Abstract. The main purpose of this article is to evaluate the impact of newly emerging big leisure and shopping centers with spacious parking in the cities to the traffic flows. The experiment was performed for this purpose. The results of this experiment were used for forecasting the traffic flows. After performing the traffic flow forecasting, the results were used in the development of the crossroad model. By applying the developed crossroad model we could perform the modelling and identify the impact of the released different traffic flows from parking to the transport flows in crossroads.

Keywords. Traffic jams, transport flow forecasting, traffic detectors technologies, transport control systems.

1. Introduction

While developing the city infrastructure in Lithuania, the consideration was not given to the fact that in future the number of cars will grow significantly, especially in the major cities. During the recent 20 years the number of cars grew by 76%. Such a significant increase of car numbers caused numerous problems for cities. One of the biggest problems is the parking problem, and traffic jams on the roads.

During these years Lithuania not only witnessed the growing number of cars but also construction of many large shopping centers. Parking problem at these centers is very acute. Some centers are solving this problem by building multilevel car parking. In Kaunas a four level, 2500 space car parking was built next to the new shopping and leisure centre. It was constructed above the busy street. As a result, the transport flow in this street grew by 26%. When the traffic flow increases, there is a high possibility for transport jams especially on the roads near crossroads, near the shopping centers. The big jams may also develop after the end of large mass events [4].

2. Problem Actuality

In order to control the transport flows next to the shopping centre, the transport management system should be developed. While developing the transport management system, data of transport flows is needed. Collection of data of transport flows in all crossroads around the shopping centre would require extensive amount of time, finances and equipment. One of the ways for solving this problem is to develop the model of transport flow forecasting. This model allows the collection of data on transport flows only in the biggest crossroads, and forecasts it in the remaining crossroads [1]. During the work, the forecast model was developed by using data from induction loops installed in one major crossroad next to the shopping centre. Results of the forecast model were used in modelling of different situations by applying Arena software.

After completing the modelling process, one of the possible transport management systems was proposed. This system is illustrated in figure 1.

![Figure 1. Transport control system architecture](image-url)

The architecture of this transport management system consists of controllable traffic lights, induction loops, video equipment, and driver notification boards. All equipment is connected to the traffic management controller TC1 via the
network. Video cameras are connected to the video signal processing unit VP1. Both the controller TC1 and the video equipment VP1 are connected via the Ethernet to the control levels. This system may have several control levels, these are:

- Crossroad line level;
- Crossroad control level;
- District level;
- City level;
- Urban traffic systems management center;
- Country traffic systems management center.
- Such positioning of levels enables the easy traffic control in the entire city or region.

### 3. Usage of traffic detectors technologies

The figure 2 represents the most popular sensors as for traffic flow measurement. As we can see, the most popular sensors are induction loops, figure 3.

#### Figure 2. Usage of traffic detectors

The main advantages of induction loops are as follows: simple technology easily adaptable for different conditions, models that may generate high frequency output, and may classify data, providing the basic traffic parameters. The main parameters of induction loops are as follows:

- **Occupancy** (*O*): % of time loop is occupied per interval
- **Volume** (*N*): number of vehicles in the observation interval
- **Speed** (*s*): vehicles speed (can be calculated)
- **Observation interval** (*T*)

### Figure 3. Inductive loop technology

The main shortages of induction loops: installation of loop requires cutting the road cover thus reducing the service life of this cover; induction loop is temperature prone and it cannot be used in certain cases (for instance, on the bridges).

The process of video image processing consists of certain stages. Firstly, the image is recorded by video camera, then the video signal is transferred to digital image processing boards, later traffic data in a compressed digital format is transferred to the central monitoring unit (crossroad control level). The advantage of such system is possibility of obtaining data on transport flows in real time (figure 4).

#### Figure 4. Video image detection

The main shortages of video system are various interferences. Video camera is affected by cold weather, rain, snow, car shadows, car positioning in rows, shifts between day and night, and other interferences [3].

The microwave sensors are the third tool by popularity. Such sensors can be used in any location of the road, and at any weather. Installation of such sensors does not require cutting of the road cover. When the microwave
radars are being used, the speed of cars may be measured. Other types of sensors are rarely used.

4. Experiment

In order to develop a model for forecasting the transport flows, we must possess data about transport flows. The main purpose of this model, while having the car flows in a large crossroad-1 next to the shopping centre (figure 5), is to forecast the flows in a smaller remote crossroad-2.

![Figure 5. Experimental system modeling diagram](image)

For this purpose data from induction loops was collected. As the cars come to this crossroad not only from the street but also from the parking, therefore data was collected also from induction loops located at the parking exits (parameter x1, figure 5). Results of the experiment are represented in figure 6.

![Figure 6. Transport flow formation](image)

There is flow formation in one week from one of exits from parking (parameter x1). We can see that biggest flow was formatted in Saturday. The smallest was formatted in Monday. From these results we may conclude that the highest possibility for forming the traffic jams at the crossroad occurs on Saturdays between 14:00 and 22:00. The lowest possibility for jams is on Mondays, Tuesdays and Wednesdays, also at night between 23:00 and 11:00.

Comparison of transport flow from parking and from main street (from station) is showed in this diagram 7. There are values of one day.

![Figure 7. Comparison of transport flows](image)

During the modelling it is very important to know the operation time of the crossroad. During the experiment the traffic light operation times were being measured. Crossroad working time diagram is showed in figure 8.

![Figure 8. Crossroad working time diagram](image)

These values were used for creating simulation model with program Arena.

5. Forecasting Model

While developing the transport flow forecasting model, data from three induction loops was used. As many as three days data was used for the model. Data from the loops was summarized every hour. As the forecasting of transport flows was performed in the crossroad-2 (figure. 5), two transport flows as a model input were calculated. This was the traffic flow from the Old Town, and traffic flow from the station. These two flows were connected into one flow. Data from induction loops at the 2nd crossroad was used for the model output. In order to make sure that the model results correspond to the experiment results, not all data was included while developing the model.
For identification of the model parameters, matrix form of least square method has been used. The polynomial assessing only the member in linear dependability from factors will be applied in the work. The model of least squares method has been designed in Matlab [5]. This method enables to make evaluations of the selected structural model parameters according to the experimental data. After developing the model, all experiment results were included into it. Forecasting of transport flows was performed. You can see the forecasting results in figure 9.

As you can see from this picture, the forecasting results sufficiently precisely represent the real results of the experiment. We may conclude that the model may sufficiently precisely forecast the transport flows in the crossroad-1 (figure 5).

In the next stage of modelling the flow in crossroad 2 was forecasted by changing the traffic flow from the parking. Firstly, the 1000 car flow per hour from the parking was modelled, i.e. it was the whole number of cars that can be parked in the parking. This modelling is very important because if the maximum flows are known in the crossroads 1 and 2, we can identify the possibility of traffic jam occurrence at the crossroad 1. The results of this modelling are represented in figure 10.

Using forecast model, we could do simulation in each crossroad around shopping mall. The results of this modelling were used in modelling of different situations.

6. Simulation model

Simulation model gives possibility to create simulation with crossroads and identify gridlocks. Using results of forecasting model, simulation model was created with program Arena. The following parameters were used in developing the model:

- Time between incoming vehicles
- Time of vehicle trip particular distance
- Time of traffic-lights
- Number of vehicles
- Probabilities
- Forecasting results

In order to identify the possibility of traffic jam development at the crossroad 2, the distance between the crossroads 1 and 2 was measured. Then it was calculated how many cars can get into this distance. If during the modelling this section of the road is filled with cars, the traffic jam is recorded. To make the model as close to reality as possible, we measured not only distances between the crossroads but also a time for the car to make this distance [2]. The time between incoming vehicles to the crossroad was calculated too. We considered that the time between incoming vehicles changes exponentially.

As we are interested only in the crossroad 2, we were modelling only the flows going to this crossroad. We calculated the possibilities in the spots of the crossroad where cars may turn right or left, or go straight. Also we calculated the possibilities in the spots of road where cars can re-form from one traffic lane to another.

The simulation model was developed with program Arena. The Arena modeling system from Systems modeling corporation is a flexible and powerful that allows analysts to create animated simulation models. Simulation analysts place graphical objects on a layout in order to define system components, such as vehicles,
material handling devices.

The simulation model with program Arena is represented in figure 11.

7. Modeling Results

When having such crossroad model, we can easily model different situations. In all modelling stages we considered that the flow from the Old Town changes exponentially.

During the first modelling stage we changed the flow from the parking. The selected number of cars leaving the parking per hour was 418. The traffic flow from the station was 662 cars per hour. Results of this modelling are represented in figure 12.

As we can see from this chart, at the described flows, the queue of only 2 cars was forming at the crossroad 1. The queue of 10 cars occurred once per hour. As the section between the two crossroads gets filled with cars completely only when the queue of 22 cars is formed, we may conclude that the traffic jams do not form.

In the next modelling stage the 1026 outcoming car flow per hour from the parking was selected. The flow from the station was 994 cars per hour. The modelling results with these flows are represented in figure 13.

As we see from the chart, twice per hour the queue of 12 cars was formed at the crossroad 1. At such queue, the traffic jam does not occur.

In the third stage of modelling we selected the 1450 outcoming car flow per hour from the parking, and 970 car flow from the station. The results are represented in figure 14. As we see from this chart, most often the queue of 2 cars was forming at the crossroad 2, and once in an hour we observed the queue of 12 cars in both
lanes. We may conclude that even at that high flow from the parking, the traffic jam at the crossroad 2 does not occur.

![Figure 14. Modeling results when flow from parking 1450 cars per hour](image1)

In the last modelling stage we selected the 2493 out coming car flow per hour from the parking which is the maximum number of cars that may be parked. Car flow from the station was selected as 979 cars per hour. The results are represented in figure 15.

![Figure 15. Modeling results when flow from parking 2493 cars per hour](image2)

As we can see from the chart, even at maximum car flow from the parking, 3 times only the queue of 14 cars was formed. This queue is not sufficient for a traffic jam development.

The performed modelling revealed that the flow from parking does not have a big impact on the crossroad 2. We may conclude that the performance of crossroads (operation of traffic lights) is being adjusted rather efficiently. After leading the car flow from the station and the parking, this summarised flow is distributed. Part of cars take a straight way, part of them turn towards the crossroad 2. At that time the traffic lights at the crossroad 2 turn green, passing forward the formed traffic flow. This way the traffic jam is prevented next to the shopping centre.

8. Conclusions

The performed analysis of transport flow measurement technologies demonstrated that the most popular and most convenient technology is the induction loop.

The experiment was completed. The experiment results revealed that the biggest transport flow from the parking occurs between 14:00 and 22:00. After opening the leisure and shopping centre, transport flows in the central street increased by 26%.

According flow data from inductive loops in one crossroad we could forecast and adaptive control flows of other crossroads.

Simulation results showed, that even we have transport flow of 2500 from parking do not cause traffic jams.

After performing the modelling, one of the possible transport flow management systems was proposed.

9. References


