REPORT

THE TRISTAR AND KRAKÓW SYSTEMS
A PTV BALANCE AND PTV EPICS
CASE STUDY

Florian Weichenmeier, Dr. Robert Hildebrandt

PTV group

Haid-und-Neu-Str. 15

76131 Karlsruhe

florian.weichenmeier@ptvgroup.com, robert.hildebrandt@ptvgroup.com

Dr hab. inż. Andrzej Szarata, prof. PK

Cracow University of Technology

ul. Warszawska 24

31-155 Krakow

aszarata@pk.edu.pl

The JCT Traffic Signal Symposium, Warwick, 18th September 2015

Abstract

PTV Balance and PTV Epics are adaptive network and local signal control methods that feature strong optimization algorithms, easy setup, coordination and TSP capabilities and full integration into the PTV Vision suite. This paper explains their background and the technics that they use as well as the supply chain and calibration workflow. Two case studies show cities in Poland where they are in use. In the Tricity (Gdansk, Gdynia and Sopot) 150 controllers are equipped with Balance and Epics, in Cracow around 30. For the latter detailed results from an evaluation study done by the Technical University of Cracow are presented. They show very promising decreases of travel time on some streets, but also the hazards of before-after studies, as the traffic situation can change a lot in a few years.

1 About PTV Balance and PTV Epics

PTV Balance and PTV Epics are a network and local adaptive control method respectively. Having been in use for many years in the German speaking area, they have now been redeveloped to fit closely into the PTV Vision Suite as a part of the PTV Real Time products. They undertake local and network wide mathematical optimization that employ traffic models to calculate and minimize the total delay and the number of stops. Dynamic TSP and integration of non-motorized traffic allow to aspire a global optimum that respects all road users. Great care has been taken to minimize the effort needed to install, supply and fine-tune the systems. The seamless integration into PTV Vissim and PTV Visum allows to test the effects of these control methods beforehand.

1.1 PTV Epics

PTV Epics is a local adaptive control designed to run on a single intersection. It was developed at the Technical University in Munich by Dr. Joachim Mertz in 2001 as an attempt to simplify the way public transport priority is usually conducted. Instead of using flow diagrams that cover each and every possible situation how one or more busses may approach an intersection, Epics tries to model and minimize the total delay that all road users experience in the near future. By giving it an adequate weight the bus will gain priority without disturbing the intersection more than necessary.

1.1.1 Detector layout requirements

Epics gets along with a wide variety of detector positions, but its favourite are sensors that are 40-50m before the stop line. Long loops can be utilized as well for on-demand signals. It is of course important that turning vehicles are counted correctly, so in case of doubt it is advisable to put the detectors nearer to the stop line.

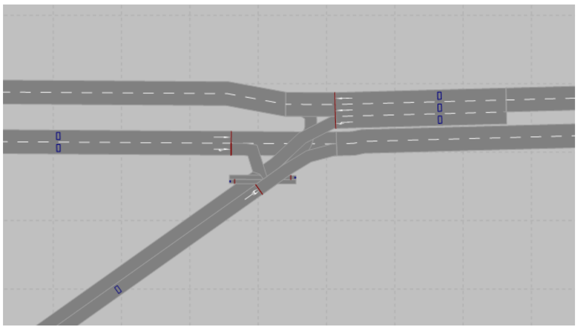

Figure 1: Epics and Balance detector layout

1.1.2 Control base

Epics is based on stages and interstages. An interstage should cover the intergreen times but not necessarily the minimum green times. The underlying fixed time programs should be well planned and coordinated, as they form the basis for all subsequent action.

1.1.3 The Epics traffic model and optimization

Epics uses a vertical-queuing approach similar to Transyt, see [Robertson, 1969]. It employs three sources of information about the surrounding:

1. The current and past detector information,
2. Public transport in the vicinity (as given by radio or V2X communication),
3. And a queue length estimator as corrective.

This information is used to estimate the traffic inflow to the intersection every second for the next 100 seconds. It serves as the basis for the optimization procedure that also takes place every second. It uses a two-step approach: firstly a time-ordered shortest way algorithm that chooses the right stage sequence, secondly a hill-climbing approach that fine-tunes the starting points of the interstages. The performance index to be minimized is the weighted sum of the delay for all approaches and traffic modes detected at this intersection.

1.1.4 Deployment

Epics is essentially a piece of source code, written in pure ANSI-C. It was designed to be implemented by hardware manufacturers into their firmware. Every second it is called by the control kernel with the current status values and returns the interstage that should be started in this very second (or 0 if none). Alternatively it can return the desired signal status.

This optimization algorithm was designed to be very fast so as to run even on weak controller hardware (minimum are 150 MHz and 4 MB of RAM), even for very big intersections (our currently biggest uses more than 80 interstages).

1.2 PTV Balance

PTV Balance is an adaptive network control that was developed at the Technical University of Munich by (now) Prof Dr Bernhard Friedrich in the late 90s. It has been brought to market by GEVAS software GmbH in many projects in Germany, Austria, Poland in the last decade and is now enhanced and refined by PTV group. Balance is a software module that is intended to be used by hardware manufacturers and system integrators alike to enable them to enhance their systems with adaptive control.

As PTV Epics, Balance is based on stages and interstages. It calculates a fixed time plan every five minutes that fits optimally to the current traffic demand in the network. Its ideal partner on the local side is PTV Epics, but many other stage or signal based systems can be used as well.

1.2.1 PTV Balance traffic model and optimization

PTV Balance uses a combination of traffic flow models to compute delay, number of stops and queue lengths for each approach. The macroscopic traffic model estimates the traffic relations from each entry to the network to each exit. The traffic volumes and turning proportions generated by PTV Optima or other traffic state systems can also be utilized.

A mesoscopic model with a one-second resolution computes the deterministic part of the measures of effectiveness. Stochastic fluctuations in traffic as well as over capacity conditions are captured through a macroscopic queuing model. The Indicator Model fuses results from both model components into a single Performance Index PI.

The control model in PTV Balance optimizes the green time lengths (splits) and the offsets relatively to the common cycle time. The result is a frame signal plan for every single junction that determines fixed intervals for the stage of the local control. The local controllers can adjust themselves to the current traffic with their local detectors or just apply the fixed signal program transmitted by PTV Balance.

Genetic Algorithms are used for optimization. This method imitates the process of natural evolution. Better signal switching will prevail over several generations and get even stronger in the process. The PTV Balance evolution, however, leads to a hopefully optimal solution in only 5 minutes. Genetic Algorithms have proven that their probability of success is very high in complex solution spaces, and that they are very close to the theoretical optimum. The quality of the genetic algorithm that is used in PTV Balance has been proven in a Ph.D. thesis at the Technical University of Munich in 2008 [Braun, 2008].

1.3 Supply and workflow

All road network and traffic related parameters for Balance are supplied with PTV Visum. It allows comfortable and flexible supply of links and intersections and eases the process of building and assigning the origin-destination matrix that Balance uses as base for its dynamic demand estimation. The Visum supply can also be used as basis for a Vissim network, so there is no need for double provision for simulation and adaptive control.

Epics as such has no road related parameters and can be supplied solely within Vissim.

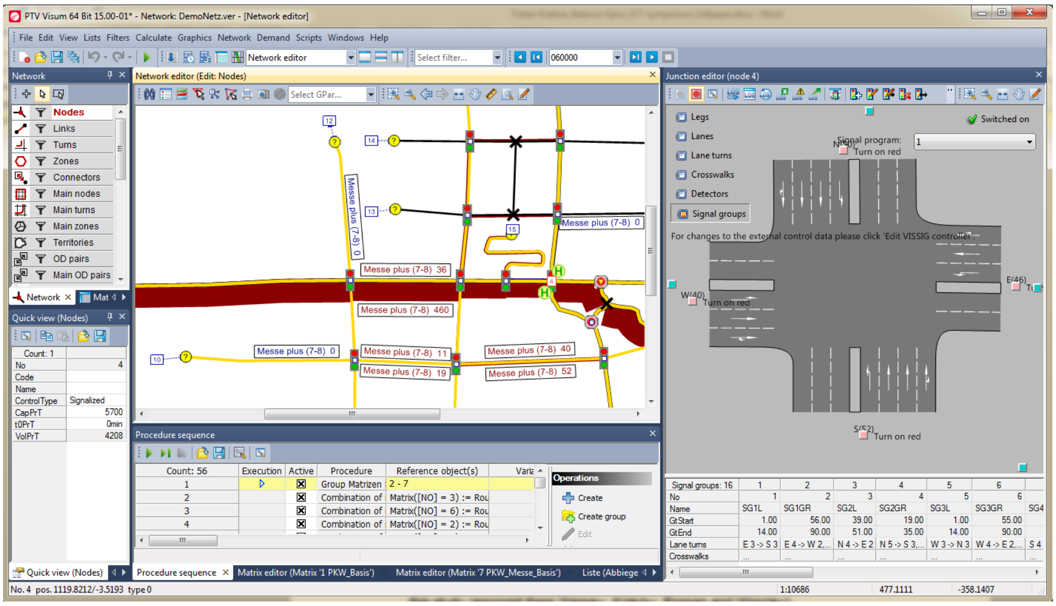

Figure 2: PTV Visum as supply tool for Balance

The supply of the signal related parameters for Epics and Balance is done in Vissig, which is a part of PTV Vissim and PTV Visum. Previously usable only for fixed time planning, it has been enhanced to cover all necessary parameters for Balance and Epics, which consist of the stages, allowed interstages, signal programs, weights, and additionally for Epics the detector-signal mapping, calling points and coordination periods.

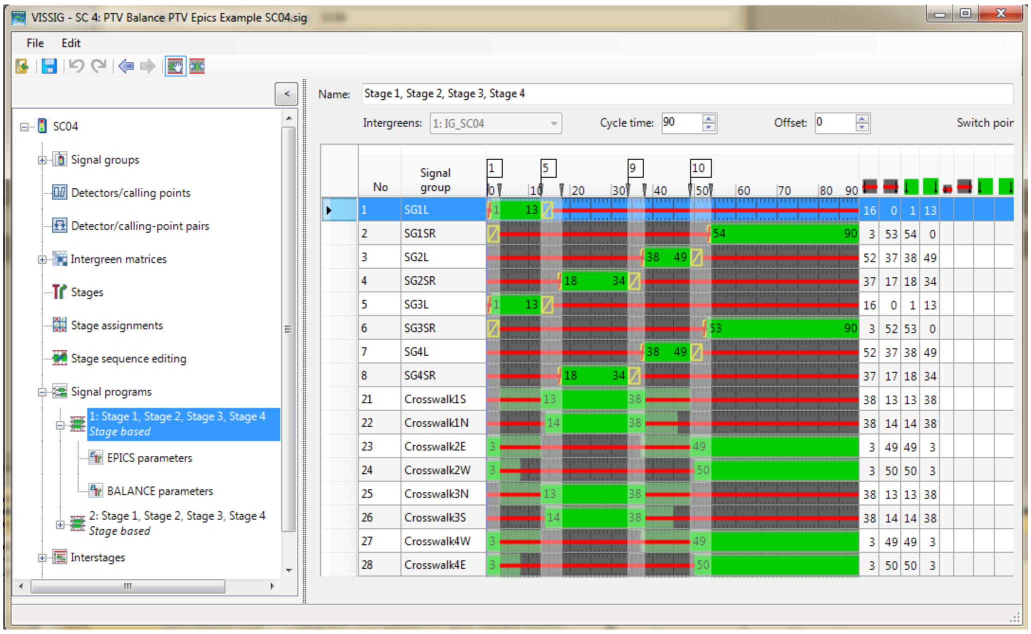

Figure 3: Vissig supply tool for Epics and Balance

During the calibration process Balance and Epics are running as signal controls inside of Vissim. This allows to test the setup thoroughly before applying it on the road. Of course the supply for the simulation is the same as for a real-world project so there is again no work doubly done, and changes later on can be quickly tested in the simulation before applying them in the field.

PTV developed a user-friendly web-based GUI that enables the user to watch the behaviour of the controls. It features the calculation results of Balance and Epics in a map as Level of Service, traffic demand, delays, queue lengths and other parameters and allows both a deep insight into the optimization process and a first-glance view of the current status. This GUI is running in simulation and in real-world systems alike.

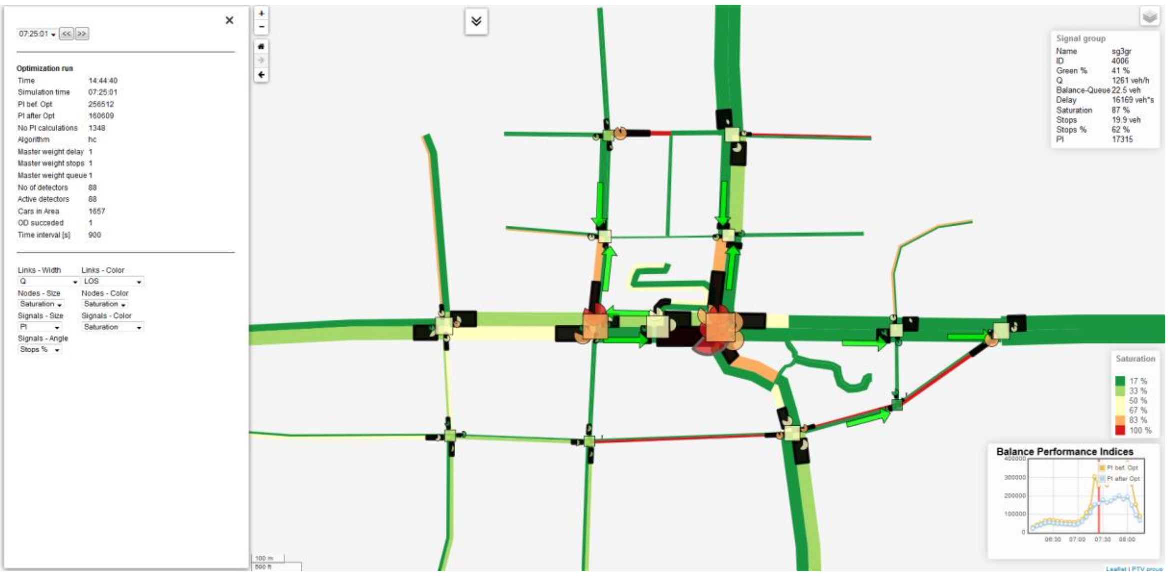

Figure 4: Web-based GUI for Balance and Epics

For example a direct comparison of the cars in Vissim and of the queues modelled in Epics allows a quick evaluation if the detectors are placed correctly and the control is working properly.

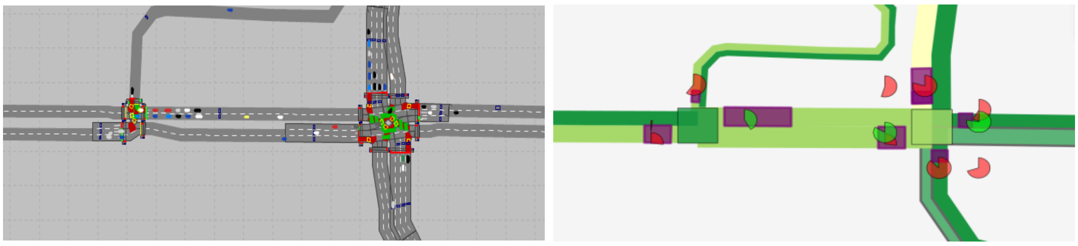

Figure 5: Queues in Vissim and modelled in Epics

1.4 Balance, Epics and PTV Optima – a complete traffic management system

Balance and Epics are able to run on their own or embedded into traffic management centres. Their ideal partner is the PTV Optima strategic management system. This new piece of software features comprehensive data fusion and traffic state estimation, using a reliable model-based short term traffic forecast. Among its unique capabilities is the integration of a real-time decision support system. This feature allows to assess and compare the results of different traffic control strategies before applying them on the road, thereby decreasing the error probability and subsequently the delays that the road users experience. Developed in Rome, it uses state-of-the-art modelling techniques and features many interfaces to connect to traffic control centres. It is currently in use in Torino, Moscow, London and many other cities and soon together with Balance and Epics in the city of Lublin, Poland.

Optima and Balance and Epics have the unique advantage of close coupling with the PTV Vision suite, so the supply for all three is done at once in PTV Visum and PTV Vissim.

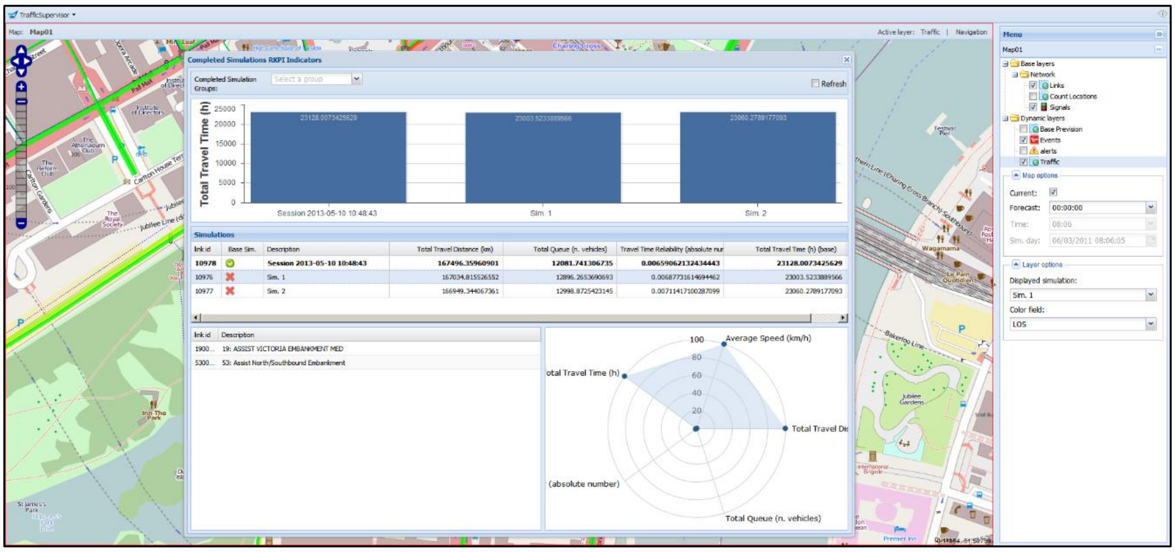

Figure 6: PTV Optima - calculation of key performance indicators

2 The Tristar system

In 2010 the three cities of Gdansk, Gdynia and Sopot decided to renew and combine their road traffic systems. Together they form the biggest conurbation on the Polish Baltic Sea coast with a total city population of 740.000. The resulting tender was won in 2011 for 134 Mio PLN (22.7 Mio £) by Qumak SA, a Polish IT and telecommunication company based in Krakow. With the help of the subcontractors MSR Traffic (Przeźmierowo), GEVAS software (München), PTV group and others over 150 controlled intersections, covering nearly all of the three cities, were re-engineered, equipped with a TSP system and put under the adaptive control of PTV Balance and PTV Epics. On top of them a strategic management system was installed, utilizing dynamic message signs, ANPR cameras and a CCTV system. A city-wide dynamic traffic model (DRIVERS by GEVAS software) calculates the traffic state and the current flows in the road network and forwards them to Balance as basis for the optimization. The resulting optimized signal plans are then transferred to the MSR Traffic controllers where Epics adjusts them to the present detector situation.

Figure 7: The Tristar area

Figure 8: Tristar control room

The project is currently being finished, and detailed before/after-comparisons of the resulting travel times in the network will be undertaken in autumn 2015 by the University of Gdansk as part of the acceptance procedure.

A study published in March 2015 by Deloitte and Targeo showed that the total time spent in traffic jams in Gdansk decreased by more than 20% between 2011 and 2014. This yielded Gdansk a well-earned top rank of the 7 big Polish cities that were examined in this study (amongst them Warsaw, Cracow, Poznan and Wroclaw).

3 The Krakow system

The city of Krakow is an old and world-famous city in the south of Poland with 760.000 inhabitants in a conurbation of 10 Mio people in a 100km radius. The city has been very actively renewing their road traffic system for a long time. They have an installation of the Siemens Motion system since 2008 at 37 intersections. In 2010-2013 they added a strategic management system by GEVAS software that included PTV Balance and PTV Epics at 30 intersections, including TSP at the local level. The local controller were produced and installed by Vialis polska (now Global Traffic Systems Sp.z.o.o, Przeźmierowo). Traffic centre and controllers are connected via fibre optics using the OCIT-O 2.0 protocol.

The area that is controlled by Balance and Epics consists of four road stretches, three around 4 km long, one (Botewa) 7.2 km. Together they form a large part of the main access roads to and from the city centre. Public transport lines with trams and/or buses are on every stretch with the exception of parts of Botewa Street.

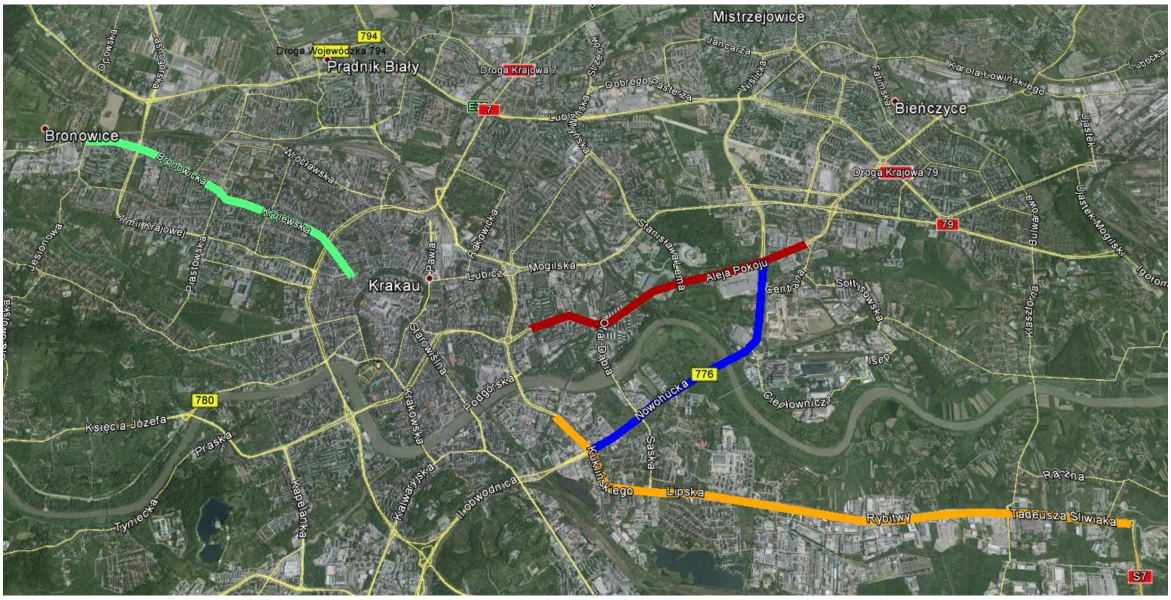

Figure 9: The Cracow system, with Bronowicka Street (green), Al. Pokoju (red), Nowohucka Street (blue) and Botewa Street (orange)

3.1 Evaluation results in Cracow

As part of the acceptance procedure the Krakow University of Technology conducted extensive field tests before and after the installation of the system. The focus of the evaluation was on Bronowicka Street, Aleja Pokoju and Nowohucka Street as Botewa Street was installed in a separate construction stage.

Several cars equipped with GPS sensors drove the streets up and down for several days, while students, also equipped with sensors, were placed in the trams and took note of every stop. There is both, trams and cars traffic on this area. Two-way double tramway track is located in the middle part of roadway, outer lanes are dedicated for car traffic. All important intersections are equipped with traffic signalling. Within the framework of this investment, a traffic control system was installed, providing priorities for trams. Expectations were related to the reduction of travel time both, of public and private transport. According to the assumed methodology, the measurements were carried out in two series: “before” and “after” the implementation of the investment, each time for three days. For the purpose of public transport vehicles, the number of measurements for each stage were established according to analysis of PT traffic conditions and didn’t exceed 110 routes. For private transport, number of run (in each stage) of the test car through the analysed corridors was 65.

3.1.1 The hazards of signal control evaluations

The before- and after-measurements in the Krakow-project was provided within 2 years. This alone imposes a major hazard that was promptly met in this evaluation: In the after-measurements one major road (Al. Jana Pawla II, just north of Al. Pokoju) was blocked due to construction works, resulting in a 12% increase in car traffic volume on Al. Pokoju in the main directions and in traffic changes also on Nowohucka, where one direction had greatly decreased traffic in the morning. Furthermore the amount of tram passengers in

Al.Pokoju and Bronowicka was greatly increased (43-118%), which had an influence on the dwell times in the stations and thus on the approach times to the traffic lights, affecting TSP quality in general.

But we still wanted to estimate the quality of the new controls compared to the old ones. To get a general feeling about this we decided to focus on the results on Nowohucka and Bronowicka, as Al.Pokoju had too many changes to be really comparable.

3.1.2 Results of the evalution

On Nowohucka there is a remarkable decrease in traffic volume in one direction in the morning (45% less), but it affects the lesser traffic stream, while the main direction in the morning stays the same. It gave Balance and Epics the opportunity to make life much easier for the main direction, resulting in a 20% decrease in delay for it, while increasing the opposite direction a meagre 2%. So the total delay in the morning is 14% decreased in Nowohucka for the car traffic. In the afternoon the traffic volumes are much (11%) higher in one direction, but the overall delay is still reduced by altogether 23% which is an outstanding result.

The buses on Nowohucka experience an overall reduction of travel time of 5%, ranging from -6% (so an increase of delay) to +11%. They don’t have separate lanes and are quite tightly bound to the car traffic. And the priority the system reserves for them is not very high because of the huge car traffic volumes.

On Bronowicka the situation is completely different: The tram lines on this street are mostly on separate lanes, so their travel time is more or less determined by the traffic lights. And due to the dense tram schedule (42 trams / hour during peak period) any PT prioritization will severely affect the individual traffic. The results of the evaluation show just this: The trams on Bronowicka have their travel time reduced by 10% on average, with 5% in the morning and 15% in the afternoon peak hour. The individual traffic had their travel times reduced by 9% in the morning and increased by 10% in the afternoon. The changes of travel time for the individual traffic on Bronowicka are indirect proportional to those of the public transport there, except for the morning peak in direction one, where both fare a lot better.

Detailed results can be found in Table 1 below.

4 Conclusion

PTV Balance and PTV Epics are adaptive controls that are both technically mature and newly adjusted to provide city administrations with an alternative that uses all the advantages of the PTV Vision suite. Their core features are:

- Dynamic green wave calculation in arterials and grid networks with genetic optimization algorithms.
- Based on the current traffic demand in the network.
- In combination with PTV Optima also based on the forecasted traffic demand, e.g. due to road blockages, accidents or VMS detours.

- Minimizing travel times and the number of stops and thereby reducing the traffic emissions.
- True mathematical optimization also on the local level, with a time horizon of 100 seconds or more.
- Features strong Transit Signal Priority without disregard for all other road users.
- Easy setup and reduction of parameters as far as sensible
- Seamless integration in PTV Visum and PTV Vissim.
- Easily integrated into modern controllers and signal management centres.

New evaluation studies from Cracow show that Balance and Epics are capable of reducing the travel times both for individual traffic and public transport. But they also show that sometimes it's not possible to reduce both travel times at the same time, as no one is able to overcome the physics of traffic. And often other effects in traffic completely superpose the signal control possibilities.

Table 1: Evaluation details

Street	Mode	Period	Direc-tion	Count before, passen-gers or [cars/h]	Count after, passen-gers or [cars/h]	Absolute change of passengers /cars	Relative change of passengers / cars [%]	Travel Time before	Travel Time after	Travel Time change absolut	Travel Time change relative
Al.Pokoju	Car	06:00-10:00	I	1047	1027	-20	-2%	6,24	6,32	0,08	1%
Al.Pokoju	Car	06:00-10:00	II	1395	1577	182	13%	7,71	9,25	1,54	20%
Al.Pokoju	Car	14:00-18:00	I	1485	1659	174	12%	8,41	9,11	0,70	8%
Al.Pokoju	Car	14:00-18:00	II	1176	1175	-1	0%	8,71	10,86	2,15	25%
Al.Pokoju	Tram	06:00-10:00	I	686	1402	716	104%	11,72	10,83	-0,89	-8%
Al.Pokoju	Tram	06:00-10:00	II	1348	2944	1596	118%	12,32	12,64	0,32	3%
Al.Pokoju	Tram	14:00-18:00	I	1604	2603	999	62%	12,89	11,65	-1,24	-10%
Al.Pokoju	Tram	14:00-18:00	II	1164	2320	1156	99%	12,4	12,29	-0,11	-1%
Bronowicka	Car	06:00-10:00	I	520	525	5	1%	8,6	7,69	-0,91	-11%
Bronowicka	Car	06:00-10:00	II	683	692	9	1%	8,17	7,58	-0,59	-7%
Bronowicka	Car	14:00-18:00	I	741	758	17	2%	10,88	11,11	0,23	2%
Bronowicka	Car	14:00-18:00	II	619	623	4	1%	8,49	10,05	1,56	18%
Bronowicka	Tram	06:00-10:00	I	815	1164	349	43%	10,85	9,73	-1,12	-10%
Bronowicka	Tram	06:00-10:00	II	1105	1799	694	63%	10,91	10,97	0,06	1%
Bronowicka	Tram	14:00-18:00	I	1342	1694	352	26%	12,78	10,27	-2,51	-20%
Bronowicka	Tram	14:00-18:00	II	1253	1790	537	43%	10,85	9,73	-1,12	-10%
Nowohucka	Bus	06:00-10:00	I	642	620	-22	-3%	11,02	11,63	0,61	6%
Nowohucka	Bus	06:00-10:00	II	684	534	-150	-22%	12,18	11,35	-0,83	-7%
Nowohucka	Bus	14:00-18:00	I	814	544	-270	-33%	16,81	16,33	-0,48	-3%
Nowohucka	Bus	14:00-18:00	II	595	473	-122	-21%	13,98	12,63	-1,35	-10%
Nowohucka	Car	06:00-10:00	I	1596	877	-719	-45%	6,25	6,39	0,14	2%
Nowohucka	Car	06:00-10:00	II	2288	2283	-5	0%	6,61	5,28	-1,33	-20%
Nowohucka	Car	14:00-18:00	I	2171	2410	239	11%	7,81	6,76	-1,05	-13%
Nowohucka	Car	14:00-18:00	II	1771	1765	-6	0%	9,34	6,17	-3,17	-34%

5 Literature

- Bauer, M., Szarata, A. (2015). The Methodology of Urban Transport Corridors Evaluation, proceedings of 2015 Models and Technologies for Intelligent Transportation Systems (MT-ITS) conference, 3-5. June 2015. Budapest, Hungary
- Braun, R. (2008). Ein echtzeitfähiger Evolutionärer Algorithmus zur netzweiten Optimierung der Lichtsignalsteuerung. München: Dissertation am Lehrstuhl für Verkehrstechnik, Technische Universität München.
- Braun, R., Kemper, C. (2008). GALOP-Online – ein Genetischer Algorithmus zur netzweiten Online-Optimierung der Lichtsignalsteuerung. Forschungsgesellschaft für Straßen- und Verkehrswesen, HEUREKA '08, Optimierung in Verkehr und Transport - Tagungsband . Köln: FGSV Verlag, ISBN 978-3-939715-48-1.
- Deloitte, Targeo (2014). Raport o korkach w 7 największych miastach Polski. http://korkometr.targeo.pl/Raport_Korki_2014.pdf [last visited 22.07.15]
- Friedrich, B. (1999). Ein verkehrsadaptives Verfahren zur Steuerung von Lichtsignalanlagen. Dissertation. Fachgebiet Verkehrstechnik und Verkehrsplanung, TU München
- Friedrich, B., Mertz, J. (1996). Abschlußbericht Munich COMFORT Arbeitsbereich 444, Städtische Verkehrssteuerung. München: Fachgebiet Verkehrstechnik und Verkehrsplanung, TU-München.
- Friedrich, B., Mertz, J., Ernhofer, O., Clark, M., Toomey, C., McLean, T., et al. (1998). TABASCO Deliverable 9.4: Urban Traffic Control with PT Priority: Final Evaluation Report. Brüssel.
- Hunt, P. B., Robertson, D. I., Bretherton, R. D., Winton, R. I. (1981). SCOOT, A Traffic Responsive Method of Coordinating Signals, TRRL Report No. LR 1014. Crowthorne UK: Transport and Road Research Laboratory.
- Kimber, R. M., Hollis, E. M. (1979). Traffic Queues and delays at road junctions. TRRL Laboratory Report 909.
- Liu, H., Wu, X., Ma, W., Hu, H. (2009). Real-time queue length estimation for congested signalized intersections. Transportation Research Board C 17 (4), 412-427.
- Mertz, J. (2001). Ein mikroskopisches Verfahren zur verkehrsadaptiven Knotenpunktsteuerung mit Vorrang des öffentlichen Verkehrs (Dissertation). Veröffentlichung des Fachgebiets Verkehrstechnik und Verkehrsplanung, TU München.
- Ploss, G. (1993). Ein dynamisches Verfahren zur Schätzung von Verkehrsbeziehungen aus Querschnittszählungen. München: Fachgebiet Verkehrstechnik und Verkehrsplanung, TU München.
- PTV AG (2015a). PTV Vissim manual. Karlsruhe.
- PTV AG (2015b). PTV Visum manual. Karlsruhe.
- PTV AG (2015c). PTV Epics manual. Karlsruhe.

- Robertson, D. I. (1969). TRANSYT, A traffic Network Study Tool. TRRL Report No. LR 253. Crowthorne, UK: Transport and Road Research Laboratory.
- Szarata, A. et al (2015). Raport końcowy z prac nad dokumentem: "Analiza korzyści funkcjonalnych wdrożenia projektu wraz z odwzorowaniem wpływu projektu w modelu symulacyjnym" (wersja ostateczna). Politechnika Krakowska. Cracow, Poland.
- Van Zuylen, H. J., Branston, D. (1982). Consistent Link Flow Estimation from Traffic Counts. Transportation Research B. Vol. 16B.