triangulum

DEMONSTRATE · DISSEMINATE · REPLICATE

D2.4 Interim Report

WP 2

March, 2017

H2020-SCC-2014-2015/H2020-SCC-2014: "Smart Cities and Communities solutions integrating energy, transport, ICT sectors through lighthouse (large scale demonstration - first of the kind) projects"
Collaborative Project – **GRANT AGREEMENT No. 646578**

Project Acronym	TRIANGULUM		
Project Title	**Triangulum: The Three Point Project / Demonstrate. Disseminate. Replicate**		
Project Coordinator	Damian Wagner (Damian.Wagner@iao.fraunhofer.de) Fraunhofer IAO		
Project Duration	1 February 2015 – 31 January 2020 (60 Months)		
Deliverable No.	D2.4 Interim Report		
Diss. Level	PU/CO/		
Status		Working	
		Verified by other WPs	
		Final version	
Due date	Feb. 2017		
Work Package	WP02 - Multilevel Impact Assessment and Monitoring		
Lead beneficiary	UoM		
Contributing beneficiary(ies)	TuE, UiS		
DoA	Copy of the Task description in the DOA		

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Executive Summary

Deliverable 2.4 Interim Report focuses on the sustainability of data generation, collection and use within the Triangulum project. Its purpose is to capture learning so far that relates to monitoring and assessment and highlight key challenges and opportunities for cities and partners. In particular this deliverable addresses the challenges to sustaining monitoring in the Lighthouse Cities over the final two years of the project and beyond to underpin long-term smart urban management. It also addresses the question of how to monitor impacts in the Follower Cities, presenting a streamlined method and predefined indicators that are optimised for efficiency and efficacy and can be easily replicated. The deliverable is structured as follows.

Section one provides a concise summary of Triangulum and the role of WP02, monitoring and assessment, in the project. It also outlines the seven stage methodology adopted by WP02 for developing impact indictors and calculating impacts to aid interpretation of this report (for a fuller account please see Deliverable 2.1: Common Framework for Monitoring and Assessment). Section two describes the approach to developing this report, which is based upon three activities: an analysis of the process of developing a monitoring framework and identifying and securing data with partners over the first 24 months; a survey of key data stakeholders in the Lighthouse Cities to further identify challenges and opportunities in terms of generation, collection and use of data beyond M36; and analysis of insights from the Lighthouse Cities that are potentially relevant to the Follower Cities, especially relating to the key areas of replication identified by WP06.

Section three addresses the challenges to sustaining monitoring in the Lighthouse Cities over the final two years of the project and beyond. It is designed to support D1.8, the Revised Data Management Plan, which identified key principles for data archiving and preservation until the end of the project. This section analyses the process of data collection and use in Manchester over the first 24 months through a structured reflection to illustrate key challenges. It then reports the results from the survey of key data stakeholders within Lighthouse Cities. Drawing together the insights from the structured reflections and survey this section identifies key challenges which face impact assessment and monitoring in the Lighthouse Cities and approaches to addressing these challenges, during, and beyond the Triangulum project. In terms of challenges, organisational and regulatory barriers relating to privacy were most frequently mentioned alongside concerns of data protection, while in terms of opportunities the survey revealed that over 80% of the respondents believed it is likely or very likely that the data would be of use to citizens and municipalities. 8 out of 9 survey participants also believe it is likely or very likely that the data will be valuable to businesses, in large part because the Triangulum project is orientated to generating and sharing data which could enable new business models and solutions to be commercially exploited. A summary of how these challenges are being addressed in Triangulum is presented in Tables 2 and 3 according to the stages of the WP02 impact assessment and monitoring methodology.

Section four makes recommendations for monitoring impacts in the Follower Cities. Based on the experiences in the lead cities, this section suggests approaching impact assessment as an iterative

process and developing strong relationships between impact assessors and module delivery teams. This section offers a streamlined impact assessment and monitoring methodology for Follower Cities. It also identifies potential challenges Follower Cities may face at each stage of the methodology based on experiences of the Lighthouse Cities, and highlights the successful approaches adopted to address these challenges. Although the Follower Cities have yet to specify modules they intend to replicate, WP06 has identified specific areas of smart city innovation that they are interested in (including smart Grids & Energy Storage; Intelligent Public Space; Open Data & Governance; and, Smart and Electric Mobility). The section concludes by presenting sets of potential indicators, based on those developed for the Lighthouse Cities, for each of these four areas of smart city innovation.

1 Summary of Impact Assessment and Monitoring within Triangulum

1.1 An overview of Triangulum WP02

This section provides a concise summary of Triangulum and the role of WP02, monitoring and assessment, in the project. For a fuller account please see Deliverable 2.1: Common Framework for Monitoring and Assessment.

The main goal of Triangulum is to demonstrate that the integration of technologies from the energy, buildings, mobility and ICT sectors within one district leads to a significant reduction of energy demand and local GHG emissions whilst at by at the same time enhancing quality of life, delivering efficient and clean mobility to residents and local workers and providing the basis for economic growth and development. Cross-sectoral smart city modules are being demonstrated in Manchester, Eindhoven, and Stavanger to provide a test bed for new business models, technologies, and strategies of citizen engagement. The first goal of WP02 is to rigorously monitor and assess the impacts of the modules, to support the work of the lead city partners and learning between them.

WP02 is tasked with the development of a common monitoring framework that will assess the success of the demonstration projects in delivering their expected impacts, and identify impact indicators to compare amongst the Lighthouse Cities. This includes three distinct tasks over the five-year duration of the project:

- Monitor the impacts of the demonstration activities;
- Assess the level of success of the demonstration activities, and;
- Evaluate the sustainability of processes of data generation, monitoring, and usage in each city.

WP02 is led by the University of Manchester - The School of Environment, Education and Development together with the Alliance Manchester Business School - with coordinating assistance from university teams in each partner city. In addition to collaborating with their respective cities, the universities bring the following expertise to WP02:

- The University of Stavanger (UiS) brings ICT expertise;
- The Technical University of Eindhoven (TuE) brings building science and mobility assessment expertise, and;
- The University of Manchester (UoM) brings smart city, urban governance and innovation expertise.

The University of Stavanger is specifically tasked with developing the Cloud Data Hub, which will house data to monitor demonstration projects (called modules) as well as open data from each of the Lighthouse Cities that can be used to support smart innovation. Baseline data collection, impact assessment, and the Cloud Data Hub role and architecture will further be coordinated with WP06 to aid in the preparation of a smart city framework for replication (see Figure 1).

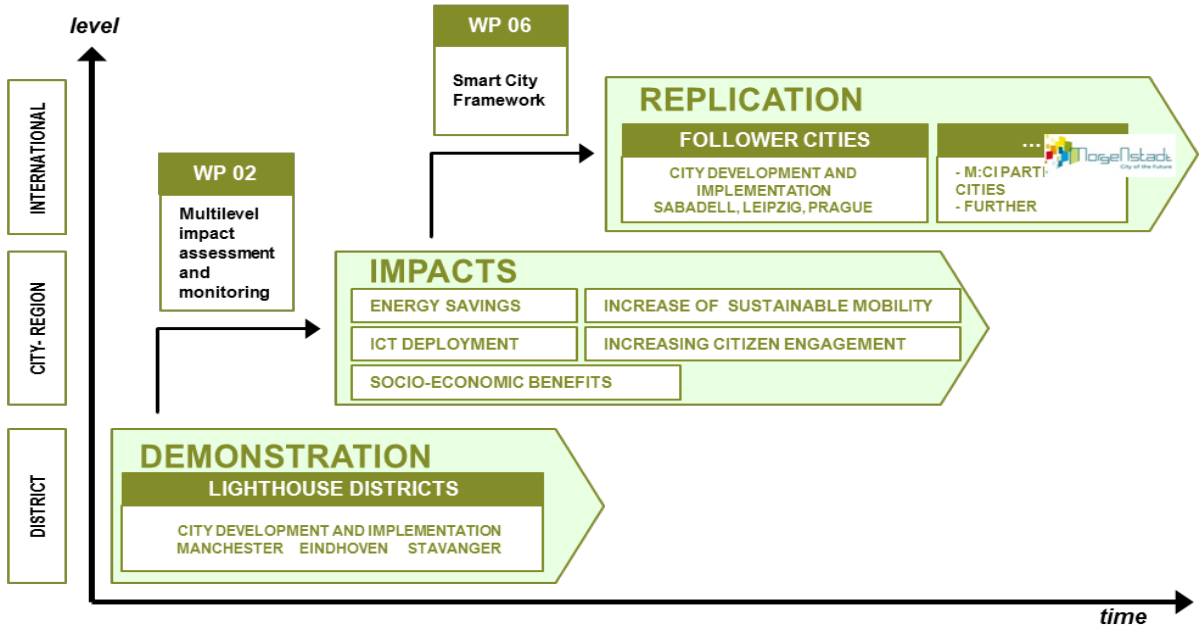

Figure 1: Scale, role, and timeline of WP02

In contrast to previous EU projects, Triangulum does not focus on a broader public policy agenda of smart city development, but rather works from the micro-scale up to the city level to determine how modular projects fit together to achieve smartness, sustainability, and in the long-term contribute to the creation of a smart city overall. Triangulum adopts a monitoring and assessment approach with a focus on the scale of demonstration project. WP02 aims to fulfil both a formative and a summative evaluation role in Triangulum[1], assessing both the impacts of demonstration projects in each city and the process through which they are identified and monitored. This will enable WP02 to:

- Support the work of the lead city partners by feeding back on the performance of demonstration projects and engendering learning amongst them about different monitoring solutions;
- Support the Triangulum replication model of WP06, and;
- Support the follower cities by advising on appropriate impact indicators and feasible monitoring strategies.

[1] Duignan, P. 2009. Evaluation Types: Formative/Developmental, Process, Impact/Outcome Evaluation. Outcomes Theory Knowledge Base Article No. 256. http://knol.google.com/k/paul-duignan-phd/-/2m7zd68aaz774/119 (accessed 6 June 2011).

1.2 Summary of methodology

The seven stage methodology adopted by WP02 for developing impact indictors and calculating impacts was presented in Deliverable 2.1 (the Common Monitoring and Impact Assessment Framework). This deliverable, D2.4 Interim Report, presents findings from the implementation of stages 1 to 5 of the methodology. The stages of the methodology are reiterated below and shown in Figure 2 (page 11) to aid interpretation of this report.

1. **Review of existing literature and frameworks.** WP02 conducted a desk based review of the key literatures on sustainability and smart city indicator development and assessment. WP02 conducted a review of on-going sister projects developing smart city indicator and assessment frameworks. The desk study was used to determine the general framework and parameters for the work, as presented in sections 3 and 4 of this report.

2. **Identify and document expected outcomes.** WP02 engaged with the city task groups delivering the modules to identify the scope and expected outcomes of each module. In each Lighthouse City, a local university researcher was tasked with developing impact indicators and associated reports for the modules of the local partners. Engagement was aligned with the operation of the task group. Methods used included contributing to task group meetings, conducting workshops and semi-structured interviews, electronic consultation and opportunities to feedback on draft WP02 documents.

3. **Co-produce and document impacts, indicators and datasets.** Based on the expected module outcomes and review of existing literature and frameworks WP02 proposed impact indicators including quantitative units. The task groups were invited to propose impact indicators. The set of indicators for the module was then collaboratively refined by WP02 and the task group through workshops and inviting comments electronically on draft WP02 documents. Follower Cities also provided input to this process at the GA in Berlin 2015.

4. **Align and verify impacts, indicators and metrics.** The impact indicators for each module were included in analyses which identify opportunities to align: with other indicators across energy, ICT and mobility activities across the three cities; established smart city indicator frameworks (CityKeys and SCIS); and, WP6 replication metrics. The aligned impacts, indicators and metrics have been verified with the task groups through electronic consultation.

5. **Prepare for impact calculation.** With support from task groups WP02 preparation for impact calculation will include: gathering baseline data; defining the approach to calculating impacts; and, identifying datasets that could be used in the calculation of the impacts. Two modes of engagement will be used: (1) ongoing collaboration through workshops and interviews; and, (2) task groups completing a *data intake form* (DIF) which formally specifies the indicators and approach to be taken to calculate them. The data intake form will be used for more complex data sets that go beyond individual data points or simple spreadsheets. Additional work may be required to facilitate documentation and transfer of data, but partners will not be asked to perform additional work to generate the data.

6. **Store data to be used in impact calculation.** Based on the details provided by stakeholders and in the data intake form WP02 (Stavanger) will import datasets required for impact calculation into the cloud data hub.

7. **Calculate impacts.** The cloud data hub will support the calculation of quantitative values for impact indicators where sufficient data and metadata has been provided by the task group delivering the module.

Table 1 shows the timescales, key input required for each activity from partners, and the key instruments used at each stage.

	Impact assessment activity (WP02)	**Timescale**	**Input required from other WPs and partner organisations**	**Key methods used by WP02 staff**
1.	Review of existing literature and frameworks	M1-M6	N/A	Desk study.
2.	Identify and document expected outcomes	M3-M9	Articulation of module scope and expected outcomes (WPs 3, 4 and 5)	Participation in task group meetings, email consultation on module outcomes.
3.	Co-produce and document impacts, indicators and datasets	M6-M12	Input to identify, review and validate indicators (WPs 3, 4, 5 and 6, and follower cities)	Semi-structured interviews, electronic consultation on module impact tables.
4.	Align and verify impacts, indicators and metrics	M9-M24	Feedback on alignment and verification of impacts indicators and metrics (WPs 3, 4, 5 and 6)	Alignment with SCIS and CityKeys. Electronic consultation with task groups.
5.	Preparation for impact calculation	M9-36	Engagement with Data Intake Form to review and validate impacts and indicators (WPs 3, 4 and 5) Collect and provide access to baseline data (data owners within and outside the Triangulum consortium)	Webinars and email support to partners to complete Data intake form. Electronic requests for data and meetings.
6.	Store data to be used in impact calculation	M12-36	Provide access to datasets required to calculate impacts (as detailed in the Data Intake Form) (WPs 3, 4 & 5)	Email reminders and communications through Triangulum steering committee.
7.	Calculate impacts	M36	N/A	N/A

Table 1: Impact assessment methodology overview

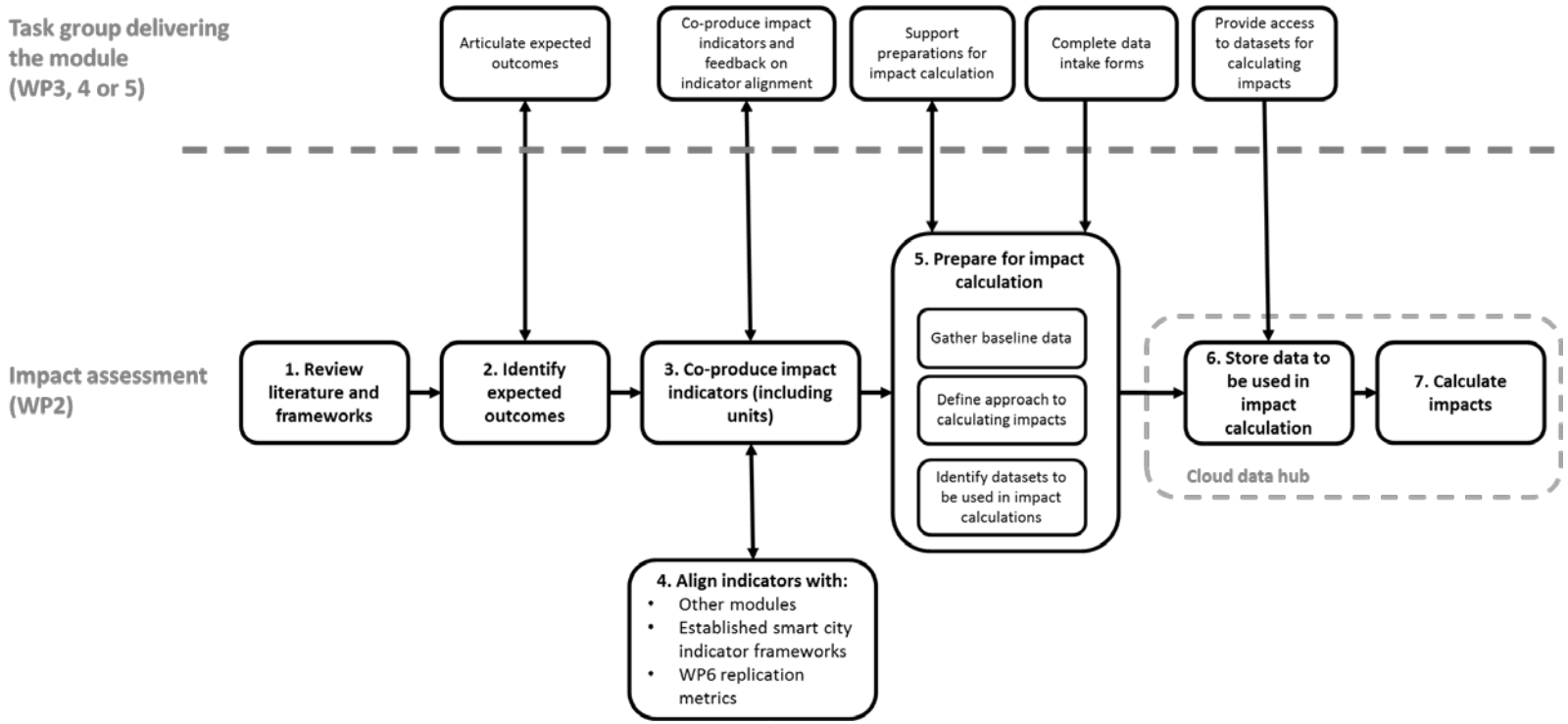

Figure 2: A Seven-Stage Methodology for Developing Indicators and Calculating Impacts

2 Approach to developing interim report

This deliverable is based upon three activities: an analysis of the process of developing a monitoring framework and identifying and securing data with partners over the first 24 months; a survey to identify key challenges and opportunities in terms of generation, collection and use of data beyond M36; and an analysis of key insights from the Lighthouse Cities relating to the Follower Cities especially relating to the key areas of replication identified by WP6.

2.1 Analysis of WP02 process

A set of structured reflections on the process of developing a monitoring framework and identifying and securing data with partners over the first 24 months was captured during the autumn of 2016. This formed part of Task 2.4 (Learning), and took the form of a qualitative assessment of the sustainability of data collection and use. Within the Triangulum bid documentation an indicative list of qualitative factors for use in this assessment was identified (see page 72):

- Policy, organisational and regulatory barriers;
- Technical issues with ICT and monitoring technologies including interoperability, open access, and data integration, storage and processing;
- Financing strategies;
- Collaboration amongst urban actors (partners), Learning between organisations / cities;
- And, citizen engagement and e-inclusion of disadvantaged groups.

WP02 used Manchester as an illustrative case study of a Lighthouse City, enabling an exploration of how these factors play out in impact assessment and monitoring activities. The insights generated are based on the reflections of University of Manchester researchers.

2.2 Survey of key data stakeholders within Lighthouse Cities

A survey was also conducted to identify key challenges and opportunities in terms of generation, collection and use of data beyond M36. The survey was conducted by WP02 during February 2017 and focused on issues associated with the generation, collection and use of data within, and related to, the Triangulum project. Specifically, data created by Triangulum modules; and, data used to assess the impact of Triangulum modules including baseline data collected from partners outside the project. The primary objectives of conducting this survey where to:

- provide a preliminary evaluation of the highly collaborative approach to monitoring and data collection, that is driven by and supports the needs and capacities of local partners, being piloted within Triangulum;

- capture insight from the on-going discussions within the project relating to data generation, collection and use;
- understand some of the key barriers around data-driven sustainable city development;
- support efforts to create sustainable processes and structures of data generation, collection and use during and beyond the lifetime of the Triangulum project;
- draw lessons about monitoring and data that can be used to inform smart city activities in Follower Cities and elsewhere.

Development of the survey, over the autumn of 2016, was led by WP02 researchers at the University of Manchester. An initial draft of the survey was circulated to WP02 researchers at the Eindhoven University of Technology and the University of Stavanger, and the WP03, WP04 and WP05 leaders for feedback and input. Through an iterative and collaborative process, the survey was designed to address key five topics as outlined below (a copy of the survey can be found in Appendix A).

1. ***Data collection.*** Questions in this section of the survey focussed on the technical, policy, organisational and regulatory barriers to generating and collecting data within the Triangulum project, and how partners had collaborated in the generation and collection of data.
2. ***Data management and sharing.*** Questions in this section of the survey focussed on: the technical, policy, organisational and regulatory barriers to sharing data generated within the Triangulum project; how data is managed within the project; and, if novel approaches to data management are being developed within Triangulum.
3. ***Data Use.*** Questions in this section of the survey focussed on how members of the Triangulum consortium expect the data generated to be valuable to citizens, businesses and municipal authorities and other public bodies.
4. ***Legacy issues.*** Questions in this section of the survey focussed on which aspects of data collection, storage or provision will or should outlast Triangulum, and the barriers to long-term data collection and provision.
5. ***Data collection and project working.*** Questions in this final section of the survey focussed on the impact of adopting a collaborative approach to data collection and project working.

Researchers in Manchester, Eindhoven and Stavanger identified potential survey participants to target within their respective cities. In particular, the survey focused on identifying partners in the Triangulum consortium who were collaborating on WP02 impact assessment and monitoring activities and engaged activities relating to the generation, collection and/or sharing of Triangulum data. As a result a total of 18 potential survey participants were identified (10 in Manchester, 4 in Eindhoven and 4 in Stavanger). An invite to participate in the survey was circulated by email to these 18 partners, and survey responses were received over a two week period (8th – 22nd February 2017). Throughout this period email reminders were sent out to all potential participants, and

targeted follow ups were conducted where few responses had been received from partners in a specific Lighthouse City. In total 9 survey responses were received (4 from Manchester, 3 from Eindhoven and 2 from Stavanger), giving a survey response rate of 50%.

2.3 Developing an impact assessment and monitoring procedures for follower cities

While the Follower Cities have not determined specific modules they will seek to replicate yet, WP6 has identified key areas of interest to the Follower Cities that form the basis for a series of workshops between M24 and M36. Drawing on the revised D.2.3 Baseline Report, it is possible to distil key impacts, indicators and datasets that are being used to monitor activities in these key areas of interest in the Lighthouse Cities that could be of use to the Follower Cities. To further support this process, WP02 have also developed a streamlined methodology for the co-production of monitoring and assessment frameworks in the Follower Cities, and general guidelines based on the experiences of the Lighthouses and the insight created through the structured reflections and survey described above. In this way D2.4 seeks to enable learning between the Lighthouse Cities and the Follower Cities, and develops an appreciation of the practical challenges to smart city impact assessment and monitoring more widely.

3 Interim reporting from Lighthouse Cities

3.1 Interim assessment of the sustainability of data generation, collection and use

3.2 Analysis of WP02 process

As part of Task 2.4 (Learning) a qualitative assessment of the sustainability of data collection and use is being conducted in each of the three lighthouse cities. Within the bid documentation an indicative list of qualitative factors for use in the assessment is identified (see page 72). This analysis focuses on identifying the challenges that are being faced in collecting and using data created within the modules. In doing so it highlights that the sustainability of these processes will be determined by the extent to which these challenges can be addressed.

In order to avoid repetition, this section uses Manchester as a case study to offer more fine-grained examples that are reflective of challenges across the three cities. This report focuses on data that is created by the module delivery teams, collected and curated by the Triangulum-I data platform, and has the potential to be used by a diverse range of actors across the public and private sectors and civil society. The Triangulum-I platform is being developed as part of the ICT work stream in Manchester, and will host data created by the Manchester modules. The ambition of the

Triangulum-I platform is to make this data as openly accessible as possible. The relationship between Triangulum-I and the Cloud Data Hub (being developed in WP02), is in the process of being clarified by the WP02 technical working group.

Timing of module implementation

This section first reflects upon some of the challenges of assessing the sustainability of data collection at this stage of the project. The modules being developed in Manchester are progressing at different rates, with a few modules awaiting confirmation of an amendment before implementation. Until key module design decisions are made it is not possible to finalise the datasets that it will be feasible to collect. Conversely, many of the modules are being developed as trials or experiments, so it seems likely that some modules will not continue to operate beyond the timescales of the Triangulum project. However, at this stage it is difficult to predict which modules might be successful and develop a funding model which allows them to operate after the Triangulum project end date. Assessing the sustainability of data collection and use beyond the project end date is a challenge across the three cities, and is returned to below.

Policy, organisational and regulatory barriers

Potential organisation and regulatory barriers to collecting data have been observed during WP02 impact monitoring and assessment activities in Manchester. A relatively small amount of the data required to assess impacts of the energy modules has been identified as commercially sensitive (data relating to the energy costs and tariffs of Manchester Metropolitan University buildings).There are questions about the privacy implications of sharing some of the data collected within the mobility modules (data tracking the movements of low emission vehicles, and by default their drivers). There are also some challenges with collecting data from e-vehicles due to objections from worker unions. While, in both cases data can be collected for impact assessment purposes; it remains unclear the extent to which this data can be shared openly due to commercial and privacy concerns.

Technical issues with ICT and monitoring technologies including interoperability, open access, and data integration, storage and processing

Triangulum-I will collect data from multiple providers in diverse range of formats. Hence, the metadata (contextual information describing how a specific dataset was created and could be used) is also likely to be collected in a diverse range of formats. The WP02 researchers working on the development of the Cloud Data Hub are developing a standardised format for metadata collection. This format will specify the metadata required to enable datasets to be used in the automatic calculation of module impacts by the Cloud Data Hub. The extent to which this standard metadata format will be adopted by the Triangulum-I platform remains a topic for further discussion. Programmatic access to open data on the Triangulum-I platform will take place through a RESTful API; the use of the REST standard will ensure interoperability between the platform and applications which make use of the data hosted by the platform. Platform to platform compatibility is a key challenge and similar discussions are taking place with the managers of the Eindhoven Data Platform.

The Triangulum-I platform is being hosted by the University of Manchester. The University's network is well specified to support the real time streams of data which are created by the modules, and then stored on the platform. Early experiences with processing real time data streams suggest the platform's hardware is well specified to accommodate the quantities of data being created by the modules. The processes for ensuring the long term storage and archival of data hosted by the platform are currently being collaboratively developed by the academic research team delivering the platform and the University's IT services department.

Financing strategies

The Triangulum-I platform is being developed by a team of academic researchers with support from the University's IT services department. The platform itself is built upon OSiSoft, a commercial software application. OSiSoft is being used under a free licence for academics, so further costs will potentially arise if the platform is sustained beyond the end of the Triangulum project and used to underpin commercial activities. Furthermore, the financial model for sustaining the platform, including collection of data from modules, beyond commitments detailed in the Triangulum grant agreement remains unclear. The platform is likely to become a valuable resource for teaching and research, and could be financially supported by the University. However, automated processes of data capture are required to ensure the sustainability of data collection from project partners and third parties.

Collaboration and learning amongst partners

A potential barrier to collecting data has emerged in the form of the multiple data platforms being developed across the cities (four in total – one in each Lighthouse City plus the cloud data hub). Questions including which platform will which dataset be stored on and why does the data need to potentially be duplicated across multiple platforms have been challenging to answer during the first two years of the project. The WP02 technical working group are addressing these issues currently. The responsibility beyond the end of Triangulum project for technologies installed by the energy modules (potentially including solar PV, biomass CHP) is unclear. This has the potential to have a knock-on effect on sustainability of collecting data related to the operation of these technologies.

Citizen engagement and e-inclusion of disadvantaged groups

There has been consideration within WP03 around the value of data generated by Triangulum modules beyond the project itself. In particular, the level of demand for such data amongst citizens and disadvantaged groups is unclear (although as the survey results below indicate, partners are optimistic). The nature of the data created is driven by scope of Triangulum modules, which in Manchester has primarily been shaped by consortium partners rather than citizens. Furthermore, it likely that users beyond the project will require relatively specialist skills and contextual knowledge to interpret and use the data. The Triangulum-I platform is being developed to allow users to export data in a Microsoft Excel format, in addition to allowing programmatic access via APIs. However, interpreting and analysis Excel spreadsheets requires a considerable degree of data literacy and numeracy; skills which may not be well developed in a large proportion of the population. The inclusion of exemplar App development tasks has a particularly important role to play in citizen engagement.

3.3 Survey of key data stakeholders within Lighthouse Cities

This section reports the key results from the Survey of key data stakeholders within Lighthouse Cities. Insights from the survey results are presented below, relating to each of the five key topics raised in the survey. These develop the themes identified above.

1. Data collection.

Collaborating in data collection

The survey responses indicate collaborative working is taking place during data collection within and beyond the consortium, and between public and private sector actors, in each of the three Lighthouse Cities. In Eindhoven and Stavanger data created by citizens is being collected. Responses to the question relating to the benefits and impacts of adopting a collaborative approach to data collection indicate the question was not sufficiently clearly worded or understandable to survey participants. Hence, this remains a topic to follow up in future WP02 research.

Barriers to data collection

The survey participants identified a range of technical barriers to data collection including: a lack of historic data; challenges managing the large volume of data generated; lack of interoperability between devices and technologies; lack of standardisation of data formats; and, technical challenges ensuring data security and integrity. No consensus emerged over which barrier was the most prominent or widely experienced, and hence it appears likely that technical barriers are dependent on the specifics of the socio-technical configuration of each of the modules. There was a stronger consensus around the primary policy, organisational and regulatory barriers experienced, with survey participants from each of the Lighthouse Cities highlighting privacy and associated ethical concerns as barriers to data collection. In Manchester organisational challenges, in the form of the limited participation of data owners outside the consortium, were also noted.

2. Data management and sharing.

Data management practices

Within and across each of the Lighthouse Cities survey participants held differing perspectives on the question of who is responsible for facilitating, controlling, managing and curating Triangulum data. This suggests that further work is required to communicate the data management principles set out in D1.8 the Data Management Plan. Interestingly, the University within each Lighthouse City was identified as a key actor with responsibility for data management, while a number of responses named a single person as response for data management, potentially highlighting a lack of resilience within the project to loss of key staff members. There were mixed opinions on the question of whether or not innovative approaches to data management and sharing were being adopted within Triangulum. At least one survey participant from each city thought not. However, other survey participants identified innovative approaches in the form of: development of the Eindhoven data platform; the accelerated take up technologies for making use of data created by electric vehicles in

Manchester; and, opening up new discussions around data management as a prerequisite to adopting new and innovative approaches.

Barriers to data sharing
The survey participants identified similar barriers to data sharing, to those barriers to data collection discussed above, suggesting that drawing a distinction between barriers to data collection and sharing in practice is challenging or not particularly meaningful. Specific technical barriers were noted including: challenges integrating data from multiple sources within single data platform; a focus on static (rather than real-time) data in Eindhoven; and, challenges redeveloping an existing platform which was originally intended for University staff and students to allow access to data by the general public (Manchester). In terms of policy, organisational and regulatory barriers again privacy was frequently mentioned and alongside concerns of data protection.

3. Data Use.

The survey participants held high expectations that the data generated within Triangulum will be valuable to citizens, businesses and municipal authorities and other public bodies. 8 out of 9 survey participants believe it is likely or very likely that the data will be valuable to citizens. With this value expected to be realised as open access to data raises environmental awareness, and personal data leads to behaviour change (particularly in energy consumption). 8 out of 9 survey participants also believe it is likely or very likely that the data will be valuable to businesses, in large part because the Triangulum project is orientated to generating and sharing data which could enable new business models and could be commercially exploited. However, a note of caution was sounded by one survey participant, who noted that it is difficult to predict if data made openly available to business will be of value, as this “comes down to the creativity of companies and developers". All 9 survey participants it is likely or very likely that the data will be valuable to municipal authorities and other public bodies. In particular, these expectations are based on the potential of the data to be used in city management and data driven policy making (including environmental policy related to energy consumption and air quality).

4. Legacy issues.

A range of perspectives on which aspects of data collection, storage or provision will or should outlast the Triangulum project were evident within the responses to the survey, suggesting that there is a lack of clarity and formalisation around sustaining the Triangulum data ecosystem beyond the end of project. However, some insights can be gained from the survey responses. In particular, three participants expected data which has a clearly defined role to play in a partner organisation

(e.g. data from building energy management systems) will continue to be collected. Interestingly one survey response suggested that the organisational learning relating to data collection, storage or provision would be sustained beyond the Triangulum project, rather than the data itself. Again there were differing perspectives on which aspects of data collection, storage or provision should be sustained. A key theme of the survey responses was that data relating to the impacts of modules - including use of modules, economic and environmental benefits realised – should be collected and stored and shared beyond the end of the Triangulum project. D1.8, the Revised Data Management Plan, identified key principles for data archiving and preservation until the end of the project, but storage of data beyond the Triangulum project period is to be undertaken on an ad hoc basis, with considerations given to on-going use of data by smart city service providers, including municipalities, other partners and third party businesses (for example, smart city service technology start-ups). Also, research relevance will inform decisions to retain data subsets. In practice this may mean the majority or all of the data collected will be maintained and curated indefinitely, but a key task for the final two years of the project will be to manage and support this process within the Lighthouse Cities.

Barriers to long-term data collection and provision.

The primary barrier identified in survey responses to long-term data collection and provision was lack of clarity around how this might be funded. The response highlighted that sustaining data collection and provision would require funding for: staff time to maintain data platforms and perform manual data collection tasks; and, to maintain and develop an appropriate technological infrastructure. In Stavanger, a further barrier was identified in the form of the contracts between consortium partners and households participating in data collection which end at the end of the Triangulum project.

5. Data collection and project working.

This section of the survey posed the question ‘Has the collaborative process of data collection helped develop the scope and goals of the modules? If so, how?’ Although three survey participants observed no evidence of this collaborative process, other survey respondents found that this collaborative process had helped with selection of technologies and approaches to data collection. Two responses highlight the central role played by Universities; for example - "I believe that, by not having commercial interests in the data collected (or to be collected), the universities could safely play the role of coordinators and mediators in this process". Other responses suggested that there remains potential for closer collaboration between WP02 researchers and the organisations developing and deploying smart city modules.

3.4 Summary of potential monitoring challenges in Lighthouse Cities

The insights from the structured reflections and survey discussed above highlight key challenges faced in impact assessment and monitoring in the Lighthouse Cities. The key challenges include: negotiating privacy issues in open data provision; coordinating data transfer between multiple platforms, and managing data collection beyond the project end date. The Manchester case study and survey also highlight key opportunities in the form of the potential value of the data to businesses, municipalities and communities, and the value of adopting a collaborative approach to data collection and curation.

In terms of practical implications for upcoming WP02 tasks, Table 2 and Table 3 respectively identify potential challenges, and approaches to addressing these challenges, during, and beyond the Triangulum project. This summary is structured according to stages of the WP02 impact assessment and monitoring methodology (as presented in section 1.2).

Table 2: Potential monitoring challenges during the Triangulum project (M26-60)

Stages in impact assessment methodology		Potential challenges	Potential approaches to addressing challenges	WP02 actions to be taken to address challenges
5	Preparing for impact calculation	Baseline is data not available – *for example, because historically data has not been collected by external partners or is classified commercially sensitive.*	Explore the potential to construct meaningful baseline data through modelling or comparison with other smart city initiatives.	Specific WP02 actions for each indicator where baseline data is missing are detailed in the revised version of Del.2.3. Actions are planned for M26-36.
		There is a lack of clarity around how impacts can be calculated – *for example, because the scope of the module, and details of technical implementation, remain to be fully defined.*	WP02 to collaborate with module delivery teams to define approach and formula for impact calculation.	Specific WP02 actions for each indicator where a formula for impact calculation is not yet available are detailed in the revised version of Del.2.3. Actions are planned for M26-36.
		There is a lack of clarity around what datasets are available for use in impact calculation – *for example, because details of the technical implementation of modules remain to be fully defined.*	WP02 to collaborate with module delivery teams to identify and understand datasets available for use in impact assessment.	Specific WP02 actions for each indicator where there is a lack of clarity around what datasets are available are detailed in the revised version of Del.2.3. Actions are planned for M26-36.
6	Storing data to be used in impact calculation	Baseline data and data generated by modules are presented in multiple formats.	The Data Intake Form could capture details of the data formats, enabling subsequent alignment within the Cloud Data Hub.	A pilot deploying the Data Intake Form will be conducted (M26-36), with the aim of engaging modules in each Lighthouse City. Data capture and storage will be discussed at the SC April 2017 and GA October 2017.

Stages in impact assessment methodology		Potential challenges	Potential approaches to addressing challenges	WP02 actions to be taken to address challenges
		There are privacy concerns associated with the data required for impact calculation and monitoring.	Ensure that Triangulum data management plan is fully implemented to ensure privacy concerns are appropriately addressed.	WP02 to review data management plan and develop CDH accordingly (M26-36).
7	Calculating and monitoring impacts.	Automatic calculation of impacts in the Cloud Data Hub is not feasible for some indicators.	Establish systems and processes to enable the manual calculation impact for some indicators and storage of data used in calculation in the CDH.	WP02 researchers to collaborate with module delivery teams to manually calculate impacts as appropriate (M26-36). The presentation of the impact report will be scoped with Lighthouse Cities at SC April 2017.
		Challenges understanding what actions have been taken as a result of impact monitoring.	Explore the possibilities for additional research (beyond the scope of WP02) that assesses the benefits of access to smart city module impact monitoring data.	WP02 to develop recommendations for actors seeking to understand how impact data has influenced decision-making, and underpinned wider influence beyond the project (M36-60).

Table 3: Potential monitoring challenges beyond the Triangulum project (M60 onwards)

Stages in impact assessment methodology		Potential challenges	Potential approaches to addressing challenges	WP02 actions to be taken to address challenges
6	Storing data to be used in impact calculation	Changes in module scope over time lead to changes in data formats and impact calculation approaches.	Establish and embed operational model for long-term impact assessment and monitoring in Lighthouse Cities including support for manual impact calculation and changes which impact on automatic impact calculations.	WP02 to support module delivery teams in developing operational models for long-term impact assessment and monitoring (M36-60).
		The volume of data generated by smart city modules exceeds that which can economically be stored with the Triangulum ICT infrastructure.		
		Access to data, for use in impact calculation, is limited to the duration of the Triangulum project.		
7	Calculating and monitoring impacts	Continuing to manually calculate impacts for some indicators.		
		Change in module scope over time lead to change in impact calculation formula and/or the need to monitor new indicators.		
		Funding has not yet been secured for operating modules and data platforms beyond the Triangulum programme.	Develop new business models and funding streams to support operational model for long-term impact assessment and monitoring in Lighthouse Cities	WP02 to support module delivery teams in developing new business models (M36-60).

4 Streamlined monitoring for Follower Cities

4.1 Monitoring principles

The experiences in the lead cities suggest that the process of monitoring should adhere to two key principles in Follower Cities.

1. Approach impact assessment as an iterative process. Across the three Lighthouse Cities WP02 activities are on-going to understand the scope of modules and their expected impacts, to develop associated indicators and to gather baseline data. In many cases expected impacts and indicators will need to be revisited as the modules themselves are further developed and refined (for example in relation to current amendments). Such an iterative process has been necessary given that Triangulum consortium partners are engaging in an on-going process of working together to learn how specific smart city technologies can be deployed in novel socio-technical configurations (i.e. modules) in specific local contexts. Hence, an iterative approach to impact assessment may have value in Follower Cities experimenting with, and seeking to understand the value of, emerging smart solutions.

2. Develop strong relationships between impact assessors and module delivery teams. The processes of defining modules and impact indicators have progressed in parallel over the first year of the Triangulum project. WP02 researchers played a key role in supporting city partners in the modules definition work. For example, this has involved explaining the concepts of socio-technical modules and module replication to city partners, and working to refine module definitions. Hence, the role of WP02 researchers extended beyond the envisioned scope, as researchers engaged in module design activities in addition to impact monitoring and assessment activities. Extending the impact assessment researcher role in this way has both benefits and drawbacks. The main benefit has been raising the profile of impact assessment and monitoring activities with city partners, embedding these activities at the outset of module development, and forging close relationships between the academic and the city partners. However, realising these benefits has required a significant unanticipated investment of time by researchers, creating some resource management and work-flow challenges for the work package partners. Forging strong collaborative relationships between impact assessors and module delivery teams in Follower Cities is likely to be of benefit, but the resources implications of such an approach should be considered at the early stages of the project lifecycle.

4.2 Streamlined impact assessment and monitoring methodology

Based on the experiences of the Lighthouse Cities it is possible to develop a streamlined impact assessment and monitoring methodology for Follower Cities based on the WP02 methodology described in section one. The streamlined methodology has five stages as shown in Figure 3, and described below.

1. **Prepare for impact indicator development:** by identifying expected impacts for the module being replicated, and auditing the dataset that are available to support assessing these impacts. Methods that could be used in this process include observing meetings, conducting workshops and semi-structured interviews, electronic consultation and opportunities to feedback on draft documents.

2. **Co-produce and document impacts and indicators.** Based on the expected module impacts co-produce and document impact indicators with a diverse range of stakeholders. Iteratively refine indicators through flexible engagement with module stakeholders.

3. **Align and verify impacts, indicators and.** Align impacts and impact indicators with SCIS framework through refinement of module indicators adopting SCIS terminology and quantitative units where possible (to allow for future comparative analysis).

4. **Prepare for impact calculation.** Key preparatory tasks include: gathering baseline data; defining the approach to calculating impacts; and, identifying datasets to be used to calculate impacts. Where possible store datasets in the SCIS digital infrastructure.

5. **Calculate impacts.** Adopt a flexible approach to calculating impacts manually or automatically in light of the data available and technological capabilities of the stakeholders engaged in impact assessment.

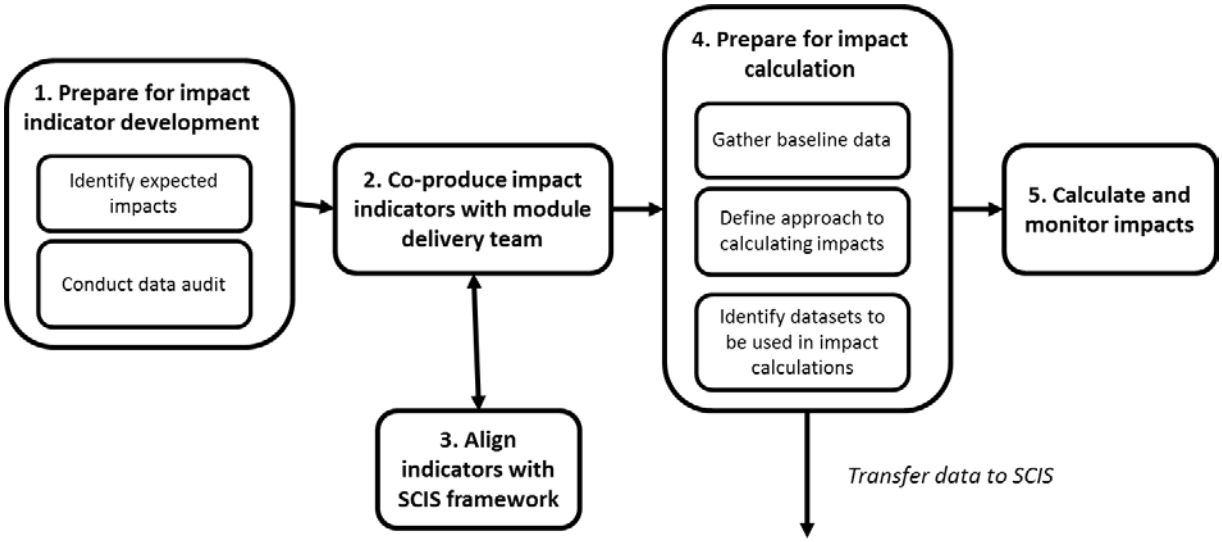

Figure 3: Streamlined impact assessment and monitoring methodology

Table 4 identifies potential challenges Follower Cities may face at each stage of the methodology based on experiences of the Lighthouse Cities, and highlight the successful approaches adopted to addressing these challenges.

Table 4: Potential challenges Follower Cities may face at each stage of the streamlined impact assessment and monitoring methodology

Suggested impact assessment activity in follower cities		**Potential challenges (identified based on experiences of Lighthouse Cities)**	**Successful approaches to addressing challenges adopted in Lighthouse Cities**
1.	Prepare for impact indicator development	Module delivery teams are unclear on scope of module, and hence unclear on expected impacts and relevant datasets.	Develop impact assessment plan to align with module development timescales.
2.	Co-produce and document impacts indicators	Module delivery teams are unclear on scope of module, and hence face challenges defining impacts indicators and datasets	Develop impact assessment plan to align with module development timescales.
3.	Align and verify impacts and indicators with SCIS framework	SCIS framework does not identify indicators relevant to the module being replicated.	Consult other smart city indicator frameworks (e.g. CityKeys).
4.	Preparation for impact calculation	Limited baseline data availability	Construct baselines based on data that is available and appropriate assumptions.
		Feasible approaches to calculating unclear until module implementing is complete and operating.	Develop impact assessment plan to align with module development timescales.
		Details of datasets available unclear until module implementing is complete and operating.	Develop impact assessment plan to align with module development timescales.

4.3 Indicators for Follower City Replication Activities

Although the Follower Cities have yet to specific modules they intend to replicate, WP06 has identified specific forms of smart city innovation that they are interested in. These include: smart Grids & Energy Storage; Intelligent Public Space; Open Data & Governance; and, Smart and Electric Mobility. Sets of potential indicators are presented below, based on those developed for the Lighthouse Cities, for each of these four areas of smart city innovation (see Table 5, Table 6, Table 7 and Table 8 below). For each impact the tables show the possible indicators and quantifiable units, as well as whether the indicator is aligned with the SCIS framework and if the value can be automatically calculated or has to be entered manually (see Deliverable 2.3 Baseline Report for a more detailed explanation of these column headings).

Table 5: Suggested indicators for Smart Grids & Energy Storage

Impact	Impact indicator	Quantifiable unit	Aligned with SCIS	Auto. calc.
Reduced energy consumption	Change in annual primary energy use	kWh	Y	Y
	Percentage change in annual primary energy use	Dimensionless decimal	Y	Y
Reduced energy costs	Change in annual energy costs	€	Y	Y
Reduced greenhouse gas emissions	Change in annual greenhouse gas emissions	tCO_2e	Y	Y
Increased use of low carbon energy sources	Energy delivered by the low carbon energy generation assets (MMU buildings)	kWh	Y	Y

Table 6: Suggested indicators for Intelligent Public Space

Impacts	Impact Indicators	Quantifiable Unit	Aligned with SCIS	Auto. calc.
Fostering citizen engagement and co-creation	Number of citizens involved in project-planning	Dimensionless integer	Y	N
Fostering citizen engagement and co-creation	Number of citizens using apps which enable engagement with intelligent public space	Dimensionless integer	N	Y
Developing a digital infrastructure	Number of sound sensors installed	Dimensionless integer	N	Y
Developing a digital infrastructure	Number of video sensors installed	Dimensionless integer	N	Y
Developing a digital infrastructure	Number of water sensors installed	Dimensionless integer	N	Y
Improving quality of life	Recorded happiness of residents and workforce using the public space	Not applicable – qualitative data is needed to assess this impact.	N	N

Table 7: Suggested indicators for Open Data & Governance

Impact	Impact indicator	Quantifiable unit	Aligned with SCIS	Auto. calc.
Enhanced digital infrastructure	Total number of datasets made openly accessible	Dimensionless integer	N	N
	Number of datasets relating to energy modules made openly accessible	Dimensionless integer	N	N
	Number of datasets relating to mobility modules made openly accessible	Dimensionless integer	N	N
	Number of real time[2] data feeds made openly accessible	Dimensionless integer	N	N
	Quantity of data made openly accessible	GB	Y	N
Increased engagement with data	Number of downloads of datasets	Dimensionless integer	N	N
	Number of users downloading data	Dimensionless integer	Y	N
	Quantity of data downloaded	GB	Y	N
	Number of people participating in events which promote use of smart city module data	Dimensionless integer	N	N
Increased commercial activity	Number of apps developed by for-profit organisations using smart city module data	Dimensionless integer	Y	N
Increased environmental awareness and behaviour change	Number of apps developed in response to innovation challenges which use smart city module data and seek to change user behaviour	Dimensionless integer	Y	N

[2] Data feeds which are updated hourly or more frequently

Table 8: Suggested indicators for Smart and Electric Mobility

Impact	Impact indicator	Quantifiable unit	Aligned with SCIS	Auto. Calc.
Reduced Greenhouse Gas Emissions	Number of electric vehicles/bicycles within	Dimensionless integer	Y	N
	Percentage of electric vehicles within vehicle fleet/district	Dimensionless decimal	Y	N
	Reduction in greenhouse gas emissions as a result of using electric vehicles/bicycles	tCO_2e	Y	Y
	Number of journeys made by electric vehicles/bicycles	Dimensionless integer	N	Y
	Average time electric vehicles/bicycles are in use per day	hh:mm	N	Y
Reduced emissions of air quality pollutants	Reduction in NOx emissions as a result of using electric vehicles/bicycles	g/vkm	Y	Y
	Reduction in CO emissions as a result of using electric vehicles/bicycles	g/vkm	Y	Y
Evaluating new technologies	Number of electric vehicle charging stations installed	Dimensionless integer	Y	N
	Quantity of energy supplied by EV charging stations	kWh/yr	N	N
	Percentage of users satisfied with telematics	Dimensionless decimal	N	N
	Percentage of users satisfied with electric vehicles/bicycles	Dimensionless decimal	N	N
Reduced traffic congestion	Number of journeys by motorised vehicles replaced by electric vehicles/bicycles journeys	Dimensionless integer	N	Y

Appendix A

Copy of survey focused on "Sustainability and Stewardship of Data Generation and Collection"

Triangulum has piloted a highly collaborative approach to monitoring and data collection that is driven by and supports the needs and capacities of local partners. This brief questionnaire seeks to provide a preliminary evaluation of this process and understand some of the key barriers around data-driven sustainable city development. The questionnaire has two goals:

- To ensure a sustainable process, structure and organisation of generating and collecting data during and beyond the lifetime of the Triangulum project.
- To draw general lessons about monitoring and data that can be used to inform smart city activities in follower cities and elsewhere.

The results will form the basis for WP02 Deliverable 2.4 Interim Report and be shared with all partners. The questionnaire is targeted at all city partners who have actively engaged with WP02 to help identify impacts and data for the impact assessment. Please note responses will not be anonymous. The following questionnaire contains 18 questions in 5 sections and will take 10 minutes to complete.

Name:

Job title:

Role(s) in Triangulum:

1. Data collection.

1.1 To what extent have module partners, policy makers, users and the public been included in the collection of Triangulum data? (Please include names of participating partners/actors).

1.2 What are the main technical barriers to collecting data created by Triangulum activities in your city?

1.3 What are the main policy, organisational and regulatory barriers to collecting the data created by Triangulum activities in your city?

1.4 How has the collaborative approach of working with partner organisations impacted on the data that will be collected? (For example, will more datasets be created / made available? Does it relate to a greater range of impacts? Will it be of more use to partners / users beyond Triangulum?)

2. Data management and sharing.

2.1 What are the main technical barriers to sharing data created by Triangulum activities in your city?

2.2 What are the main policy, organisational and regulatory barriers to sharing the data created by Triangulum activities in your city?

2.3 Has Triangulum driven new approaches to data collection, stewardship and open data?

2.4 Who is responsible for facilitating, controlling, managing and curating Triangulum data?

3. Data Use.

3.1. Who is responsible for the provision of open data in standardized, easy-to-use formats for sharing with partners and city stakeholders?

3.2 How likely is that data produced by Triangulum activities in your city will be valuable to citizens?

Delete as appropriate: *very likely / likely /unlikely / very unlikely / unsure*

Why is this?

3.3 How likely is that data produced by Triangulum activities in your city will be valuable to businesses?

Delete as appropriate: *very likely / likely /unlikely / very unlikely / unsure*

Why is this?

3.4 How likely is that data produced by Triangulum activities in your city will be valuable to municipal authorities and other public bodies?

Delete as appropriate: *very likely / likely /unlikely / very unlikely / unsure*

Why is this?

4. Legacy issues.

4.1 Will any aspects of data collection, storage or provision outlast Triangulum?

4.2 What are the most important impacts that should be monitored beyond the lifetime of the project?

4.3 What are the main barriers to ensuring long-term data collection and provision? How can they be overcome?

5. Data collection and project working.

5.1 Has the collaborative process of data collection helped develop the scope and goals of the modules? If so, how?

5.2 How has the process of data collection impacted upon working across organisations?

5.3 How has the coordinating role played by local universities impacted this process?