Trigger Framework - final report

Author: Preben Andersen, BLIP Systems A/S
Kees Den Hollander, Imtech Traffic & Intra
Lars Rosenberg Randleff, Hermes Traffic Intelligence ApS

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1 Introduction

This document describes the concept and work carried out by team 8, consisting of representatives from Imtech Traffic & Intra, BLIP Systems, and Hermes Traffic Intelligence, in relation to the Copenhagen Municipality Public Private Innovation (PPI) collaboration on Intelligent Transport Systems in spring 2014.

2 Concept description

The subject of the team is the implementation of a data trigger framework that will invoke actions (automatic or semi-automatic) based on triggers setup on a number of data sources. The trigger framework is basically divided into three parts: the triggers (from one or more data sources), trigger handlers, deciding which actions to take based on the current triggers, and finally the actual actions. The handlers are evaluated by a *Dispatcher* component that will actually initiate actions based on triggers and handler definitions. A graphical user interface (GUI) is added to the system to allow usage, inspection, and maintenance.

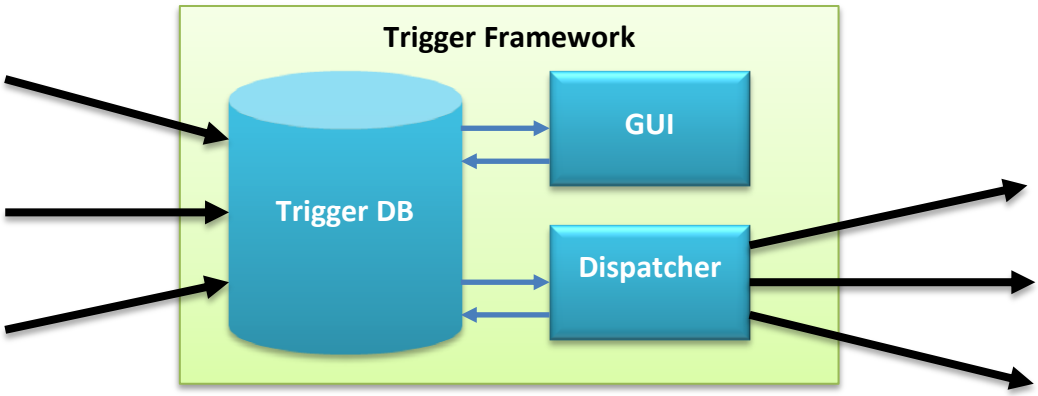

Figure 1: Trigger framework outline

Data sources may be either traffic dependent, e.g. current travel times detected by Bluetooth sensors, or non-traffic related, e.g. an online event calendar. Trigger handlers are initially divided into simple handlers based on (Boolean) logic and complex handlers based on algorithms working on a set of triggers and possibly access to the data feeding the triggers. Actions should be designed to e.g. change light settings, lane usage, sign texts, or dispatch traffic regulators (police). They will integrate with e.g. traffic light controllers to trigger program changes.

Traditionally real-time traffic data has been used to inform drivers of expected travel times, either via variable signs, radio/TMC broadcasts, or via webpages. Historical data has been used to model changes to e.g. infrastructure and light settings. With this trigger framework traffic data can be used not only to inform drivers about the current situation but also to manage traffic on a holistic scale. With an open framework architecture it will be possible to add several sources, actions and trigger handlers, e.g. based on methods from the field of artificial intelligence, at any time during the framework lifecycle.

The intention with the work carried out by team 8 was to design and partly implement a data trigger framework. The trigger framework should ideally be part of a city traffic management centre. Here it will assist traffic decision makers in managing traffic by suggesting proper actions based on current traffic, and it

will take actions on some traffic situations automatically. Having a trigger framework will also make it easier to implement both new events and new data sources for future use.

Disruptive events in daily traffic will be easier to detect and mitigate using the trigger framework, thus improving the traffic flow. This will decrease the time spent in traffic and make it less stressful for everyday commuters and travellers, regardless of their mode of transportation. Decreasing the overall time spent in traffic will also lower carbon emissions and pollution from busses and cars, and by that the trigger framework will indirectly help the City of Copenhagen on reaching its goal as being a CO_2 neutral capitol by 2025.

Users of the trigger framework are divided into two groups: people on the streets, and staff at the traffic management centre. On the street the users need an improved traffic flow to minimize both the time spent in traffic and the anger related to unexpected behaviour in traffic. Traffic management staff will be able to make informed decisions, and for trivial changes to the traffic situation parts of their work may be automated.

The work carried out by the team is primarily based on knowledge within the areas of traffic data acquisition, handling and processing. Also knowledge about how to actually change e.g. the settings of lights has been vital to the project.

3 Concept business-case

3.1 Market potential

It is the impression of the team that among road administrators the awareness of how changes in traffic conditions can be measured using dedicated sensors is rising. The same can be said about using different automatic actions to mitigate traffic problems. Having sensors and actions linked together to improve traffic flow is not unseen, but believed to be up-coming in the years to come. To do this in a relatively easy way, exploiting the vast amount of data sources already existing, will become more and more interesting, especially in larger metropolitan areas where data sources are widely available. Therefor it is believed that other Danish cities like Aalborg, Aarhus, and Odense also will be interested in implementing a trigger framework as that proposed for Copenhagen. Since there is nothing in the trigger framework that restricts its usage to Denmark it might be interesting to expand onto the entire European market, as every city with a complicated multi-modal infrastructure may mitigate traffic conditions by utilising existing and new data sources.

3.2 Scalability

Although the use of a trigger framework is based on data from multiple sources, each of which is capable of producing large amounts of data, the trigger framework itself does not need to handle all the data available for it to work. This makes the system itself easily scalable. The implementation of a single system should be enough for a road administrator unit, regardless of the size of the area under administration. As the system is cloud based it is possible to add resources to the system if necessary without any apparent changes as seen from the users.

3.3 Scale of investment

The system can be almost as covering as the customer (e.g. the City of Copenhagen) would like it to, and the more it covers the higher the investment. Also the coverage can be changed at any time during the product life cycle.

The initial costs, to implement a system as the one used for the trigger framework test (see section 4), would cover the development of the framework itself, installation of a number of sensors, and programming a small amount of signals around the inaugural area.

To broaden the scope of the framework more sensors / data sources should be added, as should changes to signal programs. While the initial setup of the trigger framework should easily be able to handle data from multiple sources of the same type it might be necessary to improve the framework to incorporate more sources, each source delivering data in a different format. The same goes for including more actions to be taken. By introducing more complex trigger handlers in the framework the outcome of it may improve drastically. Estimating time or cost of these improvements depends on the type of improvements to make.

3.4 Risks

The risks related to implementing the system can be divided to the risks concerning data from different data sources, risks from determining which actions to take as response to the data triggers recorded, and risks implied with the actual actions to take.

One risk concerning the input from several sources is that there will not be enough sources available for the trigger framework to have any effect. This is deemed a relatively small risk, as the framework can rely on both existing sources, which are numerous, and on sources that can be set up, e.g. by the municipality, with the sole purpose to feed the trigger framework. Another risk is that corrupt data may trigger unwanted actions. These data may stem from both erroneous sensors and malicious attacks. As with all other types of data retrieval security measures must be taken to ensure both the validity and the quality of input data.

With simple trigger handlers it will be quite easy to see the effects of different trigger patterns. When the number of handlers in the framework increases, so does the complexity of the handlers. There is a risk of having handlers that work in opposite directions, e.g. by having one handler requesting a given signal program while another request another program, both at the same intersection. To avoid situations like this the trigger framework should have a build in functionality to detect the possibility of these. Also proper education of the persons responsible of maintain the handlers in framework must be ensured. A third risk with the trigger handlers is that they may become obsolete and no longer work in a future situation. To mitigate this it must be ensured that all handlers are periodically checked and maintained. Also ways of the handlers to evaluate themselves based on e.g. feedback from data sources after actions have been triggered are possibilities.

If the only action to be taken by the trigger framework is to alert a person responsible for handling traffic situations within the city the framework risk not showing its full potential. To prevent this simply add more suitable actions to the framework, allowing it to take low risk actions automatically (e.g. broadcast text messages, e-mails, and alert the press). If the framework is to take high risk actions (e.g. changing signal programmes dynamically) there of course is a risk of these actions to be wrong. Therefore any possible action to be taken by the framework must be tested thoroughly before run on a live system.

4 Test description

The intention of the proof-of-concept test carried out from April 11th till April 28th 2014 was to demonstrate and prove that the trigger framework would improve traffic flow around Parken, and that various real-time and historical data sources can be used to trigger changes in the traffic handling for planned and un-planned events in Copenhagen.

Following set-up was used for the test:

- 18 BlipTrack Bluetooth and Wifi sensors were used to collect real-time data around Parken on Østerbrogade and Øster Allé (see Figure 2). Eight sensors were permanently installed and 10 were running on battery (see Figure 3).
- The BlipTrack backend and frontend was used for data processing, filtering, and data analysis (see Figure 4).
- A trigger interface was developed in BlipTrack.
- A trigger framework website was developed (see Figure 5)
- Additional program for the Imtech traffic controller at Trianglen was developed and implemented (see Figure 6).

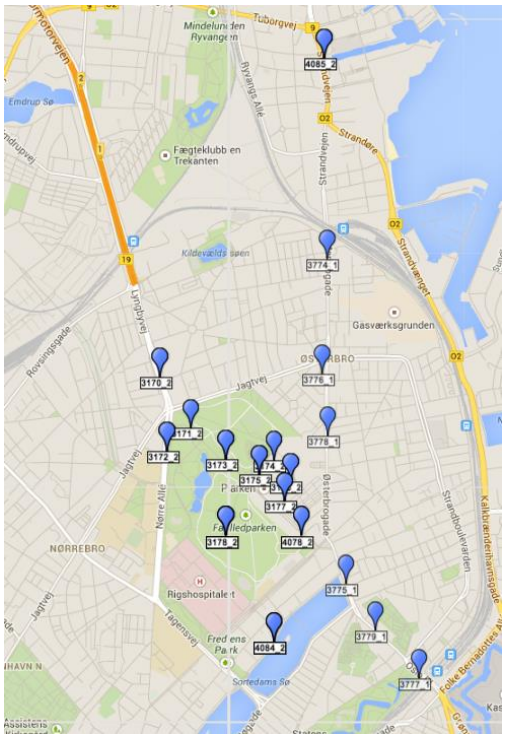

Figure 2: Sensor locations

Figure 3: Battery-driven sensor

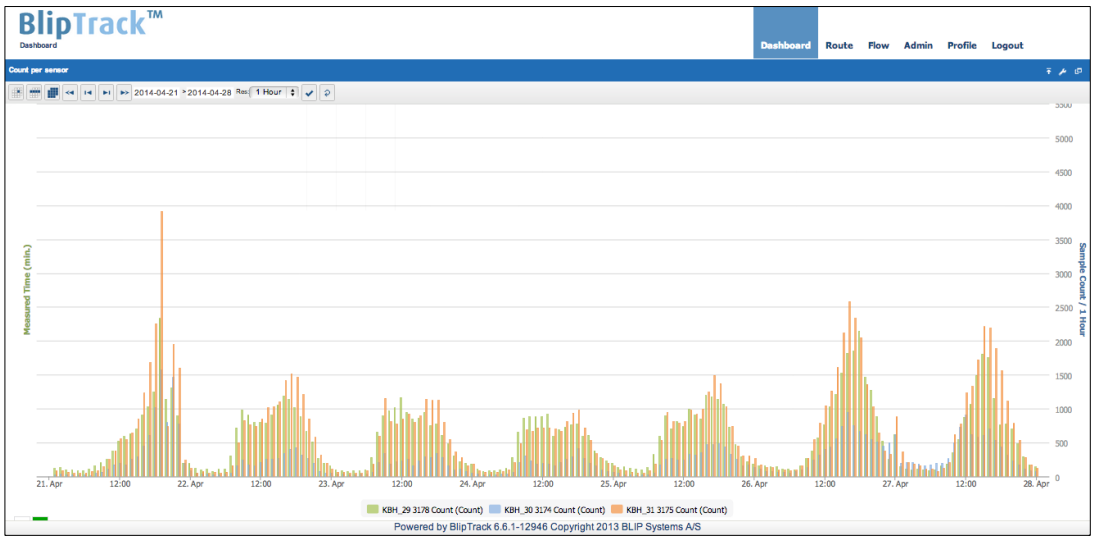

Figure 4: BlipTrack web frontend

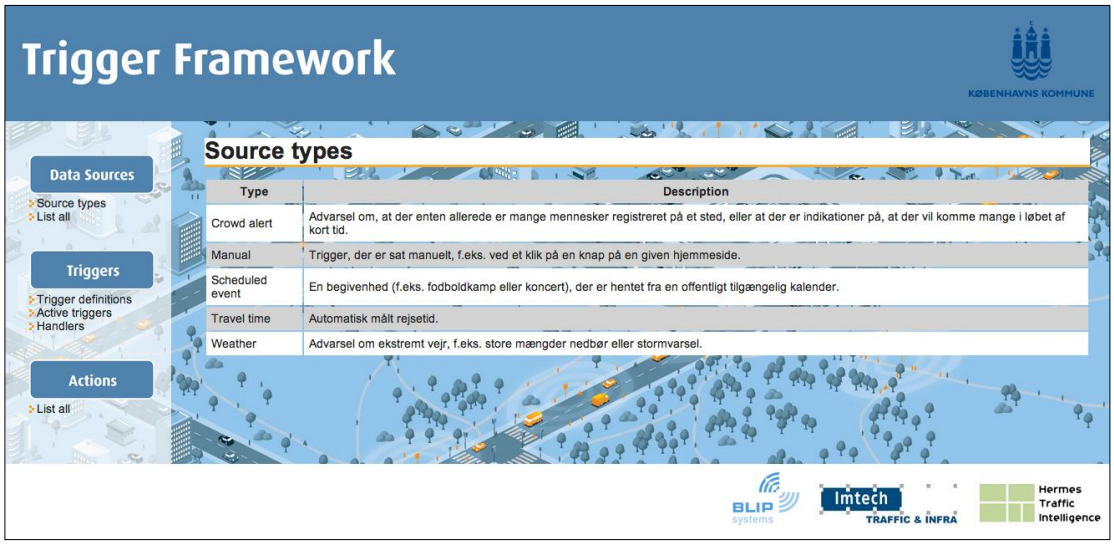

Figure 5: Screenshot from trigger framework website

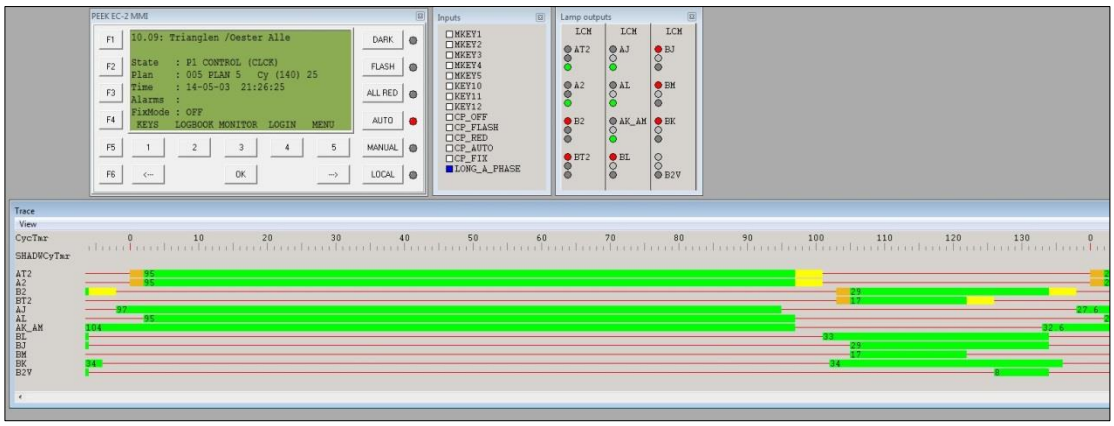

Figure 6: Imtech traffic controller, extended green program (#5)

After the football match April 21st the trigger framework was set to actually change the red/green periods for an intersection at Trianglen near Parken. For comparison of travel patterns the prototype also recorded real-time data after a football match April 13th and a concert April 26th. Two normal weekdays, April 23rd and 24th, were used as reference.

The data sources for the demonstration were:

- The Parken event calendar which can be found online at www.parken.dk.
- Travel time and crowd estimations provided by BLIP Systems.
- A manual trigger, which tells when the exits open after an event in Parken (simulated with a push-button placed in the traffic controller cabinet).

The change in the traffic controller program was as follows (see Figure 7 the for normal program #3 and Figure 6 for trigger program #5):

- As there is a fixed cycle time in the signal at the moment we needed to keep this to stay in synch with the other controllers in the area.
- The only way to easily give more green time to people leaving Parken is to give a whole number of cycles of green to the people exiting Parken.
- To not disrupt other traffic too much we then run one whole cycle with normal traffic handling.

Figure 7: Normal program (#3)

4.1 Data analysis

After endinf the test period the crowd and travel time data were analysed to find traffic pattern for normal traffic, football matches, and concerts. Analysis was also performed to see the effect of the traffic controller program change. To simplify the analysis, we looked at travel times for vehicles only (Bluetooth data from handsfree devices) and Bluetooth/WiFi crowd (counts) data from the sensors placed at the Parken entrances A, B, C, and D, and at Fælledparken and Trianglen. The analysis described here is only an example of the comprehensive possibilities with real-time and historical traffic data.

The crowd counts were configured to count any visible Bluetooth and WiFi devices entering the zone and not seen again within five minutes. Various studies have shown a combined Bluetooth/WiFi detection rate of more than 50% of all devices in a zone. For this test no reference people count was conducted.

The tables below show detected devices on a daily basis, before/after events, and on reference weekdays.

Event	Date	Venue	Spectators	Sensor Locations / Counts					
				A 3174	B 3176	C 3177	D 3175	Fælled parken 3178	Trianglen 4078
Football Match FCK vs. AGF	13/04/2014	Parken	15427	12984	26022	17644	24557	14170	19644
Football Match FCK vs. Esbjerg	21/04/2014	Parken	11917	8542	22007	18084	17753	13546	16839
Top Charlie Concert	26/04/2014	Parken	4700	9151	19280	19951	20294	17756	18786
Reference Day (Wednesday)	23/04/2014	Parken	-	3847	7432	11424	13176	12749	18196
Reference Day (Thursday)	24/04/2014	Parken	-	3837	7740	11154	11076	11860	18644

Figure 8: Detected devices on different days

Event	Date	Spectators	Time		Sensor Locations / Counts					
					A 3174	B 3176	C 3177	D 3175	Fælled parken 3178	Trianglen 4078
Football Match FCK vs. AGF	13/04/2014	15427	Before:	15-17	3414	7167	4648	6280	2645	4220
			After:	18-20	2911	7112	4071	4100	2636	3880
Football Match FCK vs. Esbjerg	21/04/2014	11917	Before:	17-19	2594	6301	5514	6171	3598	4232
			After:	20-22	2245	6069	3678	3561	2219	2780
Top Charlie Concert	26/04/2014	4700	Before:	16-18	1422	2336	3109	4394	4002	3041
			After:	23-01	824	1797	2461	1242	779	2099
Reference Day (Wednesday)	23/04/2014	-	Before:	17-19	630	822	1323	1933	1391	2302
			After:	20-22	212	416	949	657	528	1342
Reference Day (Thursday)	24/04/2014	-	Before:	17-19	681	1004	1284	1705	1374	2278
			After:	20-22	262	604	1055	609	670	1426

Figure 9: Detected devices in different time intervals (before/after)

Following map and graph show crowd counts for one of the events compared with the average daily crowd counts from normal weekdays

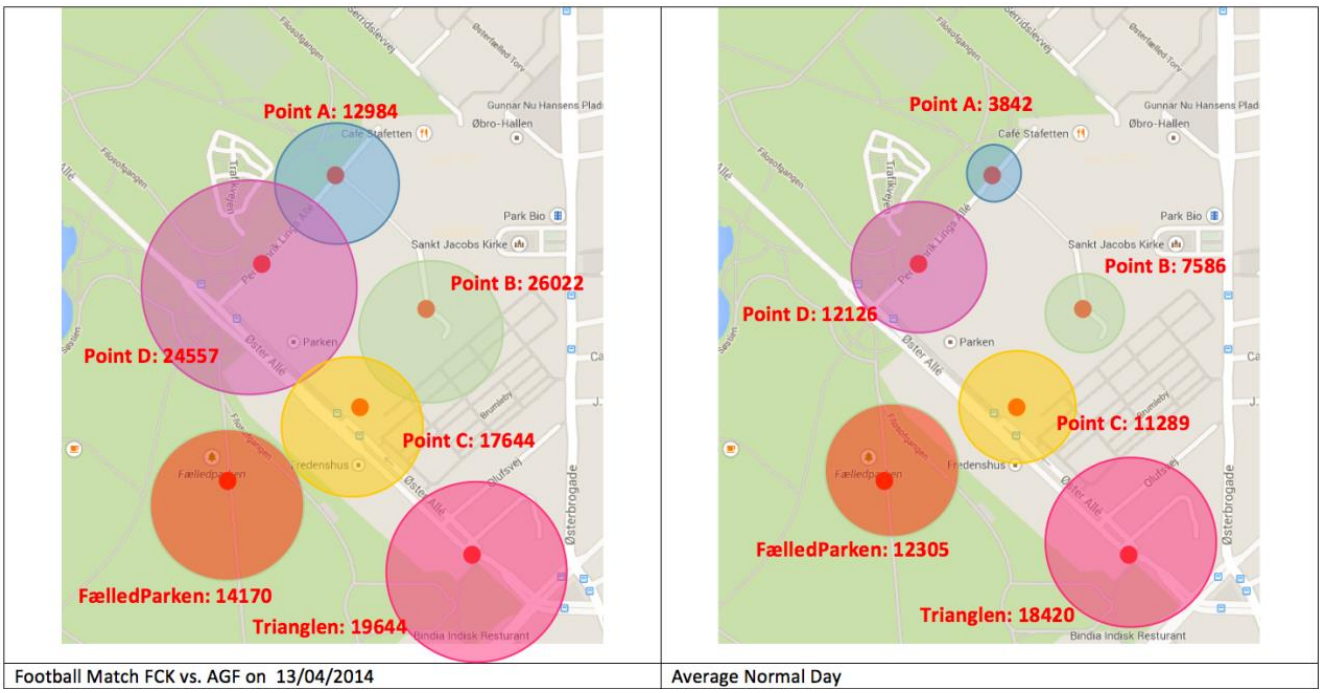

Figure 10: Counts at different locations

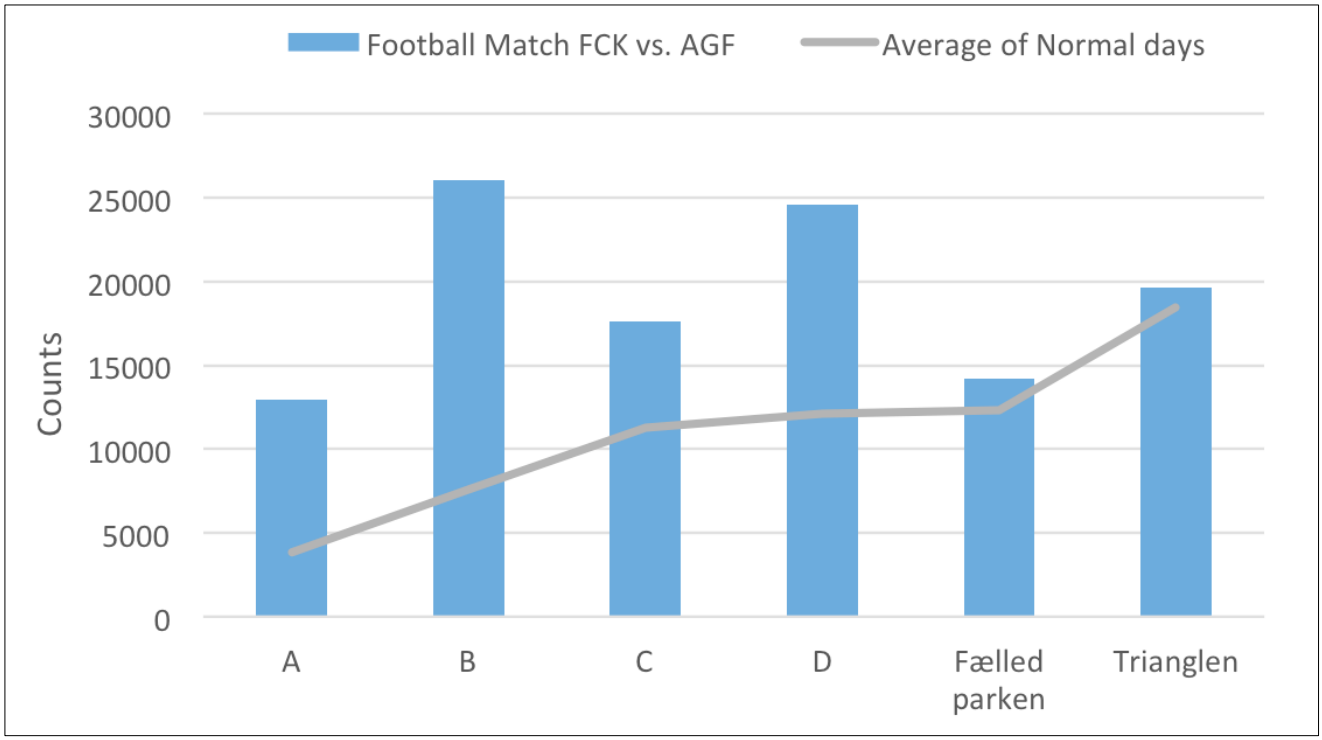

Figure 11: Counts at different locations, football match compared to average of "normal" days

Figure 10 and Figure 11 show the comparison of the counts recorded for an average normal day and also on the day of the football match between FCK and AGF on April 13th 2014. It is clearly shown that the number of counts recorded for the access points to the stadium are doubled or tripled. This indeed emphasizes that the number of Bluetooth/WiFi detections were quite representative of the number of spectators. The same pattern was seen at other events during the test phase.

Next graphs show crowd numbers from the first footballmatch two hours before and two hours after compared with normal weekdays:

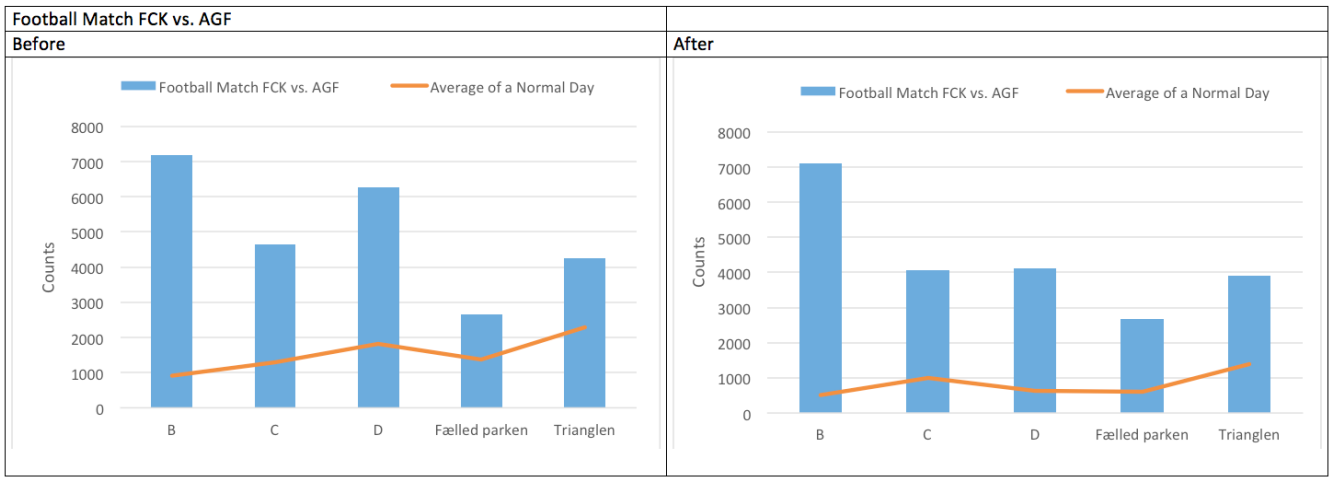

Figure 12: Variation on the number of detections recorded

Figure 12 shows the variation on the number of detections recorded for two hours before the match and two hours after the match. It is clear that there is a significant increase in the number of counts over the match compared to a normal day. It is evident that the number of counts on the designated points shows a significant increase over the match compared to a normal day. This indeed emphasizes the importance of traffic planning for facilitating the movements before and after such events to minimize traffic congestion.

To evaluate the effect of "more green" for pedestrians, bicycles, and vehicles leaving Parken after the football match April 21st we compared the "peak" of the crowd numbers for the two football matches and the result shows a significantly improvment in the traffic flow. An onsite verification was made by team people at Trianglen and by asking Parken and the Police for feedback. The onsite verification concluded the same outcome.

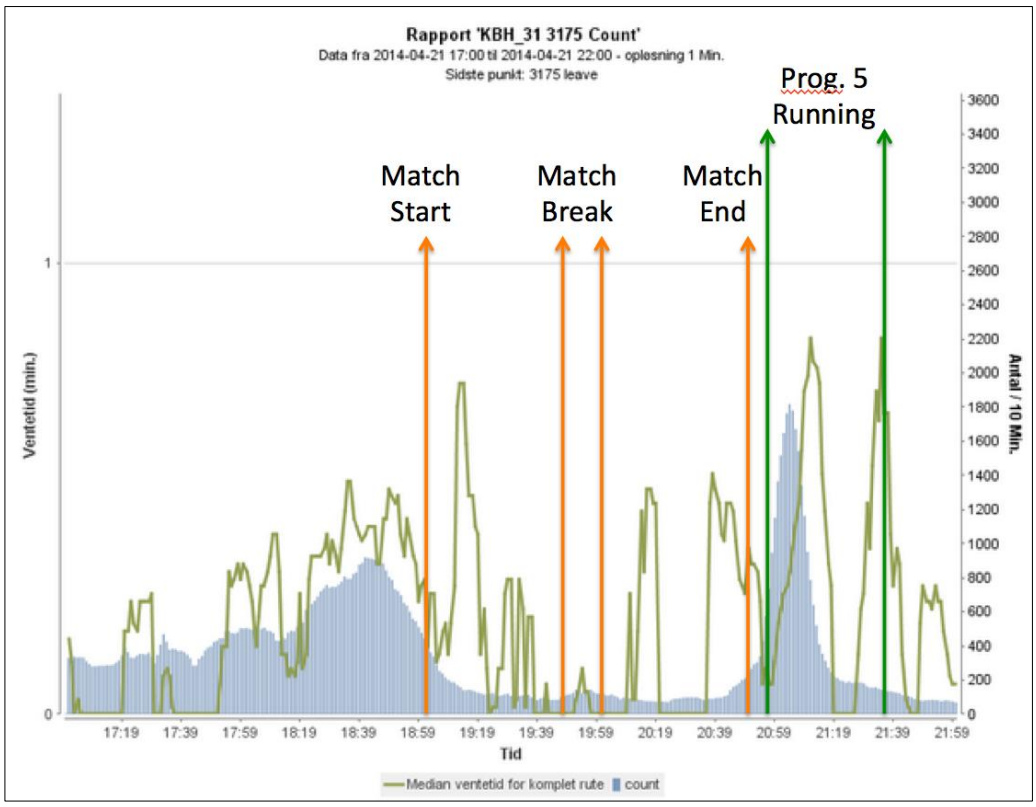

Figure 13: Crowd numbers from station 3175 on April 21st

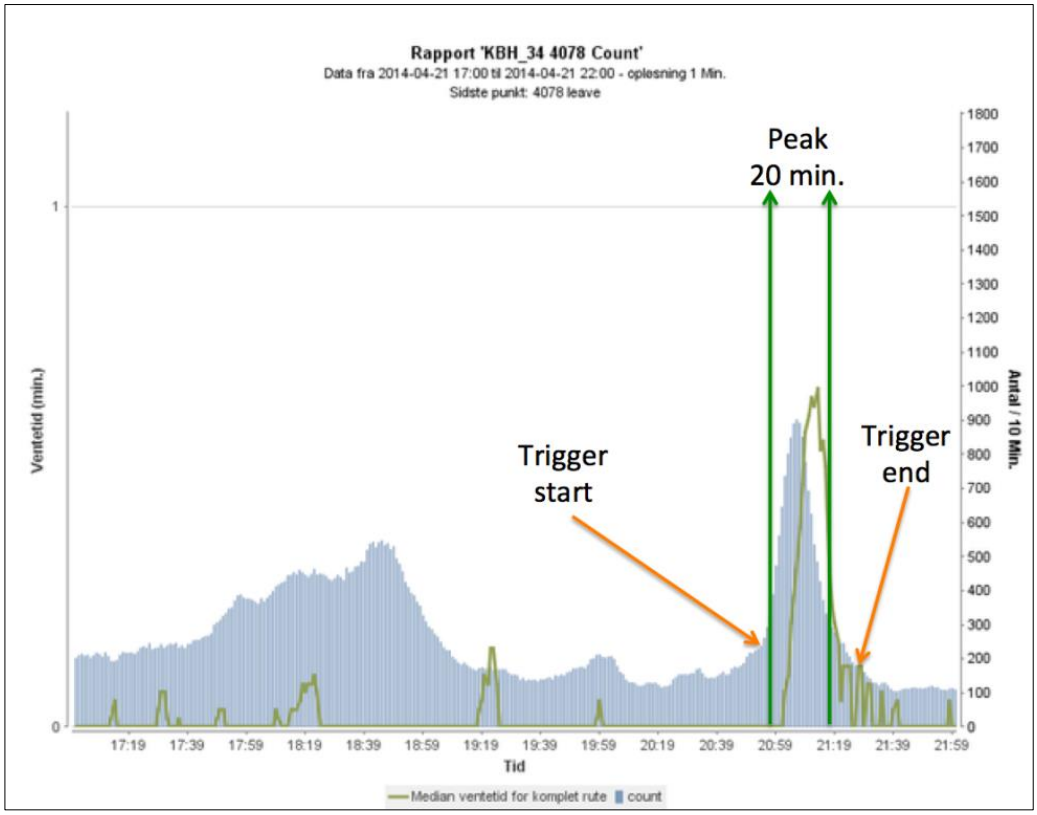

Figure 14: "Peak" from station 4078 on April 21st

Compared with the match on April 13th the peak decreased from 40-30 min. to 20-25 min. depending on location. To gain a higher effect before and after events with more spectators, more intersections have to be included and syncronized.

Travel times for cars in the area were also analysed, and they clearly show that cars leaving Parken created queues in the direction away from Parken towards Nørre Allé and Lyngbyvej. It also shows that the traffic pattern is very different when comparing football matches with concerts: much more car traffic in the area before and after a concert, and many more pedestrians and bicycles before and after a football match. It also showed that there is a significantly build up of traffic the day before and the day after a concert (probably transport of goods etc.).

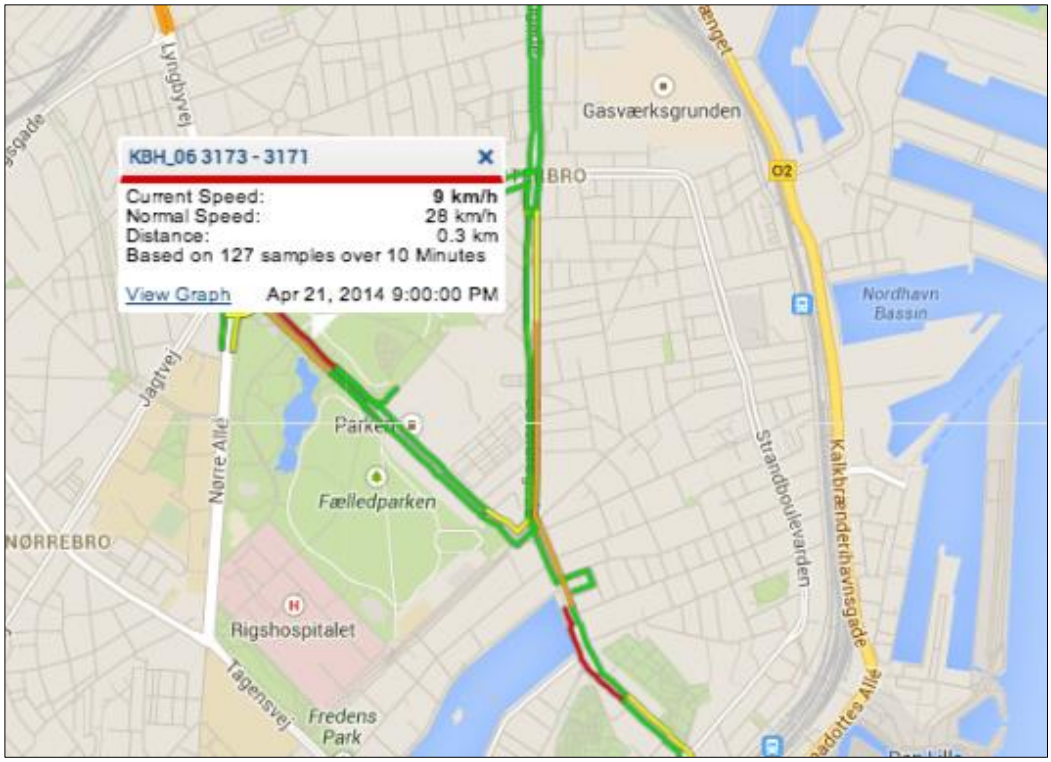

Figure 15: Travel time after the match on April 21st

4.2 Conclusion

In short the team believes that the proof-of-concept showed that planned and un-planned events could be triggered from various data sources such as calendar, travel times, people counts etc, and that by reacting to these triggers the traffic flow can be improved. By changing cycle time (more green) the traffic flow from people leaving Parken was improved.

> "With the system, we experienced a significant improvement of the traffic flow after yesterday's football match at Parken"
>
> *Deputy Police Inspector, Preben Johannesen.*

5 Recommendations

The team recommends that the municipality initiates a survey to show which areas, both geographical and administrative, the focus of the trigger framework should first be aimed at. Within each area a number of situations must be identified, and for each of these the data source leading to the detection of the situation must be described, as must the desired actions to take. As data source, both existing sources and technologies (e.g. Bluetooth sensors as applied in the test described in this report) as well as completely new inventions should be considered. From the set of situations, data sources, and actions a first version of the trigger framework can be designed.

For the trigger framework to show its full potential a number of situations requiring more complex trigger handlers may be identified. From these situations complex algorithms for determining the proper actions may be developed and tested. Development of these trigger handlers may either be done by contractors or by other participating partners, e.g. universities.

To continuously improve the implementation of a trigger framework the municipality should become involved with other cities implementing similar solutions for exchange of best practices. During the PPI project the team have seen interest from countries like Canada, UK, Ireland and France, so there will undoubtedly be cities similar to Copenhagen who share more or less the same requirements.