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MINNISBLAÐ

Staða og framtíðarsýn umferðarljósa í Reykjavík

Umferðarljós eru hluti af grunninnviðum samgöngukerfis höfuðborgarsvæðisins. Þau stjórna flæði ökutækja, gangandi og hjólandi vegfarenda og gegna lykilhlutverki í öryggi, flæði, sem og forgangsröðun almenningssamgangna og neyðarþjónustu.

Þessu minnisblaði er ætlað að veita yfirsýn yfir núverandi stöðu kerfisins, hvar tækifæri til umbóta liggja og í hverju helsta áhætta er fólgin.

Bakgrunnur um veghald, samgöngusáttmála og kostnaðarskiptingu

Reykjavíkurborg sér um rekstur umferðarljósa á höfuðborgarsvæðinu í samstarfi við Vegagerðina og eftir atvikum önnur sveitarfélög á höfuðborgarsvæðinu.

Reykjavíkurborg og Vegagerðin skipt jafnt með sér kostnaði við rekstur miðlægrar stýritölvu umferðarljósa höfuðborgarsvæðisins en fjárfestingarkostnaður á einstökum gatnamótum skiptist milli viðkomandi sveitarfélags og ríkisins (Vegagerðarinnar) í samræmi við veghald aðkoma að gatnamótunum. Þetta fyrirkomulag hefur verið viðhaft mjög lengi og er í samræmi við samning um miðlæga umferðarljósatölvu og nú einnig mörkun samgöngusáttmála. Þetta þýðir í flestum tilfellum að á X-gatnamótum skiptist fjárfestingakostnaður 50/50 en á T-gatnamótum skiptist hann 67/33. Fjármunir ríkisins (Vegagerðarinnar) í þessum tilfellum koma frá Betri samgöngum sem heldur utan um fjármuni samgöngusáttmálans[1]. Sveitarfélög greiða því allan kostnað við fjárfestingu á gatnamótum sem eingöngu eru í veghaldi sveitarfélags sem og kostnað í samræmi við veghald annarsstaðar.

Samgöngusáttmálinn kemur ekki að rekstri kerfisins en þegar kemur að fjárfestingu í miðlægum kerfum eða umbótum á stýringu fyrir kerfið í heild er heimild fyrir því að sáttmálinn greiði fyrir slíkt. Til að mynda greiddi sáttmálinn á síðasta ári fyrir uppfærslu miðlægrar stýritölvu umferðarljósa í skýja lausn sem jók rekstaröryggi kerfisins til muna.

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[1] Þeir fjármunir samgönguáætlunar ríkisins sem Vegagerðin réði áður yfir til fjárfestinga í umferðarljósum færðust inn í samgöngusáttmálann.

Núverandi umferðarljósakerfi

a. Lýsing

Hér á eftir er stutt samantekt á umferðarljósakerfinu en nánari lýsingu má sjá á heimasíðu borgarinnar[2], Vegagerðarinnar[3] og Betri samgangna[4]. Þar má m.a. sjá kort sem gefa yfirlit yfir virkni kerfisins á mismunandi stöðum og „spurt og svarað“. Til viðbótar fylgir sjálfstæð greining á umferðarljósakerfi höfuðborgarsvæðisins sem sænska verkfræðistofan Sweco vann árið 2020[5]. Skýrslan gefur ítarlega samanburðargreiningu á kerfinu miðað við fjórar Evrópuborgir. Niðurstöður greiningarinnar voru þær að almennt væri kerfið á pari við kerfi viðmiðunarborga sérstaklega hvað varðar tæknibúnað en leggja ætti áherslu á fjárfestingu í mannauði umfram tækni til að nýta sem best þá úrbótarmöguleika sem núverandi kerfi og áframhaldandi framþróun þess bíður upp á. Þannig skili tækni og bætt verklag saman sem mestum ávinningi fyrir vegfarendur.

Umferðarljós eru staðsett á yfir 200 stöðum á höfuðborgarsvæðinu og þau gegna því hlutverki að stýra umferð á öruggan og skilvirkan hátt. Í einföldu máli samanstanda umferðarljós af ljóskerum, hnappaboxum og skynjurum sem tengjast stýrikassa, þar sem sérstakur rafbúnaður sér um að stýra umferðarljósunum. Auk þess teljast staurar, festingar, ídráttarrör, kaplar, vírar og tengibrunnar einnig til umferðarljósabúnaðar.

Umferðarljósastillingar eru mismunandi og fara eftir aðstæðum á hverjum gatnamótum fyrir sig. Þar sem skynjarar eru ekki fyrir hendi, eru umferðarljósin stillt eftir fastri lotu sem þó er mismunandi eftir tíma dags. Algengara er þó að umferðarljós séu umferðarstýrð, þ.e.a.s. skynjarar kalla eftir grænu ljósi þegar vegfarendur eru skynjaðir.

Stærstur hluti stýrikassa er orðinn tengdur við miðlæga stýritölvu umferðarljósa (~80%), auk skynjara á milli gatnamóta (2100 skynjarar tengdir stýritölvu[6]). Stýritölvan sér um um að vakta búnaðinn, þannig að hægt er að bregðast hratt við bilunum eða öðrum vandamálum. Einnig eru skynjarar notaðir til að greina umferðarmagn og stýritölvan velur hentugustu ljósastillingarnar hverju sinni. Að auki sér stýritölvan um að samstilla umferðarljós á ákveðnum köflum, þannig að bílaumferð flæði sem best og töfum sé haldið í lágmarki. Rétt er að taka fram að yfirleitt er ekki hægt að samstilla umferðarljós í báðar akstursstefnur samtímis. Á morgnanna eru umferðarljósin samstillt þannig að bílaumferð flæði sem best í átt að miðborginni, en á öðrum tímum í átt frá miðborginni. Að lokum sér stýritölvan um að veita neyðarbílum forgang á umferðarljósum, ásamt því að framlengja grænu ljósi fyrir strætisvagna svo þeir komist greiðlega yfir gatnamót.

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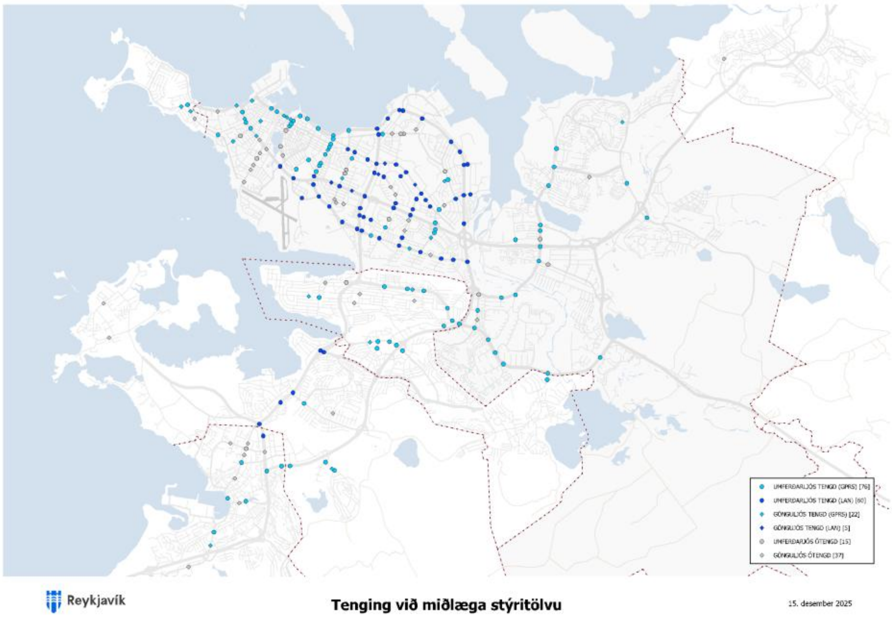
[2] Síða Reykjavíkurborgar um umferðarljós höfuðborgarsvæðisins: https://reykjavik.is/Umferdarljos
[3] Síða Vegagerðarinnar um umferðarljós: https://www.vegagerdin.is/samgongukerfid/vegakerfid/vegir/umferdarljos
[4] Síða Betri samgangna um Umferðarstýringar, - öryggi og -flæði: https://betrisamgongur.is/projects/oryggi-og-flaedi/
[5] Skýrsla Sweco umferdarljosastyringar_a_hofudborgarsvaedinu_0.pdf – er líka aftast
[6] Enn fleiri skynjarar eru svo tengdir umferðarljósum sem ekki eru enn tengd stýritölvu

Enn frekari upplýsingar um núverandi kerfi má sjá á áður nefndum heimasíðum en einnig eru viðbótarupplýsingar í borgarvefsjá[7], t.d. hvar skynjarar eru, stýriprógrömm og hvar ljós eru samstillt (græn bylgja).



Mynd 1 Tenging umferðarljósa við miðlæga stýritölvu, staðan í lok árs 2025. Gráir punktar tákna þau gatnamót sem ekki eru enn tengd miðlægri stýritölvu. Kortið má sjá stærra á síðunni [Umferðarljós | Reykjavik](#)

b. Tölulegar upplýsingar

Lýsing	Höfuðborgarsvæðið	Þar af Reykjavík
Fjöldi umferðarljósa		
- hefðbundin gatnamót	151	117
- gönguljós	64	42
Samtals	215	159
Hlutfall tengd miðlægu kerfi	77%	80%
Hlutfall LED	73%	77%
Hlutfall með umferðarstýringu	88%	86%
Fjöldi starfsmanna		
— stjórnun	0	0,1
— skipulag, hönnun og innkaup	0,5	2,0
— uppsetning, prófun og rekstur	0	3,0

[7] Borgarvefsjá, upplýsingar um umferðarljós, skynjara og samstillingu https://borgarvefsja.reykjavik.is/borgarvefsja/?x=359667.7&y=406382.8&z=6&visiblelayers=695,51

Tækniframfarir

Umræðan um „snjallljós" einkennist oftar en ekki af upplýsingaóreiðu, líklega vegna þess að tæknilega stöðluð skilgreining á snjallljósum er ekki til og í reynd er um markaðshugtak að ræða. Í faglegri umræðu er frekar talað um:

- *Adaptive signal control* (rauntímastýring)
- *Traffic-actuated signals* (umferðarstýrð ljós)
- *Intelligent Transport Systems (ITS)* – breiðara hugtak sem nær yfir allt kerfið

Spurninguna hvort um „snjallljós" sé að ræða er einfaldara að nálgast með því að snúa við; hvernig eru umferðarljós sem ekki eru snjallljós? Líklegast eru þau eins og klukka, alltaf sami hringurinn, allan sólarhringinn, alla daga. Ef bætt er við einum skynjara á einni akrein sem gefur grænt eingöngu þegar ökutæki er skynjað á akreininni, eru umferðarljósin þá orðin snjöll? Svona mætti áfram halda. Líklega er réttara að tala um mismunandi stig snjall- eða tæknivæðingar, líkt og þekkt er t.d. þegar rætt er um sjálfkeyrandi ökutæki.

Í þessu minnisblaði er miðað við þá skilgreiningu á „snjallljósum" að þau noti gögn og tækni til að laga umferðarstýringu í rauntíma að raunverulegum aðstæðum — í stað þess að fylgja föstum tímasettum áætlunum. Þetta getur falið í sér:

- Umferðarstýring með aðstoð skynjara (slaufuskynjarar, radar, myndavélar) sem greina umferðarþunga og laga stýringu í samræmi við hann.
- Miðlæga stýritölvu sem samhæfir umferðarljósin á mismunandi svæðum og bregst við breytingum á umferðarmynstri með vali á fyrirfram skilgreindum umferðarljósastillingum þar sem einstakir straumar vegfarenda geta verið umferðarstýrðir.
- Forgangskerfi fyrir strætó og neyðarbíla í rauntíma.
- Rauntímastýring sem getur brugðist við umferð á mörgum gatnamótum samtímis, aðlagað sig eftir umferðarflæði og bætt heildarskilvirkni.

Hið gagnstæða eru umferðarljós með föstum tímaáætlunum sem breytast ekki eftir umferð, þ.e. breytast aðeins eftir vikudegi og tíma dags. Sum ljós á höfuðborgarsvæðinu eru enn þessarar gerðar.

Mikilvægt er að átta sig á því að stór hluti þessarar tækni er þegar til staðar í dag í Reykjavík, en aðeins 14% umferðarljósa keyra í dag á fastri lotu (sbr. klukka) og þeim fer fækkandi. Spurningin er frekar hvort verið sé að fullnýta þau tækifæri sem kerfið býður þegar upp á og hvort nægileg aðföng séu til staðar til þess, sbr. niðurstöður Sweco-úttektarinnar.

Á undanförnum árum hefur Reykjavíkurborg unnið að innleiðingu nýrra tæknilausna samhliða nauðsynlegri endurnýjun á búnaði til að bæta skilvirkni á gatnamótum, án þess að draga úr umferðaröryggi. Meðal þeirra verkefna sem eru í gangi eða undirbúningi:

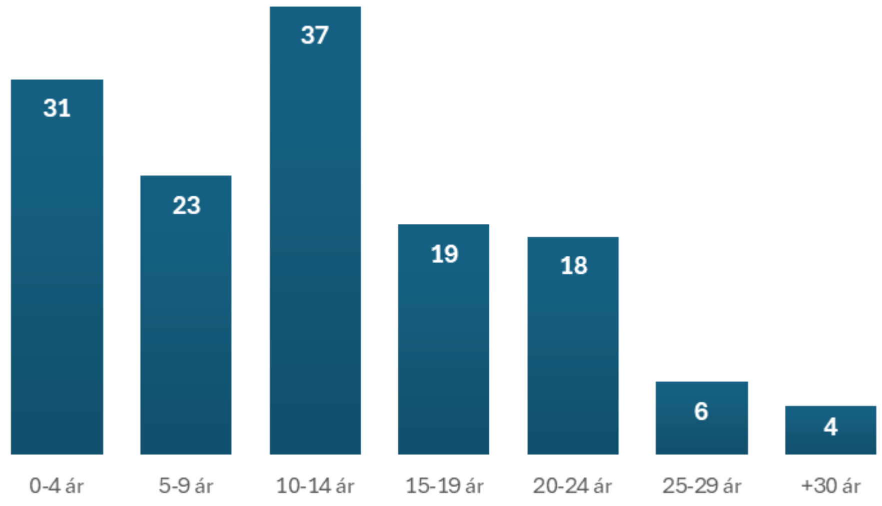
- SmartAI-rauntímastýring á Bíldshöfða/Breiðhöfða – með aðstoð LiDAR-skynjara sem skila gögnum til að stýra umferðarljósunum.
- Fusion-rauntímastýring á Hringbraut – undirbúningur er langt kominn og áætlað er að virkja kerfið í haust.
- AwareAI-lausn á Háaleitisbraut/Smáagerði – nýtir myndavélar til að skynja umferð akandi, hjólandi og gangandi og stýra umferðarljósunum. Á sama stað verða sett upp „roadside-units“, þ.e. búnað við vegkant sem hefur samskipti við búnað í ökutækjum. Þetta er fyrsta tilraunaverkefnið í Reykjavík í V2X/C-ITS tækni til gera ökutækjum kleift að eiga samskipti við innviði og öfugt.
- Smart-Corridor á Höfðabakka, rauntímastýring – að loknum yfirstandandi framkvæmdum á Höfðabakka/Bíldshöfða verður hægt að virkja rauntímastýringu á öllum umferðarljósum á Höfðabakka milli Stórhöfða og Bæjarháls. Þar er ný tegund radarskynjara notuð til að veita upplýsingar um umferðarflæði og stilling umferðarljósa ræðst þannig af umferðinni í rauntíma.

Áhættur og áskoranir

c. Aldur búnaðar

Ein stærsta áskorunin í umferðarljósakerfinu í dag er aldur búnaðarins. Notast er við fjölda mismunandi tegunda stjórnkassa og nokkrir eru orðnir yfir 30 ára gamlir. Þessi fjölbreytni gerir viðhald krefjandi og eru framleiðendur hættir stuðningi við elstu gerðir stjórnkassa (varahlutir og viðgerðir), þá eru aðrir við það að detta úr þjónustu hjá framleiðanda. Súluritið að neðan sýnir fjölda stjórnkassa á hefðbundnum gatnamótum í Reykjavík á hverju aldursbili (gönguljós undanskilin).

Almenn þumalputtaregla er að líftími stjórnkassa er um 15 ár og samkvæmt því eru 47 stjórnkassar í Reykjavík komnir yfir líftíma sinn. Með 138 stjórnkassa í rekstri þýðir þetta endurnýjunarþörf upp á um 9 stjórnkassa á ári. Síðustu fimm ár hafa að meðaltali 6,2 stjórnkassar verið endurnýjaðir á ári, sem er tæplega 70% af því sem þarf til að mæta áætlaðri meðal endurnýjunarþörf.



Mynd 2 - Fjöldi stjórnkassa umferðarljósa í Reykjavík á hverju aldursbili

Málið er þó aðeins flóknara en svo því samkvæmt upplýsingum frá framleiðanda um áætluð þjónustulok er ekki lengur hægt að panta varahluti í 92 stjórnkassa sem eru í rekstri í Reykjavík í dag (e. *end of spare parts*). Þar af eru 58 stjórnkassar sem ekki er lengur hægt að senda í viðgerð (e. *end of repair*). Á einföldu máli þýðir þetta að ef einhver þessa stjórnkassa bila eða tjónast alvarlega er eini valkosturinn að skipta þeim út. Pöntun á nýjum stjórnkassa getur tekið 3-4 mánuði, forritun og framkvæmdir við uppsetningu nokkrar vikur til viðbótar, ef allt gengur að óskum. Á meðan væru umferðarljósin óvirk. Sem stendur hefur ekki verið talið forsvaranlegt að halda lager af nýjum stjórnkössum, enda sem betur fer fáttítt að stjórnkassar verði fyrir þannig skemmdum að þörf sé á því. En áhættan er til staðar. Kapp hefur verið lagt á, þess í stað að, að hraða eins og unnt er endurnýjun stýrikassa sem ekki er hægt að þjónusta og í neyðrartilfellum hefur verið gripið til stjórnkassa sem hafa verið ætlaðir annað, með tilheyrandi töfum fyrir viðkomandi stað.

Þegar endurnýjun umferðarljósabúnaðar er skipulögð, er forgangsraðað eftir nokkrum þáttum, s.s.:

- aldri búnaðar og staða á þjónustu hjá framleiðanda
- skipta út perum fyrir LED
- tengingu við miðlæga stýritölvu upp á vöktun og stuðning við forgangskerfi neyðarbíla og strætisvagna
- stöðu á varahlutum á lager og fjölda sambærilegra stjórnkassa í rekstri (stundum er hægt að nýta ýmsar einingar í stjórnkössum milli kynslóða)
- möguleikum á innleiðingu tæknilausna til að auka umferðaröryggi og bæta skilvirkni

d. Mannauður

Stærsta áskorunin í rekstri umferðarljósakerfisins höfuðborgarsvæðisins er líklega tengd mannauði. Þetta er í samræmi við niðurstöður í fyrrnefndri skýrslu Sweco. Kerfið er einfaldlega of umfangsmikið m.v. fjölda starfsmanna sem sinna því í dag.

Í samantektarskýrslu NOCoE[8] kemur fram að stofnanir með sambærilega stærð kerfis og höfuðborgarsvæðið (150–450 umferðarljós) voru að meðaltali með 20,9 stöðugildi sem unnu að umferðarljósamálum — allt frá tæknifólki til stjórnenda. Meðalstærð kerfisins í þessum flokki var 287 umferðarljós, eða um 0,07 stöðugildi á hvert ljós. Miðað við sömu reynslutölur kallar umferðarljósakerfið á höfuðborgarsvæðinu á 15,7 stöðugildi, þar af 11,6 stöðugildi í Reykjavík.

Afleiðingar þess að hafa ekki nægan mannskap til að reka umferðarljósakerfið eru margar og samtengdar:

- Búnaður eldist hraðar en hægt er að endurnýja.
- Ekki er hægt að yfirfara stýringu, endurstilla og hámarka skilvirkni.
- Möguleikar kerfisins eru ekki fullnýttir.
- Þekking er á fárra höndum og ef lykilstarfsmaður er fjarverandi getur það haft veruleg áhrif á gæði þjónustu.
- Tækninýjungar kalla á aukna sérfræðiþekkingu og aukna viðhaldsþörf til að tryggja að kerfið virki rétt (ein af niðurstöðum Sweco).

Til að bregðast við ofangreindum takmörkunum hafa verktakar verið nýttir í auknum mæli í verkefnum sem tengjast rekstri, viðhaldi og uppsetningu umferðarljósa, sérstaklega á umferðarljósum utan Reykjavíkur, en þó einnig innan. Aðkoma þeirra kallar á langan tíma í þjálfun, þar sem umferðarljós eru mjög sérhæfðir en krítískir innviðir, og mjög mikilvægt að verktakar hafi nauðsynlega þjálfun og reynslu til að sinna þeim. Aukin umsvif í framkvæmdum vegna endurnýjunar umferðarljósa getur leitt til þess að verkefnastaða verktakanna verði flöskuháls. Það virðist vera að raungerast m.v. stöðuna í dag og því er þörf á fleiri höndum við rekstur, viðhald og uppsetningu umferðarljósa. Reykjavíkurborg hefur einnig í auknum mæli leitað til ráðgjafa vegna rýni og hönnunar stillinga umferðaljósa. Það hefur byggt upp þekkingu og reynslu hjá ráðgjöfum sem áður var ekki til staðar. Almennt hefur verið nokkuð auðvelt að fá ráðgjafa í verkefni en erfiðara hefur verið að fá verktaka.

Tækifæri og verkefni næstu ára

Fram til ársins 2019 voru öll umferðarljós á höfuðborgarsvæðinu frá sama framleiðanda. Á undanförnum árum hafa fleiri framleiðendur bæst í hópinn, en slíkt hefur bæði kosti og

[8] National Operations Center of Excellence (NOCoE). 2019. Traffic Signal Benchmarking and State of the Practice Report. https://transportationops.org/publications/traffic-signal-benchmarking-and-state-practice-report

galla í för með sér. Dæmi um slíkt er aukin samkeppni (hagkvæmari innkaup), meiri þjálfun á nýjan búnað og aukið/flóknara lagerhald. Hverjum framleiðanda fylgdi nýtt hönnunarforrit til að stilla umferðarljósin, sem kallar á þjálfun og uppbyggingu á þekkingu, bæði hjá starfsfólki og ráðgjöfum. Auk þess þarf að hafa leyfisgjöld í huga. Því var tekin sú ákvörðun að einfalda ferlið og notast aðeins við eitt hönnunarforrit. Innkaupaferli á nýju forriti lauk 2025. Innleiðing er í gangi og ráðgjafar eru byrjaðir að nota það við hönnun á umferðarljósastillingum.

Í kjölfar úttektar Sweco var stofnaður samstarfshópur um umferðarljósastýringar á höfuðborgarsvæðinu. Samstarfshópinn skipa fulltrúar frá öllum veghöldurum á höfuðborgarsvæðinu, þ.e.a.s. Vegagerðinni og sveitarfélögunum. Hópurinn skilaði t.a.m. frá sér aðgerðaáætlun til úrbóta (2020-2025) sem byggði á tillögum Sweco. Unnið er eftir þeirri áætlun að einhverju leiti. Upp á síðkastið hefur dregið umtalsvert úr vinnu samstarfshópsins þar sem öllum hlutaðeigandi reynist erfitt að sinna verkefnum með afar takmörkuðum aðföngum, þá fyrst og fremst mannafla. Hópurinn er þó mikilvægur m.a. til að samhæfa aðgerðir mismunandi veghaldara og vinna með kerfið sem heild.

Síðustu 7 ár, 2019-2025, hefur fjárfestingaráætlun Reykjavíkurborgar gert ráð fyrir að meðaltali 100 milljónum kr á ári til umferðarljósa. Í ár var áætlunin hækkuð töluvert (400 millj kr.) til að bregðast við viðhaldsþörf kerfisins (sbr. umfjöllun að framan). Gert er ráð fyrir að stærstum hluta verði varið til innkaupa á búnaði en framkvæmdir verði að stærstum hluta á næsta ári[9]. Ákveðin tækifæri eru á að ná fram aukinni skilvirkni í kerfinu með núverandi búnaði. Þau tækifæri eru þó mest utan annatíma en takmörkuð á annatíma þegar kerfið er nánast mettað og sveigjanleiki lítill. Vegna takmarkaðs mannafla, bæði til rýni/hönnun stýringa og við að tæknilega útfærslu hefur megin fókusinn frekar verið á að endurnýja búnað og að uppfæra stýringar samhliða því frekar en að yfirfara stýringar almennt.

Af framansögðu má sjá að mikilvægustu verkefni næstu ára eru að halda áfram að uppfæra og endurnýja umferðarljósabúnað Reykjavíkur ásamt því að fjölga og byggja um þekkingu tæknifólks og ráðgjafa.

Virðingarfyllst,

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[9] Sjá nánar kynning á fundi umhverfis- og skipulagsráðs 17. desember 2025
https://fundur.reykjavik.is/sites/default/files/agenda-items/Umfer%C3%B0arlj%C3%B3s%20%C3%A1%C3%A6tlun%202026.pdf

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Sweco Society AB

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Summary

Iceland and the city of Reykjavik are expected to grow in population and thereby traffic levels over the coming decades. This growth will place demands on the traffic management system and associated traffic signals. Vegagerdin and the municipalities in the capital area of Reykjavik are responsible for managing the traffic signal system and have identified a need to assess whether the existing traffic signal management system can cope with expected future developments.

In order to assess the capabilities of the existing traffic signal system and proposed future improvements, Sweco have been commissioned to conduct an independent review of the current system. The review has included three principle objectives:

1. Analysing the current traffic signal system and internal working processes for the Reykjavik capital area.
2. Comparing Reykjavik's traffic signal systems with a number of other cities, looking at: resources, operation, control and identifying common and best practice.
3. Highlighting pros and cons of different signal operating systems and working practices and identifying suitable development paths for Reykjavik.

Sweco has employed an assessment framework for the evaluation of traffic signal management capability originally developed by the United States Federal Highway Administration. Sweco has adapted this framework for the specific requirements of this project. The framework has then been used to provide an assessment platform for Reykjavik allowing comparison with a number of other relevant European cities.

Key findings

In summary Reykjavik is largely performing on a par with the four reference cities. It is only in a limited number of areas where Reykjavik is performing worse relative to the other cities. Based on the results of the assessment framework we have identified a few key areas that should be given immediate attention

We recommend producing a strategic plan containing clear goals defining what the City and Vegagerdin want to achieve with the traffic signal system. The plan should include a definition of relevant KPI's (e.g. safety-related) and a structured process for measuring progress.

Follow-up and evaluation should be performed in cooperation with key stakeholders. The city could also widen and increase the level of external cooperation, e.g. participation in European R&D projects.

We see no reason at this stage not to proceed with the chosen technical development path. The systems currently deployed in Reykjavik are comparable or in some cases better than those deployed in the other cities. Emphasis should be placed upon extracting more performance out of existing systems. Our recommendation is therefore to invest in people and processes rather than technology. However, there is a need to develop a life-cycle status plan for traffic signal system components in order to identify what items need upgrading and when.

At the moment we feel that the number of full-time staff employed on the design and operations side is perhaps insufficient to really provide a robust system. Finding the right balance with regard to staffing levels will be one of the challenges going forward. It may be necessary to increase staffing levels initially but then reduce numbers once new processes and systems are in place.

In addition to the critical points mentioned above we have identified a further list of key actions which will move Reykjavik towards a more robust and effective traffic signal management system. These actions are described in chapter 7 of this report.

1. Introduction

Reykjavik, the capital of Iceland, and the surrounding municipalities have about 233 000 inhabitants[1] and the road network has around 150 signalised intersections. The population is expected to grow by 50 000 to 75 000 people until 2040[2]. These developments place increased traffic management challenges on the transport authorities.

As a result of the forecast level of population growth the road authorities are keen to review the capabilities of the existing traffic signal system. A key focus is to assess how well the existing traffic signal system can support new transport strategies, with focus on increased traffic safety for all road users, and what system upgrades or improvements may be necessary in the future. In addition to better understanding the need for potential system improvements there is also an awareness of the need to review and improve internal processes to get the best out of chosen technical solutions.

Vegagerdin and the municipalities in the capital area have a policy of improving travel times for public transport, increasing traffic safety and focusing on sustainable transport modes.[3] Given the current modal split in the capital area of 74% cars, 5% public transport, 5% cyclists, 14% pedestrians and 2% other,[4] options are being explored to support more sustainable travel. Transport authorities plan to introduce “Borgarlinan”[5], a Bus Rapid Transit line (BRT), which is expected to be in operation by 2024 and will link the city centre with key growth areas. A crucial factor for the successful implementation of the proposed BRT line is understanding if the current traffic signal system and technology in Reykjavik can provide effective signal priority for buses on the new lines.

Given this background, the Icelandic Road and Coastal Administration (Vegagerdin) and Association of Municipalities in the Reykjavik Capital Area (SSH) have launched a project to gain a greater understanding of the traffic signal system in Reykjavik. The goal of the project is to identify and highlight priorities for future development in terms of systems, technology, working processes and organisation. Vegagerdin and the city of Reykjavik are also proactively testing and deploying new technical solutions to understand which system is most suitable for specific areas of the capital area.

Sweco, as independent traffic signal experts, have been commissioned by Vegagerdin and SSH to assess the traffic signal system currently in use in the capital area. As the main objective with the traffic signal system is to serve road users in and around the capital area, both SSH and Vegagerdin are mainly interested in how well the system is utilizing the current infrastructure and if the system is up to date and explore future development capabilities. Therefore, the study will also review if the current system can further be developed to support current and new transport strategies.

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[1] National Statistical Institute of Iceland - https://www.hagstofa.is

[2] https://ssh.is/images/stories/S%C3%B3knar%C3%A1%C3%A6tlun/Lokaskyrslur/Vaxtarsamningur/mannfjoldi_lokaskyrsla_NET.pdf

[3] https://ssh.is/images/stories/Hofudborgarsvaedid_2040/HB2040-2015-07-01-WEB_Undirritad.pdf

[4] https://www.stjornarradid.is/verkefni/samgongur-og-fjarskipti/samgonguaaetlun/ferdavenjukonnun-samgongurads-og-ssh/

[5] https://www.borgarlinan.is/

2. Description of current traffic signal system in the Reykjavik capital area

This chapter provides a brief technical overview of the existing traffic signal system in the capital area in Iceland.

2.1 Administration and collaboration

Vegagerdin owns and is responsible for the traffic signal hardware (signal heads, detectors, controllers, etc.) on the main roads, while each municipality owns and is responsible for the traffic signal hardware on local roads within their municipal border.

There are no official contracts regarding operation of the traffic signal hardware in the capital area. The city of Reykjavik traditionally services the traffic signals in the capital area in terms of planning, operation, installation and maintenance.

Vegagerdin and the city of Reykjavik have a joint ownership over the centralised traffic signal control system (see chapter 2.2 Technical system. for more details) but the operation of the centralised traffic signal control system is in the hands of the city of Reykjavik. There are no official contracts between Vegagerdin or the city of Reykjavik, and other municipalities in the capital area regarding connection of traffic signal hardware in other municipalities to the centralised traffic signal control system.

Vegagerdin runs a monitoring station that is manned 24-hours a day. The main activities of the monitoring station are to gather information regarding road and weather conditions, and organize necessary measures (e.g. snow removal, closures, etc.).

2.2 Technical system.

There are 152 signalised intersections and 45 signalised pedestrian crossings in the Reykjavik capital area. Of these there are 103 signalised intersections and 10 pedestrian crossings connected to the centralised traffic signal control system, Sitraffic Scala from Siemens (hereinafter referred to as “Scala”). The goal over the next few years is to connect all signal controllers to the central system.

Several groups of intersections operate as coordinated systems employing Traffic-Actuated Signal program Selection (TASS) which selects signal programs based on traffic volumes within each pre-defined area. Furthermore, the selected signal program for most intersections is traffic actuated and with fixed cycle times. The TASS system has been in operation since 2007 and the main benefits are that the signal timings and phase sequences are flexible based on actual traffic demand.

The Scala system offers the opportunity to add an adaptive network control system, called MOTION. This system is planned to be introduced in 2021 at seven intersections on Höfðabakki and six locations on Hringbraut. The system is capable of optimising green phases for both travel directions across several signalised intersections. Adaptive network control systems are well suited for situations with unusual traffic flow, e.g. in conjunction with crowded events or during peak times when traffic demand exceeds available capacity.

2.3 Functionality

The Scala system makes it possible to automatically send alerts and information to maintenance services. In addition, Vegagerdin and the city have access to a licence package called "Response Plans" which provides even more powerful mechanisms to automate functions based on a large range of inputs. Strategic detection, “Traffic Eye”, has been implemented and provides high quality traffic situation data for later analysis.

The Scala software system is flexible in that the full suite of software and functionality is always installed. Additional functionality can be obtained by simply “opening” up licences for additional tools.

2.4 Interoperability

The Scala software and license structure make it possible for other relevant stakeholders to gain appropriate access to the system. For example, access is provided to Vegagerdin and there is also an interface to public transport providers for public transport prioritisation. Furthermore, there is an interface that is enabled to display real-time traffic data from the Scala system on the city's web portal (Borgarvefsja).

On the central side the Scala system is composed of server hardware, a virtualised software based on standard interfaces. Integration to third party software is relatively easy but may create security issues. It is also possible to connect third party hardware to signal controllers (e.g. for detection) and third-party controllers to the Scala system via OCIT and/or CANTO.

2.5 Network management

The collection of traffic information is an important factor in centralised traffic management. TASS sensors have been installed and these collect information about traffic volumes. The sensors are connected to the traffic controller and the Scala system. TASS sensors are also updated on some counting sites to gather more detailed traffic information (e.g. vehicle classification, speed and occupancy). In September 2018, traffic sensors of type TEU5 were also installed. These sensors also collect information on traffic volumes, speeds and vehicle classification, and are connected to the Scala system via the mobile network. Despite the collection of traffic information, the data is not systematically being used to optimise the traffic signal programs, but rather manually on an on-demand basis.

The traffic signal technicians at the office of Land and Road Operation in the city of Reykjavik, are in charge of installation, maintenance and repair of traffic signal heads, traffic controllers and traffic detectors.

2.6 Prioritisation

Vehicle priority is enabled for public transport lines and emergency service vehicles on all major arterials. The system (STREAM - Simple Tracking Real-time Application for Managing traffic signals) was enabled in 2016. Vehicle on-board units (OBU) communicate with the Scala system, which sends commands to the signal controllers on-street. Approaching buses are detected and green times are extended to allow a bus to clear the intersection. It is possible to implement other types of transit signal prioritisation, by defining it in the traffic signal program logic for each intersection. The system also allows emergency vehicles to automatically trigger a specific traffic light sequence providing a green wave for emergency vehicles on the most direct route to an incident. The technology is already available in the existing system to support the operation of "Borgarlinan", the future BRT line.

3. Methodology

This chapter describes in summary form the methodology employed in reviewing Reykjavik's traffic signal system.

The scope of the project includes three principle objectives as follows:

4. Analysing the current traffic signal system and internal working processes for the Reykjavik capital area.
5. Comparing Reykjavik's traffic signal systems with a number of other cities, looking at: resources, operation, control and identifying common and best practice.
6. Highlighting pros and cons of different signal operating systems and working practices and identifying suitable development paths for Reykjavik.

In order to meet the abovementioned scope, Sweco has employed an assessment framework for the evaluation of traffic signal management capability originally developed by the United States Federal Highway Administration[6]. Sweco has adapted this framework for the specific requirements of this project. The framework has then been used to provide an assessment platform for Reykjavik allowing comparison with a number of other relevant European cities. More details of the assessment framework are provided later in this chapter.

3.1 Project tasks

The project has been broken down into the following tasks.

3.1.1 Information gathering

The first task involved developing the assessment framework through which Reykjavik and the other relevant cities would be assessed. This framework was then used to conduct a series of in-depth interviews with relevant personnel in each city. In Reykjavik interviews were conducted with the following individuals:

Interviewee	Role
Thorsteinn	Head of the Reykjavik transport department
Pall and Gudmundur	Subtitutes for Hinrik, Head of the Reykjavik traffic signal technicians
Nils and Gretar	City engineers and signal planners
Bryndis	Regional director for the capital area at Vegagerdin
Bergthora	Director of service division at Vegagerdin

Parallel interviews were also conducted, using the assessment framework, with key staff in cities in Sweden, the Netherlands, Belgium and the United Kingdom.

3.1.2 Comparison and benchmarking

Based on the responses from the interviews Sweco performed a benchmarking exercise comparing the five cities against each other. The purpose of the benchmarking exercise was twofold: firstly, to determine Vegagerdin's and Reykjavik's performance in a wider context and secondly to identify to what extent, if any, the four cities demonstrated best practice in any areas.

3.1.3 Identifying areas for improvement

Finally drawing on all the information collated in the previous tasks a number of improvement paths have been identified for Reykjavik. These improvement paths are designed to highlight areas where Sweco feel the most useful and valuable improvements can be made.

[6] https://ops.fhwa.dot.gov/publications/fhwahop16028/index.htm

3.2 City selection

One of the key drivers behind the selection of cities for comparison with Reykjavik was choosing locations where Sweco had first-hand experience and a close working relationship with city authorities. Another important factor was comparability with Reykjavik in terms of size and scope, whilst a third consideration was comparability in terms of systems and technology suppliers. Efforts were also made to include cities that had a somewhat different approach or circumstances to Reykjavik.

Based on the above criteria the following four cities were selected for comparison with Reykjavik:

- Gothenburg, Sweden
- Almelo, the Netherlands
- Edinburgh, United Kingdom
- Ghent, Belgium

Each of the four cities is described in more detail in Chapter 4.

3.3 Assessment Framework

The purpose of the assessment framework is to facilitate evaluation of traffic signal management capability across a range of processes or program areas. It is critical not to focus on any one area, such as technology or equipment, but to look at the whole spectrum of factors which determine an organisations performance with regard to traffic signal management. As mentioned in the introduction to this chapter, the assessment framework employed in this project is derived from the United States Federal Highway Administration Traffic Management Capability Maturity Framework. A full description of the framework is available here https://ops.fhwa.dot.gov/publications/fhwahop16028/index.htm. The framework is broken down into six process or program areas as follows.

3.3.1 Business processes

This process area refers to activities related to planning, operational development, improvement and upgrade paths as well as resource allocation and funding. The business process aspects have their focus outside day-to-day operational issues and highlight the need for a broad stakeholder involvement. Well defined business processes are an essential starting point for effective traffic signal management and performance.

3.3.2 Systems and technology

This theme places focus on having processes in place for the design, selection and implementation of appropriate technology and system solutions. It draws attention to the need for clearly identifying how systems should meet operational objectives and include a high level of flexibility and interoperability.

3.3.3 Performance and measurement

Measuring performance is essential for determining the effectiveness of systems and working processes and to support decision making. Performance measurement can be used to drive and support new investment, providing vital input to policy makers. It also provides information that can be relevant for a wider external audience including the public and other relevant stakeholders.

3.3.4 Organisation and workforce

Well trained staff with clear goals and working processes are vital for supporting effective traffic signal management. It is also essential to have a clear picture of in-house capability and a structured staff development path.

3.3.5 Culture

Culture focuses on an organisations ability to connect with and communicate its knowledge and values. It addresses issues related to management and leadership.

3.3.6 Collaboration

Effective traffic signal management requires a broad range of collaboration. It is essential to identify and engage with key partners to work towards achieving common goals.

4. Comparison cities

This chapter provide a brief description of each of the cities selected for comparison with Reykjavik and why they have been selected.

4.1 Gothenburg

Gothenburg is the largest non-capital in the Nordics and is located on the west coast of Sweden. Home to the biggest port in the Nordic region it is also a city of bridges, hills, water and trams. The city is a cornerstone of regional development including the automotive industry led by Volvo Cars and Volvo Trucks as well as research-intensive industries like Ericsson and AstraZeneca. With its 500 000 inhabitants, Gothenburg combines the intimacy of a small town with the opportunities of a big city.

In terms of traffic signals, the city has a strong emphasis on public transport priority. This is part of a key goal of the regions traffic strategy to promote a modal-shift towards public transport from traditional car traffic. System-wise, a variety of suppliers provide equipment which are integrated by the authorities according to the needs of the city. There is an emphasis on the definition of technical requirements and functionalities on behalf of the road operator, which needs to be followed by the different suppliers. Much of the traffic signals expertise is provided by external actors, consultants, who are independent of the suppliers. In-house expertise is relatively limited. The local automotive industry also provides opportunity for developing and testing new traffic signal/connected car applications (for instance V2I).

4.1.1 Why has Gothenburg been selected?

The city has a combination of low and high traffic volumes on its roads, in a Nordic context. In terms of size the city could be compared to Reykjavik, although somewhat larger. It is representative of a typical Scandinavian city in terms of traffic signals.

4.1.2 Traffic signals in Gothenburg

The technology used in traffic signals in Gothenburg could be described as traditional. Coordinated traffic signals are time-controlled to a large extent whereas isolated intersections are traffic-controlled (primarily by inductive-loops). Public transport uses GPS/radio-technology for priority requests. The same technology is used by emergency vehicles. From a traffic-technical perspective, the ambitions are limited – there is no equivalent to TASS for instance. There is also no usage of adaptive signal control (although Utopia/Spot was tested several years ago). On the other hand, there is a strong emphasis on the technical operation of the traffic signals. All intersections are connected to a superior system which provides detailed control and monitoring of all critical equipment. In terms of the processes, these are lifecycle-oriented and aimed towards letting the market provide cost efficiency and innovation through framework agreements based on specified requirements.

4.2 Almelo

Almelo is a typical medium sized city in a peripheral region of the Netherlands, near the German border. It has a large port on a branch of the Twenthe Canal, some heavy industries, and in recent decades it has developed into a logistics and distribution hub, so there is a lot of heavy goods traffic.

Almelo is generously endowed with local highways, including a full outer ring road, a north-western bypass, and two motorway connections. Following Dutch practice, there is a clear distinction between motorways and other roads, with fully level junctions among local highways and with streets, most of them as signal-controlled intersections.

With 73 000 inhabitants the town is smaller than Reykjavik. However, it is part of the Stedenband (Twenthe belt of cities), together with Borne, Hengelo and Enschede, with a total population of 335 000.

4.2.1 Why has Almelo been selected?

Almelo has been selected for its ground-breaking innovations in both the technical and the traffic management domain.

The technical innovation is the introduction of Smart Traffic, an entirely new type of signal control software. Arrival of vehicles is predicted by microsimulation software, and a cost basis optimisation step distributes green time among approaching vehicles. This software runs in the cloud, and directly controls the signals, through the local controller cabinets that act as slave and backup devices.

The management innovation is the outsourcing of traffic management by the Stedenband cities. Almelo, Hengelo and Enschede jointly tendered out a TMaaS contract (Traffic Management as a service) that was won by Sweco and Heijmans in a joint venture. In a nutshell, this means that the client cities define the desired performance of the traffic network, and the contract partners will deliver that for a fixed annual fee, or for a fee based on performance of the network. This includes all monitoring and tuning of signal control.

4.2.2 Traffic signals in Almelo

The Almelo traffic signal system is typical for a city of its size in the Netherlands, and it follows common Dutch practice. Dutch signal control is notably different from surrounding countries in several aspects:

- Intersections are controlled locally. Co-ordination is extremely rare.
- All signals are fully traffic actuated, with typically 3-4 loop detectors per vehicle lane.
- Control is by movement wherever possible, not by approach.
- There is no concept of stages, let alone of a predefined cycle; instead, a “preferred sequence” determines the order in which conflicting movements are handled.
- In medium sized cities including Almelo, all movements are protected; a lane that has right turning vehicles is considered to be in conflict with an adjacent cycle path or pedestrian crossing.
- The IVERA protocol offers a platform and supplier independent interface between traffic management centres and signal controllers. The IVERA protocol is a data communication standard for traffic control devices and the associated central computer systems. By implementing the IVERA protocol,

traffic control systems and power stations from different manufacturers can be linked. The protocol specification is also freely available, so that other manufacturers can join the open communication network.

Almelo municipality employs two staff, now working in design, procurement, monitoring and organising maintenance. Signal equipment and controllers are supplied by Vialis and Imtech (Peek traffic). For monitoring and remote control (changing settings) all 45 controllers are linked to a traffic management centre. Public transport and emergency vehicles use radio messaging technology for priority requests.

A budget of around EUR 850 000 per annum is mostly spent on replacement of ageing equipment.

Almelo recently entered a transition phase in both the technical and the traffic management domain

Rolling out Smart Traffic has begun on the outer ring road and on both motorway connectors, amounting to nearly 25 intersections. For the time being all current controllers are retained, some of them nearly 20 years old

The ongoing implementation of the TMaaS services entails a transfer of maintenance and management tasks to the service providers in the contract.

Actual technical maintenance is already carried out by contractors.

4.3 Edinburgh

Edinburgh is the capital city of Scotland with a population of 470 000. Situated on the Firth of Forth, in the south east of Scotland, it was historically a major port on the east coast of the country but in the last 50 years has grown up to be a major financial centre with the headquarters of many national banking, insurance and investment organisations; second only to London in the United Kingdom.

Edinburgh city's transport strategy sets out objectives to improve public transport and active travel infrastructure, to encourage a modal shift away from car use. This is relevant in terms of considerations made during design proposals for implementing new signals. Signals operate, giving priority to public transport where possible, with the tram timetable also accommodated where applicable. Opportunities to improve the city's signal network to benefit other road users are reviewed when they arise. The City of Edinburgh Council has a good level of in-house expertise, employing 11 staff, working in design, procurement and implementation. The majority of signal equipment and controllers are Siemens; however other manufactures have integrated hardware in the system.

4.3.1 Why has Edinburgh been selected?

The city has a variety of arterial routes leading into the city centre, and numerous other local roads and streets, all of which use and accommodate signal control to various levels. While the population of Edinburgh is larger than Reykjavik at 482 000, the geographic size is almost identical. As Edinburgh also has a larger number of signal controllers, it was selected to hopefully provide some best practice in terms of systems, technologies and culture. Edinburgh is typical of a UK city in terms of variety of signal equipment, influence of stakeholders, and investment in prioritising non- car modes.

4.3.2 Traffic signals in Edinburgh

The traffic signal control system in Edinburgh uses a variety of technologies. A large proportion of the key central and corridor network(s) are linked to an Urban Traffic Control (UTC) system which centrally monitors network operation and faults. Most of the controllers work off fixed timing plans, with an element of vehicle actuation where required. Pedestrian and or cycle phases are generally demand dependant. Some junctions (the minority) have adaptive control systems such as SCOOT or MOVA. The central and key corridor networks are hard wired into the UTC system, while other more remote controllers, or non-strategic locations can dial in via Remote Monitoring.

Active travel and improvements for non-car-based travel is high on the agenda, and therefore improvements to vehicle capacity or car borne journey times are not targeted or indeed measured.

Most of the time and budget is spent on maintaining the existing infrastructure. However, working alongside the Capital roads program allows the Council to combine resources and deliver more Capital upgrades per annum than would be possible if we just operated within the constraints of the signal teams capital budget. Generally, the Council has enough revenue funding to provide a comprehensive maintenance and operational service. With say, a 70% to 30% split in favour of maintenance. Funds are generally sufficient to provide a comprehensive service as opposed to a basic service.

4.4 Ghent

Ghent (Dutch: Gent) is a city and a municipality in the Flemish Region of Belgium. It is the capital and largest city of the East Flanders province, and the third largest in the country, exceeded in size only by Brussels and Antwerp.

The city originally started as a settlement at the confluence of the Rivers Scheldt and Leie and in the Late Middle Ages became one of the largest and richest cities of northern Europe, with some 50 000 inhabitants in 1300. It is a port and university city.

The municipality comprises the city of Ghent proper and 13 surrounding suburbs. With 262 219 inhabitants at the beginning of 2019, Ghent is Belgium's second largest municipality by population. The metropolitan area, including the outer commuter zone, covers an area of 1 205 km^2 and has a total population of 560 522 as of 1 January 2018, which ranks it as the fourth most populous in Belgium.

In terms of traffic signals, the city has a strong emphasis on public transport priority and cyclists. This is a result of the traffic strategy in the city to promote modal-shift towards public transport and cyclists instead of traditional car traffic. Historically, a variety of suppliers provided equipment and traffic light plans which were tailored to the needs of the city. Today, there is a single supplier of equipment (Trafiroad) and a single consultant (Sweco) for signal plans. Much of the traffic signal expertise is provided by external suppliers and consultants, which are independent of each other. In-house expertise is available to some extent and focuses on requirements definition, coordination and quality control.

4.4.1 Why has Ghent been selected?

The city and metropolitan environment is comparable in size with the Reykjavik region. Its layout is typical for many west European cities with a city centre composed of narrow streets in a spiderweb pattern and wider arterial roads and ring roads connecting it to the suburbs and neighbouring towns. It is representative of a typical Belgian city in terms of traffic signals. In terms of process, the city of Ghent has set up a solid collaboration with the regional authority, which manages some of the larger arterial roads, and the public transport company for all matters related to road design and traffic lights.

4.4.2 Traffic signals in Ghent

The technology used in traffic signals in Ghent could be described as traditional. Most of the traffic lights are installed at isolated intersections and are traffic-controlled (primarily by inductive-loops or Doppler radars). Signal cycle times are dynamic and green distribution is driven by traffic demand. Public transport uses selective inductive loops for priority requests. There are no special provisions for emergency vehicles.

From a traffic-technical perspective, the ambitions are to provide a solid system at a reasonable price/quality ratio. TASS is installed on the R40 ring-road, but this is operated by the regional authority and not by the city. There is also no usage of adaptive signal control, although the city staff keep a close eye on evolutions in the ITS domain. On the other hand, there is a strong emphasis on the process. In a monthly coordination meeting, the city staff, the regional authority, the public transport company and external consultants analyse traffic signal issues in a structured manner. Problems and complaints are analysed, new projects are discussed, and actions are assigned and followed-up.

5. Reykjavik capital area– assessment framework

This chapter contains a short summary of key points from Reykjavik's responses to the questions contained in the assessment framework. The complete framework and all responses are available as an Appendix.

5.1 Basic Facts

In total there are 230 traffic signal controllers in the capital area. Staffing levels (FTE: full-time equivalent) are as follows:

- management: ~0.1 FTE
- design/procurement: ~1.5 FTE
- installation/maintenance: ~5.0 FTE

The annual budget for traffic signals is around EUR 1 030 000, split between investment (EUR 590 000 or ISK 80 000 000) and maintenance (EUR 440 000 or ISK 60 000 000).

5.2 Business Processes

The traffic signal planning process is based around a number of key documents including the National Transport Plan 2020-2034, the Reykjavik Municipal Plan 2010-2030 and the Reykjavik Traffic Safety Plan 2019-2023. The public transport authority and emergency services are involved in the planning process as needed.

Users of the transport system can register traffic signal related comments by email or by telephone to Vegagerdin or the municipalities. Additionally, the city of Reykjavik has a comments system on their webpage, where every comment is logged and the aim is to provide feedback to the user within three days. Comments are prioritised and responded to, based on individual staff member's experience.

Vegagerdin is financed by the government and the municipalities' budget comes largely from taxes. Operational and investment costs for traffic signals are generally split between the two organisations based on the number of approaches at an intersection, regulated by each organisation.

Vegagerdin and municipalities in the capital area have funds to provide, in many cases, a better than basic service. The size of the current budget means that it will take several years to replace all the equipment that is currently ear marked for replacement. Funds are increasing slowly and there are opportunities to invest in new technology (see chapter 5.3 Systems and Technology).

5.3 Systems and Technology

The city of Reykjavik has been servicing all traffic signals in the other municipalities in the capital area for a long time and has acquired considerable in-house knowledge and experience. External consultants have become more involved over the last several years and the city provides instructions to the consultants and then assess work done. Installation work, maintenance and repairs are performed by the traffic signal technicians at city of Reykjavik, to ensure consistency.

Procurement is performed mainly by the city of Reykjavik, but in cooperation with Vegagerdin where applicable. Currently, signal controllers and the bulk of signal hardware is procured from Siemens, but other suppliers provide pushbuttons, radar detectors and loop detectors. The main driver in procurement is if two systems deliver the same functionality, the cheapest alternative is chosen.

Approximately 65% of all traffic controllers are currently connected to the Scala central system, and the main goal is to reach 100% within the next few years. Any malfunction in controllers connected to the system is automatically detected and communicated to the central system. Equipment not connected to the central system is troubleshooted manually by technicians or reported by the public. Equipment connected to the central server is managed by the Scala system. The system monitors traffic demand and adapt signal timings through TASS and manages transit signal priority and priority for emergency services.

The Scala system can integrate with hardware from other manufacturers through different interfaces and standards, e.g. OCIT and CANTO, which is described below in more detail:

- OCIT (Open Communication Interface for Traffic)
  OCIT has been defined by a committee made up of the different system providers and is a widely used standard in the area of traffic computer systems and traffic light installations. It exists in two versions: OCIT-O (outstations) for communication with field units, and OCIT-C (centre to centre) for communication between centres.

- Canto (Communication in advanced new technology in outstations)
  Sitraffic Canto is a proprietary standard that Siemens is making available for licensing to other manufacturers in order to meet the customer's requirements for an open system. Sitraffic Canto provides an especially powerful method for centre-to-field communication and can be used to connect existing older controllers to modern traffic centres.

Connection to the system by third parties, such as public transport providers and external consultants, is also possible. On the central side Siemens use server hardware, a virtualised software based on standard interfaces. Integration with third party software is relatively easy but may lead to security issues. Third party hardware can be connected to signal controllers (e.g. for detection or signal heads) and third-party signal controllers as well as long as they fulfil the used protocols.

The previously described TASS system (see chapter 2.1) consists of five corridors in the capital area (see Figure 1). Based on pre-defined optimum signal plans for each corridor, the TASS system selects the right signal plan to meet current conditions. TASS uses a rule-based system and threshold values to identify the situation and then activates the corresponding signal plan.

Figure 1 – Five TASS areas in the Reykjavik capital area

Vehicle detection is accomplished principally through inductive loops and push buttons for pedestrians. At some locations, radar is used for detection of vehicles, bicycles and pedestrians. Public transport vehicles and emergency vehicles use on-board units with GPS, which communicate with the Scala system through the mobile network (for the purpose of signal priority).

MOTION is an adaptive signal control system, which uses model-based, traffic-actuated signal controllers to determine the current traffic situation based on observed data. The controllers calculate the optimum signal programs, while the Scala central system carries out the network-related tasks. Therefore, the MOTION system can react quickly and efficiently to current traffic events by optimizing traffic control on both a local level and centrally. MOTION will be tested at thirteen intersections during 2021 and the aim of the tests is to determine whether MOTION provides better network performance than TASS.

5.4 Performance and Measurement

There are no official policies regarding performance or measurement of the current traffic signal system in the Reykjavik capital area. Vegagerdin and the city of Reykjavik are aware of the need to:

- Update and define new goals and policies regarding how performance is measured and followed up.
- Identify and increase the number of key performance indicators (KPI's) deployed.

Additionally, as most staff are new, there is a need to define clear role descriptions and working processes.

5.5 Organisation and Workforce

As described earlier, the city of Reykjavik performs almost all aspects of the work related to traffic signals. Before 2016, the Reykjavik staff focused on basic operation and maintenance. Since then, the city has acquired 1.5 FTE traffic signal system experts, who conduct much of the signal planning, junction design and procurement, while the traffic signal technicians at the city of Reykjavik perform most installation and maintenance tasks.

Traffic signals are managed by two departments within the City, tackling design and operation and maintenance. Staff members in both teams can define priorities and take decisions that are in line with departmental strategic plans. There is also some level of backup, as staff can perform each other's roles. Management is involved in discussing future plans and setting annual budgets. Due to recent structural organisational changes within Vegagerdin, the capital area is now a new region and one issue is how to staff the region e.g. within traffic signals.

External consultants are used in a variety of situations. The traffic signal manufacturer provides the initial signal programming for a new controller and other detailed input, particularly related to TASS and MOTION. Whether external consultants are required when changes are made to a signal program, depends on the significance of the changes. For example, change of green times does not require external assistance, but adding new signal groups, such as protected left-turn, requires reprogramming from the traffic signal controller manufacturer. Other consultants are used to assist in the planning process, transport modelling and to install certain hardware (e.g. inductive loops). Typically, consultancy contracts are based on unit price, e.g. the manufacturer charges a pre-defined fee per junction, based on junction complexity. Delivery times are about 8-12 weeks for equipment. Local consultants are used for installation and work to a fixed price per loop or an hourly rate.

The workforce has an annual evaluation of development where career, courses and training are discussed. Staff can apply for training and arrange their own funding. Management is positive to educating their staff. The traffic signal controller manufacturer offers training in Germany and has also performed training in Reykjavik. Mostly, new staff "learn by doing" as there is no set training process.

5.6 Culture

Both Vegagerdin and the city of Reykjavik have their own public relations departments to manage communication with external bodies. The city typically answers any questions related to traffic signals, because of the in-house knowledge available. Traffic signal staff occasionally participate in interviews if technical knowledge is required. Both Vegagerdin and the city of Reykjavik employ a variety of communications channels, including social media (e.g. Instagram, Facebook or Twitter), a web site and press releases.

The traffic signal profession or arena is not considered to be of high status internally in Reykjavik, but this is changing. The culture is changing as a new generation is employed and a generation shift is ongoing. In addition, there is an interest from media and politicians regarding traffic signal systems.

5.7 Collaboration

There is no official contract between Vegagerdin and the Reykjavik municipality regarding the traffic signals. However, the city of Reykjavik sends a quarterly invoice to Vegagerdin for maintenance and operation of the Scala system. There is collaboration through regular consultative meetings between the two bodies where traffic signal related projects are discussed (amongst other things) and traffic signal issues are addressed as needed. The monitoring station at Vegagerdin has access to the Scala system, which is physically located in the city office building, and can monitor the condition of the network and the traffic signal hardware that is connected to the Scala system.

Collaboration between the city of Reykjavik and the surrounding municipalities is limited and there are no official contracts regarding the traffic signals between them.

In practice, the current process of collaboration in the capital area can be described as follows:

a) In case of installation/maintenance/repairs of traffic signal hardware on main roads outside of Reykjavik, Vegagerdin sends their service crew to try and fix the issue, but if unsuccessful, they contact the traffic signal technicians at the city of Reykjavik directly, which in turn sends an invoice for the equipment and/or hours.

b) In case of installation/maintenance/repairs of traffic signal hardware on local roads outside of Reykjavik, other municipalities contact the traffic signal technicians at the city of Reykjavik directly, which in turn send an invoice for the equipment and/or hours.

c) In case of signal plans/design/technical assistance related issues on main roads outside of Reykjavik, other municipalities or Vegagerdin contacts either external consultants or the Reykjavik transportation department directly. The city does not specifically send an invoice in this case to the other municipalities.

d) In case of signal plans/design/technical assistance related issues on local roads outside of Reykjavik, other municipalities are increasingly contacting external consultants, but in some cases, they contact the Reykjavik transportation department directly. The city does not specifically send an invoice in this case.

e) In case of c) and d) above, the external consultants contact the Reykjavik transportation department directly for advice/quality control/review. The city does not specifically send an invoice in this case.

Few third-party organisations have direct access to the system or its data, e.g. for the purpose of sharing real-time information on the city's web page (Borgarvefsja).

The city of Reykjavik and the public transportation company (Straeto bs) meet quarterly for the purpose of evaluating the performance of the traffic signal system in general, but also the transit signal priority system (STREAM).

Some traffic signal related data is available to the public through a web portal (Borgarvefsja) which provides a variety of information including traffic situation, delays, signal information and other relevant traffic data.

6. Benchmarking

This chapter contains a comparison of the five cities and benchmarks them against each other across each of the six process or program areas from the assessment framework. Each city is scored or judged based on a three-point scale as follows:

 Poor performance relative to other cities.

 Similar or standard performance relative to other cities.

 Better performance relative to other cities, potential best practice.

In this chapter, the traffic signal system in the whole capital area is being referred to when the term “Reykjavik” is used, and it applies to both Vegagerdin and all the municipalities in the capital area.

6.1 Business processes

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

With regard to business processes Reykjavik is performing on a par with two of the four reference cities. Both Almelo and Ghent are performing better and exhibit some aspects of best practice.

A yellow score in this case indicates that traffic signal management decision making processes including planning, design, operation and maintenance are not particularly integrated and often occur in isolation. Based on other interviews this situation is not uncommon.

The other cities have a more structured approach to identifying the needs of all road users and involving other stakeholders accordingly. For example, Ghent and Almelo have set up specific working groups for coordinating improvements and identifying and managing issues. These working groups meet on a regular basis. There are opportunities for Reykjavik to employ a similar strategy expanding the involvement of external stakeholders in the design process giving stakeholders new insights early in the planning process leading to better solutions.

Reykjavik has a number of strategic planning documents both at the municipal and national level. However, the content of these plans has not been fully evaluated or broken down to specific goals or actions related to traffic signal management.

Two strategic goals that have been identified and that are directly affected by traffic signal management processes are better pedestrian and cycle access and improved public transport travel times. Careful consideration regarding signal design and priority will be required to manage these potentially conflicting goals. Evidence from the references cities indicates that locations with strict public transport priority often suffer from increased pedestrian casualties due to impatient pedestrians.

It is important that Reykjavik continues investment in connecting traffic signal controllers and associated equipment to the central control system. At the same time investment needs to be made in developing suitable working processes to make best use of the control system and the opportunities it provides for effective operation and maintenance.

A lifecycle improvement process and associated roles should be defined and clearly distributed within the organisation between departments for planning, investment, maintenance and operations.

The procurement process must support the traffic strategy and defined goals, based on a mix of parameters including competition, functionality and price.

6.2 Systems and technology

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

Compared to the majority of reference cities, Reykjavik has systems and hardware which in many respects are at the forefront of current technology. Only Almelo is further ahead employing advanced future technologies. There is, however, a relatively large gap between the level of performance being extracted from the systems in Reykjavik and the level of performance actually available. In addition to the, as yet untapped, potential of the traffic management system in Reykjavik, additional functionality can be made available in the system by opening options in the software licence.

Reykjavik has one main supplier, Siemens, providing traffic signal systems hardware and software. Reliance on a single supplier has advantages and disadvantages. Siemens is a stable and robust supplier with many years of experience in a wide variety of countries. They offer an integrated system, with easy access to equipment and spare parts when needed. The key disadvantage of a single supplier is however a potential lack of competition and flexibility regarding pricing and functionality. At the moment this does not appear to be an issue as Siemens have not changed their pricing levels for Reykjavik in a number of years. It is also the case that most of the reference cities also rely on a single or limited number of suppliers for hardware and software. We currently see no reason not to continue with Siemens.

Siemens employ a number of open protocols which make it possible to use third-party software for signal control and management. This opens up a future development path for Reykjavik. Almelo is currently at the forefront, among the reference cities, regarding the use of third-party applications on top of existing hardware. The city is using a mix of old and new hardware from a variety of suppliers all controlled by a flexible software application running in the cloud. Almelo is currently in the testing and deployment stage and there is much to be learned from following the progress of traffic signal management in Almelo over the next five years.

All the reference cities, like Reykjavik, use vehicle actuation to control signals to a greater or lesser extent. Once again Reykjavik is, relatively speaking, at the leading edge in this regard employing systems like TASS and advanced adaptive signal control technologies like MOTION. However, a word of caution, experience from other cities suggest that adaptive systems can become cumbersome and ineffective if deployed over too large an area where it can be impossible to meet a range of conflicting green time demands. Another potential challenge regarding adaptive systems is that they typically require more technical maintenance than traditional signal systems. If sufficient resources or skilled staff are not available, the system can perform worse than traditional signal control. In Gothenburg for example it has been found more effective to allow junctions to operate independently of one another, using flexible phase pictures and vehicle actuated green time extensions. This usually has the advantage of keeping cycle times short which reduces waiting times for pedestrians and cyclists. Reykjavik's current plans to test MOTION at 13 intersections seems reasonable and will provide an opportunity to fully test performance and evaluate any potential benefits provided by MOTION. An important part of the evaluation process will be to include evaluating the level of staffing required to get the best out of the new technology.

One area where Reykjavik differs from the other reference cities is its approach to signal maintenance. In Reykjavik this task is largely performed in-house whilst the other cities contract this task out to one or more maintenance contractors. Experience suggests that better results can be achieved by out-sourcing maintenance. Road authorities can define contract terms that ensure a structured and effective level of maintenance, allowing in-house staff to focus on other issues. Out-sourcing may be more challenging in a small and isolated environment like Iceland, however there are opportunities for Vegagerdin and the city of Reykjavik to encourage local suppliers to develop the required skills. An increased maintenance supplier base would provide greater flexibility, redundancy and possibly improved performance encouraged by an increased level of competition.

6.3 Performance and measurement

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

None of the assessed cities demonstrated a structured approach to measuring the performance of their traffic signal systems, with Reykjavik performing the worst in this category.

In Reykjavik performance measures are not connected to city or national goals or objectives. KPI's (such as Level of service) are not measured systematically at junction level (although it's possible) and there is no connection between any KPI's and any wider objectives. There is a broad strategy with regard to traffic signals aimed at reducing vehicle throughput in favour of pedestrian, cyclists and public transport, however no measurements are performed or reported to show how this is being achieved.

Gothenburg and Ghent performed best in this category with some measurement of signal performance aspects like cycle times and also maintenance response times. Reporting of performance occurs mainly on an ad-hoc basis.

There is a clear need in all of the cities to adopt and implement measures that assess system performance. Performance should also be monitored on a regular basis, preferably using automated systems and routines to collect and evaluate system performance. Regular performance assessment should then be used to channel resources and identify areas for improvement.

The functionality to achieve effective performance measurement already exists in the Siemens management software.

Reykjavik should also involve other stakeholders in the evaluation process, to discuss performance and propose improvements. It would also be beneficial to conduct third party audits or external reviews of systems or projects.

6.4 Organisation and workforce

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

A similar level of performance was demonstrated by all five cities with regard to organisation and workforce. All are trying to balance the constraints of limited budgets and resources whilst trying to maintain daily operations and make investments for the future.

All five cities have a small number of highly skilled staff although there are differences in how these staff are deployed. The number of in-house staff is typically between four to five employees. Edinburgh employs 11 staff, but the bulk of these perform maintenance tasks. In most of the other European cities the city experts are used to define requirements and perform quality assurance on work conducted by a wide range of third-party suppliers. In Reykjavik almost all aspects of the work related to traffic signals are performed largely in-house with some support from Siemens and local consultants.

Whilst it is important to maintain a high skill level among in-house staff there are risks involved with the in-house staff performing much of the work. If a key member of the traffic signal related staff falls ill or leaves, the organisation suffers a major gap in knowledge and capability. Reykjavik is a small and relatively isolated market which may present challenges in outsourcing tasks to external consultants or suppliers. However, it also provides an opportunity to grow the market. In addition, modern technology and communication make it practical to commission design and planning work from suppliers from a wide variety of countries. Maintenance contracts, however, would need to be kept in-country.

It is important for Reykjavík to increase the level of backup within the organisation, partly be improving knowledge for in-house staff but also by adopting flexibility whereby a number of individuals can perform a variety of roles. The strength and flexibility of the organisation can also be enhanced by increasing the volume of third-party suppliers and consultants. Apart from providing additional backup, external organisations provide new ideas and input.

Related to all of the above is the need for clearly defined work roles, staff development schemes and career paths within traffic signal management.

6.5 Culture

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

None of the five cities demonstrated better or worse performance in relation to each other with regard to culture. For all five, traffic signal management is simply one of many functions within their respective organisations.

All the cities employ a relatively wide variety of communication channels based around the web and social media. Compared to Reykjavik the other cities are better at performing public consultation when conducting projects.

Traffic signals generally suffer from a lack of awareness amongst policy makers and the public. Most of the advances in traffic signals in recent years have taken place within back office functionality. There is little that has visibly changed for road users out on the streets; the traffic lights still look the same. It is therefore important to spread awareness of what is being done and why.

Given that Reykjavik is in a period of change with regard to traffic signals and has a relatively new and enthusiastic organisation it is a prime opportunity to introduce new changes. It would be useful to appoint a traffic signals "champion" in order to actively direct and promote activities related to traffic signal management, including improving communication, public consultation and cooperation.

6.6 Collaboration

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

Reykjavik performed relatively poorly compared to the other cities with regards to collaboration. The Scala system provides the functionality to give data access to other stakeholders, which is being used e.g. by external consultants for the purpose of displaying data on the city's web portal (Borgarvefsja), such as:

- signal plans,
- intersection layouts,
- real-time traffic conditions and counts.

Reykjavik could usefully increase its participation in research and development projects within traffic signals in both the European Union (EU) and other international institutions. Other cities use external funding (such as EU grants) to finance development instead of using their own funding or as a complement to their own research budgets.

The City and Vegagerdin do meet to discuss projects, processes and improvements, but no common goals or objectives from these meetings are documented. Both parties could produce a joint statement ("white paper") for the development of traffic signals in Reykjavik.

7. Identified areas for improvement

This chapter contains suggested actions for improvement. The chapter is divided into seven key sections. This first section describes priority actions in areas where Reykjavik is performing poorly relative to the four reference cities. The remaining sections describe activities that can be used to move Reykjavik forward in each of the six process or program areas.

In summary Reykjavik is largely performing on a par with the four reference cities. It is only in a limited number of areas where Reykjavik is performing worse relative to the other cities. If Reykjavik were to implement all the actions listed in the remainder of this chapter, it would place it in a leading position in terms of traffic signal management.

7.1 Priority actions

Based on the results of the assessment framework we have identified a few key areas that should be given immediate attention. These areas are primarily associated with Performance and measurement and Collaboration and are areas where Reykjavik is performing poorly relative to the other cities.

We recommend producing a strategic plan containing clear goals defining what the City and Vegagerdin want to achieve with the traffic signal system. The plan should include a definition of relevant KPI's (e.g. safety-related) and a structured process for measuring progress. Key performance indicators should be closely related to defined goals and will vary depending on whether they relate to operational traffic performance or maintenance. Examples of KPI's could include maximum waiting time for pedestrians and cyclists, public transport travel times and response times to maintenance issues. Follow-up and evaluation should be performed in cooperation with key stakeholders. The city could also widen and increase the level of external cooperation, e.g. participation in European R&D projects.

We see no reason at this stage not to proceed with the chosen technical development path. The systems currently deployed in Reykjavik are comparable or in some cases better than those deployed in the other cities (e.g. MOTION). All of the cities have a mix of old and new equipment with a range of performance. What we have seen is that the other cities have structured their working processes and organisations to get more out of their systems. We also feel this must be one of the main priorities for Reykjavik going forward. It is ineffective to buy new equipment without first clearly defining what the city wants to achieve with the traffic signal system. Our recommendation is therefore to invest in people and processes rather than technology. We believe there is more to be extracted from the technology and systems already deployed. However, there is a need to develop a life-cycle status plan for traffic signal system components in order to identify what items need upgrading and when.

We also feel it is a prime opportunity to perform and introduce changes required within the internal organization as the staff is new and enthusiastic. It is also vital to support training and capacity building efforts for all traffic signal operation staff. Determining the number of staff required to design, operate and maintain the traffic signal system will be a key part of this work. At the moment we feel that the number of full-time staff employed on the design and operations side is perhaps insufficient to really provide a robust system. Finding the right balance with regard to staffing levels will be one of the challenges going forward. It may be necessary to increase staffing levels initially but then reduce numbers once new processes and systems are in place. The general trend in the reference cities and in particularly Almelo, which is employing state-of-the-art technology and processes, is to try and keep in-house staff levels to a minimum.

7.2 Business processes

7.2.1 Strategic planning

This sub process is focused on improving Reykjavik's strategic planning process to better support operation and maintenance of its traffic signal systems. The emphasis is on clearly linking national and regional goals to traffic signal operations.

Develop a performance management/monitoring plan

This activity involves identifying the measures and data to be used to assess how traffic signal performance will be evaluated in Reykjavik and the capital region. Performance measures and time frames for collecting data and measuring performance should be defined. It is important to clearly establish a link between operational goals and performance expectations. The monitoring plan can then be used to identify the need for operational improvements. Many of the tools for performance evaluation already exist within the Siemens software package.

Integrate traffic signal operations and maintenance into regional long-term transportation plan

This activity focuses on improving coordination between relevant planning authorities, primarily SSH and Vegagerdin, to ensure that traffic signal operations and maintenance are considered in regional planning activities. The benefit of this is a clear picture of the long-term resources required to support operations and maintenance, in the context of proposed regional planning.

7.2.2 Operations and maintenance

The focus of this sub process is to improve working processes related to the operation and maintenance of the traffic signal system and associated infrastructure.

Develop policies for how the needs of vulnerable road users and public transport will be met by the traffic signal system.

This activity involves clearly defining and documenting when, where, and how these road user groups will be serviced at traffic signals. The purpose is to ensure consistency in design and that the needs of vulnerable road users and public transport users are effectively considered in the design, operation and maintenance of the signal system.

7.2.3 Schemes and budgeting

Activities in this sub process are designed to help with the improvement of scheme design and budgeting of traffic signal operations and maintenance.

Implement life-cycle planning for traffic signal and related infrastructure.

The purpose of this activity is to develop and implement processes and routines for monitoring and assessing the life-cycle status of traffic signal system components. The goal is to identify what items need upgrading and when. By adopting a structured process, it is possible to extend the life of system components that are still performing adequately and replace systems and equipment based on actual need. The same structure can be applied to non-hardware elements such as signal timing plans.

Use results of operational assessments and performance monitoring to identify intersection and arterial capacity enhancement investment projects.

This activity focuses on creating working processes to identify where new investment in road and junction improvement projects is actually needed. By employing structured processes for collecting and assessing performance data it will be possible to identify locations where optimisation measures are insufficient for correcting issues and capital investment is required.

7.2.4 Resource allocation action plan

This sub process focuses on improving working methods used to allocate resources, personnel and financial, for traffic signal management.

Implement on-demand engineering services contracts for traffic signal operations support.

This activity entails making better use of external contractors and consultants to support traffic signal operations. Consultants can be used to provide additional resources in design and planning aspects whilst maintenance contractors can provide a wider range of operations support. In this way additional redundancy is provided for the limited number of staff working within the City and Vegagerdin.

Internal resources can then focus on design, setting specifications and performing appropriate quality control of suppliers work.

7.3 Systems and technology

7.3.1 Continuity of service action plan

The purpose of this sub-process is to improve continuity of service over a multitude of different operational scenarios.

Assess the impact of declining traffic system performance caused by system and hardware malfunctions
This activity involves making better use of the fault detection and follow-up functionality offered by the Siemens signal management software. By developing working processes for assessing and tracking the degradation of traffic signal performance caused by system faults it is possible to effectively prioritise maintenance responses. This also provides justification for implementing system redundancy where needed.

7.3.2 Procurement action plan

This sub process focuses on ensuring that procurement of traffic signal systems technology is based upon achieving defined goals and objectives.

Deploy decision support system to assist with real-time operational decision making.
This activity involves developing a decision support system that can be used by operators, in real time, to select operational strategies. The goal is to use the monitoring functionality available in the Siemens system to provide operators with information regarding the best strategies to be used based on traffic conditions. These systems can be used during incidents, special events or any situation where abnormal traffic conditions arise.

7.3.3 Operational flexibility action plan

This sub process is intended to assist in the deployment of systems that provide flexible response to a wide range of operational conditions.

Implement processes to perform real-time automated traffic signal performance monitoring.
This activity involves improving the working processes associated with the use of TASS and MOTION to ensure that they are performing as intended.

7.3.4 State of good repair action plan

This sub process is focused on identifying strategies for the maintenance of the traffic signal system.

Deploy regional traffic signal maintenance database/asset management system.
This activity involves developing and deploying a regional database that the City and Vegagerdin can use to manage their traffic signal system assets, including communications, infrastructure maintenance, and timing plans. By using a single system both agencies can track their assets and make decisions that cross jurisdictional boundaries.

7.4 Performance measurement

7.4.1 Performance measures plan

This sub process is intended to help with the design of appropriate performance measures that can be used to assess the effectiveness of the traffic signal system.

Define and deploy safety-related performance measures.
Given the increased focus on vulnerable road users and public transport it is important to focus on deploying performance measures that show how junctions are operating from a safety perspective.
Define and deploy "good basic service concept" performance measures.
This activity involves identifying and documenting performance measures that can be used to compare the performance of individual intersections with defined goals and objectives. These performance measures should be used to assess the effectiveness of signal timing strategies at individual intersections to provide basic quality of service. A range of appropriate performance measures need to be selected that encompass more than just Level of Service for vehicle traffic.
Define and deploy maintenance-related performance measures.
This activity involves developing performance measures that can be used to track maintenance activities. This makes it possible to assess the effectiveness and responsiveness of maintenance teams. Such measures can be deployed as part of a process for contracting out maintenance operations.

7.4.2 Performance measure utilisation action plan

This sub process is focused on developing working processes for using performance data in support of strategic decision making to improve safety and operations.

Monitor junctions with high accident rates for safety improvements.
It is important, given the move towards priority for vulnerable road users and public transport, to identify locations with high accident rates. By doing so it is possible to prioritise improvements and implement remedial measures in a timely fashion.
Analyse peak-period operations of most congested junctions.
This activity involves using traffic data from the traffic management system and other sources to assess conditions at the most congested locations. In doing so the City and Vegagerdin can identify problems directly instead of waiting for public feedback. It should be possible to identify issues such as detector failures, damaged equipment or programming errors which otherwise might go undetected for months.
Develop prioritised listing of equipment upgrades and replacement.
This activity involves using maintenance-related performance measures to identify a prioritised list of locations needing equipment upgrades and repairs. This information can then be used in dialogue with decision makers.

7.5 Organisation and workforce

7.5.1 Staff development action plan

This sub process focuses on developing the skills and knowledge of traffic signal management and maintenance staff.

Provide funding to support formalised training and professional capacity building for all traffic signal operations staff.
This activity involves allocating a portion of the City's and Vegagerdin's budgets to providing resources for formalised training and professional development activities for all staff. This will ensure staff can develop and maintain the necessary knowledge, skills, and abilities to achieve identified operational goals and objectives.
Identify basic knowledge, skills, and abilities of staff to achieve defined goals and objectives.
This activity involves conducting an audit of the capabilities of staff to ensure that they have the necessary skills and capabilities to achieve defined goals and objectives. The purpose of the audit is to determine where there are gaps in knowledge and act accordingly to fill the gaps either through training, recruitment or out-sourcing.

7.5.2 Program structure action plan

The purpose of this sub process is to look at what structural changes could be made to improve traffic signal management performance and effectiveness

Provide staffing for real-time performance monitoring during normal work hours.
This activity involves allocating traffic signal technical staff to monitor and make real-time adjustments to traffic signal operations during normal work hours. This would make it possible to identify operational problems as they develop during normal work hours. It would also make it possible to identify locations where operational problems persist beyond the peak period and to focus resources on those locations.
Supplement City and Vegagerdin staff with contract staff.
This activity involves contracting external professional and technical staff to perform actions and activities beyond the capabilities of the internal organisation. This activity creates vital redundancy whilst expanding capability.

7.6 Culture

7.6.1 Outreach action plan

The purpose of this sub process is to improve contact and communication with a variety of external stakeholders regarding the objectives and benefits of traffic signal management.

Develop project-based traffic signal system performance reports.
This activity involves developing outreach materials that report on the benefits and effectiveness of the various projects performed by the City and Vegagerdin to improve operations. These project briefs should highlight the work performed and the measured benefits associated with the project. This makes it possible to report the benefits to be derived by projects and programs and to build political and institutional support with local stakeholders.
Establish a web presence describing operational goals and objectives.
This activity involves providing information on the web or through social media about activities related to traffic signal management. This makes it possible to provide critical information about the goals and objectives associated with traffic signal operations, and other information deemed important in order to build support.
Conduct focus groups of with road users and key stakeholders.
This activity involves convening periodic focus groups with road users and key stakeholders of the transportation system to discuss critical issues and provide feedback related to traffic signal operations. This activity is intended

to open a dialogue with users to assist in determining whether goals and objectives are consistent with those of the community. This dialogue provides an opportunity to assess performance, discuss operational priorities, and communicate trade-offs in a proactive manner.

7.6.2 Leadership action plan

This sub process focuses improving leadership aspects of traffic signal management.

Establish regional peer-to-peer exchanges/periodic staff meetings to discuss regional traffic signal operations and maintenance.
This activity involves creating opportunities for City and Vegagerdin staff to interact with personnel from other key organisations in the region to discuss common issues and concerns. This action allows regional partners to share ideas and reach mutually beneficial goals.
Encourage innovation and forward-thinking related to addressing critical or demanding issues.
This activity involves establishing processes and procedures that allow staff to provide innovative solutions and techniques for addressing unusual or demanding problems. Innovation involves encouraging creativity and providing autonomy and resources for achieving operational goals and objectives.

7.7 Collaboration

7.7.1 Data sharing action plan

This sub process focuses on improving data sharing and collaboration.

Establish well-documented procedures for archiving system and operational information.
This activity involves developing written procedures for archiving system and operational data. This makes it possible to establish standardised processes and procedures by which traffic signal performance and operational data can be stored. Data can be used to develop baseline performance metrics.
Establish processes and procedures for sharing incident information.
This activity involves establishing processes and procedures for sharing incident information, especially in real time. This includes sharing information about the location, status, and expected duration of incidents. This activity allows each stakeholder to coordinate plans for managing traffic during an event or incident.

7.7.2 External stakeholders action plan

This sub process is intended to foster collaborations with external stakeholders at all levels.

Establish a working group of external stakeholders to discuss new projects and operational improvements.
This activity involves collaborating with external stakeholders to discuss new projects and operational improvements. This activity provides a catalyst for agencies to develop common goals and reach consensus regarding infrastructure changes.
Collaborate with regional partners to develop incident management scenarios.
This activity involves working with regional partners to identify operational strategies that can be implemented during incident conditions. This activity makes it possible to develop traffic signal management strategies that promote optimum flow across the region during non-recurring congestion

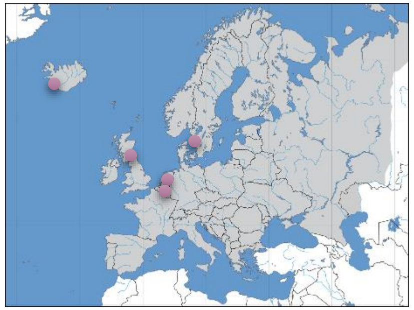
events. This action can promote smooth flow and minimise delays across jurisdictional boundaries.

Traffic signal system in Reykjavik capital area

Final presentation, 9 October 2020

Scope of project

- Analyse the current traffic signal system and internal working processes for the Reykjavik capital area.
- Compare Reykjavik's traffic signal systems with a number of other cities:
  - resources
  - operation
  - control
  - identifying common and best practice
- Highlight pros and cons of different systems and identify development paths for Reykjavik going forward.
- Key questions.
  - Can the existing traffic signal system support new transport strategies?
  - Do system improvements need to be made?
  - Are appropriate internal processes in place?



Comparison cities

Gothenburg, Sweden

- Population: 600 000
- Signalised intersections: 100
- Main supplier: Swarco

Edinburgh, United Kingdom

- Population: 550 000
- Signalised intersections: 610
- Main supplier: Siemens

Almelo, the Netherlands

- Population: 70 000
- Signalised intersections: 44
- Main supplier: Dynniq and Vialis

Ghent, Belgium

- Population: 260 000
- Signalised intersections: 94
- Main supplier: Swarco and Siemens

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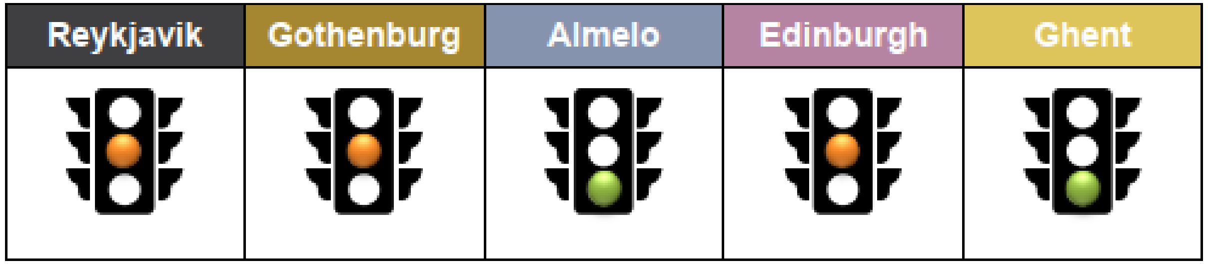
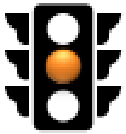
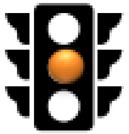
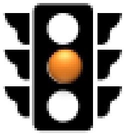
Benchmarking – Business processes



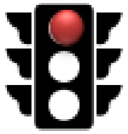
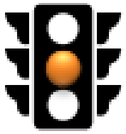
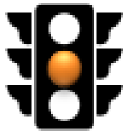
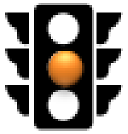
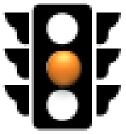
- Traffic signal management decision making processes including planning, design, operation and maintenance occur in isolation.
- Ghent and Almelo have regular meetings with stakeholder groups.
- Reykjavik has strategic planning documents that should be broken down to specific goals.
- Important that Reykjavik continues investment in connecting traffic signal controllers to the central control system.
- A lifecycle improvement process and associated roles should be defined and clearly distributed within the organization between departments.

Benchmarking – Systems and technology

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

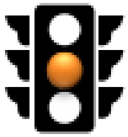
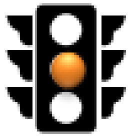
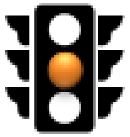
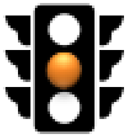
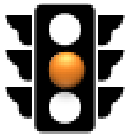
- Reykjavik has systems and hardware which are at the forefront of current technology – only Almelo is further ahead.
- Untapped potential of the traffic management system in Reykjavik.
- Siemens are stable/robust supplier offering well integrated systems.
- Siemens employ open protocols allowing future development path with third party applications.
- Important to deploy and operate adaptive control systems at an appropriate level.
- Potential for out-sourcing maintenance to allow in-house staff to focus on other issues.

Benchmarking – Performance and measurement

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

- None of the cities demonstrated a structured approach to measuring the performance of their traffic signal systems.
- Gothenburg and Ghent have limited performance measurement of cycle times and maintenance response times.
- In Reykjavik performance measures are not connected to city or national goals or objectives.
- Functionality exists in the management software for measuring performance.
- Important to involve other stakeholders in performance evaluation.

Benchmarking – Organisation and workforce

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

- Similar performance across the cities
- All cities have small number of highly skilled staff – differences in deployment.
- Almost all aspects of traffic signal related work in Reykjavik are performed in-house.
- Important for Reykjavik to improve level of redundancy within the organisation.
- Other cities define requirements and perform quality assurance on work conducted by external suppliers and consultants.
- Important to clearly define work roles, staff development schemes and career development paths.

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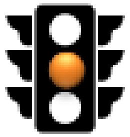
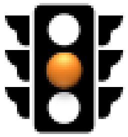
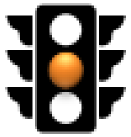
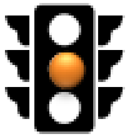
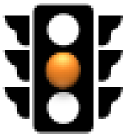
Benchmarking – Culture

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

- Similar performance across the five cities.
- Other cities are better at performing public consultation when conducting projects.
- Traffic signals generally suffer from a lack of awareness amongst policy makers and the public.
- Opportunity for Reykjavik to appoint a traffic signals "champion".

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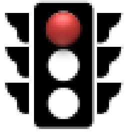
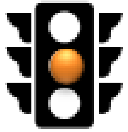
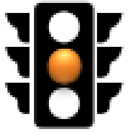
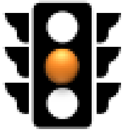
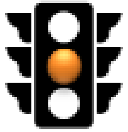
Benchmarking – Collaboration

Reykjavik	Gothenburg	Almelo	Edinburgh	Ghent
				

- Reykjavik performed poorly compared to the other cities.
- Opportunities exist to improve sharing and collaboration around data from the traffic signal management system.
- Increase participation in R&D projects within the European Union.
- Other cities use external funding to finance development instead of using their own funding or as a complement to their own research budgets.
- The City and Vegagerdin could usefully produce a joint white paper outlining collaboration objectives.

Identified areas for improvement – Priority actions

Business Processes

- Develop strategic plan with clear goals for system performance
- Integrate traffic signal operations into regional long-term plan

Systems and Technology

- Proceed with chosen technical development path
- Use existing system functionality to meet strategic goals
- Look towards ITS technology for the longer term +5 years, where appropriate

Performance and Measurement

- Define relevant KPI's
- Define structured process for measuring performance
- Develop life-cycle status plan to manage upgrades

Identified areas for improvement – Priority actions

Organisation and Workforce

- Staffing levels to match strategic plan and provide appropriate levels of redundancy
- Optimise staffing levels in the future and out-source where appropriate

Collaboration

- Follow-up and evaluate performance in cooperation with key stakeholders
- Increase external cooperation by participating in European R&D projects

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ERINDISBRÉF
Samstarfshópur um umferðarljósastýringar

Ábyrgð:
Samgöngustjóri Rvk. & svæðisstjóri höfuðborgarsvæðis Vg. f.h. SSH og Vegagerðarinnar.

Inngangur:
Niðurstöður úttektar SWECO á umferðarljósastýringum á höfuðborgarsvæðinu liggja nú fyrir. Í úttektinni felst greining á núverandi umferðarljósakerfi og rekstri þess, mat á kostum og göllum mismunandi umferðarljósakerfa og verkferla og tillaga um hvernig þróa á umferðarljósastýringar á höfuðborgarsvæðinu.

Hlutverk:
Samstarfshópur sveitarfélaganna og Vegagerðarinnar um umferðarljósastýringar á að vinna frekari tillögur og aðgerðaáætlun á grundvelli niðurstaðna SWECO.

Helstu verkefni:
Samstarfshópurinn skili ítarlegri tillögum að úrbótum ásamt aðgerða- og innleiðingaráætlun til stjórnar Betri samgangna ohf. í janúar 2021. Samstarfshópurinn haldi í framhaldinu utan um frekari stefnumörkun, innleiðingu breytinga, eftirfylgni, rekstur, viðhald og árlegar fjárfestingar í umferðarljósastýringum á höfuðborgarsvæðinu og gefi a.m.k. tvisvar á ári út yfirlit um þróun umferðarljósastýringa. Yfirlit sem lagt verður fyrir ábyrgðaraðila hópsins, stjórn Betri samgangna ohf. og fleiri eftir þörfum.

Samstarfshópinn skipa:

- Baldur Grétarsson, deildarstjóri, Vegagerðinni
- Bergþóra Kristinsdóttir, framkvæmdastjóri þjónustusviðs Vegagerðarinnar
- Grétar Þór Ævarsson, sérfræðingur í umferðarljósastýringum Rvk.
- Guðbjörg Lilja Erlendsdóttir, deildarstjóri samgangna Rvk.
- Helga Stefánsdóttir, forstöðumaður á umhverfis- og skipulagssviði Hfj.
- Katrín Halldórsdóttir, verkfræðingur á höfuðborgarsvæði Vegagerðarinnar
- Nils Schwarzkopp, sérfræðingur í umferðarljósastýringum Rvk.

Samstarfshópurinn velji formann og ritara sem halda utan um starfsemi hópsins og eru í forsvari.

Starfstímabil:
Samstarfshópurinn hefji störf í nóvember 2020. Um er að ræða varanlegan samstarfshóp sem skipaður er ótímabundið, sveitarfélögin og Vegagerðin skipi nýja fulltrúa í hópinn ef þörf krefur síðar.

Samþykkt á fundi stjórnar verkefnastofu Borgarlínu 6. nóvember 2020

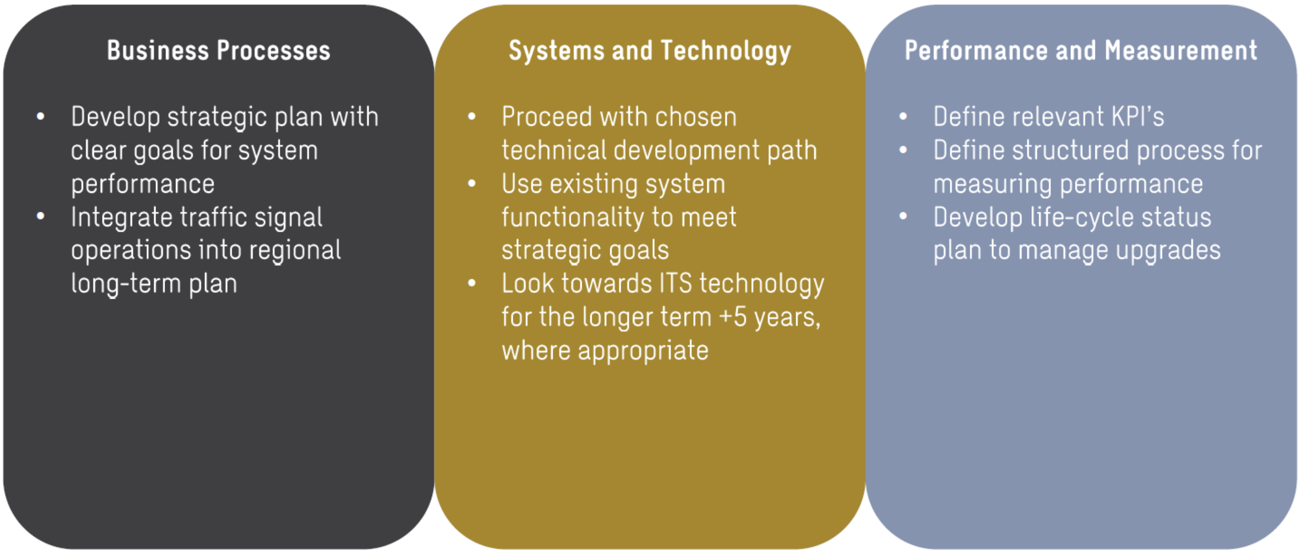
Greinargerð

Niðurstöður úttektar SWECO á umferðarljósastýringum á höfuðborgarsvæðinu liggja nú fyrir. Í úttektinni felst greining á núverandi umferðarljósakerfi og rekstri þess, mat á kostum og göllum mismunandi umferðarljósakerfa og verkferla og tillaga um hvernig þróa á umferðarljósastýringar á höfuðborgarsvæðinu. Í matinu er m.a. horft til fjögurra samanburðarborga sem eru Gautaborg í Svíþjóð, Almelo í Hollandi, Edinborg í Skotlandi og Ghent í Belgíu.

Matskerfið sem SWECO notar í úttektinni er byggt á formlegu matskerfi FHWA (bandarísku vegagerðarinnar) á uppbyggingu og rekstri umferðarljósastýrikerfa. Meginmatsþættir eru:

- *Verkferlar* – stefna, markmið og ákvarðanataka.
- *Kerfi og tækni* – staða búnaðar og stýrikerfa og möguleikar til þróunar.
- *Árangur og mælingar* – gæðakerfi, mælikvarðar og reglubundnar mælingar.
- *Vinnuskipulag og mannafli* – staða þekkingar og mönnun daglegra verkefna.
- *Menning* – staða almennrar þekkingar, samráð og upplýsingagjöf.
- *Samstarf* – við hagsmunaaðila og í rannsóknar- og þróunarverkefnum.

Í skýrslu SWECO um niðurstöðurnar eru settar fram tillögur að úrbótum og þeim forgangsraðað.
Helstu úrbótatillögur eru teknar saman á myndum að neðan:



Organisation and Workforce

- Staffing levels to match strategic plan and provide appropriate levels of redundancy
- Optimise staffing levels in the future and out-source where appropriate

Collaboration

- Follow-up and evaluate performance in cooperation with key stakeholders
- Increase external cooperation by participating in European R&D projects