INSTRUMENTAL APPROACH TO DETERMINE THE OCCUPANCY OF PUBLIC BUS: A CASE STUDY FOR ISTANBUL

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1 INTRODUCTION

In metropolitan cities where subway transportation is insufficient such as Istanbul case, city transportation is conducted widely by public buses. Productivity gets more importance in an intercity transportation system which is based on public buses specially when the travel demand and mobility is increased. The existing public bus routing and the number of reserved buses are based on rarely conducted official observations. It can not said that these observations produce data which describe the bus line characteristics exactly. The reason is that one observer can not count exact number of all passenger who get on and get off the bus. Hence, an observer gathers data that have approximate values. Moreover, they are not also valid to represent monthly or yearly situation of the line. Because sampled data is limited by a certain time period. Under the existing conditions productivity efficient of the bus transportation system depends on the actual and sufficient database.

In this study an instrumental weight measuring system has been introduced. The system measures variations on the weight of the vehicle. It is a removable instrumental device mounted on the vehicle. It also has computer hardware to record and process data. By means of this method, the collected data represent occupancy of a bus. In other words it reveals how often the bus line is used. In this approach, the aim is not to count the number of passengers. But to determine corresponding function in terms of weight. In this way, the occupancy of any bus line can be observed during any desired time period continuously.

After application of this process, a database can be constructed for global or local city regions. The database is very useful tool to determine saturation cases on the demand and to create new lines in accordance with it. In addition, it makes possible that some strategies of optimisation can be applied between separate bus lines to assure group integrations and thus in return to increase productivity.
2 INSTRUMENTAL WEIGHT MEASUREMENT

Variations in vehicle weight change the distance between body and axle of vehicle as linear relation. For this reason, it is sufficient to use a position sensor to perceive weight change at each station. For this aim, Linear Variable Differential Transformer (LVDT) device has been used as a position sensor. LVDT sensor is mounted between the vehicle body and axle with its assembly. LVDT hardware perceives the position change and convert it as a voltage level in accordance with displacement. Here, measurement instrument consists of four LVDT in case of four wheels. If one sensor was placed for vehicle, spurious data could be produced due to different slopes of the ground and irregular dispersion of the load. The weight power applied on the each wheel assumed as $P_j (P_1..P_4)$, total weight $W_T$ can be defined as follows:

$$W_T = \sum P_j$$  \hfill (1)

Actually we need change of weight. So, empty weight ($W_0$) of the vehicle must be measured. In application LVDT sensors are calibrated to zero position for empty condition. After that, weight change can be defined as:

$$\Delta W = W_T - W_0$$ \hfill (2)

$$\Delta W = \Delta P_1 + \Delta P_2 + \Delta P_3 + \Delta P_4$$ \hfill (3)

In parallel to last definition, each LVDT sensors perceive $\Delta d$ displacement and produce $\Delta V$ voltage difference following:

$$\Delta V_j = \alpha \Delta d_j$$ \hfill (4)

$$\Delta d_j = \lambda \Delta P_j$$ \hfill (5)

$$\Delta V_j = \beta \Delta P_j$$ \hfill (6)

Here, $\lambda$ and $\alpha$ are transformation coefficients. To produce total weight, all voltages are combined by an adder circuit. Total change of weight function $D$ can be written as following equation:

$$D = \delta \sum \Delta V_j$$

$\delta$ parameter is a adapting coefficient for next electronic hardware. $D$ value is an analog form of the voltage that corresponds the weight change. It is converted to numerical forms by an Analog to Digital Converter circuit (ADC) in order to transfer them to computer.

3 WEIGHT MEASURING SYSTEM

It is apparent that when the vehicle is in movement, vibration effects will happen. Under this condition, measurement system will produce spurious values. For this reason, measurement of weight should be done when the bus is in immobile. Open/close conditions of the doors
also should be take into consideration. Two factors reflect the stop condition at any station except extraordinary situations. Both of these conditions can be sensed and converted from vehicle hardware with already existing door and speed signal A and B respectively in figure 1. After an adaptation process on the signals, these two electrical signals are combined with logical AND function properly in the measurement system. Thus, the function outputs an enable signal to select valid process of the measurements for mentioned system, E signal in figure 1.

![Diagram](image_url)

Figure 1. Defining enable condition.

Figure 2 shows block diagram of the designed system. Data sampling process is activated and some data are recorded during period of the enable signal. At the end of the process, computer temporary has collected a string data. They belong to just one station. However it is necessary to record only one value for one station. As a first view, last value in the string represents correct result. However when the string values are examined, it is realised that some small vibration effects are still exist. Eliminating this effect without loss of information depends on to calculate mean value of last few samples. In applications, number of last samples are assumed as number of collected samples in last two seconds according to sampling period. This is necessary process but should be defined as heuristically. Because some factors may effect the number of final samples. Let $D_i(k)$ defines string values for $i$ th station. The valid value is calculated as:

$$E = A \cdot B$$

Figure 2. Weight Measuring System
\[ D_i = \frac{1}{(m-c+1)} \sum_{k=m-c+1}^{m} D_i(k) \quad (7) \]

\( k=1,2,...,m; \quad i: \text{station number}; \)

Where \( m \) is total number of samples and \( c \) is the number of last samples.

In the measurement software, last 5 values are chosen to calculate mean value and it is recorded as a valid value permanently. Produced value is highly approximate with real value.

4 WEIGHT FUNCTIONS

The function can be constructed with weight values that come from weight measurements at each bus station. It is belong to only one service period. The function array can be defined as follows:

\[ D_1(t), D_2(t), ..., D_i(t), ..., D_n(t) \quad (8) \]

Where, \( t \) is the departure time/number and \( i \) is the station number.

In the application, the measurement system has been tested on different two bus lines for a limited period. Figure 3 and 4 show the weight functions related to bus lines. According to the first figure, variation of the weights reflects that there is high occupancy between 1 and 8 stations than others. In this manner, second part of occupancy can be observed between 8 and 19 stations. In addition, it is seen that there is a saturation case on the fourth function at service time 8:30. This saturation case also has been fixed real observations. It should be noticed that saturation value (Ws) of each lines must be recorded (such as empty value) by an observer before analysis of any produced function. Hence weight function is defined meanly between two limits as empty and saturation conditions.

The second line (figure 4) reflects steadier rate of dispersion than first one. In this figure, dispersion of the high occupancy takes place in part of the function related to between station 7 and 15. There is also a potential of the saturation between station 12 and 15 in future.

Change of weight function defines only quantity of passengers in the bus. It does not reflect exact number of passengers, which get on and get off the bus at certain station. But it represents a rate of difference between the numbers of the passengers who get on and get off the bus. Therefore, small variations on the function reveal that differences are not to much. On the other hand it keeps giving information about demand of the bus for along bus line.
5 CONCLUSIONS

Productivity gets a vital importance in city transportation models, which depend on bus lines. The productivity in question here is treated from point of passenger quantity, not financial cost. Specially, during time periods when increasing demand of passengers, productivity gets utmost importance. Because, model is not flexible and fast enough to compensate unexpected situations. Therefore all predictions about such transportation model must be designed at highly correct. It depend on preparation of a database which describe occupancy of related bus lines in detail and precise. Weight function can be used as a tool to produce a precise database.

The suggested instrumental system can be mounted on any bus on any lines and at any desired time period. With such a database daily, monthly occupancy characteristic of the bus
lines can be explored to establish coordination among bus lines to achieve optimum performance of service.
The benefits of a database produced for a specific line or for all of the bus lines can be described as follows:

- Determination of bus departure time in accordance with line occupancy,
- Determination of quantity of buses reserved for the line,
- Optimum determination of line,
- Determination of new lines and testing them,
- Determining the ratio of express lines,
- Development of new transportation strategies in accordance with holidays and changing seasons,
- Evaluation of variations in passenger demand which occur in accordance with weather and traffic conditions,
- Optimum determination of location of stations,
- Development integration strategies by other bus lines or alternative transportation lines.

In addition to these, by registering weight measurements and real time data together in combination, the occupancy of buses related line could be extracted. Thus, the gathered data can be projected to line for related new strategies and also it can be used as a parameter to manipulate traffic signals.

REFERENCES


