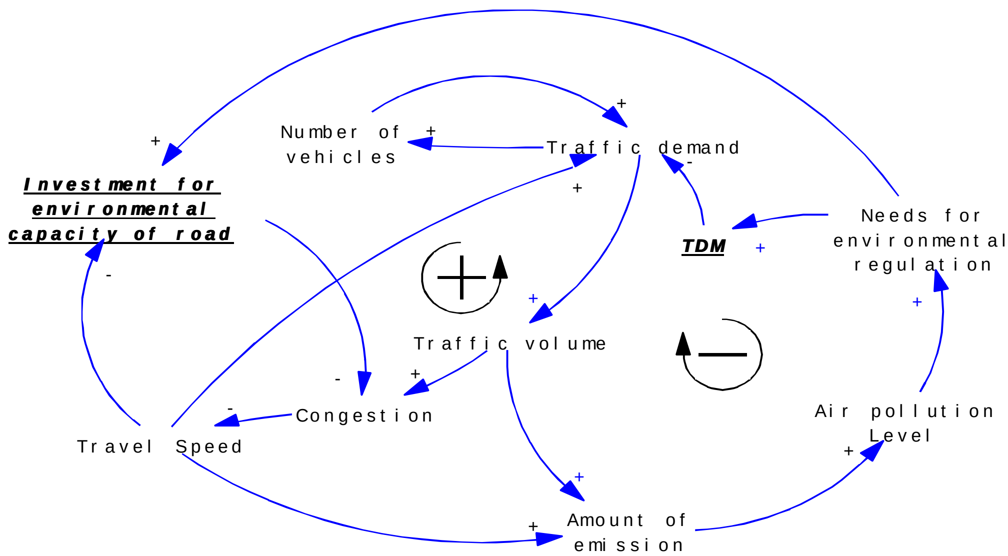

Figure 6. Feedback structure between travel speed and environment

4. Fuel of vehicle and air pollution

In case of Seoul, the portion of light oil used vehicle in pollutant exhaust volume is 43.6% of total and it also produces 98% of PM and 74% of NOX. Accordingly, the contamination level by light oil used vehicle is very serious. Generally, the pollutant from a vehicle is varied with its engines and fuels. For example, a vehicle using gasoline and LPG emits mainly CO and HC, a bus and truck using light oil discharge NOX and smoke pollution abundantly (the ministry of environment, 1999).

Table 7. Emission rate of gasoline and diesel

	Total	Emission rate		
		Passenger car (Gasoline)	Diesel	
			Total	Bus and Truck
National	1,552	641(43.1%)	911(58.7%)	665(42.8%)
Seoul	280	158(56.4%)	122(43.6%)	83(29.6%)

Hence, it is important to grasp interacting loop on the interrelationship between fuels and pollutants and to establish the logic of policy simulation according to this.

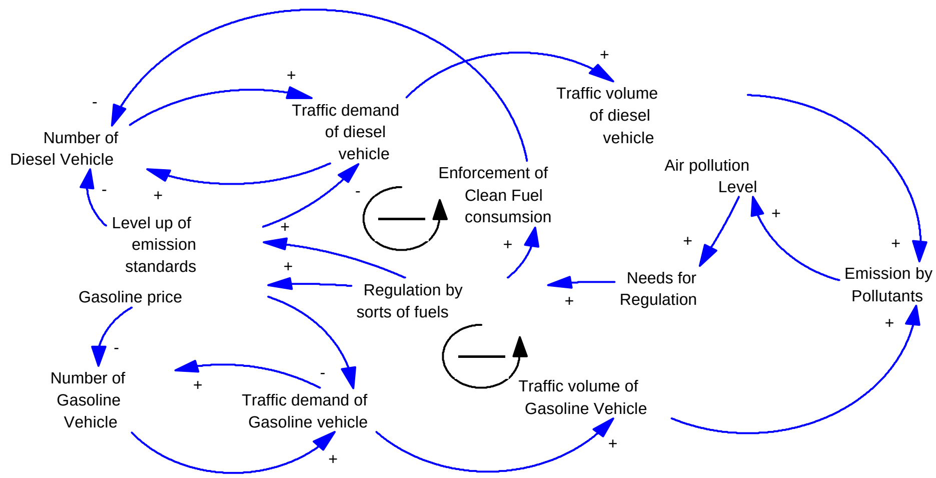

Figure 7. Feedback structure between Fuel and environment

IV. Policy simulation structure based on the dynamics of urban transportation & air pollution interactions

In the above causal maps, we examined 4 causal loops to be considered seriously in the transportation -air pollution interaction (Figure 3, 5, 6, 7). At this part, based on the above, the causal map of transportation - air pollution will be reconstructed (Figure 8). In Figure 8, 4 air pollution reduction policies are presented(environmental tax-levy, affordable exhaust standard, preferential treatment for small car, efficient energy use policy)) These policies were selected from Seoul metropolitan air environmental improvement planning in 2000 , and it shows the process of these policies' affecting the dynamic transportation - air pollution relationship. Through this, simulation logic is constructed to search for air pollution policies hereafter.

1. Environmental tax-levy and the dynamics of transportation & air pollution

According to the causal map of Figure 8, when the increase of total air pollution volume induce to carry out environmental tax-levy, it decreases the allotment ratio of car traffic, daily traffic volume, and total traffic volume. This increases the average traffic speed and decreases the total air pollution volume lowing the discharge of CO especially. On the other hand, when environmental tax-levy is less strict due to a decrease of total air pollution volume, it iterates previous process and in return will increase the air pollution volume. Namely, Figure 8 shows the mutual feedback dynamics of transportation & air pollution through environmental tax variable.

2. Affordable exhaust standard and the dynamics of transportation & air pollution

In Figure 8, affordable exhaust standard is set up dividing regulating factors and level by the type of vehicle. For example, gasoline used vehicles controlled with CO, HC, and overflow of air and light oil used vehicles with smoke, the permitted limit of smoke is reinforced below 35% from 40% in case of light oil used vehicles made in 1996 and below 30% in ones made in 1998(Seoul, 2000).

Technology development of exhaust gas reduction is carried out due to the increase of total air pollution volume, and then it decreases total air pollution volume in the end by lowering the hourly pollutant discharge. In return, the decrease of total air pollution volume weakens the policies and increases it in reverse repeating the previous process. Namely, Figure 8 is about the mutual feedback dynamics of transportation & air pollution through affordable exhaust standard variable.

3. Preferential treatment for small car and the Dynamics of transportation-air pollution

When we look at Figure 8, preferential treatment for small car increases the ratio of it and helps to reduce the total volume of air pollution. But the result, the decrease of the total volume of air pollution weakens the policy and because of this, the total volume of air pollution increases again, repeating the previous process. Namely, this shows the mutual feedback dynamics of transportation-air pollution through the preferential treatment for small car variable.

4. Efficient energy use and the Dynamics of transportation-air pollution

When efficient energy use policy is carried out by the increase of the total volume of air pollution, the ratio of clean-energy used, gasoline used and light-oil used vehicles varies. This changes the volume of each air pollutant and accordingly the total volume of air pollution varies. The decrease of the total volume of air pollution as the result, however, weakens the policy and the total volume of air pollution increases again, repeating the previous process. Namely, this shows the mutual feedback dynamics of transportation-air pollution through the efficient energy use policy variable.

The causal map for the construction of simulation logic, proposed above, can be looked at like this: If the policies to lower the volume of air pollution are operated, then they interact with air pollution variously. So its implication is that it's essential to consider situations long-sightedly and comprehensively in policy implementation.

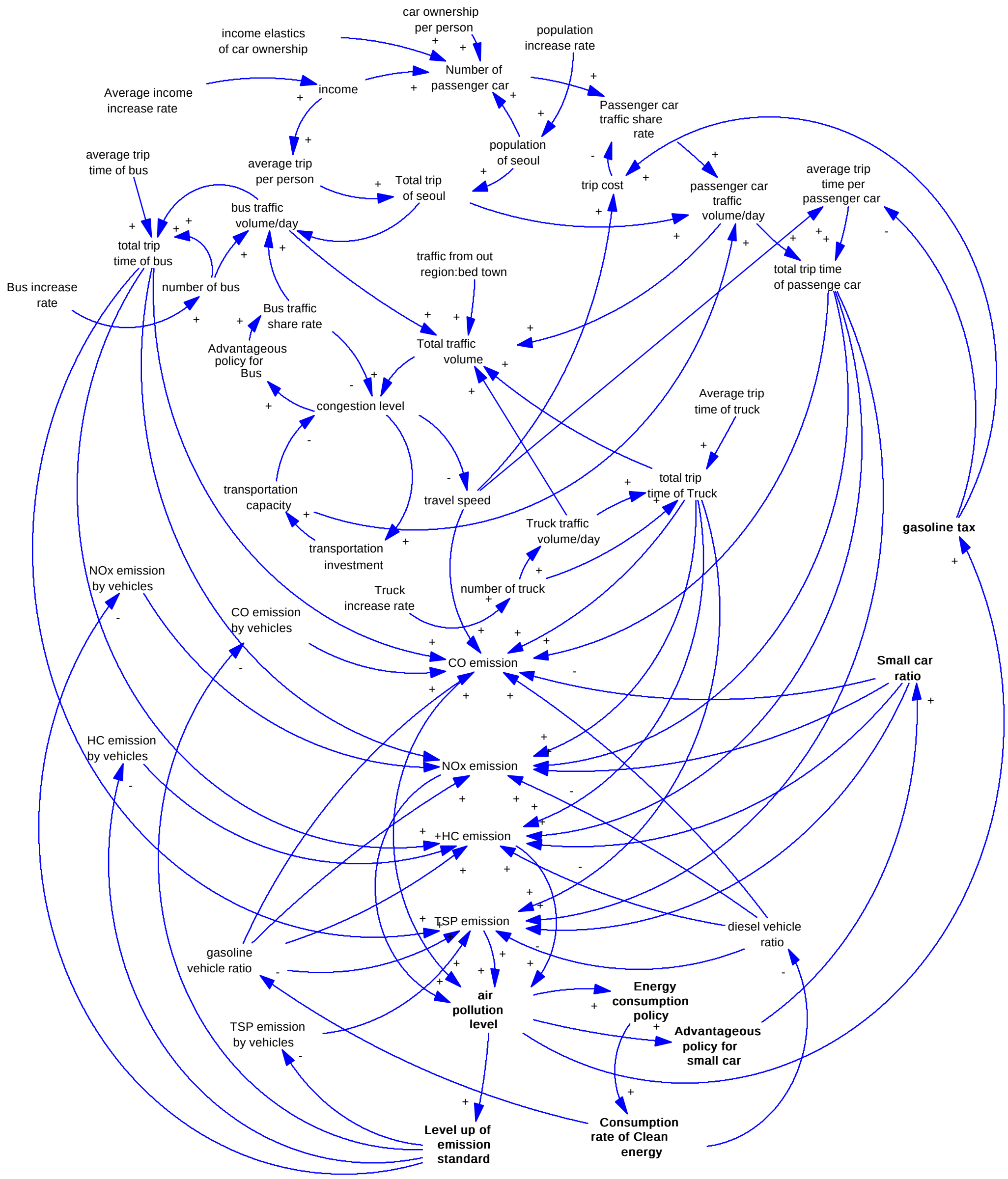

Figure 8. Causal Loop Diagram for Policy simulation

V. Conclusion

The urban transportation and air pollution has a trade-offs relationship. So it accompanies difficulty to solve the problem. For this, above all, we need to understand the complex inter-relationship of transportation-air pollution. Complying with this, we looked at the mutual feedback dynamics of transportation-air pollution through the causal maps as a methodology of system dynamics in this study.

As the first step, we structuralized the causal maps to look at the dynamics of transportation-air pollution, dividing it by traffic demand traffic volume, by means of transportation, by traffic speed and by fuels of vehicles. Next, we restructuralized the overall causal map around policy variables to build simulation logic for the evaluation of the effect of policies. We checked out the mutual feedback dynamics of transportation- air pollution according to policy variables.

It will be able to scrutinize the inter-relationship of transportation-air pollution more substantially through the analysis of the dynamics of the two. Also, it will be possible to search for policy alternatives based on complex interaction system of all factors, not the simple cause-effect relationship.

Forward research, it is required study the simulation more elaborately to discover the dynamic patterns using modeling of feedback loops based on the analysis of causal map.

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