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# System Dynamics Modeling To Evaluate the Capacity Utilization of LRT System to Cater Increasing Demand

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**Abstract.** The response and the increase usage of light rail transit which is known as Kelana Jaya Line (KJ Line), shows that KJ Line would seem to be reasonable choice for most people to travel in the cosmopolitan city of Kuala Lumpur. The trains are noticeably more crowded during busy rush hour in the early morning and evening especially on weekdays. Previously, it has been reported that the use of the system has exceed the maximum carrying capacity thus resulting heavy congestion on the platforms and in trains. The introduction of the new sets of four car trains with higher capacity to cater more city dwellers to ride has resulted in significant ridership growth. Therefore, this study aims to investigate the ability of systems to meet the demand in terms of influence on the use of public transport. The System Dynamics models is use to study the cause and effect relationship on the effect of changes and the capability in utilization of capacity.

**Keywords:** Increasing Demand, Maximum Capacity, Public Transport.

## 1. Introduction

The light rail transit (LRT) system offer an alternative travel mode for people to commute that seems to encourage modal shift to public transport in order to reduce traffic congestion especially in Kuala Lumpur. One study reports that public transport usage only accounts for 16 percent of all motor vehicle journeys. However, the increment of passengers over time on Kelana Jaya Line LRT illustrates the strong demand by most people to travel.

The KJ Line is one of the light rail transit system in Kuala Lumpur that connects important locations in its vicinity. This system covers a total distance of 29 km in length with 24 stations which runs mostly on an elevated guideway. The entire operation of the system is totally driven under computer control with driverless automatic train operation. The first operations commenced on September 1, 1998 with a total of 35 sets of two-car trains were introduced to the line that capable to carry up to 10,000 passengers per hour per direction (pphpd) as its initial capacity.

Kelana Jaya LRT ridership continues to increase that shows passenger trips on the line has reached 6,240,531 during the period of January 1, 2011 to February 7, 2011 in comparison to 5,507,490 passengers during the same period of 2010, as reported in the press relating to the statements by former Minister of Transport, Dato' Sri Ong Tee Keat [1]. The introduction of the new sets of four car trains with higher capacity to cater more city dwellers to ride has resulted in significant ridership growth.

The upgrading service with more coaches provides more capacity, however enormous crowd especially during peak hours has reached maximum capacity of the train stations. The overload capacity can cause congestion at platform or in train and eventually affects passengers discomfort and dissatisfaction to the system.

In this study, the transit network design with capacity restraint assignment problems to illustrate the capability of system to cater increasing demand. An application of system dynamics modeling to study the LRT system and to simulate and compare policy options under different scenarios that might affect the system performance to support decision making process.

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## 2. The Benefits of LRT

Light rail's contribution to public transport provision would facilitate better modal shift for passenger benefits and enhancing the image of the city, however lack of integration with deregulated bus services and abandonment of light rail policy targets have shown that Government is unlikely to put more effort to improve quality of public transport services as a whole [2]. In addition, despite the success of light rail schemes in encouraging on modal switch from cars and increasing passengers volumes for commuting, however it has made minimal impacts in declining frequency use of car to mitigate road congestion which due to partly no enforcement of car restriction policies [3].

On the other side, the arguments against conventional wisdom that LRT maximizes benefits to provide better transport system in large United States urban areas has been reported by [4]. However, the main weakness is that [4] failed to address the reliable source of information and assess the hidden conflict of interest by means to perpetuate the myths as well as the fact that has not been ever mentioned on the potential of light rail has attracted transit riders move from buses into trains [5]. According to [6], the large system expansion and fare reduction policies have been identified as major contributing factors for the increase of ridership growth achieved by transit systems in Houston (all bus) and San Diego (bus and light rail). Nevertheless, the investment strategy for expanding light rail line in US city has been heavily criticized for its effectiveness of system and having high capital costs.

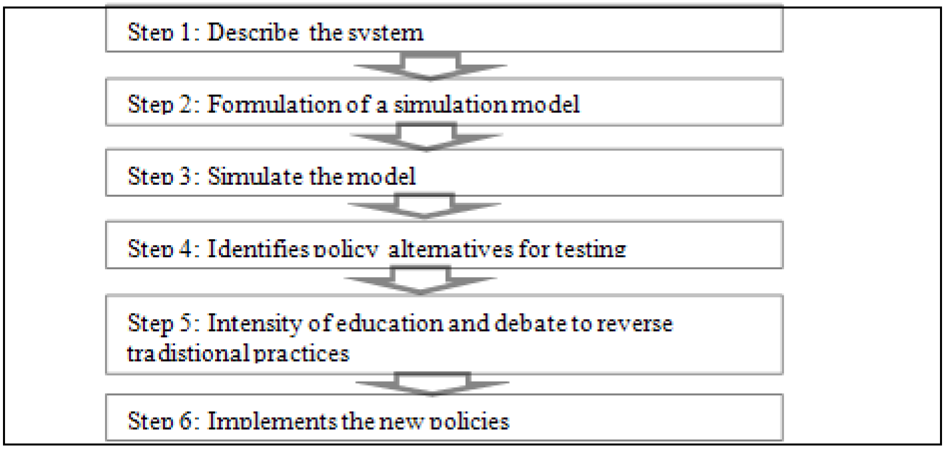
It has been suggested that learning through experiences of various projects abroad is emphasized in order to introduce LRT system successfully in urban regions, in which it could create the interactions between the high-quality public transport, real estate development and urban vitality [7] In Tunis, the combined traffic plan with the restriction of car users in the central city area was among the factors contributed to the success of LRT network [8].

## 3. System Dynamics Modelling and Simulation

The advantage of modeling in system dynamics environment is its iterative nature that yields understanding, which forms for further analysis, theory testing and extension. It is essential to define the constituent elements and their possible interaction towards understanding the behavior of system. It aims to gain understanding of the structural causes of a system's behavior.

The model must represent the real system under study in order to provide accurate results for further analysis. The result of field studies should provide a descriptive model, on which SD conceptual feedback structure can be developed. The feedback structural model is developed with the help of a causal loop diagram. The next step is the conversion of the cause loop diagram into stock and flow diagrams, which is a formal quantitative model of the problem in question. In order to simulate the model, we must define the mathematical relationship between and among variables. The following steps are identified for model development

Table 1: The steps in system dynamics modelling




## 4. Simulation result

The simulation result allows the modeler and the end-user to gain insights into the model's performance, and facilitates in decision making process.

### 4.1. Verification and Validation of Simulation Model

Validation is the process of ensuring that the model is sufficiently accurate for the purpose to build the right model. While, verification is the process of ensuring that the model design (conceptual model) has been transformed into a computer model with sufficient accuracy or in other words, building the model right [9].

The process verification and validation is conducted to determine whether the simulation model has met the acceptable criteria. There are many methods of model validation and verification.

During verification and validation, the model is evaluated based on data set that capable to represent the reality Data that is obtained from the real system for instance the number of passenger arrivals and exits at stations can be compared to the results of the simulated system (average value).

Table 2: Comparisons of historical and simulated number of passengers enter the station.

| | Entry | | |
|---|---|---|---|
| Time | Historical data | Simulation output | Difference (%) |
| Peak period | 35980 | 36005 | +1 |
| Off peak period | 68823 | 68868 | +1 |
| Total | 104803 | 104873 | +1 |

Table 2: Comparisons of historical and simulated number of passengers exit the station.

| | Exits | | |
|---|---|---|---|
| Time | Historical data | Simulation output | Difference (%) |
| Peak period | 37648 | 34375 | -0.09 |
| Off peak period | 65684 | 67861 | +1.03 |
| Total | 103332 | 102237 | -1.00 |

### 4.2. Capacity Utilization

Initially, each LRT can be loaded up to maximum capacity of 472 passengers. The maximum numbers of passengers are taken in presenting the capacity in train within a specified time period.

## 5. Discussions

Simulation allows experiment on the system under several alternatives/ scenarios of system configurations without disruption to the real system. These alternatives can then be used by selecting and comparing to the changes that will derive substantial value in total system performance.

Following that, further analysis of potential alternatives should be considered in this study. These concern the factor changes in meeting better requirements of service to ensure passenger satisfaction and improvement of the system. In addition, the changes also concern the management of available track asset utilization. The model should include the evaluation for cost or revenue analysis in finding cost-effective solutions for operating the system. In addition, simulation allows for cost estimation that would help in managing cost effectively by verifying the need for additional resources such as trains, tracks, or other equipment as well as managing the existing resources.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