Periodica Polytechnica Transportation Engineering, 51(1), pp. 49–56, 2023

Integrated Smart System for the Coordination of Traffic Light Traffic Management and Intelligent Public Lighting in Hungary

Nikolett Fecser[1*], Tamás Árvai[2], István Hausel[3], László Könözsy[4], István Lakatos[5]

[1] Department of Automation, Faculty of Mechanical Engineering, Informatics and Electrical Engineering, Széchenyi István University, Egyetem tér 1., H-9026 Győr, Hungary
[2] HOFEKA, Cinkotai út 23., H-2142 Nagytarcsa, Hungary
[3] JEL-KÖZ Mérnöki Iroda Kft., Dózsa György rkp. 15., H-9026 Győr, Hungary
[4] Centre for Computational Engineering Sciences, Cranfield University, College Road, MK43 0AL Cranfield, Bedfordshire, United Kingdom
[5] Department of Automotive and Railway Engineering, Faculty of Mechanical Engineering, Informatics and Electrical Engineering, Széchenyi István University, Egyetem tér 1., H-9026 Győr, Hungary
[*] Corresponding author, e-mail: fecser.nikolett@sze.hu

Received: 09 May 2022, Accepted: 18 August 2022, Published online: 30 August 2022

Abstract

In our study, the operation of a smart system in current operation and the implementation plan of traffic management by traffic lights of a junction are presented. Public lighting has a major effect on the efficacy of cities and the well-being and safety of their inhabitants. The energy consumed for public lighting entails significant costs for the urban management. In our constantly evolving world, there is an ever-growing demand for lighting, leading to the increase in expenses, as well. Smart cities are dedicated to apply the most energy-efficient solution in order to decrease expenses in respect of the safety of all road users.

Keywords

junction, traffic management, motion sensor, smart city, HDMR system, public lighting

1 Introduction

The smart city concepts have come into existence due to the social and economic challenges of the 21st century. An essential element of the smart city concepts is smart mobility. Smart mobility can include, for instance, the implementation of traffic management and traffic monitoring systems, the intelligent coordination of traffic lights, which facilitates urban transport (Benevolo et al., 2016).

Nowadays, urban development is no longer just about networks, buildings, and utilities. In addition to technical development, the protection of our environment should also encourage urban planners and the decision-makers to apply smart solutions bearing future in mind, while the range of opportunities is expanding (Duan et al., 2019).

Smart cities play an increasingly important role in the sustainable economic development of a specific area. The first goal in achieving sustainability is to reduce energy consumption (Castro et al., 2013).

In smart cities, traditional networks and services will become more and more efficient by using digital and communications technologies. In smart cities, street lighting is developing rapidly. Traditional light sources are replaced with energy-efficient and well-controllable light-emitting diodes (LED) (Cangeloso, 2012).

One of the most important goals of public lighting improvements is to increase visibility. With modern lighting systems, the recognisability and visibility of road signs can be improved. The deployment of street lighting systems with dynamically changing luminous flux improves the efficiency of energy use. They can be applied either on transit roads or in low-traffic public areas (Šemanjski et al., 2018).

The long-term solution may be the introduction of an intelligent traffic-dependent traffic light system, which can take into account the traffic and capacity of a particular road section and can dynamically manage traffic accordingly (Bilal and Jacob, 2007).

The regulation of traffic systems is very important factor in the safety of transport. In intersections control has to take the density of input and output sections into consideration (Péter, 2012).

Cite this article as: Fecser, N., Árvai, T., Hausel, I., Könözsy, L., Lakatos, I. (2023) "Integrated Smart System for the Coordination of Traffic Light Traffic Management and Intelligent Public Lighting in Hungary", Periodica Polytechnica Transportation Engineering, 51(1), pp. 49–56. https://doi.org/10.3311/PPtr.20397

The world of urban mobility is changing very fast, with the result that cities are constantly struggling with the impact on security. The task of providing safe mobility is a complex challenge, because more and more cars, pedestrians, cyclists and public transport vehicles are on the roads (Péter and Fazekas, 2014; Lakatos et al., 2016).

Traffic accidents have become an important problem over the last few decades. Accidents frequently occur on the road and cause injury, death and damage to infrastructure in Hungary. Therefore, there is a need to apply for an Intelligent Transportation System to avoid traffic accidents (Aldegheishem et al., 2018).

An important part of the intelligent transportation systems is that they make it easier and cheaper to collect and store data (Sumalee and Ho, 2018).

2 HDMR systems in transport

In Hungary, the interest of protecting our environment encourages the city leaders to use smart solutions in transport (Salama et al., 2010).

One such solution is HDMR systems, which are networked motion sensor systems installed on poles as well as luminaries. HDMR systems allow achieving energy-savings and ensure the possibility of safe operation of public lighting and the improvement of comfort, as well.

2.1 HDMR system installed at roundabouts in Hungary

1 pc Gateway central controller (red) for wireless systems, 9 pcs HDMR SL-Zhaga controllers (yellow) and 14 pcs HDMR CS+ motion sensor (blue) have been installed at the roundabout. Fig. 1 shows the motion sensors installed at the roundabout.

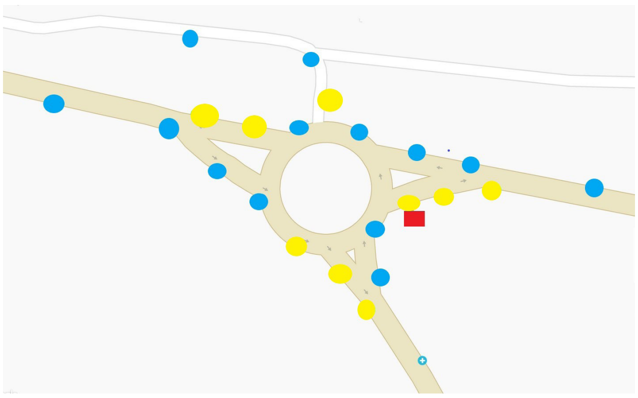


Fig. 1 Location of HDMR motion sensors

2.1.1 CS+ outdoor wireless motion sensor and SL-Zhaga outdoor wireless controller

The characteristics of CS+ outdoor wireless motion sensor and SL-Zhaga outdoor wireless controller are as follows (HOFEKA, 2022):

- Motion sensor for outdoor use with an installation on poles and lighting fixtures.
- Lighting is controlled according to pedestrian, bicycle and vehicle traffic.
- Dynamic and real-time control of roundabout lighting.
- Detects high-speed vehicle traffic.
- The HDMR system adjusts the lighting of the roundabout during a traffic-free period according to the settings.
- Activates the pre-set lighting profile after motion detection and sends the instruction to the specified adjacent luminaries.
- By the time the car has approached the entrance to the roundabout, due to the HDMR system the lighting will be operating at 100% level.
- The system intervenes immediately if necessary and modifies the operating parameters.
- Measurement data, status signals, and warnings are retrieved via a Web interface.
- Depending on the settings, up to 80% energy savings can be achieved.

2.1.2 Tweet Stelium luminaire

10 pcs of Tweet Stelium S1 3BLSB12 LRL 68W 4000K DALI luminaires have been installed. The power consumption of the luminaire is 68 W.

In terms of Tweet Stelium S1 3BLSB12 LRL 68W 4000K ZHAGA, SMART, SVP luminaires, 9 pcs have been installed. The power consumption of the luminaire is of 68W. Main technical data of Tweet Stelium Luminaries (HOFEKA, 2022) are as follows:

- Moulded aluminium housing;
- IP 66;
- IK 10;
- ULR < 1%;
- Optics: ORALENS;
- Optional RAL colour;
- Colour temperature: 3,000 K or 4,000 K.

2.2 The operation test of the HDMR system

In Section 2.2, the operation of the HRMR system installed at the roundabout is examined. Fig. 2 shows the pre-set lighting profile.

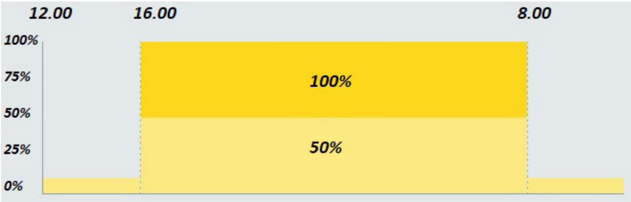


Fig. 2 Pre-set lighting profile

If no movement is detected, the lights will light up at 50%, if there is movement (e.g. a car arrives), they will light up at 100%. Fig. 3 shows the variation in energy consumption data between 25 February and 29 March 2022.

The highest energy consumption is 14.48 kWh, while the lowest is 11.52 kWh, with an average of 13.49 kWh. Fig. 4 shows the rate of energy-savings.

The highest rate is 22.84 kWh, while the lowest is 20.44 kWh, with an average of 21.50 kWh. Table 1 depicts energy consumption and savings together.

Table 1 shows that with an energy consumption of 11.52 kWh, the savings are 65.7%. Fig. 5 shows the savings rates in percentage.

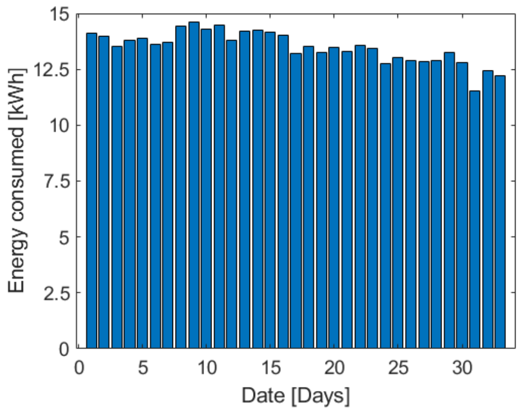


Fig. 3 Data of energy consumption

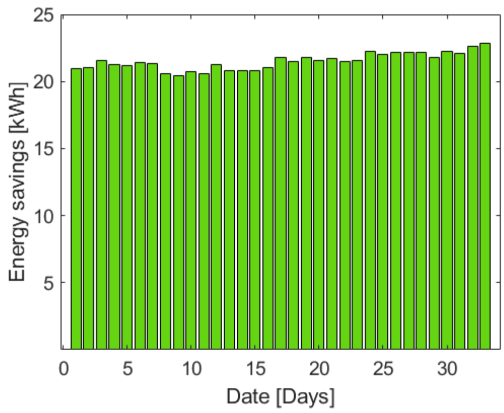


Fig. 4 Rate of energy-savings

Table 1 Alteration of energy consumption and savings

Date [days]	Date [days]	Energy consumed [kwh]	Energy savings [kWh]	Energy savings [%]
1	25.02.2022	14.12	20.93	59.72
2	26.02.2022	14	21.04	60.05
3	27.02.2022	13.51	21.53	61.44
4	28.02.2022	13.8	21.24	60.63
5	01.03.2022	13.87	21.17	60.43
6	02.03.2022	13.62	21.42	61.14
7	03.03.2022	13.72	21.33	60.86
8	04.03.2022	14.44	20.6	58.8
9	05.03.2022	14.6	20.44	58.34
10	06.03.2022	14.28	20.76	59.24
11	07.03.2022	14.48	20.56	58.68
12	08.03.2022	13.81	21.23	60.58
13	09.03.2022	14.21	20.83	59.45
14	10.03.2022	14.25	20.79	59.34
15	11.03.2022	14.18	20.82	59.5
16	12.03.2022	14.04	21	59.93
17	13.03.2022	13.23	21.81	62.25
18	14.03.2022	13.54	21.5	61.36
19	15.03.2022	13.25	21.79	62.19
20	16.03.2022	13.46	21.58	61.58
21	17.03.2022	13.3	21.74	62.05
22	18.03.2022	13.56	21.48	61.3
23	19.03.2022	13.45	21.59	61.63
24	20.03.2022	12.76	22.28	63.58
25	21.03.2022	13.04	22.04	62.84
26	22.03.2022	12.9	22.14	63.18
27	23.03.2022	12.86	22.18	63.3
28	24.03.2022	12.88	22.17	63.26
29	25.03.2022	13.24	21.8	62.2
30	26.03.2022	12.81	22.23	63.44
31	27.03.2022	11.52	22.06	65.7
32	28.03.2022	12.44	22.6	64.5
33	29.03.2022	12.21	22.84	65.17

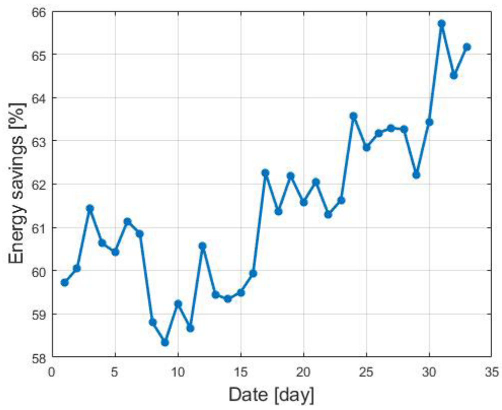


Fig. 5 Savings rates in percentage

The maximum savings rate is 65.7 %. The data clearly shows that after installing the new system, the energy consumption values are optimal. According to the catalogue, the potential savings are up to 80%, which is approximated by the system examined in this study.

Reducing energy consumption is of paramount importance today. That is the goal for example reducing the energy consumption required for the operation of a transport hub. In the case of the intersection examined, the measurement results supported the assumption that the energy consumption of a transport node using smart technology could lead to significant energy savings. Among the elements of the operation of traffic junction in our example, we only compared the energy costs of lighting for the so-called conventional and LED lighting.

3 On-going implementation of traffic control by traffic lights of the junction at the intersection of Liget Street – Szalay Imre Street – Nyár Street located in Győr

In the study, the current situation of the implementation of the traffic control by traffic lights at the Liget Street – Szalay Imre Street – Nyár Street junction (here in after Győr junction) and the underlying idea are presented. The volume of the traffic did not, but the number of the accidents made the early transformation of the junction necessary. This junction will be the first in Győr, where the traffic lights are controlled not through traditional, cable or GMS based communications, but through state-of-the-art cloud communications.

3.1 Solution of traffic control in the Győr junction by traffic lights

The junction was rebuilt in 2014. Separate left-turn lanes and to the right straight ahead mixed lanes were constructed on Szalay Street and Nyár Street legs.

Liget Street is of 2 × 1 traffic lanes. On its west leg, a couple of bus bays can be found, whereas on its east leg a parking space was constructed. In parallel with Szalay Street, through Liget Street, bicycle crossings were installed. Pedestrian crossings were established on all legs of the junction. New street lighting was installed in and around the junction. The substructure of the traffic lights has been built along 4 junction legs, but the entire installation is still in process.

The Szalay Street – Nyár Street route was given a new network role as a continuation of Radnóti Street, therefore the priority rule was reversed at the junction. 'Stop' and 'Give Way' traffic signs regulate the priority of passing vehicles on Liget Street.

Stop signs are also repeatedly placed on the left side. Due to the expected increase in traffic in the primary direction of Szalay Street – Nyár Street, at the junction traffic control by traffic lights is to be introduced.

3.2 Traffic control design of the road junction

The current geometrical and traffic technology design of the junction can be preserved when introducing traffic light control, no modification is required.

The design of the traffic technology complies with the current regulations of the 'KRESZ' (Highway code). Due to traffic control by traffic lights, stop lines are to be painted in front of the pedestrian crossing. Long-wearing road markings are to be made. The design of the road markings is to comply with the parameters specified in 'ÚT 2-1.150' (2007) and 'ÚT 2-1.113' (2005) Highway Design and Specification Standards.

Video cameras are to be installed to monitor vehicle traffic at junction legs. The cameras shall be placed on the overhanging console jibs on Szalay Street and Nyár Street. On Liget Street, the cameras are to be installed on the extension of the main display columns. The cameras cover 2–2 detector loops on the pavement. Loops close to the stop line are also fitted with magnetic detectors to enhance operational safety. Fig. 6 depicts the traffic site plan.

During the operation of the traffic light, pedestrians and cyclists can check in with the help of push buttons. The

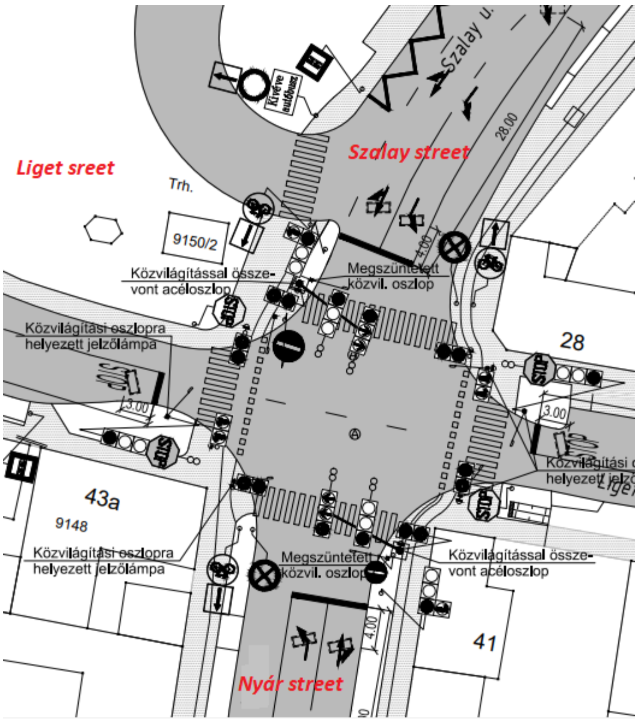


Fig. 6 Traffic site plan

entire traffic-dependent operation of the junction can be ensured in accordance with the phase time plans.

A phase is released when a sign-in occurs on the detectors belonging to the given phase. If a phase is not on demand, then it is skipped. If no sign-in occurs in either direction, a general red signal will light up. If the maximum green phase extension is exhausted and there is no sign-in from the other direction either, the green light phase can be extended as necessary.

Detector functions:

- Close loop: extension, sign-in;
- Distant loop: extension, sign-in.

In case of detector failure, a pre-set programme is activated.

3.2.1 Vertical signs

When installing traffic control by traffic lights, temporary warning signs of changes in traffic order are to be placed 50 m before the stop lines, along with the 'Traffic Lights' warning sign.

3 colour signal lights (main signals) on the side are to be placed between the stop lines and the edge of the pedestrian crossing. Pedestrian and cycling sign-in is enabled by using push buttons. Traffic lights and signs are to be placed in accordance with the relevant regulations.

3.2.2 Horizontal signs

Road marks are to be made in a long-wearing design based on the site plan. The stop lines planned in side direction are to be painted 1.5 m from the main signals on the side.

The new road markings are to be made in a long-wearing way. The design of the road markings is to comply with the parameters specified in 'ÚT 2-1.150' (2007) and 'ÚT 2-1.113' (2005) Highway Design and Specification Standards.

3.2.3 Traffic control devices, phase plans

The traffic light is to operate from 5:00 a.m. to 10:30 p.m. At night, the control is to be switched to flashing amber mode of operation. In the event of a detector failure, a pre-set programme is activated. The start-up shall occur in the main direction phase according to the activation programme.

The deactivation of the programme is to occur in one of the side-directional phases according to the deactivation plan.

The de-activation can occur at the end of the side-directional phase. After the end of the side-directional phase, the vehicular traffic lights switch to flashing amber, the pedestrian lights change to dark mode.

The speed allowed in the junction is 50 km/h, therefore the transitional amber signal lasts for 3 sec. The calculation of intermediate time is based on 'ÚT 2-1.219' (2009) Highway Design and Specification Standard, according to which:

- K: interim time;
- A: passage time (vehicle: 3 sec, cyclist: 3 sec);
- U: exit (clearance) time;
- B: entry time;
- E: start-up time (2 sec).

Calculation of clearance time ($\ddot{U}$):

$$\ddot{U} = \frac{s_{ü} + j}{v_{ü}}, \tag{1}$$

where:

- $s_{ü}$: clearance distance;
- j: vehicle length;
- $v_{ü}$: clearance speed.

Table 2 shows the turning radius and clearance time of the vehicle related to the direction of the given movement.

Clearance times:

- For pedestrians: 1.5 m/s;
- For cyclists: 4 m/s;
- For vehicles in case of straight exit: 10 m/s;
- For vehicles in case of exiting by turning:
  - if R ≤ 6 m, then $v_{ü}$ 5 m/s;
  - if 6 m < R < 25 m, then $v_{ü} = \sqrt{4 \cdot R}$ m/s;
  - if R ≥ 25 m, then $v_{ü}$ = 10 m/s.

Table 2 Turning radius and clearance time of the vehicle

Direction of movement	R [m]	$v_{ü}$ [m/s]
Nyár Street, left-turn direction (Leg 1)	16.00	8.00
Nyár Street, right-turn direction (Leg 1)	16.00	8.00
Liget Street, west side leg left-turn direction (Leg 2)	20.00	8.94
Liget Street, west side leg right-turn direction (Leg 2)	16.00	8.00
Szalay Street, left-turn direction (Leg 3)	16.00	8.00
Szalay Street, right-turn direction (Leg 3)	12.00	6.93
Liget Street, east side leg left-turn direction (Leg 4)	16.0	8.00
Liget Street, east leg right-turn direction (Leg 4)	12.00	6.93

R stands for vehicle turning radius. Fig. 7 shows the traffic junction sketch. Apart from the clearance time, the entry time is also considered as a significant parameter.

Calculation of entry time (B):

$$B = \frac{s_b}{v_b}, \quad (2)$$

where:

- s_b: entry distance;
- v_b: entry speed.

Entry speeds:

- For pedestrians: 1.5 m/s;
- For cyclists: 11.1 m/s;
- For vehicles in case of straight entering: 13.9 m/s;
- For vehicles in case of entering by turning: 11.1 m/s.

The light-signalling devices are switched on and off in accordance with 'ÚT 1-1.204' (2003) of Regulation of Traffic Control by Traffic Lights (FISZ).

Possible phase orders:

- P1-P2-P3;
- P2-P1-P3;
- P1-P2;
- P1-P3;
- P2-P3.

Fig. 8 depicts the course of phases:

- GT_{min}: Minimum Green Time;
- GT_{max}: Maximum Green Time;
- HT: Headway time.

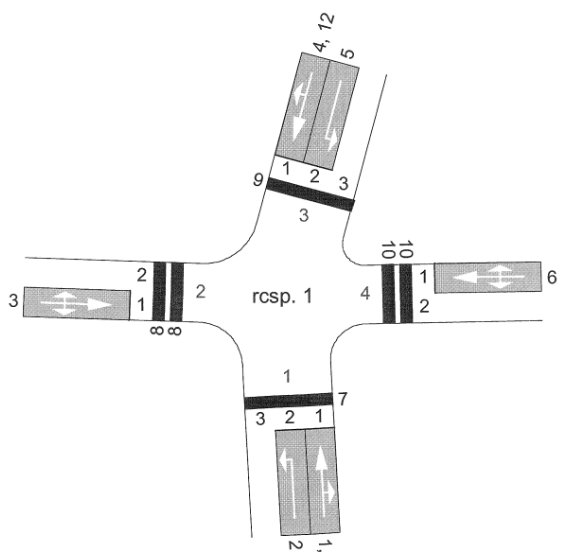


Fig. 7 Traffic junction sketch

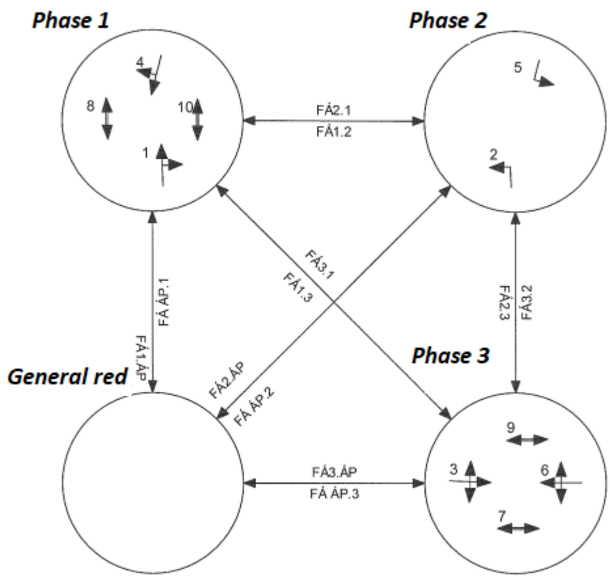


Fig. 8 Course of phases

Table 3 shows the extensions of green times. Light-signalling devices can only be switched on or off with the on/off computer programme.

The order of the signal images of the switch-on programmes is as follows:

1. All signals are dark if not in flashing amber mode.
2. Flashing amber signal in each direction for at least 5 seconds, pedestrian signals are dark.
3. Pedestrian signals are set to danger-mode.
4. On the road with priority, a clear (green) signal with a minimum duration is activated on the traffic signals for vehicles. In the other directions, after the transitional (amber) signals, the lights for vehicles are switched to red.
5. After the last danger-image signal lit up, transition to the valid signal-image programmed to the switch-on point in the phase plan, which shall preferably be the clear signal of the main direction.

Scheduled cycle switches:

- 5 a.m.: flashing amber;
- 5 a.m. – 22.30 p.m.: P1 program depending on traffic;
- 22.30 p.m.: flashing amber.

Table 3 Extension of green times

Phase	GT_{min} [sec]	GT_{max} [sec]	Headway [sec]	Extension [sec]
P1	10	23	4	0-13
P2	7	16	3	0-9
P3	12	25	3	0-13

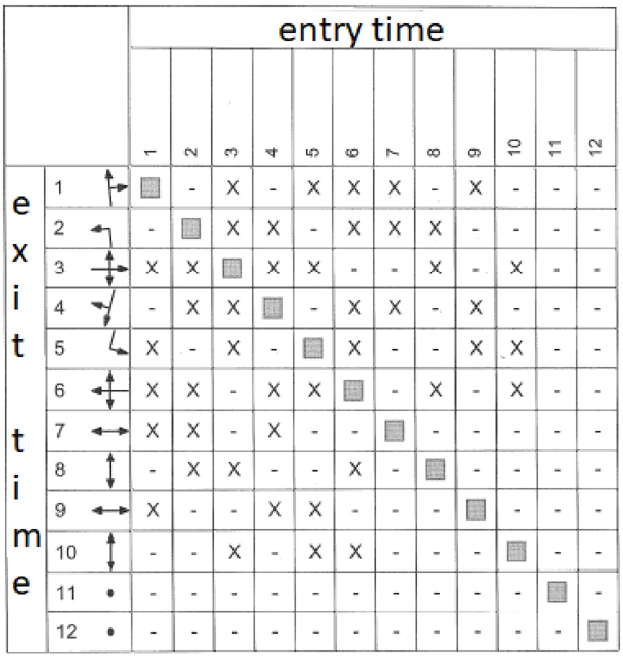
While observing traffic safety and national signal-orders, departing from the order is allowed only if the derivation cannot be achieved due to technical limitations or a complex junction design (or a number of junctions are jointly controlled).

With the exception of technical failure requiring immediate shutdown, the switch-off mode of the equipment is to be carried out by a separate switch-off program so that the transition from traffic light control to the road sign control of priority is to be in accordance with the principle of continuity and aspects of traffic safety.

The switch-off programme shall be designed in the way that priority provided by road signs for the main direction or for the direction with higher priority can only be exercised when vehicles and pedestrians arriving properly at the end of the clear signal from subordinated directions or roads with lower priority have already left the conflict zone. The minimum 'green time' period of signal groups for vehicles is uniformly 5 sec.

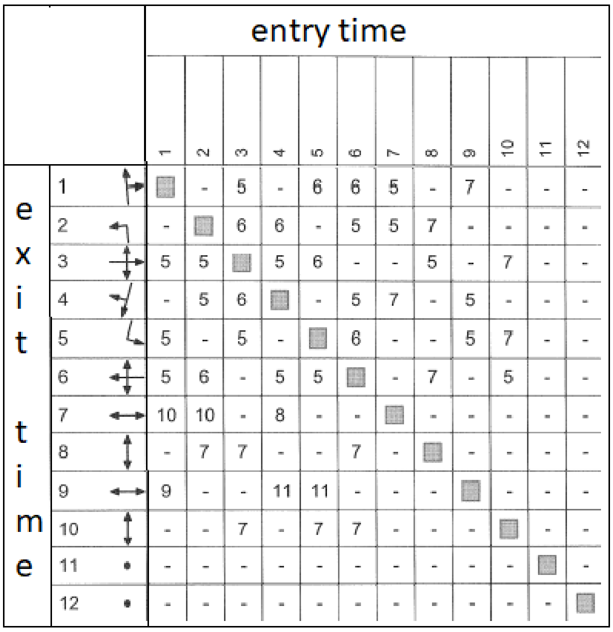
Fig. 9 depicts the matrix of the clear signals simultaneously prohibited. Fig. 10 shows the matrix of intermediate times. Table 4 shows the directions controlled by traffic lights in case of a vehicle.

Transport is a multi-factor activity, and it follows that the continuous, rapid development and co-operation of the elements affecting transport requires a well-functioning transport system. The solution to the situation is complicated by the fact that the coordination of the development



exit time \ entry time	1	2	3	4	5	6	7	8	9	10	11	12
1	■	-	X	-	X	X	X	-	X	-	-	-
2	-	■	X	X	-	X	X	X	-	-	-	-
3	X	X	■	X	X	-	-	X	-	X	-	-
4	-	X	X	■	-	X	X	-	X	-	-	-
5	X	-	X	-	■	X	-	-	X	X	-	-
6	X	X	-	X	X	■	-	X	-	X	-	-
7	X	X	-	X	-	-	■	-	-	-	-	-
8	-	X	X	-	-	X	-	■	-	-	-	-
9	X	-	-	X	X	-	-	-	■	-	-	-
10	-	-	X	-	X	X	-	-	-	■	-	-
11	-	-	-	-	-	-	-	-	-	-	■	-
12	-	-	-	-	-	-	-	-	-	-	-	■

Fig. 9 Matrix of simultaneously prohibited clear signals



exit time \ entry time	1	2	3	4	5	6	7	8	9	10	11	12
1	■	-	5	-	6	6	5	-	7	-	-	-
2	-	■	6	6	-	5	5	7	-	-	-	-
3	5	5	■	5	6	-	-	5	-	7	-	-
4	-	5	6	■	-	5	7	-	5	-	-	-
5	5	-	5	-	■	6	-	-	5	7	-	-
6	5	6	-	5	5	■	-	7	-	5	-	-
7	10	10	-	8	-	-	■	-	-	-	-	-
8	-	7	7	-	-	7	-	■	-	-	-	-
9	9	-	-	11	11	-	-	-	■	-	-	-
10	-	-	7	-	7	7	-	-	-	■	-	-
11	-	-	-	-	-	-	-	-	-	-	■	-
12	-	-	-	-	-	-	-	-	-	-	-	■

Fig. 10 Matrix of interim times

Table 4 Directions controlled by traffic lights

Line number	Directions controlled by traffic lights				
	Place of entry	1	2	3	4
1	1			x	x
2	1		x		
3	2	x		x	x
4	3	x	x		
6	3				x
6	4	x	x	x	

of the factors from the point of view of transport is not self-evident. Participants in the development described in this study sought to apply high-level solutions that represent the technical standards of the age. The study provides insight into how the coordinated, optimal and economical operation of the system is achieved through a specific practical example. The given example, in addition to showing the coordinated operation between the individual elements (operation of traffic lights, optimal traffic control), considers the protection of human life to be the most important task of any system.

4 Conclusions

In the study, an already operating traffic light junction, and a junction under redevelopment were presented.

Redevelopment was required for two underlying reasons:

- to make the junction safer,
- to make energy-consumption more economical.

The data presented in the first part of the study shows that applying smart solution results in energy consumption reduction, which entails a more economical operation of the system.

The installation of traffic light-controlled system of the junction described in the second part was particularly necessary, since at this road junction there are about 4–5 accidents per year.

Our goal with this study is to raise awareness of the importance of smart transport and to draw conclusions that may be appropriate for the development of a mathematical model (Péter and Fazekas, 2014).

References

Aldegheishem, A., Yasmeen, H., Maryam, H., Shah, A. M., Mehmood, A., Alrajeh, N., Song, H. (2018) "Smart Road Traffic Accidents Reduction Strategy Based on Intelligent Transportation Systems (TARS)", Sensors, 18(7), 1983.
https://doi.org/10.3390/s18071983

Benevolo, C., Dameri, R. P., D'Auria, B. (2016) "Smart Mobility in Smart City", In: Torre, T., Braccini, A., Spinelli, R. (eds.) Empowering Organizations, Springer, Cham, pp. 13–28. ISBN 978-3-319-23783-1
https://doi.org/10.1007/978-3-319-23784-8_2

Bilal, J. M., Jacob, D. (2007) "Intelligent Traffic Control System", In: 2007 IEEE International Conference on Signal Processing and Communications, Dubai, United Arab Emirates, pp. 496–499. ISBN 978-1-4244-1235-8
https://doi.org/10.1109/ICSPC.2007.4728364

Cangeloso, S. (2012) "LED Lighting: A Primer to Lighting the Future", Make Community, LLC. ISBN: 1449334768

Castro, M., Jara, A. J., Skarmeta, A. F. G. (2013) "Smart Lighting Solutions for Smart Cities", In: 2013 27th International Conference on Advanced Information Networking and Applications Workshops, Barcelona, Spain, pp. 1374–1379. ISBN 978-1-4673-6239-9
https://doi.org/10.1109/WAINA.2013.254

Department of Transport Infrastructure of the Ministry of Transport, Comminications and Energy (2003) "ÚT 1-1.204 Highway Design and Specification Standard on Regulations on traffic light based traffic management", Hungarian Road- and Railway Company, Budapest, Hungary.

Department of Transport Infrastructure of the Ministry of Transport, Communications and Energy (2005) "ÚT 2-1.113 Highway Design and Specification Standard on the design of road markings", Hungarian Road- and Railway Company, Budapest, Hungary.

Department of Transport Infrastructure of the Ministry of Transport, Communications and Energy (2007) "ÚT 2-1.150 Highway Design and Spacifications Srtandard on Form, size, colours and arrangement of vehicular road markings", Hungarian Road- and Railway Company, Budapest, Hungary.

Department of Transport Infrastructure of the Ministry on Transport, Communication and Energy (2009) "ÚT 2-1.219 Highway Design and Specification Standard on the design, installation and operation of traffic light based trafficc management", Hungarian Road- and Railway Company, Budapest, Hungary.

Duan, W., Nasiri, R., Karamizadeh, S. (2019) "Smart City Concepts and Dimensions", In: ICIT 2019: Proceedings of the 2019 7th International Conference on Information Technology: IoT and Smart City, Shanghai, China, pp. 488–492. ISBN 978-1-4503-7663-1
https://doi.org/10.1145/3377170.3377189

HOFEKA Electrical Industry and Trade Ltd. (2022) "HDMR – Dinamikus Mozgásérzékelő Rendszer" (HDMR – Dynamic Motion Detection System) [online] Available at: https://hofeka.hu/hdmr-dinamikus-mozgaserzekelo-rendszer [Accessed: 05 March 2022] (in Hungarian)

Lakatos, I., Péter, T., Óberling, J., Pup, D., Szauter, F. (2016) "An in-depth analysis of cycling and pedestrian accidents in Hungary", In: 2016 12th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications (MESA), Auckland, New Zealand, pp. 1–6. ISBN 978-1-5090-6191-4
https://doi.org/10.1109/MESA.2016.7587113

Péter, T. (2012) "Modeling nonlinear road traffic networks for junction control", International Journal of Applied Mathematics and Computer Science, 22(3), pp. 723–732.
https://doi.org/10.2478/v10006-012-0054-1

Péter, T., Fazekas, S. (2014) "Determination of vehicle density of inputs and outputs and model validation for the analysis of network traffic processes", Periodica Polytechnica Transportation Engineering, 42(1), pp. 53–61.
https://doi.org/10.3311/PPtr.7282

Salama, A. S., Saleh, B. K., Eassa, M. M. (2010) "Intelligent cross road traffic management system (ICRTMS)", In: 2010 2nd International Conference on Computer Technology and Development, Cairo, Egypt, pp. 27–31. ISBN 978-1-4244-8844-5
https://doi.org/10.1109/ICCTD.2010.5646059

Šemanjski, I., Mandžuka, S., Gautama, S. (2018) "Smart Mobility", In: 2018 International Symposium ELMAR, Zadar, Croatia, pp. 63–66. ISBN 978-953-184-244-0
https://doi.org/10.23919/ELMAR.2018.8534693

Sumalee, A., Ho, H. W. (2018) "Smarter and more connected: Future intelligent transportation system", IATSS Research, 42(2), pp. 67–71.
https://doi.org/10.1016/j.iatssr.2018.05.005

Integrated smart system for the coordination of traffic light traffic management and intelligent public lighting in Hungary

Nikolett, Fecser

2022-08-30

Fecser N, Árvai T, Hausel I, et al., (2023) Integrated smart system for the coordination of traffic light traffic management and intelligent public lighting in Hungary. Periodica Polytechnica Transportation Engineering, Volume 51, Number 1, 2023, pp. 49–56

https://doi.org/10.3311/PPtr.20397