Transportation Demand Forecasting System using System Dynamics

Rio Aurachman
Telkom University, Bandung, Indonesia
Rioaurachman@telkomuniversity.ac.id

Abstract. The transportation system has a certain capacity. The needs of the transportation system need to be predicted. The predictions made are the basis for providers to prepare existing transportation facilities. Through this paper, we propose a system to predict the capacity requirements of the transportation system using a dynamic systems approach. We use the Stella application as a dynamic system modeling tool. It was found that using the dynamic systems approach, the relationship between variables that form complexity can be modelled.

1. Introduction
Transportation system of a city needs to be prepared so that it can serve the needs of the community. Without the capacity that is prepared properly, it will cause the community's needs cannot be met. The unavailability of this capacity causes people to prefer private vehicles. The increasing number of private vehicle users will cause an increase in the volume of vehicles on the road. This can cause traffic jams.

On the other hand, too much capacity in the transportation system will cause waste. Buses, trains and other public vehicles that are part of the city's transportation system will operate without enough passengers. Due to the absence of income from user, the transportation system manager will suffer financial losses. This loss can be covered by the government. However, this will cause the transportation system to be not sustainable.

A system that can predict the needs of the transportation system is needed. So that transportation system providers can make optimal decisions. This optimal decision fulfills the transportation service needs of the public. In addition, this decision also provides optimal financial benefits.

The system under study is a complex system. Complex system is a combination of variability and dependency [1]. Variability means that the components of the system have a change in behavior. These changes can be of uncertainty or probability. Dependency means that the components of the system are interrelated with one another. Changes in the behavior of one component will affect other components.

The needs of the transportation system are influenced by several components. These components are population size, level of use of the population, and readiness of the capacity of the transportation system. Meanwhile, the population itself is influenced by population growth and reduction. Not all of the population are interested in becoming users of the public transportation system. The large number of these variables is the reason for the need to be analyzed using a method capable of handling complex systems.

Several studies have conducted research on how to forecast transportation system requirements [2]; deep learning [3], discrete choice analysis [4], macrosimulation[5] ,agent based analysis [6] and many more. The forecasting process is also carried out for several modes of transportation, such as high speed...
rail [7], taxi [8], road [9], and many more. Dynamic systems are also used in the transportation sector in several studies, including the urban transportation system [10], air pollution [11], participation in environmental decision [12], and many more. So this study tries to propose a dynamic system for demand forecasting of the transportation system by involving population growth variables.

Through this paper, we propose a method for forecasting transportation system requirements using the Dynamic Systems approach. The diagram that will be used is the Stock & Flow diagram. These diagram and models will be run using Stella software.

2. Method and algorithm
The method used to design this system is to use a systems approach [13]. At the initial stage, the problem formulation was formulated. In problem formulation, it is possible to determine the six problem elements. Apart from using the six problem elements, a rich picture can be used to understand the situation of the existing problems. Other useful tools at the understanding stage of the problem are creating a mind map and cognitive map.

After the problem formulation is carried out, the next step is modeling aspects of the system. Some of these aspects can include the hierarchy of the system, the system boundary, the relevant environment, the system behavior, and the control of the system.

In the dynamic system design process, an important diagram that needs to be made is the causal loop diagram. Causal loop diagrams are important to illustrate how one variable can affect another variable in the form of feedback loops. From the causal loop diagram, the Stock and Flow diagram will be formulated. In the stock and flow diagram, there is a stock variable that has memory in a dynamic system. The value of these variables at one time is influenced by the value of these variables at the previous time.

3. Result and discussion
In Figure 1 we display the Stock and Flow diagram that we have designed. The variables that become stock are non-customer citizens and customers. Non customer citizens can transform into customers. The number of non-customers who turn into customers depends on the number of customer citizens and conversion rates. Non-customer citizens can increase in number due to an increase in population that occurs naturally. Nor is the result of the customer changing his mind and no longer a customer. Apart from the consequences of changing to become a customer, non-customer Citizen can be lost due to the reduction in population that occurs naturally. However, the population growth that occurs naturally only occurs in non-customer citizens. This is because there is an assumption that every person who is just born or just comes to a city area cannot directly become a customer. This is because it takes time for people to learn about the existing transportation system.
Figure 1. Comparison of Distance and Noise based on Weight

From the number of residents who become customers, it can be determined how much the needs of the transportation system are. Demand is a formula of the customer usage level combined with the number of customers. The amount of demand affects the status of the transportation system, whether it is out of supply or oversupply. If the demand is greater than transportation capacity, there will be an out of supply or there are some people who cannot get transportation system services. However, if the transportation capacity is higher than demand, there will be an over supply, that is, some of the transportation system capacity is not utilized by the users.

Figure 2. Comparison of Normalized Distance and Noise based on Weight
Figure 2 contains the equation in the Stock and Flow Diagram. If the icon accepts an arrow from another icon, then the equation in that icon is in the form of a mathematical formulation. For example, the oversupply variable is a function of the Transportation_capacity_to_use variable minus the demand variable. Meanwhile, if the icon does not receive an arrow from any icon, then the contents of the equation icon are a constant. For example, the population growth variable has a value of 0.01 and is not a mathematical formula. Equation of an icon or a variable in the form of a mathematical function, the function must contain a variable that gives an arrow. For example the New_Customer equation does not contain an oversupply variable, it is because there are no arrows originating from oversupply pointing to the New_Customer variable.

![Diagram showing the movement trend of data in the system.](image)

**Figure 3.** Comparison of Normalized Distance and Noise based on Weight

As can be seen in Figure 3, there is a diagram that shows the movement trend of the data in the system. The scenario being developed is that the system provides transportation services for 240,000 users. System capacity is assumed to be the same for 12 years. Demand increased from the initial 22000 to 260000. This increase occurred due to an increase in the number of customers.

| Table 1. Total Score Calculation |
|----------------------------------|
| **Years** | **Demand** | **Out of Supply** | **Over Supply** |
| .00   | 221,454.81 | 0.00            | 18,545.19       |
| 1.00  | 224,384.99 | 0.00            | 15,615.01       |
| 2.00  | 227,206.14 | 0.00            | 12,793.86       |
| 3.00  | 229,921.21 | 0.00            | 10,078.79       |
| 4.00  | 232,533.06 | 0.00            | 7,466.94        |
| 5.00  | 235,044.51 | 0.00            | 4,955.49        |
| 6.00  | 237,458.28 | 0.00            | 2,541.72        |
| 7.00  | 239,777.03 | 0.00            | 222.97          |
| 8.00  | 242,003.34 | 2,003.34        | 0.00            |
| 9.00  | 244,139.73 | 4,139.73        | 0.00            |
| 10.00 | 246,188.66 | 6,188.66        | 0.00            |
| 11.00 | 248,152.51 | 8,152.51        | 0.00            |
| Final | 250,033.62 | 10,033.62       | 0.00            |

In year 0, capacity exceeds demand, there is an oversupply of 20000. Then when time moves, the amount of demand continues to increase while capacity does not increase, the level of oversupply
continues to decline. Unused capacity becomes used over time. Until around the 7th year, the amount of demand is exactly the same as the capacity so that there is no oversupply. After that the amount of demand continues to increase while the capacity is no longer able to meet so that there is an out of supply. The system is no longer able to meet needs. Until the 12th year demand continues to increase and the level of out of supply also continues to increase. This is because demand continues to increase while the capacity of the transportation system is constant.

The graph in Figure 3 is based on the data contained in Table 1. It can be seen that between year 7 and year 8 the amount of oversupply starts to change to zero and the out of supply variable which was initially zero changes to a certain value. Demand increases gradually by an amount of approximately 2000 per year.

4. Conclusion

Based on the design process that has been carried out, it is concluded that the forecasting process of the transportation system capacity design requirements can be done using the Dynamic systems approach. A suitable diagram to use is Stock and Flow Diagrams. Software that can be used is Stella. The software has an animation feature that gives users insight into how the system works. Dynamic systems provide insight to users and decision makers about how the system works and how the complexity that occurs due to the variability of each variable and the interdependence between these variables.

Some further research can be done. One of them is involving several other variables as part of the system. For example, examining more deeply about what variables affect capacity availability. It can also be modeled what variables that influence the level of use of each individual which are the determining factors for demand. In addition, a feedback loop can be formulated between the capacity and the number of customers. For example, if there is an out of supply, it will cause the customer to be disappointed and turn into a non-customer. It can also be done an automatic system which recommends if there is an increase in demand or an increase in the population of a certain number, then the transportation system capacity is increased.

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