Parking Profit Estimation by Monitoring

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Abstract - Salary from the car parking business is mostly known only for the authorities who are charging the money. The mathematic model for external estimating the profit from parking payment is presented and application is demonstrated. Considering the usually camera partly monitoring, authors are giving the method for general salary calculation based on regression analysis. Method is giving opportunity for external monitoring the salary.

Keywords: parking, trapezium formula, correlation, regression, profit control.

1. Introduction

The phenomenon of parking payment in cities is becoming the subject of increasing interest for traffic experts (Burinskiene, Gražvydas 2003). The World's rapid urbanization process of living, staying and working in the cities is increasing the focus of attention (Colin, 1996).

The whole income from the parking place is well known only for subject who is taking it. Failure of this concept is in possible manipulating by original data, especially if one public firm has many parking complexes in a city. This problem arises when observation time is getting longer.

The reason for a systematic approach to make a model for total parking income computation lies in the fact that the local community, in most cases, monitors, controls and regulates the collection of parking (Rye, 2010). Underpriced and overcrowded curb parking problems were considered in (Pierce, Shoup 2013).

Effective management of optimal parking complexes in cities was demonstrated in (Brčić *et al.* 2012). The parking space dimensioning problems was determined in (Maršanić *et al.* 2011). Debate over the best allocation for parking place is given in (Lee, March 2010).

Parking place occupancy monitoring is possible by video cameras. At the base of recording video snapshots it is possible to calculate, as precise as is required, the exact profit taken from the recorded parking place. If the cameras are able to cover only the part of the parking complex (Jajac *et al.* 2014), it is possible to make advanced measuring and estimate the salary by regression analysis.

Parking problem appears in literature together with problem of traffic congestion. In (Basarić *et al.* 2013) authors determined relationship between limiting the parking duration with decisions to commute to work with passenger car. In (Malić *et al.* 2000) authors considered parking charge as a tool for solving parking and congestion problems. Authors in (Pandhe, March 2012) suggested parking reducing for employs in town's centres.

In all literature we have considered there is no any similar problem investigating. This article overgrows from an exact problem we considered.

2. Methodology and Mathematical Model

The exact cumulate profit C from the parking place complex is depending on the cumulate time that the every car is spending on its parking place:

$$C = c_1 \cdot \sum_i t_i$$

where i is a parking car, t_i are the hours that the i-th car is spending in its parking place and c_1 is the price of one parking hour. When we create the mathematical model, we suppose that every driver is paying his parking. It is because we have only the record of parking with places that are occupied by cars and empty parking places.

Let $a(t)$ be the number of parking cars in a moment t which could be taken from the snap-shoot recorder during the parking payment period. If there exist a formula $a(t)$ depending on a variable t, then

$$C = c_1 \int_{t_1}^{t_2} a(t)dt \qquad (1)$$

with $[t_1,t_2]$ as observed snapshoot interval, usually the daily parking charging time. Under the very special assumption that $a(t)$ has a constant value a during the period from t_1 to t_2, we get the calculus (2):

$$C = c_1 \int_{t_1}^{t_2} a(t)dt = c_1 \int_{t_1}^{t_2} a dt = c_1 a \int_{t_1}^{t_2} dt = c_1 at \Big|_{t_1}^{t_2} = ac_1(t_2 - t_1) \qquad (2)$$

Notice that value C is a product of an hour parking price c_1 and the value of area shown on the Figure 1:

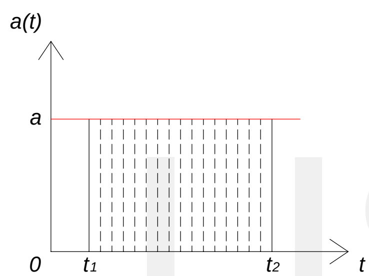

Figure 1. Area in a constant car number case

In general, the number of cars in every moment is variable, but $a(t)$ continuously depends on t. So the value given in (1) is again the product of an hour parking price and the value of area shown on the Figure 2:

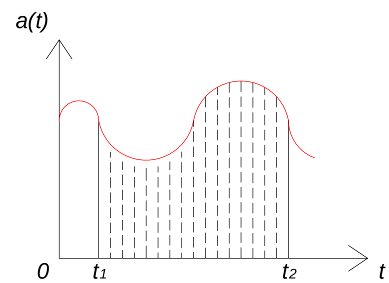

Figure 2. Area in variable continuous car number case

Parking cars can be counted in discrete moments $t_1, t_2, t_3,...,t_n$. So there are discrete values of $a(t)$: $a_1, a_2, a_3,..., a_n$. The values between them are approximate by polygonal lines as is shown on the Figure 3:

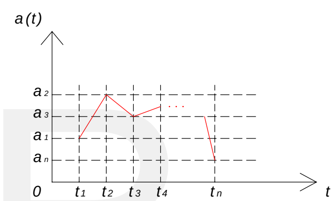

Figure 3. Polygonaly approximated function a(t)

The area below the polygonal line on Figure 3 is calculated by the well-known trapezium formula:

$$\int_{t_1}^{t_2} a(t)dt = \frac{a_1 + a_2}{2} \cdot (t_2 - t_1) + \frac{a_2 + a_3}{2} \cdot (t_3 - t_2) + ... + \frac{a_{n-1} + a_n}{2} \cdot (t_n - t_{n-1}) \qquad (3)$$

Formula (3) can be simplified if the counting moments are in advance periodically determined. Then:

$$t_2 - t_1 = t_3 - t_2 = ... = t_n - t_{n-1} = \Delta t$$

and the final suitable formula is given:

$$c_1 \int_{t_1}^{t_2} a(t)dt = c_1 \left[\frac{a_1 + a_2}{2} \cdot \Delta t + \frac{a_2 + a_3}{2} \cdot \Delta t + ... + \frac{a_{n-1} + a_n}{2} \cdot \Delta t \right] \qquad (4)$$

In the further example we will note articles in (4) with

$$P_i = \frac{a_i + a_{i+1}}{2} \cdot \Delta t, \quad i = 1,...,n-1. \qquad (5)$$

3. Daily Measurement Example

On the considered parking place complex, daily payement period begins at 7:00 and ends at 21:00. The cars were counted from 7:15 till 20:30 in the interval $\Delta t = 15 \text{ min.} = 0.25 \text{ h}$. So we get:

a_1 = number of parked cars at 07:15
a_2= number of parked cars at 07:30
⋮
a_{n-1}= number of parked cars at 20:15
a_n = number of parked cars at 20:30

The area shown on the Figure 3 is calculated by (4) and results are displayed in the Table 1:

TABLE I.
SUMMARY RESULT OF DAILY MEASUREMENT IN CAR-HOURS

TIME	t_i	**7:15**	**7:30**	**7:45**	**8:00**	**8:15**	**8:30**	**8:45**	**9:00**	**9:15**	**9:30**	**9:45**
CARS	a_i	162	164	141	133	119	115	113	105	117	119	118
ARTICLES	P_i	40.75	38.13	34.25	31.50	29.25	28.50	21.80	27.75	29.50	29.63	29.63
TIME	t_i	**10:00**	**10:15**	**10:30**	**10:45**	**11:00**	**11:15**	**11:30**	**11:45**	**12:00**	**12:15**	**12:30**
CARS	a_i	116	117	122	117	120	127	134	124	133	132	134
ARTICLES	P_i	29.13	29.88	29.88	29.63	30.88	32.63	32.25	32.13	33.13	33.25	32.75
TIME	t_i	**12:45**	**13:00**	**13:15**	**13:30**	**13:45**	**14:00**	**14:15**	**14:30**	**14:45**	**15:00**	**15:15**
CARS	a_i	128	128	131	129	131	134	136	129	125	125	126
ARTICLES	P_i	32.75	32.00	32.50	32.50	33.13	33.75	33.13	31.75	31.25	31.38	31.25
TIME	t_i	**15:30**	**15:45**	**16:00**	**16:15**	**16:30**	**16:45**	**17:00**	**17:15**	**17:30**	**17:45**	**18:00**
CARS	a_i	124	134	131	132	136	137	140	149	147	154	148
ARTICLES	P_i	32.25	33.13	32.88	33.50	34.13	34.63	36.13	37.00	37.63	37.75	37.25
TIME	t_i	**18:15**	**18:30**	**18:45**	**19:00**	**19:15**	**19:30**	**19:45**	**20:00**	**20:15**	**20:30**	**TOTAL INTEGRAL**
CARS	a_i	150	145	144	151	155	160	166	178	180	180	
ARTICLES	P_i	36.88	36.13	36.88	38.25	39.38	40.75	43.00	44.75	45.00		**1 788.84**

The one hour parking price is 4HRK ≈ 0.53 €. The total daily income is 7,155.36 HRK and equals about 954.05 €.

4. Limited Observation Problem

Problem appears when there is impossible to overtake the whole parking complex by cameras. Then we have to estimate the number *(Y)* of parking vehicles in whole complex by the number of parked vehicles *(X)* which is overtaken by camera. In the purpose of solving the problem, effective number of vehicles that are parked in the whole complex need to be counted and then correlated with those which are recorded by camera.

Firstly we calculate correlation coefficient by formula from (Kovač *et al.* 2008):

$$R = \frac{\sum_{i=1}^{n} x_i y_i - n \cdot \bar{x} \cdot \bar{y}}{\sqrt{\left(\sum_{i=1}^{n} x_i^2 - n \cdot \bar{x}^2\right) \cdot \left(\sum_{i=1}^{n} y_i^2 - n \cdot \bar{y}^2\right)}} \tag{5}$$

where:

$\bar{x}$ - recorded number's arithmetic mean
$\bar{y}$ - counted number's arithmetic mean
n - correlated pairs of numbers.

If the correlation coefficient is high, then the number of all cars parked at the complex (*Y*) is linearly depending on the number of parked cars overtaken by camera (*X*) with relation

$$Y = a + bX \,, \tag{6}$$

where coefficients are calculated by formulas from (Kovač *et al*. 2008):

$$a = \frac{\sum_i y_i \cdot \sum_i x_i^2 - \sum_i x_i \cdot \sum_i x_i y_i}{n \cdot \sum_i x_i^2 - \left(\sum_i x_i\right)^2} \tag{7}$$

$$b = \frac{n \cdot \sum_i x_i y_i - \sum_i x_i \cdot \sum_i y_i}{n \cdot \sum_i x_i^2 - \left(\sum_i x_i\right)^2}. \tag{8}$$

The original data are presented in the Table 2. Considered parking complex was consisted of 193 parking places. There were 110 places overtaken by camera.

TIME	t	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45
RECORDED	***X***	88	95	88	84	77	74	73	68	75	76	76
COUNTED	***Y***	162	164	141	133	119	115	113	105	117	119	118
TIME	***t***	**10:00**	**10:15**	**10:30**	**10:45**	**11:00**	**11:15**	**11:30**	**11:45**	**12:00**	**12:15**	**12:30**
RECORDED	***X***	75	75	78	75	77	80	85	80	84	84	85
COUNTED	***Y***	116	117	122	117	120	127	134	124	133	132	134
TIME	***t***	**12:45**	**13:00**	**13:15**	**13:30**	**13:45**	**14:00**	**14:15**	**14:30**	**14:45**	**15:00**	**15:15**
RECORDED	***X***	82	82	83	82	83	85	86	82	80	80	80
COUNTED	***Y***	128	128	131	129	131	134	136	129	125	125	126
TIME	***t***	**15:30**	**15:45**	**16:00**	**16:15**	**16:30**	**16:45**	**17:00**	**17:15**	**17:30**	**17:45**	**18:00**
RECORDED	***X***	79	85	80	84	86	82	79	93	92	96	90
COUNTED	***Y***	124	134	131	132	136	137	140	149	147	154	148
TIME	***t***	**18:15**	**18:30**	**18:45**	**19:00**	**19:15**	**19:30**	**19:45**	**20:00**	**20:15**	**20:30**	**TOTAL**
RECORDED	***X***	99	84	91	90	97	100	103	97	98	98	**4560**
COUNTED	***Y***	150	145	144	151	155	160	166	178	180	180	**7345**

TABLE II.
COMPARISON OF PARKED VEHICLES BY THE WAY OF COUNTING

Correlation coefficient is calculated by the formula (5), for $n = 54$ pairs of number with arithmetic means $\overline{x} = 84.4$ and $\overline{y} = 136.0$. Correlation coefficient is high:

$$R = 0.927. \tag{9}$$

The reason lies in the fact that counted vehicles are also recorded by camera, so the recorded number of vehicles is the part of counted number of vehicles.

Applying the values from Table 2 in (7) and (8) we get (6):

$$Y = 2.03X - 35.48. \tag{10}$$

Formula (6) estimates the number of vehicles parked in whole complex by the number of vehicles (*X*) recorded by cameras. Results given above are presented in Figure 4.

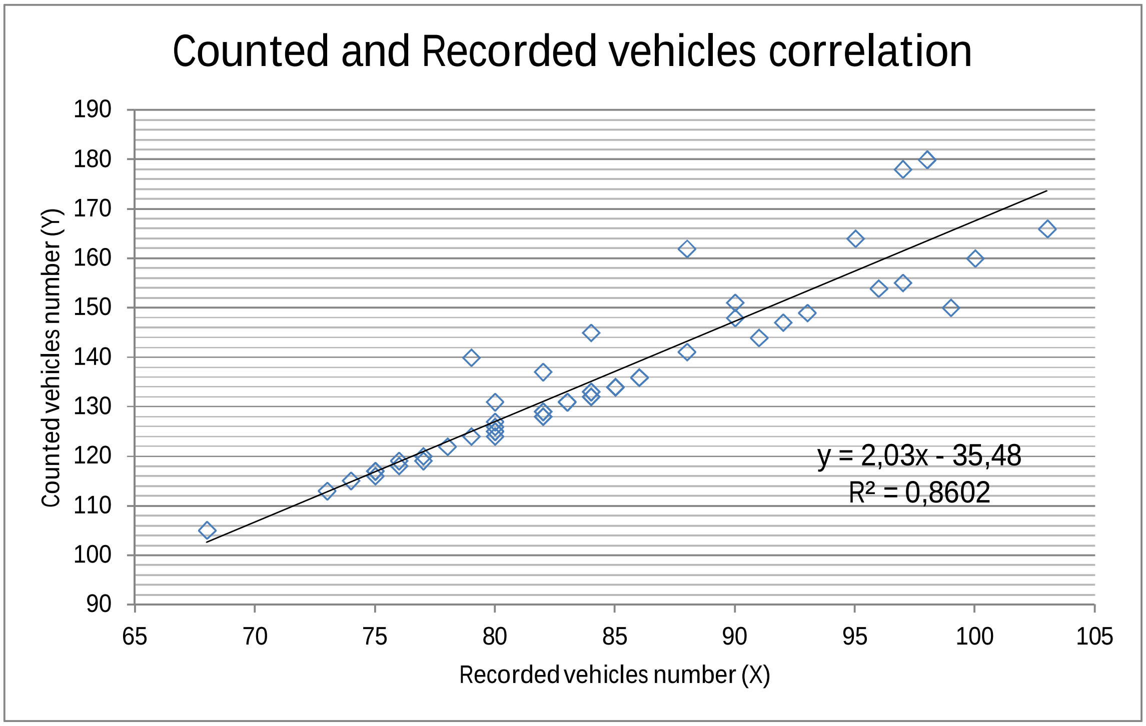

Figure 4. Linear regression between vehicles counted and recorded numbers

Notice that coefficient 2.03 is not equal with rate 193/110, which means that cameras in example are overtaking those parking places that are low desired by drivers who are parking their cars.

5. Conclusion

In the first part of article we showed the method for independent estimating the parking salary. It could be applied for over-sighting the companies which take money from parking places. In the second part we demonstrate the method for collecting data of parked vehicles number when oversight couldn't be completely conducted. This method is suitable for managers to control its incomes easily. The main reason for not to take the rate of whole number of places and overtaken number of places is that all parking place are not equally eligible.

Results of the research showed that it is possible to evaluate the revenue from the parking by video monitoring the number of parked vehicles at random intervals. In the absence of cameras ability to cover entire parking space, it is possible to determine the correlation and linear regression for total occupancy. The physical counting of parking spaces occupancy is very simple method presented in the paper.

Research results indicate that the reliability affects the number and frequency of the physical counting cars on a parking complex. It shares a part of the parking complex that is accessible by cameras and total capacity of the parking complex.

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