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# OPEN SOURCE FOR PUBLIC SERVICES

Approach, Evidence & Lessons  
from European cities

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**Interreg**  
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EUROPEAN UNION

**Gemeente  
Amsterdam**



**Hamburg**

UNIVERSITY of  
**BRADFORD**



CITY OF  
BERGEN



City of  
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DORDRECHT

ghent  
the match city



# INDEX

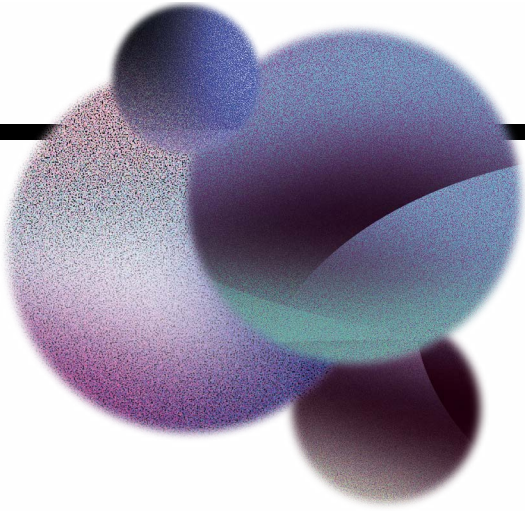
Foreword ..... 4

Background ..... 5

Open collaboration for better public services ..... 6

Results and Impact ..... 10

Lessons learned ..... 28



## FOREWORD

Digital innovation is core to improving public services, and relies heavily on supporting software. Cities and governments have a responsibility in exploiting digital innovation for public services as it represents a key opportunity for meeting citizens' expectations of next generation public services and helps our cities in solving societal challenges. Open collaboration around software development and data sharing can improve public services, making our cities more efficient, transparent and resilient for residents and visitors. By replicating existing open-source software solutions for public service, cities can stay in control of their data, while accessing wider expertise and networks in the co-development process. The bottom line is better public services at a lower cost.

This white paper illustrates the potential of open-source software for public services through the lens of open collaboration for all cities. Drawing conclusions from 8 European cities, the benefits of open-source software for public services are proven. However, the city stories show that the process to get there is not as easy and straightforward and requires willingness to share and invest time and resources in the short term. This is also my personal experience.

Using open-source software and open data by authorities should not be considered the end-goal, but as a step towards better public services. The city of Amsterdam aims to reuse codes as much as possible making use of open standards and supporting the publication and accessibility of code developed internally. Open collaboration improves the quality, support and development time significantly. This is also clear in my role as program manager covid data & design at the Dutch Ministry of Health, Welfare and Sport where we are collaborating successfully with the Open Source community and developed an application to tackle the COVID-19 crisis.

I welcome this ground-breaking work by frontrunner cities in open source, and ambitious newcomers. It provides valuable lessons on working open source grounded in practice. By demonstrating the benefits of working open source, the publication inherently strengthens the Open Source community. Open collaboration between cities allows cities to learn from each other on their common challenges. I hope this inspires more work and collaboration.

Enjoy the read!

**Tamas Erkelens**

Program Manager Covid Data & Design at the Dutch Ministry  
of Health, Welfare and Sport  
Former Program Manager of Data Innovation at  
the city of Amsterdam

# BACKGROUND

This publication shares the stories of 8 European cities working together to improve public services through open collaboration: collaboration to develop and (re-)use open data and to develop open-source software solutions. Based on nearly 5 years of transnational collaboration, it reflects on the Open Source approach used by European cities and universities, provides evidence on the impact created within the cities and presents the lessons learned, enabling other cities and interested organisations to enact their own effective open-source software initiatives.

## **Intended audience**

This publication aims to inspire and inform anyone interested in working with open data and open-source software solutions for improving public services. The target audience includes policy and decision makers of cities, regions and national governments, governmental directors of urban planning, digital innovation managers, and practitioners of open source within and outside of the Open Source community.

# OPEN COLLABORATION FOR BETTER PUBLIC SERVICES

The world is changing. Transformations to mobility patterns, pressing air quality issues, and growing flood risks present new challenges for European cities. Now, however, thanks to data and digitisation, cities can tackle these challenges together. Rather than reinventing the wheel or going down the traditional software vendor route with all its associated issues, cities can improve local services by co-developing and replicating digital solutions based on open-source software.

What are the main visions, underlying assumptions and potential methodologies for open-source collaboration? This section presents the building blocks of a challenging but fruitful transnational collaboration of European cities with the ambition to explore the potential of open-source collaboration. The vision for open collaboration, the principles for open-source software development used during this period will be addressed, followed by the methodology used to collaborate around open source, open data, and open standards.

### **Vision of open collaboration between cities**

Open collaboration between cities requires a partnership that is inherently transparent and collaborative. Open collaboration allows anyone to re-use, change, and redistribute what has been made. Furthermore, it allows anyone to view the conversations around the production and offers ways for people to contribute. These methodologies enable large groups of people to solve complex issues together by allowing natural connections to form between challenge owners. At the core of this approach is the open data and Open Source philosophy. The open data principle encourages making data accessible to all if possible under a licence that allows for re-use of the data by anyone. The Open Source principle emphasises the importance of making software accessible to everyone, and open for everyone to use, change, improve, and share it through initiatives such as GitHub.

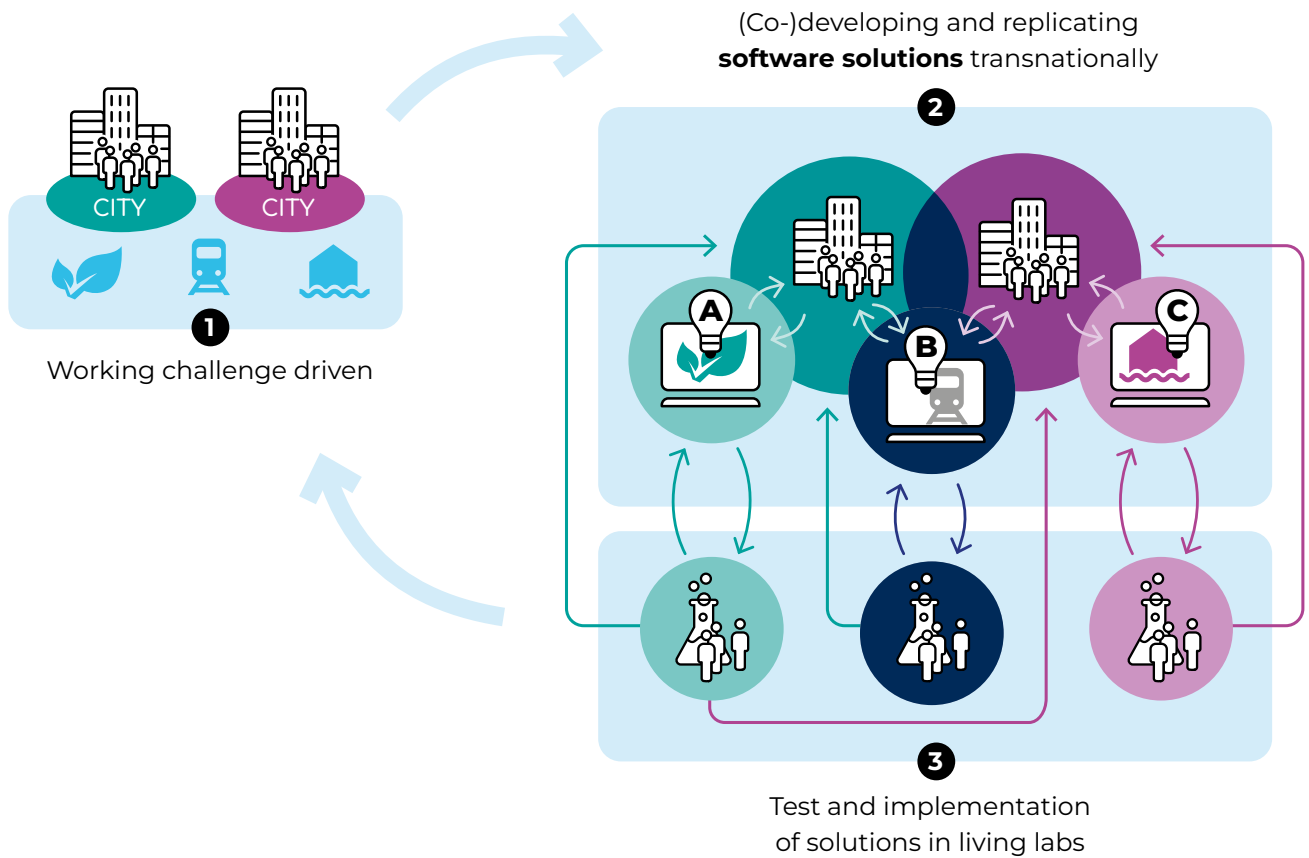
Through open collaboration, the risks individual organisations face are mitigated, public organisations become more economically sustainable and ethical in their digital sourcing, and as a result are able to deliver better public services. By delivering better public services, the quality of the services for the end-users will increase whilst the costs of service provision are reduced. Using open collaboration, i.e. collaborative efforts to develop and re-use software, is expected to decrease the time needed for solution development.

### **Principles for open-source software development**

To develop open-source software, the following principles apply:

- Produce replicable code
  - Develop modular, customisable and scalable solutions
  - Make data open when available
  - Adhere to EU standards and ethical guidelines
  - Harmonise with existing legacy IT systems
  - Integrate with ongoing city operations
  - Let go of fixed standards
-

## Methodologies for collaborating around open-source software development



### 1 Working challenge-driven

Cities active in an open collaboration try to tackle urban problems together by working with a challenge-driven approach, thereby increasing the value of public service delivery.

Working challenge-driven, allows cities to benefit from what is already out there. The challenge driven approach takes the challenges cities are facing, the knowledge of the cities' operations, the available data and existing initiatives as a starting point. By creating a partnership, different cities try to share and identify common challenges as well as re-using each other's solutions, improving them collaboratively and sharing their own developed solutions. Cities share the learnings of solving their own challenges whilst exchanging ideas and best practices in an agile way. Continuing to develop what is already there (e.g. through replicating and adapting) allows cities to accelerate at the start, produce quick and tangible results, and create direct impact for partners.

For challenge-driven development to work effectively, certain requirements need to be considered. First of all, the challenges need to be scoped and framed correctly – explaining user needs and providing an actionable scope of work. The challenge should be specific enough to focus cities on common goals, for example scoping challenges to the fields of environment, water ma-



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agement and mobility, but open enough to accommodate for different priorities, jurisdictions, governance structures, and context. Secondly, the appropriate stakeholders need to be consulted and involved from the start, defining the challenge together. This creates an ecosystem of co-ownership and shared commitment, providing an inclusive process. Involving and aligning the diversity of stakeholders from both inside and outside the partner organisations (e.g. technical IT workers, domain experts, problem owners and financial staff) can be challenging. Lastly, the process of working challenge-driven is not linear, but requires iterations with different stakeholders and user needs.

## **2 (Co-)developing and replicating software solutions transnationally**

The open collaboration vision argues that cities collaborate in different forms on the agile process of software development and reuse.

Collaboration on software development follows the open-source software development standards as stated above, making the code editable and adaptable to local contexts. This collaboration can range from direct collaboration on code development (through e.g. agile development sprints) to providing input and feedback on other cities' approach and code. This can take the form of working on the same solution, different modules of the same solution, different solutions to the same challenge, or even different challenges within the same domain. Direct collaborative development is likely to work best with high personal involvement and intense and frequent (face-to-face) meetings between developers.

Collaboration on replication and reuse of solutions is made possible through the principles of sharing open data and open-source software development as stated above. The solutions are developed using open standards and with open data availability in mind, making the data and code centrally accessible and interoperable. In parallel, guidelines guaranteeing the quality and reusability of the code and solutions are developed and maintained by the partnership.

Although cities are unlikely to have the exact same challenge and solution requirements, the methodology assumes collaboration will still be valuable, feasible, and desirable by cities, resulting in improved public services.

## **3 Testing and implementation of solutions in living labs**

Once software solutions are designed, developed, and functional, cities test and implement the solutions in real-life ecosystems through urban living labs.

Living labs are considered an integral part of the challenge and solution development phases, as they allow end-users to be included in problem definition, solution ideation, and feedback on solutions. Experimenting in a living lab allows for open collaboration between different stakeholders active in the local context. Using urban living labs gives end-users such as citizens the opportunity to experience the solution in an everyday setup.

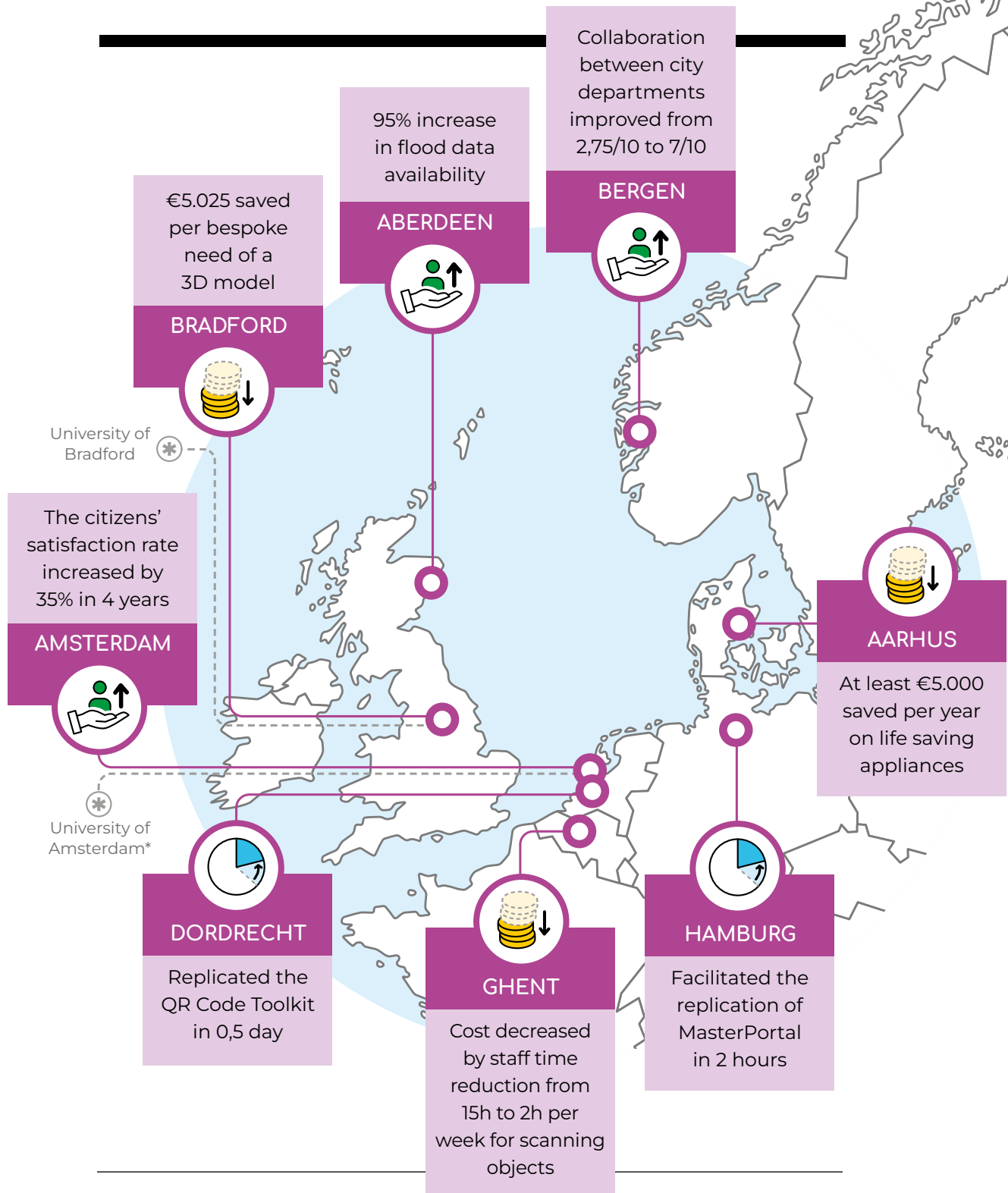
# RESULTS AND IMPACT

The use of open-source software solutions and open data by authorities aims to improve public services. This section presents the experiences of 8 European cities working open source with the aim to improve their public services. The results of open collaboration on the quality and costs of public services and the time needed to develop targeted solutions within cities and beyond will be assessed using illustrative case studies. The section provides a picture of the impact of the collaboration around open-source software between European cities and universities.

## THE SMART CITIES AND OPEN DATA RE-USE (SCORE) PROJECT

The Interreg North Sea Region SCORE project is a partnership of governments, universities, and other organisations that collaboratively discover, develop, and test open-source solutions for urban challenges. SCORE aims to increase access to open data in order to push for new innovative solutions for smart cities. SCORE is about increasing quality and reducing cost of public services, with special regard to air quality, flood risk and mobility flows. Cities pool resources and expertise to co-develop innovative solutions to be tested and replicated in existing urban living labs.

The SCORE partners leverage open collaboration methodologies – open source, open data, open standards and an open attitude – to learn together, communicate effectively, share challenges, and collaborate on solutions with the goal of improving public services in cities.



**Indicators**



Improvement in quality of service services



Reduction in solution development time



Reduction in public service costs using open-source software solutions

\* Additional impact created



### Improvement in quality of service services

Digital innovation is core to improving public services, and relies heavily on supporting software. To measure and evaluate public service provision, cities look at the satisfaction and quality levels of the specific service, for example the ability to report street incidents to the city authorities and the response time. This is valued and assessed by end-users. They can be either groups of citizens or civil servants and city workers making use of services in their daily tasks.

Improvement and higher quality is ensured through the challenge-driven approach. Urban challenges are first defined by cities and shared ones identified. The underlying assumption is that solutions emerging are solving specific challenges in the fields of mobility, environment, and flood risk, therefore improving service provision. This is measured through comparing the end-user's satisfaction pre and post solution implementation.

### THE ABERDEEN CITY COUNCIL



The Aberdeen City Council suffers from a large amount of surface water flooding, which causes significant disruption to businesses, transport networks, and city properties.

Due to low quality data for watercourses, there was no statistical information to allow the verification of Flood Models, which could be used to create maps showing the areas at greatest risk of flooding and allowing the Aberdeen City Council flooding team to mitigate the risk. Additionally, there was no system to allow people to have advanced local warning of a possible flood risk, other than the SEPA (Scottish Environmental Protection Agency) regional scale warnings for the Grampian Area.

The team shared challenges related to flood risk with the city of Bradford Metropolitan District Council, with whom they collaborated during the SCORE project.

CHALLENGE

SOLUTIONS

Aberdeen's first flood warning system has been established through the implementation of water level gauges, a dashboard, and a new LoRaWAN communication system. The flood monitoring solution establishes water level data records leading to improved flood risk response prioritisation, emergency resilience planning and will assist urban planning services. Through collaboration with the University of Bradford, Aberdeen City Council trialled a citizen science application for flood monitoring. This app should allow citizens to report early signs of floods.



The adoption and implementation of a flood monitoring solution in the city of Aberdeen resulted in the establishment of a primary calibrated dataset of water level data. The city estimates **a 95% increase in data availability**. Better monitoring of water levels allows remote assessment of flood risks, and quicker reaction in case of early signs of flood improves management of resources by reducing false call-outs and prioritising high flood risk events. Approximately **2 to 3 hours of service time per flood event** in reference to attending the site to evaluate are saved thanks to remote assessment. Typically one van attendance with one person, would account for 15 litres of Diesel. This frees up worker hours and presents a saving to the local authority. Finally, the engagement of citizens has led to increased awareness of flooding responsibilities and enhances community resilience due to the quality of flood alert notifications.

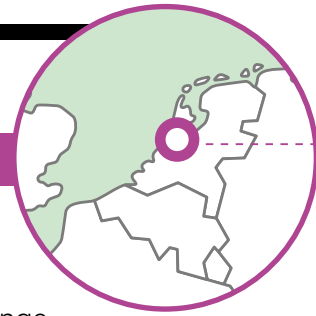
RESULTS AND IMPACT

Better monitoring of water levels allows remote assessment of flood risks, and quicker reaction in case of early signs of flood improves management of resources by reducing false call-outs and prioritising high flood risk events.

COLLABORATION BENEFITS

The city of Bradford Metropolitan District Council assisted the discussion on selecting appropriate sensors, suppliers, and placement. As a result, Aberdeen City Council procured services to deliver the flood warning system. Building on lessons learned from this initial procurement of services, a second commissioned contract with increased detail of requirements saw the **time installing pressure sensors decrease from 4 days to 1 day**. The participation and discussion at events and meetings has identified the opportunities and constraints in establishing open-source solutions and managing open data that weren't known to local authority problem owners.





## CITY OF AMSTERDAM

The city of Amsterdam is a leading city in the use of open data and the development of open-source software solutions. Within SCORE, the city of Amsterdam identified a challenge around the response to and prediction of disturbances in the public space, such as noise complaints, waste, and traffic jams. Although applications, cameras, and sensors were in place, the data collected through these technologies was not optimally used, connected, or interacting. The old engine, proprietary software that was used, needed replacement. Moreover, the data was not monitored and analysed on a structural basis. This led to a long reaction time to handle complaints, inefficiencies amongst the civil servants dealing with the disturbances, and many disturbances in the physical space.

CHALLENGE

Amsterdam embraced this challenge as an opportunity to develop a solution without licensing costs that perfectly fits their specific challenge. A development team was set up that developed the open-source software solution 'Signalen'. The solution supports civil servants by classifying and directing complaints automatically with the help of historical data and machine learning.

SOLUTIONS

A potential result of the increased efficiency of reporting is that the number of complaints about disturbances in the city of Amsterdam increased significantly from 173.460 complaints in 2017 to 408.165 complaints in 2021.

RESULTS AND IMPACT

As a result of Signalen, the **citizens' satisfaction rate of handling disturbances by the municipality increased from 29% in 2017 to 64% in 2021**. The reaction time went down to 20 minutes after Signalen's implementation, which also increased trust and transparency as citizens see their complaints being addressed quickly. A potential result of the increased efficiency of reporting is that **the number of complaints about**



**disturbances in the city of Amsterdam increased significantly from 173.460 complaints in 2017 to 408.165 complaints in 2021.** Furthermore, the distribution of complaints from the different neighbourhoods increased. At the start of Signalen, most complaints were coming from the wealthier neighbourhoods of Amsterdam, whilst currently the complaints received from less developed neighbourhoods are increasing, showing the inclusiveness of the system.

RESULTS AND IMPACT

With help of the SCORE replication guidelines, Signalen is currently replicated in various Dutch cities, such as Den Bosch, Alphen aan de Rijn and Heerlen. The municipalities spent some extra time to replicate the solution: firstly to make the solution as developed by Amsterdam more generic and secondly to adjust the parameters and the properties specific to the city and region replicating Signalen. The municipalities encountered two main hurdles during the process of replication. First, the ICT departments had to get used to working with a hosting partner with open-source software instead of buying software or cloud services. Secondly, because the process of agreement and setting up the system was time-intensive. Due to its open-source and modular development, municipalities with an existing handling system in place also reuse certain elements of Signalen to improve and build upon their own system.

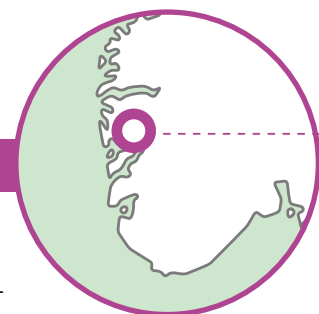
COLLABORATION BENEFITS

Participating in the SCORE project allowed the city of Amsterdam to improve the quality of their developed solutions through criticism of the partners. Making the solutions replicable-by-design forced the developers to come up with a way that others understand the code that is written.



## CITY OF BERGEN

The city of Bergen aimed to provide a real alternative to private car use for the first/last mile problems of public transport by integrating environmental friendly mobility solutions in one package. This required more development and a better integration of data and solutions.



CHALLENGE



SOLUTIONS

To solve the mobility challenge, Bergen developed a Mobility Dashboard. The solution improves the services within mobility and urban planning by making open data more available and accessible for practical use on various challenges for different departments within the city.

The Mobility Dashboard has reduced the **time spent on data gathering for urban planning by 5%**. The local crisis team and the health agency both saved 30 minutes per week during lockdown by using the data provided by the mobility dashboard. Using the data-driven and open-source mobility dashboard, the **collaboration between different parts of the city has improved from 2,75 to 7 on average**, and the **insight into mobility improved from 3,5 to 8 on average**.

The Mobility Dashboard has stimulated the collaboration between departments of the city. As a result of this process, the local crisis teams and health agencies could accelerate the process of data gathering for their prediction model, improving the efficiency of the services.

RESULTS AND IMPACT

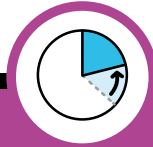
The Mobility Dashboard has stimulated the collaboration between departments of the city. As a result of this process, the local crisis teams and health agencies could accelerate the process of data gathering for their prediction model, improving the efficiency of the services.

COLLABORATION BENEFITS

By participating in a smart city project with leading cities on working with open source, the municipality improved its ability to create open solutions based on data reuse. Additionally, the city of Bergen built upon the Mobility Dashboard by starting to replicate the SCORE solution Dash Data Dialogics developed by the city of Ghent. Bergen has, as a direct result of their work on dashboard solutions in SCORE, decided to develop a new dashboard solution that will show climate emissions from different sources and in different sectors. The dashboard will be a tool to provide data driven insights for city planners, politicians, and the general public.







## Reduction in solution development time

Co-development or close collaboration between development teams of different authorities can accelerate the process to conceptualise and code the software. In the short term, time must be invested to facilitate the collaboration, for example by making sure the materials are translated in English and adjusting datasets to the required formats. These up-front investments pay off in the long term as they facilitate smoother collaboration and save on development time.

Reduction in solution development is really proven when replication takes place. It can further speed up the development process thanks to the reusing of certain components of the solution and tailoring these to local needs further increases the positive impact on solution development time. The reduction is measured through comparing the time spent on developing a solution versus co-developing or replicating the same solution.

## CITY OF DORDRECHT

The city of Dordrecht identified challenges around their ambitions for a Blue-Green city. Dordrecht has a large green zone running through the middle of the city that consists of neighbourhood parks, sport fields, and nature. The city aims to transform the green zone into a City Park XXL that every citizen will visit at least once a week. Sterrenburg Park is located within this green zone. The park has experienced some renovations over the last years such as a natural playground and new catering facilities. As a result, the number of citizens visiting the neighbourhood park is expected to have increased. However, the real number supporting this claim is unknown. Moreover, it is unclear how the citizens experience their visit to the park.



CHALLENGE

Dordrecht uses the QR Code Toolkit - developed by the city of Ghent together with their ICT partner District09 and replicated in Aarhus and Bradford - to monitor and evaluate the use of the park. Through a short survey with a QR code, visitors are asked for feedback about the facilities of the park and their experience in the park. Additionally, the city of Dordrecht laid the foundations for replication of the Dash Data Dialogics solutions also developed by the city of Ghent and District09. This solution helps Dordrecht to visualise data gathered by crowd flow sensors in Sterrenburg Park, and links this with data on weather conditions. These visualisations help the neighbourhood and park managers to understand user patterns: for example, which places attract most visitors on hot summer days?

SOLUTIONS



RESULTS AND IMPACT

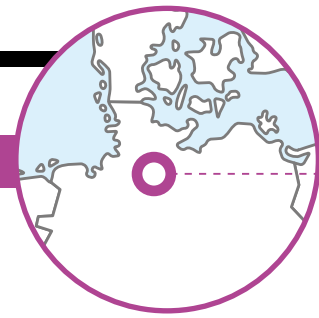
The city of Dordrecht managed to **replicate the QR Code Toolkit in half a day**, instead of the approximate 45 days of District09 to develop the toolkit. However, District09 did make this solution replicable-by-design, which demands more investment in the first place. The use of the QR Code Toolkit for a citizen survey has improved the city's ability to collect feedback from visitors of neighbourhood parks regarding their experience of places and facilities within the park. This enables Dordrecht's landscape architects and park managers to improve the (re)design and maintenance of the city parks. On top of that, the city is looking into using the QR Code Toolkit in other parts of the city to incentivise citizens to walk and exercise more often, for example with a pod walk and a puzzle walk. These new use cases will strengthen the ownership of this SCORE solution.

With a limited internal capacity for developing solutions, Dordrecht benefitted from participation in the project by replicating solutions developed by other SCORE partners.

COLLABORATION BENEFITS

SCORE allowed the city of Dordrecht to experiment with open-source software solutions. With a limited internal capacity for developing solutions, Dordrecht benefitted from participation in the project by replicating solutions developed by other SCORE partners. For the technical replication process, the city successfully worked together with a freelance developer.





## FREE AND HANSEATIC CITY OF HAMBURG

The Authority for Geoinformation and Survey in Hamburg developed the Urban Data Platform to meet the increasing demand for digital spatial data and to fulfil political decisions and directives, e.g. the Digital Strategy of the city of Hamburg or the Geodata Access Act based on the European INSPIRE Directive.

As the digitisation process is speeding up, challenges in the uptake, storage, and provision of data are manifold: The increasing amount of data, new methods in measurements and monitoring, new requirements on the provision of data (in time and amount) and their formats (e.g. real-time data or 3D-data) as well as sophisticated search and filter functions to merge multiple data. In addition every public authority needs to provide accessibility to all persons.

CHALLENGE

The Masterportal is a growing, modular, full client application. It enables the preview, advanced filtering, search, and retrieval of geospatial data from multiple data sources. Its development and implementation in Hamburg was initialised in 2014 with first code development by the Agency for Geoinformation and Surveying (LGV). Operating with standardised and internationally proven open data interfaces (OGC compliant) and data formats, the Masterportal facilitates the access to data mapping and download services, as shown with the implementation in Hamburg. The publication under the open-source MIT licence allows access to the code and hence supports a straightforward replication of this solution. The Masterportal implementation partnership provides networking and cooperation.

SOLUTIONS

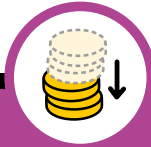
Through their involvement in SCORE, the Free and Hanseatic City of Hamburg pushed the internationalisation of the Masterportal. It has created a unique opportunity for Hamburg to share and test their solution with European partners. In collaboration with their IT provider Dataport, they helped **the cities of Ghent and Bradford replicate the Masterportal in two hours**. Both cities provided valuable feedback and lessons learned on replicability, as well as possible obstacles due to administrative organisation and culture.

RESULTS AND IMPACT

As SCORE comes to a close, the city of Hamburg has made great achievements. Through the project, they developed a fully functional web-based open-source client and built an implementation partnership of 36 organisations in Germany and neighbouring countries. Their success incentivises others to pursue similar developments, and the city actively supports entities that wish to join this partnership.

COLLABORATION BENEFITS





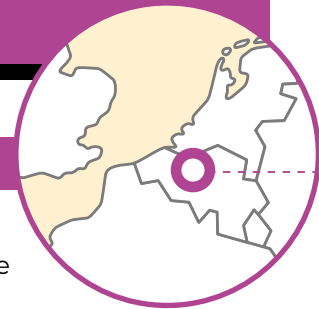
## Reduction in public service costs using open-source software solutions

Relying on digital innovation for public services has the potential to make operations and processes more efficient, and lead to important cost savings without compromising the quality of the services delivered to citizens. Additionally, building on already existing software of components leads to cost savings (see reduction in solution development time).

Cost reduction can emerge in different ways, such as enabling civil servants to deliver a public service quicker, or to eliminate costly steps such as physical monitoring of water levels, possibly done remotely. The cost reduction is measured through comparing the cost of delivering a public service pre and post solution implementation.

### CITY OF GHENT

The city of Ghent collaborates extensively with her ICT partner, District09. Together, they work on innovative, sustainable and inclusive (ICT) solutions that improve the liveability and experience of the city. Because of this intensive collaboration, the city was able to apply the challenge-driven approach. This allowed the civil servants of the municipality to identify challenges within as many as 10 of the city departments. Additionally, the approach provided the ICT team with the capacity and resources to develop prototypes and demos that have the potential to evolve further into solutions around these challenges. This resulted in more challenges being identified in areas that were not foreseen by the project, for example the COVID-19 pandemic.

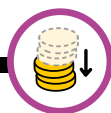


CHALLENGE

In the SCORE project, the city of Ghent was active in both developing and upscaling new open-source solutions (QR Code Toolkit, Dash Data Dialogics) and in replicating open-source solutions developed by partner cities (IoT Registry, Masterportal). As the QR Code Toolkit allowed the city to improve many kinds of service delivery in many different ways, this toolkit created the largest impact within the city. Therefore, the solution is examined in further detail below.

The QR Code toolkit was initially developed to support challenges in the city unit and test new ideas of working with IoT devices within the city in a lower level proof-of-concept way. For example, instead of investing in expensive sensors and technologies, innovators would start with using a setup based on QR codes and mobile devices.

SOLUTIONS



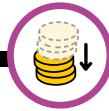
However, as the project evolved, the SCORE QR Code Toolkit was developed further to allow a broader range of civil servants to generate and use QR codes as a generic, expandable, and reusable starting point for a variety of city services and citizen workflows. Instead of QR codes being a static hyperlink, the toolkit develops dynamic QR codes that can serve as a contextual access point to which different actions can be attributed in different service delivery contexts (to citizens, to employees, or to a combination of both). In practice this means that the same QR code can be used for different purposes. Currently, the solution has been used for multiple purposes by different departments across the city. For example, the Service for Roads, Bridges and Waterways uses it for support in asset management, while the Tourism Service uses the toolkit to gather structured data from tourists about their experience in Ghent.

The SCORE QR Code Toolkit made it easier for citizens, organisations, tourists, students, and city personnel to interact with the city administration, all through any standard mobile device.

As a result, the different departments across the city using the QR Code toolkit save lots of time due to the improved efficiency of their processes. For example, the Service for Roads, Bridges and Waterways saves time and paper as workers scan objects and materials with the QR Code toolkit: **the administration/data staff reduce time spent from 15 → 2 hours per week**. City worker staff carry less paper and don't have to log their actions with pen and paper anymore, **reducing each work order significantly from 60 → 40 minutes** while also improving the quality of the department's data.

SCORE and the QR Code Toolkit helped the city of Ghent create flexible, multipurpose, and reusable solutions, as the team ensured that development remained replicable-by-design from the very first prototype all the way through to production. All SCORE tools were developed with both re-use within the city and replication by other cities in mind. As a result, the solution was easily adaptable for different use cases across departments within the city. By the end of SCORE, the solution was made available to all departments in the city, upscaled to a citywide tool where every single city employee can be onboarded in less than one hour. Moreover, the QR Code toolkit was fully replicated by two other SCORE cities Aarhus and Dordrecht in a mere fraction of the time it took Ghent to develop it.

The process used by Ghent and District09 to develop, replicate, and upscale the QR Code Toolkit has played an important role within the digital transformation of the city of Ghent. The way Ghent and District09 approached the QR Code Toolkit was promoted as best practice on Ghent's internal communication channels about the digital project portfolio. The QR Code Toolkit was initially developed as a proof-of-concept in collaboration with



other SCORE partners, but after the first successful cases the team decided to take it to the next level. They committed the budget and resources necessary to launch the SCORE QR Code Toolkit into production, after which it was fully adopted in both the frontend application portfolio and in the internal repository of IT building blocks (microservices) behind the scenes of the city of Ghent.

RESULTS AND IMPACT

The approach of developing multipurpose solutions that easily combine reusable building-blocks is gradually replacing a more conventional approach to public service challenges

COLLABORATION BENEFITS

This challenge-driven generic solution, as well as other SCORE solutions such as the IoT Registry and the Masterportal, helped Ghent start the conversation about the needs of challenge-owners within the city.

The Open Source vision and ambitions of SCORE brought innovative changes in the way new solutions are developed for the city. The approach of developing multipurpose solutions that easily combine reusable building-blocks is gradually replacing a more conventional approach to public service challenges. This mindset did not only benefit the city itself through different departments, but also makes the solutions easier to replicate across European cities.

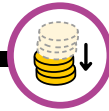
Participating in the SCORE project allowed the city of Ghent to learn how to successfully engage in challenge-based innovation with open-source software solutions, both in solution development and solution replication.

## CITY OF AARHUS

In 2018, about 50 life-saving appliances disappeared by the river in central Aarhus and towards Aarhus Bay. They always tend to go missing in the same busy areas of the city where there are cafés and bars. If these missing appliances go unnoticed by the local authority and are not replaced, lives could be at stake, especially with the added risks brought by cold waters.



CHALLENGE



To mitigate this challenge and to comply with their municipal IoT strategy, the city of Aarhus developed the Stay Put solution: a GPS LoRaWAN sensor attached to a life-saving appliance. If the appliance is moved, the responsible department is alerted and is able to follow the position on a map to quickly replace it or sometimes retrieve it.

SOLUTIONS

After the Stay Put implementation in the busiest area, city workers estimated **an increase in awareness of missing life-saving appliances in the city environment by 50%.**

RESULTS AND IMPACT

The solution substantially increased the ability to locate stolen life-saving appliances. Additionally, it reduced both staff time and travel costs. Before the implementation of the Stay Put solution, city workers were driving around every other week to check the status of the life-saving applications and take actions if they were missing. This delayed reaction time put people at risk, as a missing appliance could be needed before the municipality was able to replace it.

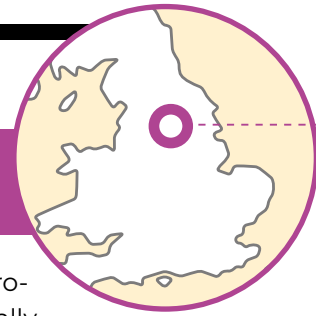
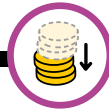
Now, appliances are monitored at distance, preventing unnecessary driving and time spent checking, especially in the more remote areas of the city. Thanks to the ability to locate and reclaim missing appliances, the solution reduces further costs. Instead of buying new appliances (the price of one unit is around €100), they can be easily found through geolocalisation and reused.

SCORE helped the city of Aarhus highlight the need for close internal collaboration to identify relevant challenges and secure the necessary buy-in from domain departments (push vs pull).

As an example, Aarhus replicated the QR Code toolkit solution developed by District09. The city of Aarhus is adding QR codes to the life-saving appliances to expand the IoT network of the city and inform citizens about IoT sensors. They are in conversations with the manufacturer of the life-saving appliances to integrate GPS sensors and QR codes during the manufacturing process. The city of Gothenburg is closely following the work with life-saving devices as they also face this challenge in their city.

COLLABORATION BENEFITS





## CITY OF BRADFORD METROPOLITAN DISTRICT COUNCIL

The urban challenges identified by the city of Bradford Metropolitan District Council range from smart and environmentally friendly management of street lighting to monitoring of water courses and air quality.

Like many other cities in the world, Bradford Council's interest in having a digital twin of the city has grown. A digital twin is a valuable tool for the council to estimate impacts and make informed decisions before committing to new projects. It provides insight on traffic systems, flood prevention, how a new building or a refurbishment of an old building will look, and where to create green spaces or pedestrianised areas.

CHALLENGE

To solve their identified challenges, the city of Bradford, with the School of Archaeological and Forensic Sciences at the University of Bradford, created Virtual Bradford - an open 3D city model free of copyright for anybody to use. The solution also consists of a tender procedure that allows the city to facilitate the uptake of an open, transparent, and flexible 3D model of the city. The experience of Bradford Council in defining and procuring Virtual Bradford, together with the creation of open-source code for its dissemination as a CityGML model, has provided the basis for a successful SCORE solution.

SOLUTIONS

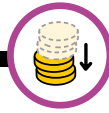
Virtual Bradford offers the possibility to revolutionise how the council deals with planning, air pollution, and traffic management, but it will also enable a myriad of other potential uses, such as creation of heritage trails and mapping cultural assets in 3D. It could also transform how people interact with the city - businesses could open virtual shops, allowing customers to browse virtual aisles, while artists could install virtual exhibitions.

The solution template enables the efficient procurement of an open data model with limitless use cases. The open data platform freely available from GitHub facilitates the storage and dissemination of the model, contributing to an **improvement in the service(s), a faster procurement process reduced to 5 days only, and savings of costs through the reuse of the documentation.**

RESULTS AND IMPACT

The methodology is being replicated in Southern Ireland, in Bagamoyo, Tanzania and Saltaire, UK.





SCORE enabled the city of Bradford Metropolitan District Council to promote and encourage collaboration with the University of Bradford for the first time, bringing skills and resources not present in the Municipality. Additionally, further exchange of practices and experiences took place with cities of Ghent and Gothenburg on digital twins.

COLLABORATION BENEFITS

SCORE enabled the city of Bradford Metropolitan District Council to promote and encourage collaboration with the University of Bradford for the first time, bringing skills and resources not present in the Municipality.



## ADDITIONAL IMPACT CREATED

### UNIVERSITY OF BRADFORD

Poor air quality is a growing concern in European cities. Getting accurate data on air quality and monitoring the level of pollution is key to taking actions towards cleaner air in urban areas.

Raising awareness is one part of the Bradford Air Quality Plan. The plan outlines the case for change and includes an evidence base that the Council has developed in assessing air quality and associated health impacts such as respiratory problems, heart attacks and strokes, low birth weight babies and premature deaths.



CHALLENGE

SOLUTIONS

The University of Bradford has looked at how low cost IoT sensors can be used by citizens to monitor air quality in their communities. Through the LOV-IoT internet of things project, the city of Gothenburg and Johanneberg Science Park have run workshops as part of the International Science Festival sho-

SOLUTIONS

wing how to construct affordable air quality devices. Meanwhile in Bradford, the University and City Council have organised joint workshops in local schools.

Bradford Council and the University of Bradford, in collaboration with Open Data Institute Leeds, hosted AirHack events to explore devices that measure air quality, the availability and use-ability of existing air quality data, and proposals to address air pollution such as Clear Air Zones.

As a result, the University of Bradford deployed 10 outdoor air quality sensors (in and around the park), 10 indoor air quality sensors (Households around the park) working with Friend of Horton Park, and 15 more sensors in collaboration with local schools. The collected data feeds an urban observatory on air quality monitoring analysing indoor/outdoor air quality in connection with parameters such as activities/health and socio-economic status. The urban observatory offers open air quality data for consumption of citizens, businesses, and policy makers.

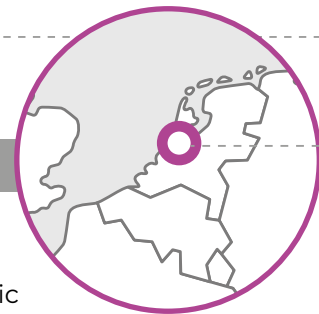
The University of Bradford, in collaboration with Bradford Council, Gothenburg City and Johanneberg Science Park, shares knowledge and experience in building an urban observatory for monitoring indoor and outdoor air quality using low cost sensors.

RESULTS AND IMPACT



## UNIVERSITY OF AMSTERDAM

With urbanisation on the rise, cities are facing major challenges in a variety of fields. Due to the complex and dynamic nature of cities, knowledge from different research fields must be combined to address these challenges. In this context, urban computing and using various heterogeneous data sources shows great promise in providing potential solutions to improve urban liveability. The Amsterdam Data Science team started exploring this potential by tackling local challenges around liveability in the city of Amsterdam.



CHALLENGE

SOLUTIONS

The Amsterdam Data Science team used open GIS and urban multimedia data to gain insights into liveability and common urban objects through computer vision and multimedia analysis. This helps determine the state of assets in the public space and whether the visual appearance of urban objects could have an influence on liveability (e.g. social housing, the value of the house, the amount of services). The datasets used, called PanorAMS-gt and PanorAMS-noisy, were collected by the city's camera cars and boats

SOLUTIONS

driving around to periodically take panoramic images. These datasets were further enriched with large-scale information on urban objects in the public space, automatically extracted using novel SCORE algorithms from openly available GIS sources maintained by the city of Amsterdam. To facilitate further development and evaluation of computer vision algorithms for urban object detection, a part of the collection was accurately annotated through crowdsourcing using annotation tools designed for this specific purpose. While it was created using openly available panoramic images, the solution also works with images from platforms such as Google Street View. The dataset enables training deep computer vision algorithms for urban object detection at an unprecedented scale and helps involve the broader academic community.

RESULTS AND IMPACT

The PanorAMS framework will save the city of Amsterdam significant costs associated with heavily manual urban asset registration and monitoring. The solution can handle large amounts of data and can therefore be applied to different use cases in the entire city. For example, the city of Amsterdam used PanorAMS for registering and managing assets, detecting issues in the public space, and as a tool for urban planning. Linking the solution to liveability in cities, it can be used for analysing specific objects to identify characteristics that affect the liveability of a neighbourhood, like the presence of parks or particular architectural styles. With the help of MSc students, the team also recognises and locates different objects such as street lights and bike lanes using the panoramic images and deep computer vision methods. The Amsterdam Data Science Team collaborated with the IT University of Copenhagen to develop computer vision approaches that allow public order and security departments of SCORE's partner cities to perform rapid image geo-localisation. Collaboration with the colleagues from the IT University of Copenhagen resulted in a novel approach to aiding investigative journalists and public servants in rapidly verifying visual content location and authenticity. Amsterdam Data Science have used these results for mobilising a broader computer vision and multimedia community for addressing SCORE-related challenges through e.g. UrbanMM'21 workshop organised at ACM Multimedia 2021, a leading conference in the computer science field.

COLLABORATION BENEFITS

The SCORE project intensified the collaboration between the Amsterdam Data Science Team and the city of Amsterdam, creating impact in the city. Additionally, the project allowed Amsterdam Data Science to develop the PanorAMS completely open source and to its full potential. As the solution processes large amounts of data in different formats, and is applicable to different use cases, PanorAMS has become an intelligent methodology that can easily be reused and replicated by other cities in the future.



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# LESSONS LEARNED

**8 European cities have worked together to improve public services (specifically in the fields of air quality, flood risk and mobility flows) with open-source software solutions and open data. The quality and costs of public services and the time needed to develop the targeted solutions have been assessed through illustrative case studies. The main lessons are presented below to guide action in other cities.**

## **1** Replication makes open-source software development cheaper, faster, and better

The benefits of open-source software for public organisations are harnessed when replication of software solutions comes into play. Where replication has been successful, meaning a city fully or partially replicates a software from another city, the replicator city has reduced development time drastically from months to a few hours of copying and adapting the codes to the local needs and contexts.

Replication of software solutions is apparent and valuable in different forms. Conversations around replication have enabled others to get inspired on how to approach a challenge, gain experience for selecting sensors, replicate components of a software, or replicate a software fully. With the abovementioned different levels of replication, the quality of the software and therefore of the service provided is increased. More brains and hands have gone through the codes, fixed potential bugs, provided feedback and improved user experience.

Replication of open-source software has allowed for a reduction of costs of services: direct savings in software development, and indirect savings through efficiency of cities' operations (including material and fuel savings).

## **2** Challenge-driven helps as conversation starter, but data determines feasibility

The challenge-driven approach, i.e. improving public service delivery, was to provide purpose and to make good use of taxpayers' money. Starting with the challenges helped to frame software development, anchoring the solutions within the organisations (engaging challenge owners) and sustaining funding for maintenance and updating.

Although challenges were useful as a conversation starter, data availability soon became a reality check and guided software development. The quality and quantity of the data available within cities determines whether a software solution can be developed and/or replicated successfully. Software development that focused on improving cities' own operations (to improve public services) was more effective, as the cities had control over data and implementation.

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### 3 Solutions should be replicable-by-design: open, modular, and scalable

A main criterion for smooth software replication is building the software 'replicable-by-design'. It means the software is built so that other cities are able to reuse and customise it. Building a solution replicable-by-design requires a change of mindset to deliver a codebase suitable for more generic use. It has shown great potential, especially for *meta solutions* that can be deployed and upscaled to different use cases, such as the QR Code Toolkit for managing assets and collecting feedback by citizens. Here, cities actively sought use cases based on the existing software, driven by a desire to replicate code. Matching the software solutions to the use cases is essential and helps in linking the urban challenges and data availability.

### 4 Need for brokerage and facilitation of cross-departmental and inter-organisational collaboration

'Open source is not about code, it is about community', as stated by the Foundation for Public Code. Software development and replication requires an ecosystem of developers, multiple data providers, and users, and many stakeholders are involved in public service delivery. Challenge owners (policy advisors, operators) should collaborate with developers. Though this requires time, it generates valuable learning. Urban challenges, for example climate change, often involve many adjacent policy domains (e.g. greening, mobility), organisations, and departments. Internal and external facilitators have effectively stimulated collaboration and progress.

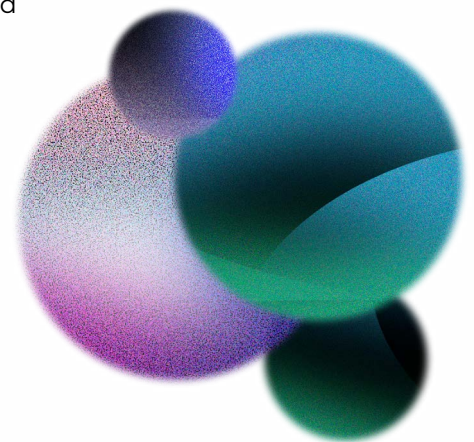
City-to-city replication requires the replicating city or department to be aware of the opportunities and solutions available. The developing city should have the time to develop a solution replicable-by-design and be available for consultation and guidance on necessary parts of the solution being replicated. By doing so, recognition and feedback for the solution developers is created, resulting in better quality and reduced replication time of the solution. Successful cases were observed where entrepreneurial individuals invested time to support the process of solution development within the city and replication across cities, or where external brokers (consultants, universities) matched people, challenges, and solutions.

## 5 Benefits of co-development need to be further explored

Developing an open-source software solution together has the potential to reduce the development time. The process of co-development can take place in various forms, ranging from several developers working together physically towards the same product or service (strict co-development) to active collaboration, inspiration and sharing of ideas and best practices. Strict co-development took place once, as bringing developers together proved difficult due to issues of availability, timing, and priorities. The success story of co-development is illustrated by the IoT registry solution currently used in the cities of Amsterdam, Hamburg, Aarhus, and Ghent. Building upon the codebase developed by the city of Amsterdam, the collaboration of in-house developers of the different cities accelerated the development and adoption of the solution in the other cities. Success factors indicated by developers were working together face-to-face, all having an open-source mindset, and because they built upon framework sketches or building blocks developed beforehand. Although this specific case shows potential to accelerate the development and replication of solutions, the willingness to organise co-development sessions remains to be seen, particularly without the context of a specific joint project.

### What next?

This paper illustrates and provides evidence of the potential of open-source software for public services. But how can public organisations know when it is more accurate to make their own solutions, build on someone else's work and replicate, or to buy a solution off-the-shelf from a private supplier? And when buying, should open source be a precondition to avoid vendor lock-in? Public authorities need a decision framework to help navigate the many available options. In addition, they should strategically integrate modular and open software (future proofing), and should be willing to invest upfront in sharing and learning to increase the innovation potential of public services.



# SCORE

SMART CITIES AND OPEN DATA RE-USE