SYSTEM DYNAMICS IN TRAFFIC MANAGEMENT SCHEMES

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Abstract: Severe traffic problems occur in most Indonesian cities, and the problem is more severe in larger cities rather than in smaller cities. Jakarta as the largest metropolitan in Indonesia faces the worst traffic condition. The main reason behind it is the poor management of the traffic as well as many other problems. Effective mechanisms are needed for reducing the frequency of traffic jam formation, and for the dispersing jams once they have formed. This paper investigated the impact of traffic problems and how to solve it using the approach of a dynamic simulation.

Traffic management schemes purposes usually addressed to improve quality of life, to measure the result of the improvement is calculated in the form of reduction in travel time, due to better traffic flow arrangement and performance, reduction in the number of traffic accident and improvement in the environment.

Keywords: congestion, traffic management, and system dynamics

1. INTRODUCTION

The issue in this paper will address to improve our understanding of how traffic flow behave to the circumstances, where all aspect are related each other in a complex causal loop diagram. Once known, system dynamics makes a lot of intuitive and logical sense to most people. But it is a tool that serves as a means to extend limitations of the human mind. The human mind finds it difficult to process more than a handful of dynamic and interacting influences. System dynamics tools enable us to think about such processes. Humans cannot process dynamic interactions with the completeness and speed of system dynamics tools, with the consequence that system dynamics models are sometimes perceived as black boxes. If that happens, remember the motorcar. When we drive a car, there are hundreds of little things in the traffic that work together, we do not have to think about them, except if it becomes really necessary. When someone needs to manage the traffic, it can be done step-by-step. System dynamics modeling works in the same way.

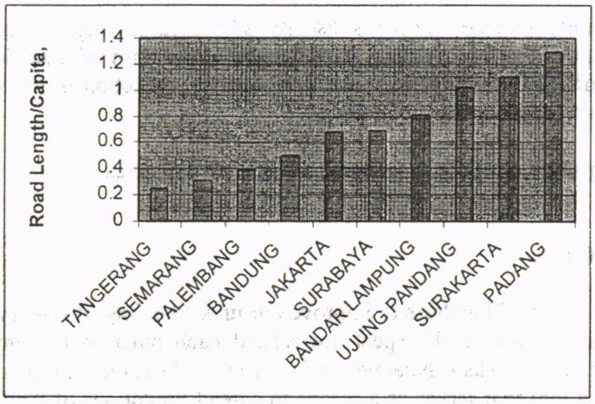
Improvement in the management is a key factor in improving the traffic in the metropolitan. According to Blok M – Kota Basic Design, it is estimated 1n 1996 that within Jakarta, the annual monetary lost due to traffic congestion is in the order of 896 million US $ per annum, and the amount of people killed on the road amounted 600 people p.a.

Within Jakarta most of the high capacity roads as well as where the congestion occur are concentrated in the urban area. The study will look at traffic problems Small/Local Area Traffic Management Schemes in central area of Jakarta and other metropolitan cities in Indonesia such as Surabaya and Bandung. The focus on the paper will be based on the information from Jakarta; the other cities will be used to test the model. Testing the model in other cities will be used as comparison and it will also be used to support the accuracy and reliability of the model, although different cities have different characteristics.

2. ROAD NETWORK CHARACTERISTICS

2.1 Road Length

Comparing road provisions in Indonesians major cities shows that Jakarta is in the middle, 0.68 m per capita, whereas in contras[1] to European cities which are at an hirer average of 2.3 m and North American are on average even hirer 6.8 m, but on the other hand Hong Kong has only 0.3 m Manila and Bangkok both has the same amount of 0.6 m.



Source: Wahana Tata Nugraha 1997

Figure 1. Road length per capita of major Indonesian cities, 1996.

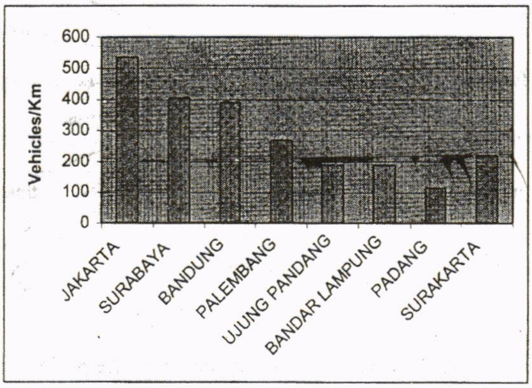
2.2 Road usage

A rapidly increasing motorization process (13 to 15% a year) is happening during the high economic growth leading to very high use of the road, it stops at the early economic crisis in 1998 but it's growing again since the end of 1999. The highest composition of the motorization is the use of motorcycles, which amounted more than two third of the total fleet.

The next figure shows the comparison of road usage in major Indonesian cities, measured in vehicles per kilometer of road length. The figure of Jakarta is among the highest in Indonesia

[1] Barter, An International Comparative Perspectives on Urban Transport and Urban Form in Pacific Asia: The Challenge of Rapid Motorization in Dense Cities, Thesis, 1999.

with 533 vehicles for every kilometer of road length, but internationally is quite similar to those of Bangkok or Manila



Source: Wahana Tata Nugraha 1997

Figure 2.The number of vehicles per kilometer of Road Length in major Indonesian cities.

3. MODEL STRUCTURE

The approach in this paper will use System Dynamic Modeling using the software developed specially for dynamic modeling. The definition of a Systems Theory[2]: the trans disciplinary study of the abstract organization of phenomena, independent of their substance, type or spatial or temporal scale of existence. It investigates both the principles common to all complex entities, and the (usually mathematical) models, which can be used to describe them.

Dynamics Systems requires different skills, the primary skill one needs is System Thinking. The essence of system thinking lies in being able to identify feedback (how actions reinforce or counteract/balance each other) and learning to recognize structure types that recur again and again[3].

3.1 MODEL SIMULATION

Dynamic modeling will be the base for calculating the impact of management schemes; the basic concept of the approach, which will be developed in the model, shall include aspects such as shown in the following figure:

[2] What is System Theory?., http://pespmc1.vub.ac.be/systheor.html

[3] Maggie's System Definition, http://www.cs-staff.stanford.edu/~johnso/system.html

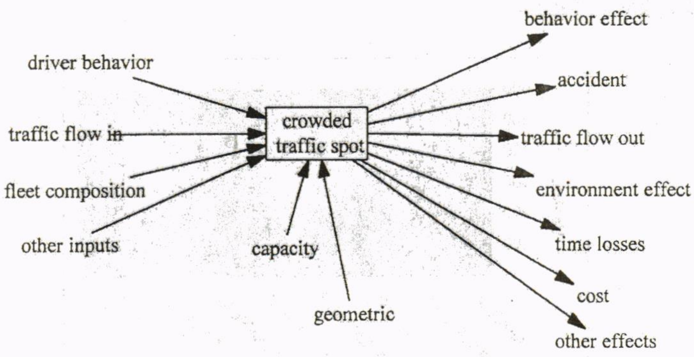


Figure 3.Basic simplified approach to the project.

The models shall be based upon a common set of accurate assumption, to enable comparisons between the outputs of the different models. Comparisons will then give an indication of the policies effectiveness as a traffic management measure.

3.1.1 Capacity

Traffic characteristics could be measured with several approaches, one of the most important approach in Indonesia the Indonesian Highway Capacity Manual[4] (IHCM) which was developed by SweeRoad, a Swedish consultant for the Government of Indonesia. The approach what they are using are prity much similar to the US Highway Capacity Manual. The basic formula for capacity is as follows:

$$C = C_O * F_1 * F_2 * F_3 * \ldots\ldots * F_n \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where C is the capacity, and Fi is correction factors.

For an unsignalized intersectio the capacity formula is:

$$C = C_O * F_W * F_M * F_{CS} * F_{RF} * F_{LT} * F_{RT} * F_{LT} \ldots\ldots\ldots\ldots \quad (2)$$

Where: F_W is entry width correction factor; F_M is the major road correction factor; F_{CS} is the city zise correction factor; F_{RF} is the road environment type and side friction correction factor; F_{LT} is the left turning % correction factor F_{RT} is the right turning correction factor; and F_{SP} is the split correction factor.

Example of the calculation of unsignalized intersection capacity following the Indonesian Capacity Manual using simulation program developed by Vensim[5] is shown in the following figure..

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[4] Directorate General oh Highways, Indonesian Highway Capacity Manual: Part I Urban Roads, Jakarta 1993

[5] VensimPLE32, Ventana Simulation

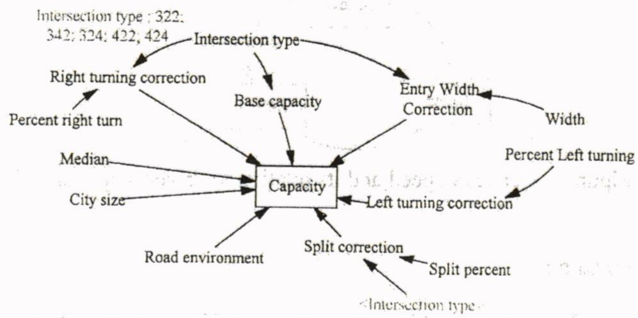


Figure 4. Example of capacity calculation for unsignalized intersection using a modified KAJI[6] model,

3.1.2 Driver behavior

Poor driver behavior is one of the main traffic problems in Indonesia, which reduces traffic capacity of intersections and links. These driver behavior consist among others:

- Lane discipline,
- Failing to give priority,
- Keep moving while the traffic lights already turns to red or enter the intersection at red,
- Force to enter the intersection in a jam condition which will lead to lock the intersection,
- Using the opposite right of way, etc.

This could happen in places where there is minimum enforcement, especially in the sub urban areas, it less a problem in the center of the cities. These driving habits tend to reduce the capacity of the intersection and sometimes the road link as seen in the following basic causal loop.

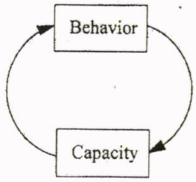


Figure 5.a. The capacity behavior loop

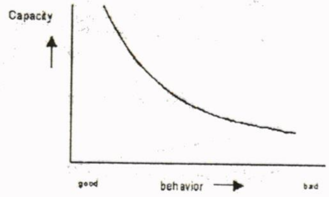


Figure 5 b. Effect of behavior to capacity

The travel speed directly influences by the capacity the lower the capacity the lower the speed the higher its influence to driver behavior as seen in the following figure.

[6] Kapasitas jalan Indonesia/ Indonesian Highway Capacity Manual

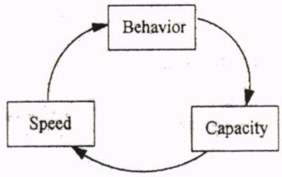


Figure 6. Capacity speed and its relation to driver behavior

3.1.3 Traffic Performance

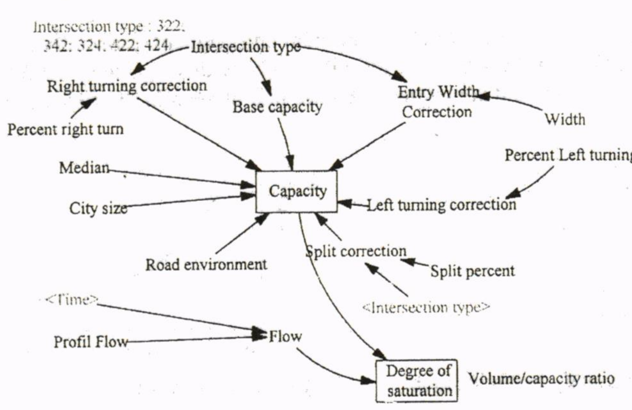
The indicator that would be used in this paper will be traffic mobility, which will be in the form of degree of saturation, travel time losses, journey speed, delays, environmental effects and traffic accident. These traffic performance indicators will not be explained in detail in this paper, but degree of saturation instead, as one of the examples of the traffic parameters will be explain briefly.

Degree of saturation for the whole intersection, DS, is calculated as:

$$DS = Qp/C \qquad \text{(3)}$$

Where Qp is the total actual flow in pcu/h[7] and C is the capacity, which has been found previously.

Degree of saturation then could be found as shown by the archetype below. After calculating the capacity with expanding the archetype developed for capacity?



Degree of saturation result is as follows

[7] pcu is passenger car unit

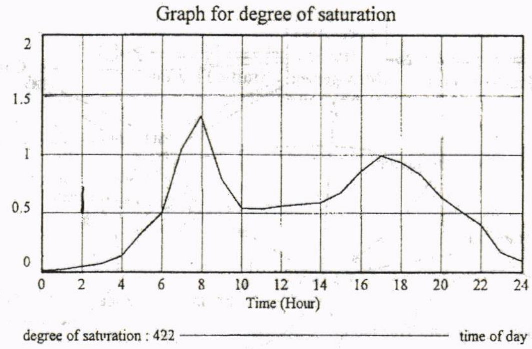


Figure 7.Degree of Saturation simulation result.

4. SCENARIOS

The next step after all the factors which are connected has been analyzing, then some scenarios could be propose to solve the traffic problem, i.e. by implementing traffic management strategies to improve the traffic management scheme.

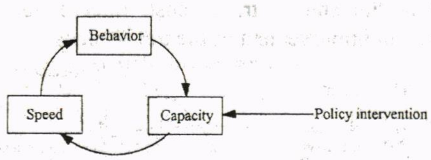


Figure 8. Policy intervention

5. MODEL DEVELOPMENT

This section illustrates how the model can be developed for traffic management scheme. The model is a simplified local area traffic management system. Such systems are at the heart of most traffic problem especially in developing countries.

Using the approach of system dynamics and inputs from the theoretical approach as mention earlier is shown as follows:

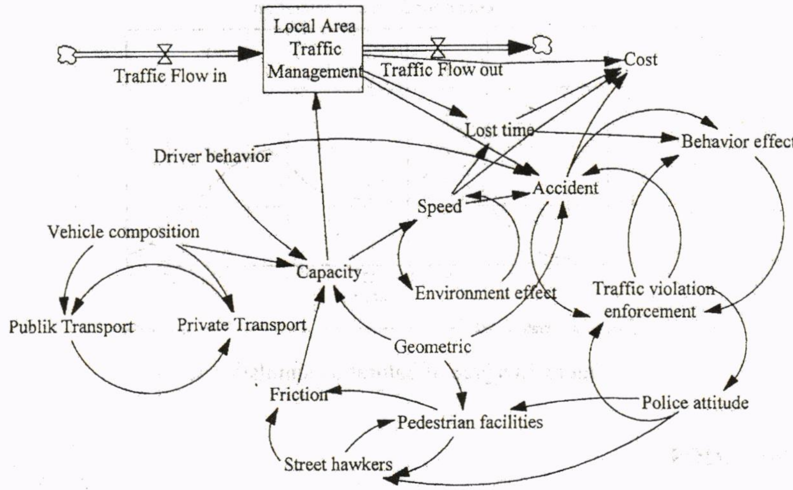


Figure 9.Dynamic model for an intersection management scheme.

From figure 9 could be seen that the effect of behavior to the traffic is to the accident, environment, speed and at the end to travel cost. Intervention to the model could be enforcement, illumination, and improvement of the traffic signs

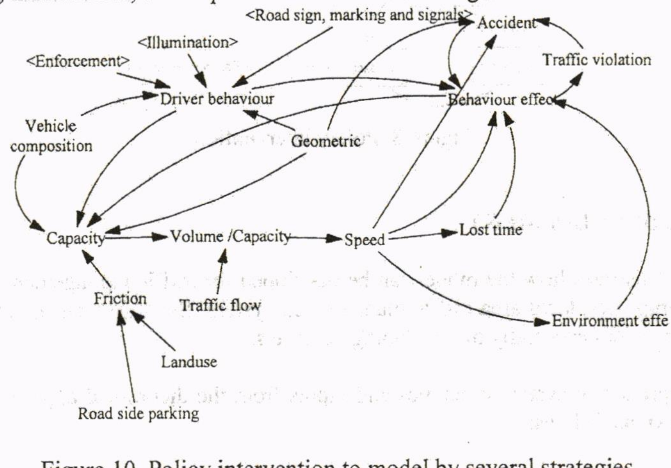


Figure 10. Policy intervention to model by several strategies.

The next step in the process is creating scenarios with the working model and testing them. The scenarios could be developed in several areas such as economic, social or political, for the traffic management model the intervention could be in the enforcement, geometric of the intersection and more macro by traffic campaigns.

6. CONCLUSIONS

In this paper we have discussed the application of system dynamics for the simulation of traffic management schemes. With this approach we could significantly look in to a traffic problem deeper and could solve the traffic problems from its root of the by implementing several strategies and test all the strategies before implementing it.

With this approach we could see all of the parameters/factors, which has a relationship to the problem. By a comprehensive analysis it is expected that the root of the problem could be found. So that, the most effective strategy would be created.

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