Data-driven and Dynamic Space and Assets for Physical Internet-led Urban Logistics and Planning

D2.2 – Digital Transition Assessment Tool

KLU

30 April 2024

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Abstract

This document provides an overview of the development of the DISCO project's PI-led digital maturity and transition assessment tool which represents the focus of Task 2.2. The document serves also as guideline for the tool itself. The structure of the tool has been developed and it will provide the foundation data that will be used to create a baseline for comparison against which future users can gauge their progress in digital capabilities. However, the integration with the SPROUT innovation assessment tool and linkage of these two integrated tools with the DISCO-X measures awaits the implementation of them and their evaluation. The tool is accessible through the SharePoint of the project while the survey to collect the input from the cities can be found at the following URL: https://forms.office.com/e/rcDgkXgQKS. This tool is constructed around the five maturity assessment categories of security, interoperability, energy efficiency (environmental impacts), social responsibility, and commercial viability. Within each category, twenty assessment questions are presented with a self-assessment score based on a five-point descriptive likert scale running from just starting to full operational compliance. Assessment categories and category questions have been derived from best practices and literature and have been developed to work in conjunction with the SPROUT assessment approach. Integration of the scoring provided by the DISCO partner cities with their responses to the SPROUT innovation readiness assessment is performed through the application of a multi-variable analysis and development of a covariance matrix. Full integration with graphical positioning and comparisons awaits the development of the baseline responses from the partner cities and the further development of the Meta Model Suite.

Summary sheet

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Organisation	Country	Abbreviation
FIT CONSULTING SRL IT Coordinator	IT	FIT
RUPPRECHT CONSULT-FORSCHUNG & BERATUNG GMBH	DE	RC
INLECOM INNOVATION ASTIKI MI KERDOSKOPIKI ETAIREIA	EL	INLE
PNO INNOVATION SL	ES	PNO
INTERNATIONAL DATA SPACES EV	DE	IDSA
FM LOGISTIC IBERICA SL	ES	FM
AKKA INDUSTRY CONSULTING GMBH	DE	AKKA
FONDAZIONE ISTITUTO SUI TRASPORTI E LA LOGISTICA	IT	ITL
ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTY XIS	EL	CERTH
LINDHOLMEN SCIENCE PARK AB	SE	LSP
KUHNE LOGISTICS UNIVERSITY GGMBH	DE	KLU
INSTITUT DE RECHERCHE TECHNOLOGIQUE SYSTEM X	FR	IRTX
STICHTING BREDA UNIVERSITY OF APPLIED SCIENCES	NL	BUAS
POLIS - PROMOTION OF OPERATIONAL LINKS WITH INTEGRATED SERVICES, ASSOCIATION INTERNATIONALE	BE	POLIS
EUROPEAN PARKING ASSOCIATION EPA EV	DE	EPA
ALLIANCE FOR LOGISTICS INNOVATION THROUGH COLLABORATION IN EUROPE	BE	ALICE
ERASMUS CENTRE FOR URBAN, PORT AND TRANSPORT ECONOMICS BV	NL	ERASMUS

INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM	BE	IMEC
VLAAMS INSTITUUT VOOR DE LOGISTIEK VZW	BE	VIL
FUNDACION ZARAGOZA LOGISTICS CENTER	ES	ZLC
BE-MOBILE	BE	BE-MOBILE
STAD GENT	BE	GENT
OPLEIDINGSCENTRUM VOOR HOUT EN BOUW VZW	BE	OHB
CITYLOGIN IBERICA SL	ES	CITYLOGIN
UNIVERSITAT POLITECNICA DE CATALUNYA	ES	UPC
AJUNTAMENT DE BARCELONA	ES	BCN
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REGION HOVEDSTADEN DK Partner	DK	REGIONH
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MESTSKA CAST PRAHA 6 / District Prague	CZ	PRAHA
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AARHUS KOMMUNE	DK	AAKS
DIMOS THESSALONIKIS	EL	THESSALONIKI
DIETHNIS EKTHESI THESSALONIKI AE	EL	TIF HELEXPO
ACS TACHIDROMIKES IPIRESIES MONOPROSOPI ANONYM	EL	ACS
ROLAN OY	FI	ROLAN
ASOCIACIÓN LOGÍSTICA INNOVADORA DE ARAGÓN	ES	ALIA
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Document history

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0.1	15 April 2024	KLU	Draft	Initial draft
0.2	19 April 2024	IRTX, FIT	Multiple	Reviewers' feedback
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List of acronyms

LL	Living Laboratory
LSP	Logistics Service Provider
PI	Physical Internet

 Version: 0.8

1. Introduction

Digital competence is a crucial catalyst for cities aiming to transition towards sustainability and climate neutrality. However, many cities lack a clear understanding of their current digital capacity or the maturity of their digital infrastructure, which hinders their ability to identify and enhance underdeveloped aspects of their ecosystem. To address this deficiency, a qualitative framework has been developed to assess the digital maturity levels of cities. Specifically, this document describes the development of the DISCO project's Digital Transition Assessment tool, the primary deliverable of Task 2.2 "Assessment Tool for PI-led Digital Transition". The tool is being developed to provide cities and appropriate stakeholders with an easy to fill out assessment mechanism to gauge progress in their digital transition to a Physical Internet approach to urban logistics employing the DISCO-X urban logistics solutions. The tool is designed to assess digital maturity of a city and forms one of the foundation elements of the project's Meta Model Suite for assisting cities in implementing the various DISCO-X solutions (DISCOCURB, DISCOPROXI, DISCOESTATE, DISCOBAY, and DISCOLLECTION). The assessment categories covered in the assessment tool focus on five areas of digital maturity obtained from a detailed review of best practices and academic literature.[1] These assessment categories are:

1. **Security** covering data, data and system access, infrastructure and equipment, users of the technologies, the data generated from the technologies, and the systems employed to monitor and manage the technologies (NIST CSWP 29, 2024).
2. **Interoperability** focused on the ability to easily exchange data between systems, integration with other city and user systems, openness of the technology, and openness of the collection, analysis, and decision-making systems used (ISO 30182:2017, Lee et al., 2021).
3. **Social responsibility** focusing on the benefits expected/derived from the implementation of digital services for city stakeholders, involvement of city stakeholders in the selection and implementation of the technologies and services, access of stakeholders to the outcomes of the services, and ongoing engagement of stakeholders in improving and expanding the services (Basu et al., 2022; Hatuka et al., 2020).
4. **Energy efficiency** of the systems employed, of the operation of the various digital technologies and service used in the city, whether there is a requirement to assess the energy efficiency or environmental impacts of technologies, whether sensor technologies are evaluated based on their energy use, etc. (D'Amico et al., 2021; Wu et al., 2023).
5. **Commercial viability** of the digital services provided by the city including stakeholder involvement/commitment, regulations for use, data access, operational transparency, flexibility of use, non-discriminatory policies, enforcement policies, and permitting processes (Björklund et al., 2017; Vij & Dühr, 2022).

[1] These five categories were derived from Brown and Kristiansen (2009).

The digital maturity assessment tool employs a five-point likert scale to evaluate the city's level of digital maturity in each category. The scale rates the city's maturity from a position of beginning the process to a fully mature implementation in all city's digital processes.

The objective of examining a city's digital maturity is driven by the observation that digital technologies are becoming increasingly important to the sustainability of cities (D'Amico et al., 2021). While it has been noted that cities are not computers (Mattern, 2020), cities are becoming too complex to manage without the use of modern digital technologies (Batty, 2009). The complex dynamics of cities has thus thrust cities into the digital age, requiring city managers to address digitalization in a direct manner (Wellar, 2012). Unfortunately, most cities have addressed their digitalization challenges in an ad hoc manner resulting in a less than flexible or secure digital infrastructure (Bibri and Krogstie, 2017). The DISCO digital maturity assessment has been developed as part of the Meta Model Suite in part to aid cities in understanding their digital maturity and how their maturity influences the best options for journeying along the path to net zero.

The sections that follow are organized around the component elements that make up Task 2.2 as described in the DISCO project. This structure is summarized in the input-output diagram that appears in Figure 1-1: Task 2.2 Input-Output Diagram.

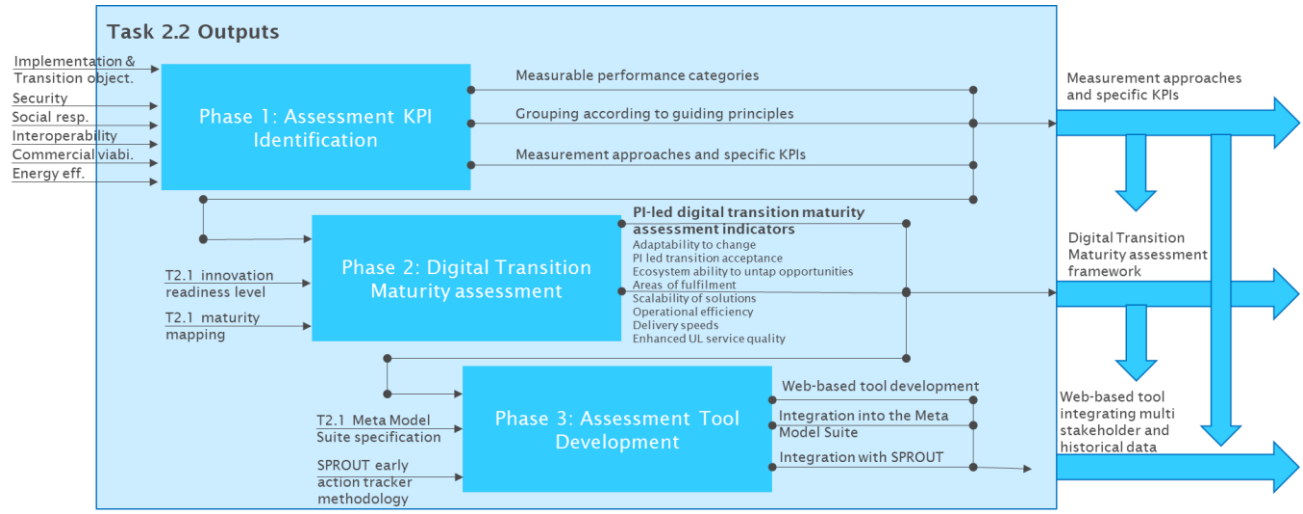

Figure 1-1: Task 2.2 Input-Output Diagram

Section 2 of this document covers Phase 1 of Task 2.2, the identification of measures for the maturity assessment. Section 3 of the document addresses Phase 2 of Task 2.2, the development of the assessment methodology. Section 4 of the document addresses Phase 3 of Task 2.3, the development of the assessment tool. Section 5 of the document summarizes the lessons learned so far in developing the digital maturity assessment and provides an overview of the next steps for Task 2.2.

1.1 The Physical Internet Paradigm

Before moving on to Section 2 and the first phase of Task 2.2 it is important to orient the reader to what is meant by the Physical Internet (PI) as this logistics model differs from most approaches currently employed by logistics service providers (LSPs) in their day-to-day business operations. The PI is a logistics operations model based loosely on how the Digital Internet operates. The Digital Internet, or more simply the Internet, is a network of independent networks connected through standardized gateways allowing the passage of data packets from an originating host to a destination host. The independent network operators collaborate by allowing the data to pass through their individual networks using the infrastructures (cables, routers, hubs, etc.) that they have developed and deployed. No single entity manages this network-of-networks and the collaborative use of the various infrastructures is facilitated by the use of standard protocols. This approach to managing the movement of data is extremely efficient and cost effective as it leverages the sharing of installed assets avoiding the need for redundant and costly infrastructure development by the collaborating networks.

The PI paradigm for logistics operations envisions a similar organization for the shipment of physical goods. In the PI paradigm, logistics service providers share their networks and assets increasing the efficiency of transport, storage, and delivery. By more efficiently using the assets in the shared networks, costs, emissions, and congestion declines and service levels increase (Montreuil, 2011; Hakimi et al., 2012). While this approach appears to be a win-win concept for all parties it is extremely difficult to implement. This is because LSPs are fierce competitors, and they have little trust that a competitor that might handle goods that come from them would do so with the same care and diligence that they themselves would use. This fact has been clearly demonstrated in projects such as NexTrust[2] in which it was shown that only when a “trusted” neutral orchestrator oversaw the collaboration process were LSPs willing to participate.

The fact that LSPs are very distrustful of their competitors is not surprising. However, this means that cities seeking to develop more efficient urban logistics operations, i.e., moving to a PI structured logistics model, must work extremely hard with all stakeholders to gain their trust and support for this type of logistics model. It also means that cities must build a trustworthy system for their logistics partners and stakeholders, or these entities will not willingly participate. It is important to understand the challenges that cities face in moving to more efficient urban logistics operations when gauging a city’s progress toward digital maturity in a PI-led transition. Most cities, if not all if they are honest, will only be starting such a journey. It may take some time to progress, but the destination is certainly worth the effort.

[2] https://cordis.europa.eu/project/id/635874/reporting

2. Phase 1: Assessment KPI Identification

The development of Key Performance Indicators (KPIs) for the digital transition process of a city towards the development of a truly collaborative urban logistics model, the Physical Internet, was the focus of Phase 1 of Task 2.2. As stated in DISCO proposal, this element of Task 2.2 was to take the implementation objective of achieving a PI informed collaborative urban logistics model within the city and the transition objectives defined through the work conducted in Task 2.1 "Defining digital transition baseline and specifications for the Meta Model Suite to enable transition" and use these inputs to create measurable performance categories for cities that would feed the assessment model. Following the original purpose of this task element, an initial list of measurable KPIs was developed and a process for assigning transition progress based on measured performance was begun.

The KPI selection process for each DISCO Living Lab (LL) was informed by prior EU funded efforts that focus on urban logistics operations and define relevant performance indicators for the various logistics activities conducted in the urban environment. Of particular use was the extensive work done in identifying KPIs in the URBANE project.[3] This project identified 66 measurable KPIs for the operation of urban logistics activities (Figure 2-1: URBANE urban logistics KPI list). These KPIs provided a foundation for developing a set of more focused KPIs for each of the DISCO LLs.

[3] Urbane - Upscaling Innovative Green Urban Logistics Solutions (urbane-horizoneurope.eu)

Impact Area	ID	Key Performance Indicator	Measurement unit
Environment	L1	CO2 emissions	g/vkm
	L2	NO2 emissions	g/vkm
	L3	PM10 emissions	g/vkm
	L5	Noise level	dB
	L8	Fuel consumption per Km	MJ/vkm
Transport and efficiency of LM operations	L9	Average number of km per trip	Km/Trip
	L10	Average number of km per vehicle	Km/Vehicle
	L11	Total distance travelled in urban area	Km/Vehicle
	L13	Number of freight vehicles per category	Vehicle category matrix
	L14	Time to complete a delivery route	minutes
	L15	Average time for loading/unloading	minutes
	L16	Number of loading/unloading areas	n.
	L17	Average vehicles speed per trip	minutes
	L18	Average vehicles load factor	% in weight or volume per Km
	L19	Quality of transport services	% of on time deliveries on total
	L20	Number of unauthorised parking in the urban area or in a part of it	n.
	L22	Average deliveries per trip	n.
Economy and society	L24	Total delivery costs	€ per parcel
	L25	Investment in clean energy networks and vehicles	€ per vehicle
	L28	Accidents involving freight vehicles	n.
	L29	People killed or seriously injured in collisions involving freight vehicles	n.
	L32	Awareness level	%
	L33	Residents acceptance level (Helsinki: (NPS score, service level rating, acceptance incentives) (>70%))	%
	L34	Social inclusion	%
	L35	Waste production	kg of saved disposable packaging
	L36	Safety of deliveries (no damages)	%
	L37	Security of deliveries (no losses or thefts)	%
	L38	Employment rate	%
	L39	Personnel turnover	Ratio
	L40	Average salary	€
	L41	Education level	Distribution per educational deg
	L42	Gender diversity	% females
	L43	Percentage of self-employed workers	%
	L44	Percentage of part-time workers	%
	L45	Precariousness rate	%
	L46	Flexibility of working hours	Qualitative (Yes/No)
	L47	Percentage of remote work	%
	L48	Percentage of customers willing to pay a premium for faster delivery	Percentage of customers willing
	L49	Adoption rate of sustainable delivery options	Percentage of customers who ch
	L50	Failures in the IT system	n./month
	L51	reverse geofencig integration system	yes/no
	L52	Presence of IT and AI driven optimisation system	yes/no
	L53	Degree of innovation of logistics companies	%
	L54	Parcel Lockers fill rate (B2C)	%
	L55	Number of PuDo in the demo area	n
	L56	Information accessibility	likert scale
	L57	Number of failed deliveries per trip	n
	L58	Return on investments	%
	L59	Responsiveness to changes	likert scale
	L60	Revenue growth	%
	L61	R&D capability	likert scale
	L62	Parking accessibility in existing consolidation/logistics hubs (microhubs, consolidation centers e.tc.)	Likert scale
	L63	Accessibility of lockers (or B2C micro-hubs) to vulnerable users	Likert scale
	L64	Affordability of shared logistics services (cost of service's provision compared to the revenue growth of th	Not sure what this means and if
	L65	Fuel cost (euros per litre) and electricity cost (euros per kWh)	€/l and €/kWh
	L66	Air pollutant emissions indicator (SUMI 03)	kg PM2.5 eq./cap per year

Figure 2-1: URBANE urban logistics KPI list

Because the Task 2.2 of the DISCO project focused on a slightly different end point than other projects, the general KPIs from the URBANE project, as well as other KPIs developed for similar projects (e.g., NOVELOG and SULPITIR), were useful as starting points, but needed to be modified to address the specific nature of Task 2.2's focus. Additional dimensions of performance measurement were added based on input from LL stakeholders. The results of this integration of prior work and stakeholder input was a set of performance indicators along with a measurement scheme indicating level of performance/maturity based on the various KPIs. An example of the outcome of this effort appears in Figure 2-2: Example initial KPI assessment for DISCOCURB.

Loading/Unloading parking spaces	What is the percentage of business establishments that have access to a loading/unloading parking zone within a distance of 10-15m.	%		0-25%	26-50%	51-75%	76-100%
Parking violations	How much money, do the city collects for double parking violations? Or How many incidents of parking violations are reported per day?	-					
Digitalization of parking	To what extent are the parking services digitalized?	Likert	Can not be answered	None of the required services for parking management are digitalized; there is no digital interface or platform in place.	Specifications for a digitalized user interface for booking/interaction have been outlined, but they are not currently operational.	Initial interactions with the services are digitalized, but there is no overarching platform; functionalities may be fragmented.	Monitoring, booking, and other interactions can be seamlessly conducted on an interactive overarching platform with an easily accessible user interface, providing comprehensive digital integration.
Loading/Unloading Operations	How does the current loading/unloading operations take place in the city?	Likert	Can not be answered	There is dedicated loading/unloading space. The parking spaces are limited and multiple violations (parking not for L/U) are observed.	There is dedicated loading/unloading space with very limited regulations to support them. There is no smart booking system for reservation.	There are multiple loading/unloading parking spaces. City supports them with regulations (zones, bays, restrictions). There is smart booking system or other smart ways.	The city is managing dynamically and effectively the loading and unloading (sufficient for all operations), either with a Smart Curbside Management System or other smart ways of managing these parking zones for logistics operations.
Available curbside infrastructure	Which of the following digital and physical infrastructure assets are installed in your city?	Select					
	Curbside signs informing drivers about the characteristics of each zone, parking spot, bay etc.	☐	if no, vote if you are planning to install it in a scale from 1 to 5.				
	Dynamic (and fair) pricing system for the movement of vehicles through the city center	☐	if no, vote if you are planning to install it in a scale from 1 to 5.				
	Security systems (e.g. cameras) to monitor the curb side	☐	if no, vote if you are planning to install it in a scale from 1 to 5.				
	Sensor-based curbside infrastracture	☐	if no, vote if you are planning to install it in a scale from 1 to 5.				
	Charging stations for electric vehicles	☐	if no, vote if you are planning to install it in a scale from 1 to 5.				

Figure 2-2: Example initial KPI assessment for DISCOCURB.

While testing whether such a tool would be useful to the cities working on DISCO-X measures it was determined that filling out such a tool, along with the other measurement requirements imposed by ongoing regulations, new objectives, and other projects created a situation where data reliability and thus answer validity rendered the approach unworkable. Data was not available, would require extensive manual labour to collect, was not consistently monitored or measured, etc. While not surprising, the results of the initial test did provide useful information for developing a better approach to the problem.

Planners indicated that they generally were not able to access hard data concerning the performance of services similar to the DISCO measures and would most likely not be able to obtain the data we were asking for prior to rolling out their projects and obtaining performance measures from the projects. Because the digital infrastructure for collecting this level of data was at best in its infancy and not fully integrated with the tools the planners could easily access, the planners felt that the work required to obtain the data would be excessive and the validity highly suspect. In addition, city personnel indicated that such an effort would not provide a good indicator of their city's digital maturity as it would focus on specific projects and not the overall state of the city's digital capabilities. Instead of trying to obtain something that would most likely not be useful or address the purpose of the maturity assessment, these individuals suggested that a more qualitative approach made more sense and would provide them with much more indicative journey statuses than a potentially more rigorous data driven concept that would be only partially filled out and not actually address their state of maturity.

The negative feedback from this first attempt at obtaining quantitative KPIs resulted in a re-evaluation of not only the approach that should be taken, but in the items that should be examined. Quantitative KPIs are very good in describing operational performance. However, when looking at

digital technology transitions, unless one is interested in how efficient a technology is operating during the transition, it is more important to understand whether a technology or capability is present or not (Kuenzel & Hartmann, 2022). As an example, one can look at all EU proposal requests where those proposing on a call are asked whether their organization has a Gender Equality Plan. Such questions provide guidance on what should be in the item being queried but rely on the individual filling out the questionnaire to answer in an honest fashion as to the item's existence and compliance.

Based on input from the planners that the assessment should be less focused on numbers and more on digital capabilities and a recognition that such capabilities could be generally represented through a qualitative assessment process, research was conducted to determine what factors should be assessed in each of the five identified categories to determine a reliable measure of digital maturity. This was an interesting exercise as a small cottage industry has developed in creating and promoting digital maturity assessments (Thordsen & Bick, 2023). Many of the models examined were either developed for a particular industry or did not have a solid basis for determining their reliability or validity. In addition, as the five categories that were selected as the primary focus areas for our maturity model resulted from the synthesis of multiple sources, no single model from the literature provided a useable framework. As a result, we went back to the source standards and articles (referenced in the Introduction) from which the five categories were selected and synthesized sets of questions for each of the categories from the source that informed their selection.

This effort resulted in a set of questions organized by category and DISCO-X measures that assessed maturity once more on a five-point Likert scale. This assessment was distributed once more to planners for their evaluation. An example of how this assessment was structured appears in Figure 2-3: Digital Assessment Model for DISCOCURB for evaluating digital maturity for a DISCOCURB measure.

Figure 2-3: Digital Assessment Model for DISCOCURB

The planners who reviewed this second assessment model indicated that it was a significant improvement over the first more quantitative model. They felt that it could work for assessing the digital maturity of their city with respect to the particular DISCO-X solution they were working on but questioned whether such an assessment actually indicated the digital maturity of their city. This question arose because assessing measures that were only beginning to be implemented using technologies that might or might not be the technologies selected for long term deployment would generally bias an assessment on maturity.

The planner feedback, along with advancing work on determining how to integrate the maturity assessment with the SPROUT innovation readiness assessment tool led to a third and final revision of the maturity assessment data collection process. This final process, the topic of the next section of the report, did away with trying to assess digital maturity by DISCO-X solutions and focuses on the city's digital maturity in general.

2.1 Assessment Process

While having an assessment tool that is acceptable to urban logistics stakeholders and planners is a necessary starting point for assessing a city's digital maturity, it is not a sufficient solution to helping the city determine which types of collaborative urban logistics measures it should begin developing. Assessment tools by themselves do little more than provide the entity filling them out with a snapshot of where they believe their current efforts in the area being assessed positions them versus some baseline established by the tool. A useful assessment tool must do much more than this (Becker et al., 2009).

To development a useful digital maturity tool that provides useful guidance to cities and their stakeholders concerning their journey towards a triple bottom line enabled sustainable city an analysis of the source material that informed the development of the five categories that structure our digital maturity model was performed. Using Becker et al.'s (2009) framework as a starting point (Figure 2-4: Becker et al. ITPM digital maturity assessment model framework (Becker et al., 2009)), each of the source articles and standards behind the five maturity categories were reviewed. Based on this review a set of questions were developed for each category that focused specifically on a city's maturity within the category. Evaluation of maturity based on each question is made along a five-point likert scale. Questions were once more reviewed with city planners to determine their usefulness and validity. Positive responses from planners who had reviewed the previous two draft models indicated that this final approach and set of questions was not only useful for the DISCO project, but for general analysis of city digital maturity. The agnostic applicability of the model is crucial as the digital maturity assessment model will be integrated with the SPROUT innovation readiness model which is a general-purpose model for cities to assess their readiness for accepting innovative solutions to urban logistics problems.

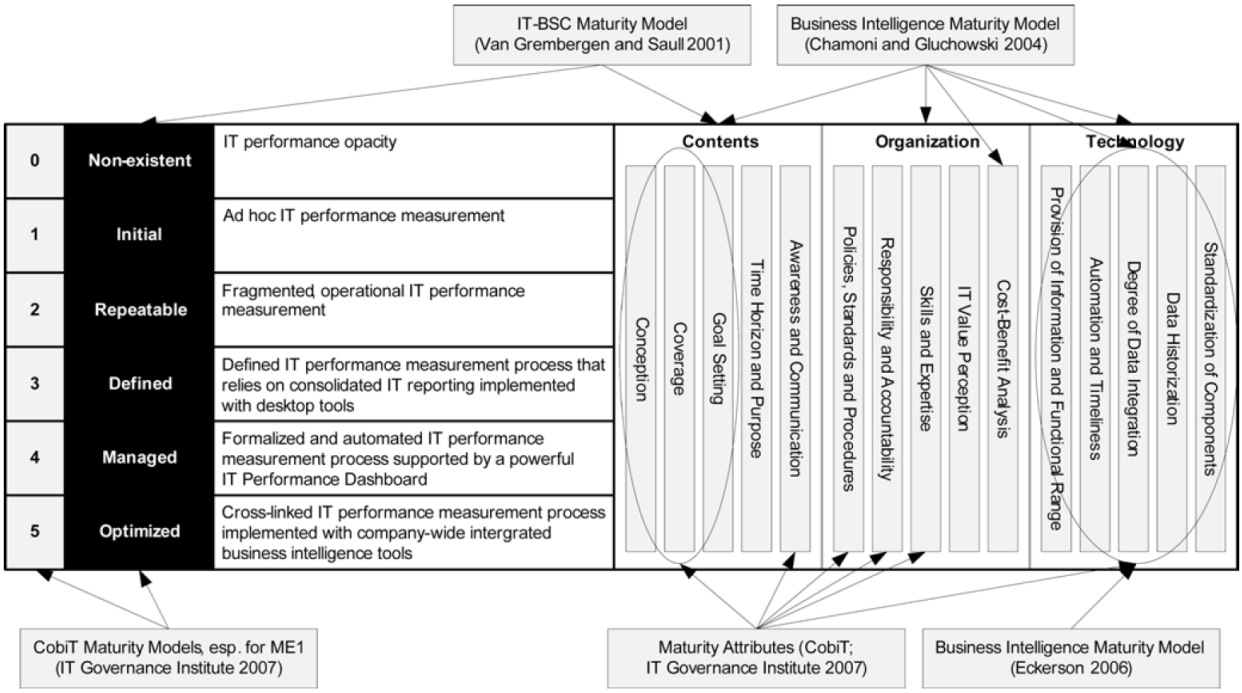

Figure 2-4: Becker et al. ITPM digital maturity assessment model framework (Becker et al., 2009)

The assessment questionnaire that was developed is an online survey that allows DISCO partner cities to assess their city's digital maturity in each of the five categories of security, interoperability, energy efficiency (environmental impact), social responsibility, and commercial viability. The survey is currently a Microsoft Forms tool accessible at the following URL: https://forms.office.com/e/rcDgkXgQKS. This tool will be integrated with the SPROUT data collection module in the future to provide a single data capture tool for assessing a city's maturity as it proceeds to a PI-led collaborative urban logistics environment. The questionnaire appears as well as an appendix to this document.

The questions developed for each category of the maturity assessment address that specific category. Within a category, questions were broken down into specific focus areas as appropriate based on the analysis of the original source material. An attempt has been made to ensure that the topics addressed are independent. This effort was made with the desire to obtain as robust a view of the city's maturity as possible. Clearly some correlation between items will exist. However, if the assessment is performed by answering the questions within the context of the category, it can be shown that this correlation is minimized.

3. Phase 2: Digital Transition Maturity Assessment

The second phase of Task 2.2, creation of the digital transition maturity assessment, involves the integration of the innovation readiness level and the maturity mapping activities of Task 2.1 and the digital assessment process developed in Phase 1 of Task 2.2.The purpose of this integration within the Meta Model Suite is to facilitate cities in their selection of measures to more rapidly, efficiently, and effectively progress on their journey to more collaborative urban logistics operations.

Task 2.1 utilized the SPROUT Urban Policy Model[4] to assess the innovation readiness of each of the cities participating in the DISCO project (see deliverable D2.1 Section 6.2 Innovation Readiness of Cities).The SPROUT model employs a weighted model to evaluate a city's innovation readiness based on a series of questions organized in eleven categories (Xenou et al., 2022).These categories are outlined in Table 1: SPROUT Innovation Readiness assessment categories (SPROUT D5.2 Urban policy system dynamics model, Table 3, p.21).

Table 1: SPROUT Innovation Readiness assessment categories (SPROUT D5.2 Urban policy system dynamics model, Table 3, p.21)

City Elements	Sub-elements		Description
Innovative Governance & Growth	R1	Inter-departmental coordination	Describes the structure and the dedicated departments of a city to better implement innovative mobility solutions
	R2	Mobility Planning	Depicts the current regulatory framework of the city against passenger and freight transportation (existence of Sustainable Urban Mobility Plan (SUMP) & Sustainable Urban Logistic Plan (SULP))
	R3	Laison	Shows the level of Public-Private Partnerships and corporations taking part in the city
	R4	Public Investments	Represents to what extent the city has ensured funding for innovative mobility solutions
Climate and City Typology	R5	Openness	Concerns about the networking of the city by assessing the level of national and international synergies of the city's institutes
	R6	Science & Education	Constitutes the educational level of the inhabitants and the number of the research institutes and universities located in the city
Smart & Easily accessible	R7	Transparency & Accountability	Corresponds to the level of the transparency of governmental processes and the availability and the level of accessibility of urban mobility data

[4] https://urbanpolicymodel.imet.gr/innovation-readiness.html

Safe & Secure		*No sub-elements identified*	-
Smart & Innovative Resources and Infra available	R8	Data Availability	Refers to how developed the data collection system is in a city (e.g. physical surveys or infrastructure to observe)?
	R9	Cities Capacity	Explains the level of capacity the city has to adopt innovation by using/providing specialists and having evidence-driven policy-making and to what extent the city has the infrastructure to help adopt innovative mobility solutions.
Innovative People & Stakeholders	R10	Culture	Shows the direction of the city and habitats towards innovation by assessing the city's previous experience of implementing Innovative Business models and the acceptance/trend of the users towards green modes.
	R11	Industry Diversity	Identifies the smartness of the city's industry by considering the number of big innovators (start-up & high-tech companies) that are established in the city

The outcome of the DISCO city partner analysis conducted in Task 2.1 using the SPROUT assessment process was summarized as follows:

> . . . the Innovation Readiness self-assessment reveals that while all DISCO cities demonstrate a maturity level of 65% to 70% in adopting innovative mobility solutions, they face challenges in aligning with the principles of the Physical Internet (PI) in freight mobility. The concept of data sharing in PI represents a significant paradigm shift, advocating for a logistics infrastructure that is more collaborative, transparent, and interconnected. However, most DISCO cities currently lack the necessary smart infrastructure & incentives or regulation to effectively collect and manage data related to freight operations. This deficiency in comprehensive freight data impedes the cities' ability to develop Strategic Urban Logistics Plans (SULP) and implement data-driven, evidence-based policy making in freight transport.[5]

This summary supports the well understood and reported lack of freight data available in cities (e.g., Pan, 2006; Jiangping & Shuai, 2012; Lindholm & Behrends, 2012), which results in serious issues when trying to measure the impact of various innovations on freight operations. It also indirectly implies that there may be a lack of digital maturity in the DISCO cities, at least with respect to urban logistics operations. The results, however, do indicate that the cities are interested in innovative solutions to mobility problems, which provides some hope that innovative logistics operations will gain traction in these cities over time.

[5] DISCO D2.1 Urban Logistics Transition Requirements, 2023, pp. 98-99.

Readiness to innovative, however, does not mean that a city is digitally mature. A recent study by SAP and KLU examining the adoption of digital technologies over time by industry found that digital aspirations were not synonymous with digital maturity[6]. This study found that a willingness to adopt innovation also requires the ability to successfully re-engineer processes, development of infrastructure that can be integrated with new technology, and personnel capable of both installing and operating the new system (processes plus technologies). Readiness is a necessary condition, but it is not sufficient. Sufficiency requires maturity and, therefore, the integration of readiness and maturity.

To integrate Task 2.2's digital maturity tool with the SPROUT innovation readiness tool requires building a multi-variate model that integrates innovation readiness and digital maturity to determine which of the DISCO-X measures a city should focus its efforts on adopting. This mapping approach requires historical data from cities to properly orient city planners to determine the mix of readiness and maturity that has led to the successful implementation of innovative projects. An initial structuring of the integrated model indicates correlation between digital maturity and a city's ranking in the categories of innovative governance and growth (interoperability and social responsibility), climate and typology (energy efficiency), smart and easily accessible (social responsibility and commercial viability), smart and innovative resources and infrastructure (interoperability, energy efficiency, and commercial viability), and innovative people and stakeholders (social responsibility and commercial viability).Interestingly, while the category "safe and secure" was initially included in SPROUT's list of high city elements, it contributed little to innovation readiness and was used only in SPROUT's analysis of a city's liveability index. However, for the determination of digital maturity, security is a critical element of a city's transition to a PI-led digital transformation. Security in the digital context has to do with the secure handling of data, management of systems, monitoring of operations, access control, and compliance with regulatory requirements for privacy. While this factor is not directly addressed in the SPROUT system it does correlate with the smart and easily accessible and the smart and innovative resources elements of the framework.

The actual integration of these two modelling processes, as well as the remainder of the Meta Model Suite of tools, is not yet finished. Work on the architecture and user interface, as well as information from the LLs and their implementations of the DISCO-X measures, is ongoing and will not be completed by the end of April 2024, which delays the integrated online tool. However, the technical integration model has been developed. With the final structure of the digital maturity model, a similar organization of factors to those developed for the SPROUT model exist. These factors are:

[6] "What Really Works in Digital Supply Chain?," https://www.sap.com/documents/2024/02/cef82b9a-ad7e-0010-bca6-c68f7e60039b.html.

Security:

- Data Security
- Network Security
- Systems Security
- Infrastructure Security
- Organization

Interoperability

- Standards and Interoperability

Energy Efficiency

- Energy Use and Environmental Impacts

Social Responsibility

- Digital Services
- Infrastructure Services
- Environmental Services

Commercial Viability

- Commercial Services

It should be remembered that these factors were developed based on the city's digital tool support for them and not on other considerations. As with the SPROUT assessment, the digital maturity assessment evaluates a city's maturity based on a five-point Likert scale.

To integrate the SPROUT innovation readiness factors with the DISCO digital maturity assessment factors and map this integrated multi-dimensional analysis to appropriate DISCO-X measures requires a multi-variate model. It was decided that the most appropriate approach for such a model would be based on a logistic regression model in which the various DISCO-Xs are injected as dummy variables and the city's innovation readiness and digital maturity variables for the city used to arrive at a binary positioning of the city with respect to the particular DISCO-X measure. Logistic regression models are particularly good at creating this type of outcome due to their output of a log-odds probability that can easily be separated into an "either/or" evaluation. The outline of the logistic regression model that will be employed in the integrated assessment tool is shown below.

$$\sum_{i,j=1}^{n,m} \alpha i(SPROUT\ Factors) + \beta j(Digital\ maturity\ factors) + (DISCO - X\ dummies) = P$$

This equation indicates the general form of the log-linear model that will be used to recommend to each city based on its innovation readiness and digital maturity the DISCO-X measures that best fit

their particular situation. The value of P, the log-odds ratio, determines whether a project is more or less appropriate. Higher values indicating greater affinity to the city's readiness and maturity and lower values less affinity.

As the process of collecting the baseline city digital maturity information, implementation of the DISCO-Xs, and development of the overall architecture of the Meta Model Suite tool set are all ongoing efforts, it has not been possible to implement the final integrated tool as originally planned. This effort continues in parallel with the developments in the related work packages and tasks and is anticipated to be formally completed when the results of the DISCO-X measures are available for incorporation into the model.

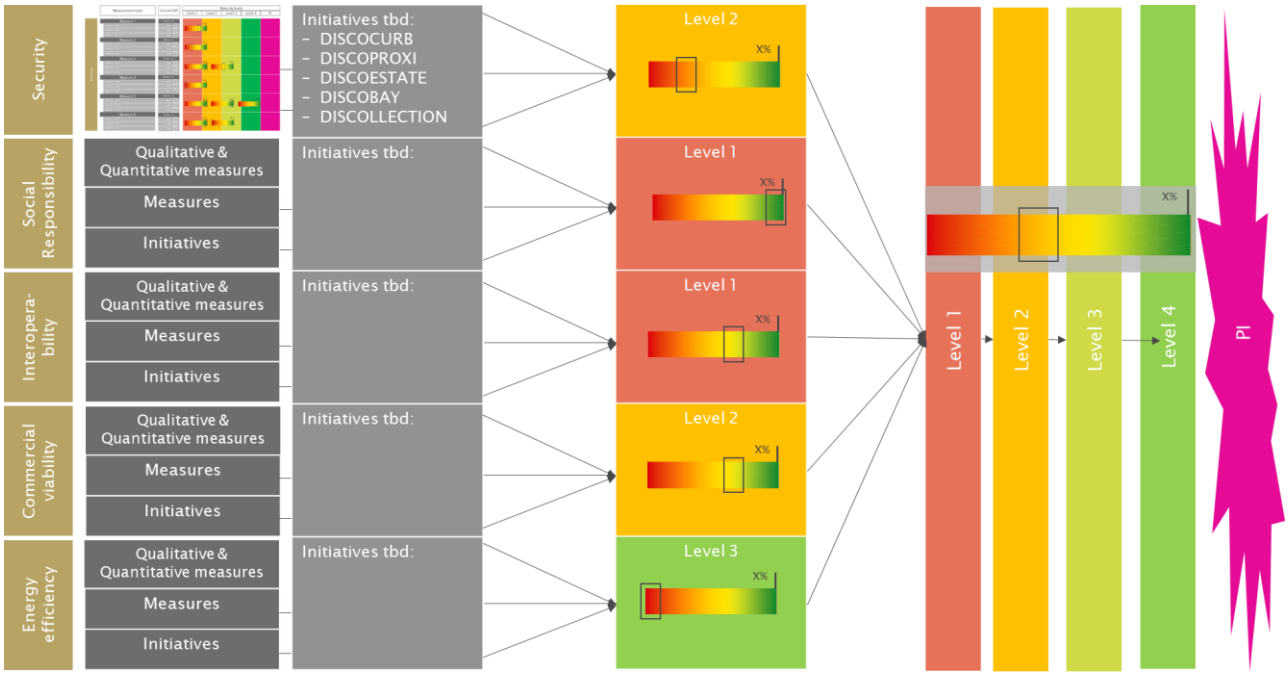

Figure 3-1: Digital maturity reporting interface – All five-evaluation criteria level (draft)

While the online tool has yet to be fully developed, designs have been developed as to how the user interface might look for reporting a city's digital maturity based on their digital maturity assessment (Figure 3-1: Digital maturity reporting interface – All five-evaluation criteria level (draft) and Figure 3-2: Digital maturity reporting interface – Single evaluation criteria level (draft)).

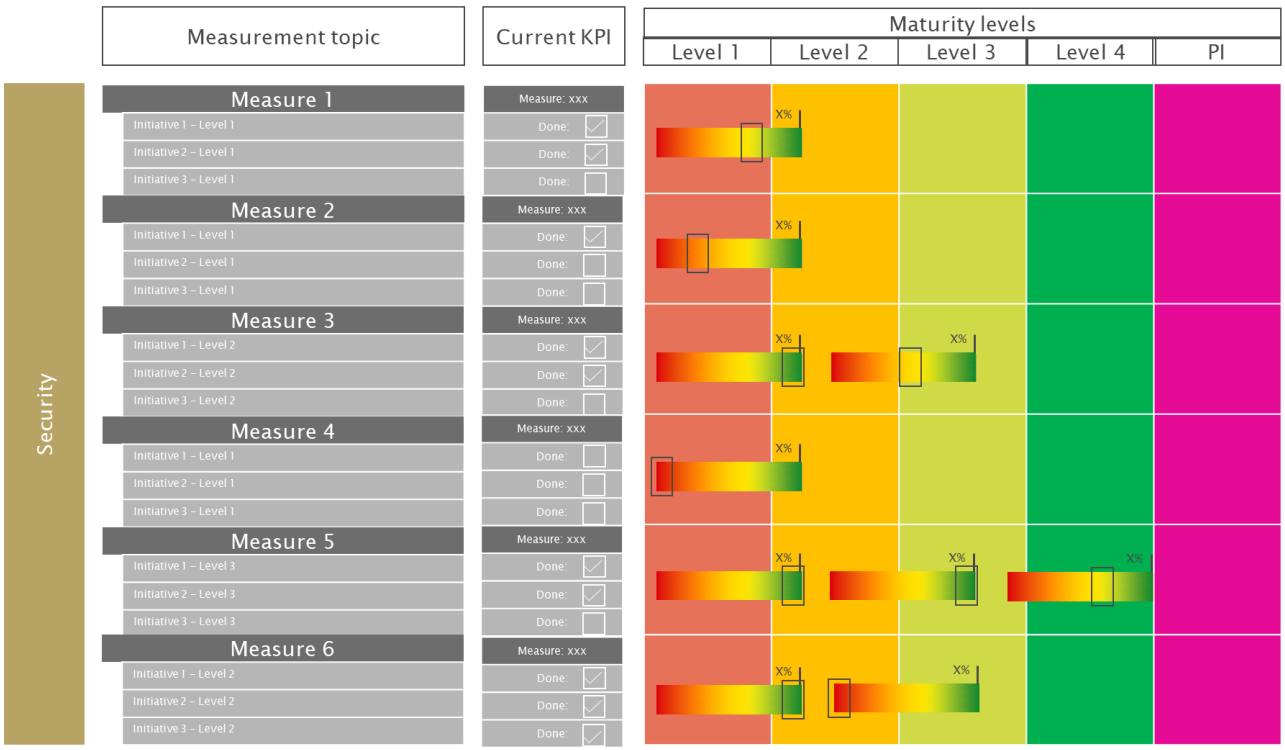

Figure 3-2: Digital maturity reporting interface – Single evaluation criteria level (draft)

Design of the input screens for the data that is captured today in the online form will follow the design outline established for the SPROUT system. These designs will be turned into code and linked to the Meta Model Suite once the suite itself has been fully specified. In the interim, the online version of the assessment model has been distributed to each of the LLs to be completed and the data collected will allow the positioning of the cities within the multi-dimensional readiness/maturity model in preparation for full integration into the Meta Model Suite.

4. Phase 3: Assessment tool development

The digital maturity assessment tool will be populated with the input collected with the survey distributed to the DISCO city partners with the aim to obtain a preliminary dataset on the digital maturity of the partners. This information will be incorporated into the formal online tool to provide a baseline for evaluation as the cities progress in their implementations of the DISCO-Xs and for use by new cities as they deploy innovative urban logistics services.

5. Summary and next steps

The development of the digital maturity assessment model has been an interesting journey. While this journey continues, several key insights have been developed. A very basic insight of dependencies and their influence on deliverables is clear. Because the digital maturity assessment model is part of the larger Meta Model Suite and is dependent on knowing the performance of the various DISCO-X measures, scheduling its completion prior to the completion of the Meta Model

Suite and implementation of the DISCO-X measures is problematic. Another lesson learned during the task is that many of the performance indicators that one might wish to report on when evaluating the performance of innovative logistics projects in the urban environment may not be available. This should not come as a surprise to anyone as the lack of publicly collected urban freight performance and operational data has been noted in a number of EU studies and is a factor that has plagued numerous EU urban freight projects. It was also reported in the deliverable D2.1 for the DISCO project where the need for a single city dataspace was identified so that cities could share what data they do have. Another lesson learned in the project was that city planners are being asked to collect multiple overlapping and sometimes conflicting data for different uses. These data come from non-integrated systems or must be manually collected if the data exists at all. These factors make the job of a planner quite difficult and result in, as some of the planners pointed out, taking short cuts that make the data that is reported suspect. Remembering that data on urban logistics operations is quite hard to find might focus evaluation strategies more on softer criteria while encouraging the cities to establish more rigorous data collection processes as funds and time permit. Finally, it is good to remember that cities are generally budget constrained which limits their ability to implement fully integrated decision support, management, and control systems. Budget constraints not only limit the systems that can be implemented, but the city's ability to hire the technical resources to implement, manage, and analyse the outputs of such systems. This means that the systems architecture that one might wish to see in a city as well as the data analytics services that use the information coming from a well-structured architecture, may be completely beyond the city's ability to implement.

With respect to next steps for Task 2.2, work will continue populating the online version of the digital maturity assessment tool and its integration with the other tools of the Meta Model Suite. While this work will continue in the background, the Forms based online version of the assessment tool has been distributed to all the city partners participating in the DISCO project to obtain a baseline of their maturity. This information will be consolidated and used to develop the baseline maturity assessment component of the online system that integrates with the SPROUT innovation readiness tool to provide cities with insights into which of the DISCO-X measures they should focus on first.

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APPENDIX

The online digital maturity assessment questionnaire questions and structures appears in the pages that follow.

DISCO PI-led Digital Transition and Maturity Questionnaire

This form is part of the DISCO project WP2 Meta Model Suite. Its purpose is to collect data on your organization's current level of digital maturity. It can be used to track how your organization is progressing along a pathway to building a trustworthy and collaborative environment for all community stakeholders. It can also be used, as it is filled in by other organizations, as a tool to compare your organization's level maturity to other communities. The questionnaire is broken down into six sections. The first section collects general data on you and your organization. This information allows the maturity assessment to position your organization with peer organizations for comparison purposes. The next five sections focus on digital maturity in the areas of security, interoperability, energy efficiency (environmental impacts), social responsibility, and commercial viability. Questions for each section have been limited to no more than 20 questions. Once you have completed the questionnaire you should be able to obtain a graphical overview of your answers and a score for each of the five categories covered in the questionnaire. Depending on how many other organizations have completed the questionnaire, you will also be able to see how your scores compare against these peer organizations. Thank you for taking the time to fill out this questionnaire.

* Required

Organization Questions

This section of the questionnaire focuses on general questions concerning you and your organization.

1. For which city are you filling out this questionnaire? *

2. What is your role in your organization? *

3. How long have you been in your role with this organization? *

- ◯ 0 - 1 year
- ◯ 1 - 5 years
- ◯ 5 - 10 years
- ◯ Over 10 years

4. How large a population does your city have? *

- ◯ 0 - 25,000 people
- ◯ 25,000 - 100,000 people
- ◯ 100,000 - 500,000 people
- ◯ 500,000 - 1,000,000 people
- ◯ 1,000,000 - 5,000,000 people
- ◯ Over 5,000,000 people

5. How large is your city's information technology budget? Please include budget figures for control systems, network and communication infrastructure, infrastructure (traffic cameras, IoT devices, etc.) if possible. Note that this is not a required question to answer, but it provides guidance for positioning your responses with respect to other city responses.

- ◯ €0 - €1,000,000
- ◯ €1,000,000 - €10,000,000
- ◯ €10,000,000 - €25,000,000
- ◯ €25,000,000 - €50,000,000
- ◯ Over €50,000,000

Security

This section of the questionnaire addresses the maturity of your city's security approach to its digital systems, data, and infrastructure. Questions ask you to score the maturity of your city according to a 5 level scale ranging from least mature (beginning or starting or not at all started) to very mature (have been doing this a long time, a key strength, etc.).

6. Data Security *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for some time	Have had for some time and is fully implemented in all functions
Does your city have a formal data security plan?	◯	◯	◯	◯	◯
Does your city have access controls for accessing data?	◯	◯	◯	◯	◯
Does your city have a formal data backup and recovery plan for all community data?	◯	◯	◯	◯	◯
Does your city manage data access on a "zero trust" basis?	◯	◯	◯	◯	◯
Does your city's formal plans for data security cover all IoT devices, infrastructure control systems, and other systems where data is generated and stored?	◯	◯	◯	◯	◯

7. Network Security *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for some time	Have had for some time and is fully implemented in all functions
Does your city have a formal network security plan?	◯	◯	◯	◯	◯
Does your city have network access controls?	◯	◯	◯	◯	◯
Does your city have redundant network services in case of failures?	◯	◯	◯	◯	◯
Does your city utilize cloud based access services?	◯	◯	◯	◯	◯
Does your city implement security controls on all devices access its networks directly or via the cloud?	◯	◯	◯	◯	◯

8. Systems Security *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for some time	Have had for some time and is fully implemented in all functions
Does your city have a formal information systems and software security policy?	◯	◯	◯	◯	◯
Does your city have formal software access controls and policies?	◯	◯	◯	◯	◯
Does your city perform regular software supply chain analyses to ensure internal and external code is secure?	◯	◯	◯	◯	◯
Does your city have internal standards for software development, testing, and security control?	◯	◯	◯	◯	◯
Does your city monitor ongoing software instances to ensure that anomalies are isolated and addressed?	◯	◯	◯	◯	◯

9. Infrastructure Security (Infrastructure systems are the control and data collection systems used by the city for operating water systems, sewer systems, traffic management systems, etc.) *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for some time	Have had for some time and is fully implemented in all functions
Does your city have a formal security policy for all infrastructure systems?	○	○	○	○	○
Does your city centrally monitor its infrastructure systems or are they monitored locally?	○	○	○	○	○
Does your city select infrastructure systems using a security evaluation?	○	○	○	○	○
Does your city have access control policies for all infrastructure systems?	○	○	○	○	○
Does your city have formal disaster recovery programs for all infrastructure systems?	○	○	○	○	○

10. Security Organization *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for some time	Have had for some time and is fully implemented in all functions
Does your city have a separate digital security office responsible for digital security?	◯	◯	◯	◯	◯
Do you regularly conduct digital security audits of your network, systems, data, and infrastructure?	◯	◯	◯	◯	◯
Does your city have a threat response plan for its digital environment?	◯	◯	◯	◯	◯
Does your city enforce security updates for all internal systems, network attached systems, and any entity that attaches to your network?	◯	◯	◯	◯	◯
Does your city have a formal digital security plan based on "zero trust" principles?	◯	◯	◯	◯	◯

Interoperability

This section of the questionnaire addresses whether digital systems and assets are purchased, implemented, and managed through a formal architecture that encourages interoperability, data exchange, and controlled access. Questions ask you to score the maturity of your city according to a 5 level scale ranging from least mature (beginning or starting or not at all started) to very mature (have been doing this a long time, a key strength, etc.).

11. Standards and Interoperability *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for a long time	Have had for a long time and is fully implemented in all functions
Does your city have a formal systems architecture for all city managed systems?	◯	◯	◯	◯	◯
Does your city require that all systems conform to international or industry standards for data and communications?	◯	◯	◯	◯	◯
For infrastructure control systems and data collection tools (IoT devices, sensors, etc.) doe the city require adherence to industry standards and its architecture?	◯	◯	◯	◯	◯
Does the city employ a "data pool" or "data lake" or "data swamp" approach to collecting key data for decision making?	◯	◯	◯	◯	◯
Does the city have the ability to integrate systems using internal resources?	◯	◯	◯	◯	◯

Energy Efficiency and Environmental Impact

This section of the questionnaire addresses the maturity of the city's approach to controlling the energy usage of its digital assets and their impact on the environment. Issues associated with using the systems to lower environmental impacts of external factors such as traffic are included in the next Section on Social Responsibility. Questions ask you to score the maturity of your city according to a 5 level scale ranging from least mature (beginning or starting or not at all started) to very mature (have been doing this a long time, a key strength, etc.).

12. Energy Use and Environmental Impacts *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for a long time	Have had for a long time and is fully implemented in all functions
Does your city use energy efficiency as a factor in selecting digital hardware and/or software?	○	○	○	○	○
Does your city regularly report on the use of energy in its systems and data centers?	○	○	○	○	○
Does your city use its systems to control the use of energy in its facilities and operational networks?	○	○	○	○	○
Does your city use "green" energy to power its operations?	○	○	○	○	○
Does your city employ "green" backup power systems to address energy outages?	○	○	○	○	○

Social Responsibility

This section of the questionnaire addresses the maturity of your city's approach to using its digital tools to improve the lives of its citizens. Questions ask you to score the maturity of your city according to a 5 level scale ranging from least mature (beginning or starting or not at all started) to very mature (have been doing this a long time, a key strength, etc.).

13. Digital Services *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for a long time	Have had for a long time and is fully implemented in all functions
How accessible to community members are your city's services through online digital tools?	◯	◯	◯	◯	◯
Does your city employ digital surveys, complaint registers, etc. to understand community sentiments and improve services?	◯	◯	◯	◯	◯
Does your city provide online forums for different citizen and business groups to discuss issues with one another and the city?	◯	◯	◯	◯	◯
Does your city's online services integrate key city functions to streamline access and improve customer journeys?	◯	◯	◯	◯	◯
Does your city use its online presence to proactively engage with its citizens and businesses providing timely and relevant information?	◯	◯	◯	◯	◯

14. Infrastructure Services *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for a long time	Have had for along time and is fully implemented in all functions
Does your city provide citizens and businesses with online access to usage data, payment services, etc. for infrastructure services?	◯	◯	◯	◯	◯
Does your city provide citizens and businesses with real-time information on activities related to the city infrastructure (outages, traffic, schedules, etc.)?	◯	◯	◯	◯	◯
Does your city have online reservation services for parking, facility use, etc.?	◯	◯	◯	◯	◯
Does your city provider infrastructure users with intelligence driven suggestions as to how they might lower their costs, improve their service, etc.?	◯	◯	◯	◯	◯
Does your city use its online services to improve the security of its citizens and businesses?	◯	◯	◯	◯	◯

15. Environmental Impacts *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for a long time	Have had for a long time and is fully implemented in all functions
Does your city regularly collect and report on the environmental impact of the various activities conducted within the city (e.g., personal travel, logistics, waste, home energy use, industrial energy use, etc.)?	○	○	○	○	○
Does your city promote processes through its digital tools that allow its citizens and businesses to reduce their environmental footprint?	○	○	○	○	○
Does your city use data to target high impact areas and codevelop with citizens and businesses in these areas improvements?	○	○	○	○	○
Does your city use traffic management systems to smooth traffic flows during high use periods to lower emissions?	○	○	○	○	○
Does your city employ asset management systems to optimize use by citizens and businesses while lower overall emissions (e.g., parking management, city center access, energy use, etc.)?	○	○	○	○	○

Commercial Viability

This section of the questionnaire addresses the approach your city takes to using its digital infrastructure to support the economic and commercial viability of the city. Questions ask you to score the maturity of your city according to a 5 level scale ranging from least mature (beginning or starting or not at all started) to very mature (have been doing this a long time, a key strength, etc.).

16. Commercial Viability *

	Not Available	Have just implemented this	Have implemented and continue to refine	Have had for a long time	Have had for along time and is fully implemented in all functions
Does your city provide tools for setting up collaborative marketplaces, tracking service levels, and making real-time decisions?	◯	◯	◯	◯	◯
Does your city proactively work with businesses and citizens to improve commercial services in communities?	◯	◯	◯	◯	◯
Does your city provide businesses with access to data to help in improving their business operations (e.g., visitor volumes, traffic data, etc.)?	◯	◯	◯	◯	◯
Does your city encourage innovation and entrepreneurship by providing transparent and easy to use services to establish and operate a business within the city?	◯	◯	◯	◯	◯
Does your city provide access to under utilized city assets that businesses might use to improve their operations and create revenue for the city?	◯	◯	◯	◯	◯
Does your city encourage business collaboration through incentives, training, regulations, etc. to increase efficiency and scale?	◯	◯	◯	◯	◯

