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Developing the Most Significant and Suitable Smart City Indicators for Smart City Pilot in Knowledge Oasis Muscat (KOM), Sultanate of Oman

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List of Acronyms

ITA	Information Technology Authority
Madayn	Public Establishment for Industrial Estate
KOM	Knowledge Oasis Muscat
ICT	Information and Communication Technology
IT	Information Technology
UN	United Nations
ISO	International Organization for Standardization
ITU	International Telecommunication Union
ETSI	European Telecommunication Standards Institute
SDG	Sustainable Development Goals

Abstract. This report presents the process for selecting and developing the most suitable and appropriate standard indicators for Smart City Pilot implemented in Knowledge Oasis Muscat (KOM) in the Sultanate of Oman by Information Technology Authority (ITA) in cooperation with the Public Establishment for Industrial Estate (Madayn). The indicators were selected from reviewing and analyzing regional and international standards that have been developed to help decision-makers developing smart cities and to measure their performance and progress. This paper analyses data from seven international urban indicator standards, published by significant international organizations, with a total of 410 indicators. The selection of the indicators depended on eight defined criteria that considered critical aspects of the pilot project. These included the strategic objective of implementing the pilot, the phase of the pilot development, the spatial scale of the pilot, the time scale for evaluation, the purpose of the assessment, the urban focus, the city sector of the pilot and the type of indicators. The report results provide the most suitable set of indicators from these standards, aligned with the assessment objective and the smart city pilot project.

1. Introduction

Economic challenges and the drop in global oil prices have forced Oman to change its strategy away from depending on oil revenue, towards several diversification strategies and to encourage growth across the board ("The National Program for Bracing the Economic Diversity (TANFEEDH)", n.d). There is a massive infrastructure investment plan with the development of Oman's logistics, transportation and information, and communication technology (Oman Vision, n.d). Oman vision 2040 along with eOman 2030 strategy are looking to improve the quality of life facilitated by technology and smart infrastructure, enabling people to enjoy social welfare and building a diversified, dynamic, globally interactive and competitive economy that meets the present and future needs of the citizens. According to the Global Information Technology Report, Oman ranked 52 in network readiness in 2016 which reflects that Oman's level of ICT development is worthy and the country is ready to leverage the opportunities from adopting several technologies and moving toward smart and sustainable infrastructure (Baller, Dutta & Lanvin, 2016).

Smart City Pilot in Knowledge Oasis Muscat (KOM) is one of Oman's national projects implemented by the Information Technology Authority (ITA) in cooperation with the Public Establishment for Industrial Estate (Madayn). The project is a translation of eOman strategy 2030 to showcase how the digital life enables more efficiency and a higher quality of life using fourth industrial revolution technologies. The main strategic objective of implementing the pilot is the development of the national strategies for smart cities and smart infrastructure including reference model, policies, regulations, standards and measurement tools. These will then guide and direct public and private entities to participate in implementing future smart city projects.

The report comes to deliver one of the objectives mentioned above from implementing the pilot, that is, selecting a set of suitable indicators to form a framework to assess and monitor the pilot progress performance overtime. The pilot currently is in the implementation phase, and the spatial scale of the pilot is one million square meters ("AboutUs", 2018). The time scale for evaluation of the pilot is agreed to be once a month as it is in the beginning stage and the primary purposes for the assessment are to monitor and evaluate the pilot progress performance overtime. Also, the

evaluation will support ITA to set any future targets, identify challenges, provide recommendations for future improvements, and formulate concrete policies and frameworks. The indicators will be selected considering all of those facets of the pilot, along with its context and needs. This report will describe and explain how the indicators were chosen and what the result was.

2. Background

Nowadays, there are many indicators available for measuring the smartness and sustainability of cities from several sources, including international bodies, private and public entities, and academic researchers (Backhouse, 2019). However, for this study, the report focused on indicator standards from regional and international organizations, after looking at the intended purpose of the tools, what they measure, the transparency, and who can use them. Based on (Backhouse, 2019), international and national bodies are creating standards that can be applied globally and at different scales, structure and types, in developed or developing countries, at national, regional or local levels. International indicators are preferred because they are more applicable for comparability over time and within several cities, and they tend to be transparent (Huovila, Bosch & Airaksinen, 2019). Therefore, it will be more relevant for the pilot context to use the international indicators for the assessment, rather than those from other sources.

2.1 Standard Indicators

This report studied and analyzed seven international indicator standards that were published recently by important regional and international organizations and applicable as measures of a smart and sustainable city. Seven standards from four different sources (ISO, ITU, ETSI, and UN-Habitat) with a total of 410 indicators, were reviewed and analyzed. Below is list of the standards.

Name	Description	Categories	# of Indicators
ISO 37122:2019	Sustainable development in communities- indicators for Smart cities	Economy, education, energy, environment , climate change, finance, governance, health, housing, population and social condition, recreation, safety, solid waste, sport and culture, telecommunication, transportation, urban/ local agriculture and food security, urban planning, waste water, waste.	82
ISO 37120:2018a	ISO37120:2018 sustainable development of communities–	environment , climate change, finance, governance, health, housing, population and social condition, recreation, safety, solid waste, sport	104

	indicators for city services and quality of life	and culture, telecommunication, transportation, urban/ local agriculture and food security, urban planning, waste water, waste.	
ETSI TS 103 463:2017a	Key performance indicators for sustainable digital multi service cites	People, planet, prosperity, governance	76
ITU 4901:2016b	Key performance indicators related to the use of information and communication technology in Smart sustainable cities	ICT, environmental sustainability, productivity, quality of life, equity and social inclusion, physical infrastructure	48
ITU 4902 (ITU,2016c)	Key performance indicators related to the sustainability impacts of information and communication technology in Smart sustainable cities(ITU,2016c)	Environmental sustainability, productivity, quality of life, equity and social inclusion, physical infrastructure	30
ITU 4903:2016d	Key performance indicators for Smart sustainable cities to assess the achievement of sustainable development goals	Economy, environment, society and culture	52
UN SDG 11+	Monitoring framework (UN-Habitat etal.,2016)	UN SDG target 11.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.7, 11a, 11b, 11c, 1.4, 6.3	18
TOTAL number of indicators			410

(Table 1: Summary of indicator standards on smart sustainable cities)

The ISO standards on smart and sustainable cities were established by the working group of the sustainable city community responsible for the city indicators. The recently published ISO 37122 standard focuses more on smart enabling technologies, and it was released on May 2019 as a complement to ISO 37120. The ISO 37120 standard focuses on the performance of city services and quality of life and was published in July 2018. Huovila, Bosch & Airaksinen argued that ISO 37122 should use in combination with the ISO 37120 indicators on sustainability evaluation to provide a comprehensive set of indicators to assess progress toward a smart city and get the best result (Huovila, Bosch & Airaksinen, 2019).

The three ITU standards focus on smart sustainable cities with different minor focus areas. For instance, ITU 4903 concentrates on assessing the SDGs, where ITU 4902 focuses on sustainability impacts and ITU 4901 on the usage of ICT. There were no definitions available for the ITU indicators and the way to measure and collect the data, except for the ITU 4903 standard, where the information is available on the KPI manual prepared by the United 4 Smart Sustainable Cities (U4SSC) (Huovila, Bosch & Airaksinen, 2019).

ETSI indicators were developed by the European Union based on an analysis of 20 city's requirements. This standard, with 43 indicators using an existing framework, was tested for feasibility by about 50 cities. The standard was published in January 2017 with a focus on the sustainable digital multi-service city indicators (Huovila, Bosch & Airaksinen, 2019).

Finally, SDG is an international framework established in September 2015 with 17 goals, 169 targets, and 230 indicators to guide country plans, priorities, and investment to reduce poverty and promote development. The goals developed on the guiding principles of the charter of the United Nations (UN) and international law. The SDGs are universal, and they provide a clear policy framework for regulatory actions at national, regional, and international level. One of the 17 goals is goal 11: Sustainable Cities and Communities, which is effectively fit for this study as the goal includes eleven objectives aims to make cities inclusive, safe, resilient, and sustainable and achieving sustainability at the international level ("Goal 11 .:. Sustainable Development Knowledge Platform", 2019).

2.2 Acceptance Criteria

The criteria defined for selecting the indicators were drafted from web search, looking to other experience in this field and what was their objective. The report agreed on the following criteria which meet the pilot's strategic goals and the reason behind the assessment. Having acceptance criteria is important for the selection process.

CRITERIA	DESCRIPTION
RELEVANCE	Each indicators should have a strong link to the subthemes of the framework and should have a significant importance for the evaluation process.
RELIABILITY	• The definitions of the indicators should be clear • The calculation methods behinds the indicators should be specified. • Guidance on how the indicators are to be applied
DATA AVAILABILITY	Data for the indicators should be easily available, or easy to collect
MEASURABILITY	The indicators should be capable of being measured (Quantitative, Qualitative and descriptive)

ALIGNMENT	Alignment of the indicators with the rationale behind implementing the smart city pilot and the purpose of the assessment
COMPARABILITY	The set of indicators should be defined in a way that data can be compared between different phases of urban development.
FAMILIARITY	The indicators should be easy to understand by the users
NON- REDUNDANCY	Indicators within a framework should not measure the same aspect of a subtheme.

(Table 2: Summary of acceptance criteria)

2.3 Classification for Indicator Analysis

Huovila, Bosch & Airaksinen claimed recently that urban focus, the city dimension, and the indicator type are critical criteria for the process of selecting the most suitable indicators for cities planning to become smart. Consequently, this study classified the indicators based on those three aspects.

2.3.1 Urban Focus

For the urban focus, both sustainability and smartness are critical for the pilot. Therefore, the report analyzed what kind of urban focus the indicators addressed. This study is looking for the indicators which achieving both goals (smartness & sustainability) Therefore, the selected indicator should focus on accomplishing both urban focus to accomplish the rationale behind implementing the smart city pilot.

2.3.2 City Dimension

Second is the city dimension. The ITA smart city pilot covers three primary dimensions. 1. Environment dimension (air quality, smart energy management, smart water management, and smart waste management), 2. Quality of life dimension (public transportation, and safety and security), 3. Infrastructure dimension (urban mobility). Hence, this study classified each indicator based on the city dimension covered by the pilot, and any indicators that were not related to those city dimensions were eliminated from the list.

2.3.3 Indicator Type

Finally, the indicators were classified in terms of what they were measuring (input, process, output, outcome, and impact). As the pilot is in the implementation stage, the pilot needs indicators with a balance of five types of indicators (input, process, output, outcome, and impact). However, input, process, and outcome indicators are more important for the pilot as they are more readily available for new projects. On the other hand, outcome and impact measures can often only be calculated

sometime after the project, sometimes only years afterward; therefore, it is not that much important for the pilot at this stage.

3. Methods

The methodological approach of this report started with identifying the international standard indicators available for the smart city measure (Table 1). Based on web search and some academic research, the report ended up choosing global or regional standards. Seven indicator standards, published recently between 2016 – 2019, with a total of 410 indicators altogether were reviewed. The international indicator standards are more applicable for the pilot due to their ability to be adapted by different cities around the world regardless of its scale, structure, implementation phase, the population as mentioned previously in the introduction.

Secondly, the criteria for selecting the most appropriate indicators were defined (Table2). The criteria were chosen after having some online search and looking to other experience in selecting the best acceptance criteria, considering the needs of ITA and the pilot project. The report identified eight criteria in total, and every single criterion is critical for the evaluation process. Each indicator should meet all the acceptance criteria selected for the pilot. For instance, the relevance of the index to the subthemes of the specific pilot framework is essential for the assessment, and if the indicator does not meet this criterion, it would be excluded from the selection.

Thirdly, specifying and analyzing for every single indicator the three main aspects of the pilot, including the urban focus of the pilot, the city dimension of the pilot, and the indicator type (section 2.3). The indicator taxonomy analysis process adopted in this report followed the method used by Huovila, Bosch & Airaksinen on developing their study. Indicators were reviewed and classified based on several categories of the indicator.

The scoring process takes place after excluding all the indicators that were not part of the agreed indicator taxonomy (urban focus and city dimension). Each criterion had one point as a score, and a total of eight scores should be calculated for each accepted indicators. Finally, the indicator scored based on its alignment to the selected criteria where an indicator that did not fit one of the criteria and did not get a total of eight scores excluded from the list. Details of analysis and scoring are available in Appendix B.

4. Result

The result of the study are summarize into four main findings below:

- Out of 7 international standards and 410 indicators, a total of 31 indicators are suitable for the pilot, and the primary sources of the indicators are ISO 37122, ISO 37120, ETSI, and ITU 4903. The indicators from both ITU 4902 & ITU 4901 were excluded from the report due to their inability to pass the evaluation process, as they did not meet the whole acceptance criteria. Reliability, comparability, and familiarity were not meet on both ITU4902 & ITU 4901 standards. The report found that there is a concise description of the definition of the indicators, and no clear guidance on the calculation methodology and how the indicator

should be applied which consequently makes the indicators less readily applicable and not easy for the users to understand the concept. As a result, it is also not clear if the indicators can be compared between different phases. In addition, the UN SDG 11+ was removed for the report as its urban focus was only on sustainability, and not on smartness, where the urban concentration of the Pilot project is achieving both sustainability and smartness.

- 55% of the indicators are coming from ISO 37122 standard and 26% from ITU 4903 and followed by ETSI with 13% and ISO 37120 with 6%. ISO 37122 and ITU 4903 standards are more appropriate for the pilot than the other indicators. The study found that both standards cover all the city aspect of the pilot. For the ISO 37122, out of 31, 17 indicators are from ISO 37122 standard. 11 indicators cover the environment dimension; 3 indicators cover the quality of life dimension, and two include the infrastructure dimension. ISO 37122 is the only standard that covers all the sub-dimension of the pilot. On the other hand, ITU 4903 provides around 8 indicators applicable to the pilot. The standard includes all city dimension of the pilot while missing some sub-dimension. Two indicators were identified for the environment dimension, 4 for the quality of life, and 2 for the infrastructure dimension.

Standard	Dimension	# of Indicators	%
ISO 37122	Environment, quality of life, and urban mobility	17	55%
ISO 37120	Quality of life	2	6%
ETSI	Quality of life & urban mobility	4	13%
ITU 4903	Environment, quality of life, and urban mobility	8	26%

(Table3: Indicators Distribution by Standards)

- 45% of the indicators are covering the environment dimension, 36% quality of life dimension, and 19% urban mobility. This result is fulfilling as the pilot project is focusing more on the environment dimension. 86% of the environmental indicators are coming from ISO 37022 and 14% from ITU 4903. For the quality of life dimension, 55% of the indicators are coming from both ISO 37022 & ISO 37021, 27% from ITU 4903, and 18% from ETSI. For the infrastructure dimension, all ISO 37022, ETSI, and ITU 4903 are covering around 33 % of the indicators selected.

Dimension	# of indicators	%
Environment Dimension	14	45%
Quality of life Dimension	11	36%
Urban Mobility Dimension	6	19%

(Table4: Indicators Distribution by City Sector)

- For the type of indicator, 52% of the indicators are outcome indicators, 36% are output indicators. Both impact and process indicators represent only 6% and with no input indicators (0%). This result does not fulfill the needs of the pilot project as the report was looking for a balance of the indicator typology. Input, process, and output indicators are more critical for the pilot at this implementation stage than the outcome and impact indicators as mentioned before.

Sub - Dimension	Input	Process	Output	Outcome	Impact	Total
Air Quality	0	0	2	0	0	2
Energy	0	0	4	1	0	5
Waste	0	1	1	2	0	4
Water	0	0	0	3	0	3
Security and Safety	0	1	2	1	0	4
Transportation	0	0	1	5	1	7
Urban Mobility	0	0	1	4	1	6
Total	0	2	11	16	2	31
%	0%	6%	36%	52%	6%	100%

(Table5: Indicators Typology Distribution by City Aspect)

Overall, the indicator sets have no input indicator and a slight amount of process and impact indicators. At the same time, there is a high amount of output and outcome indicators. This result was expected as 55% of the indicators are coming from ISO 37122 and 26% from ITU 4903, and both standards are focusing and include more output and outcomes indicators. Considering all reviewed standards, we noticed the lack of input and process indicators where there is a high focus on measuring output, outcome and impact indicators as those standards have considered more developed countries and have a preference towards impact indicators.

And concerning the distribution of indicator typology across sectors, the environment dimension stands out with mostly output and outcome indicators, almost no process indicators and with no impact indicators. Most of the quality of life sector indicators are outcome indicators with nearly no impact indicator. The dimension shortage input and process indicators, which is a quiet challenge for the pilot at this period. This finding reflects the same for the infrastructure dimension, where it lacks input and process indicators and have mostly outcome indicators with very nearly output and impact indicators.

5. Recommendation

With the above analysis, the report recommend to consider having input and process indicators to fill the gap in the existing indicators and get a better result.

According to (Bosch et al., 2017) Inputs indicators are these indicators refer to the resources needed for the implementation of an activity, assessing the quality, quantity, and timeliness of resources,

policies, human resources, materials, financial resources are examples of input indicators. Below are suggested inputs indicators (Appendix C):

Indicators	Description	Calculation Methodology	Pilot City Aspect
Proportion of financial support that is allocated to the pilot	How much budget government has allocated for the smart city initiatives	The total amount of budget that is allocated for the smart city projects	Economy Dimension
Total expenditure by ITA for implementing and operating the pilot	How much spent till now from the total budget allocated for the smart city initiatives	Total expenditures by ITA for a transition of KOM towards a Smart City/total population	Economy Dimension
Population density	Number of people per Km	Population density is calculated as the ratio of the number of inhabitants (numerator) divided by the overall area of the city (km²) (denominator).	Economy Dimension
Percentage of labour force employed in occupations in the smart city pilot	The percentage of the labour force employed in occupations in the smart city pilot with the ICT background and experience	The percentage of the labor force employed in occupations in the smart city pilot with the ICT background and experience shall be calculated as the number of city residents in the labor force employed in occupations in the ICT sector.	Economy Dimension
Existence of strategies, rules and regulations	The extent to which the smart city strategy has been assigned to one department/director and staff resources have been allocated	Likert scale: Not at all - 1 - 2 - 3 - 4 - 5 - Very supportive: 1. Not at all: the complete absence of a smart city strategy from the side of the government create a difficult environment for starting smart city initiatives. 2. Poor: The smart city strategy of the government does, to some extent, hamper the environment for smart city initiatives.	Governance Dimension

Indicators	Description	Calculation Methodology	Pilot City Aspect
		3. Neutral: The smart city strategy of the government has had no significant, positive or negative, impact on the environment for smart city initiatives. 4. Somewhat supportive: The smart city strategy of the government has to some extent benefitted the environment for smart city initiatives. The city has created roadmaps and actions to support vision implementation. 5. Very supportive: The comprehensive smart city strategy on the future of the city stimulates the environment for smart city initiatives to a great extent.	
Development of smart city policy	The extent to which the city has a supportive smart city policy	Likert scale: Not at all - 1 - 2 - 3 - 4 - 5 - Very supportive: 1. Not at all: the complete absence of the smart city policy from the side of the government create a difficult environment for starting smart city initiatives. 2. Poor: The smart city policy of the government does, to some extent, hamper the environment for smart city initiatives. 3. Neutral: The smart city policy of the government has had no significant, positive or negative, impact on the environment for smart city initiatives. 4. Somewhat supportive: The smart city policy of the government has to some extent benefitted the environment for smart city initiatives. 5. Very supportive: The comprehensive smart city policy on the future of the city stimulates the	Governance Dimension

Indicators	Description	Calculation Methodology	Pilot City Aspect
		environment for smart city initiatives to a great extent.	
Adoption of information security and privacy protection strategies	The extent to which the strategies is adopted and the level of data protection by the pilot	Likert scale Not at all — 1 — 2 — 3 — 4 — 5 — Very high 1. City doesn't follow national regulations/laws on protection of personal data. 2. City follows national regulations/laws on protection of personal data. 3. City follows relevant national regulations on protection of personal data and the EU Directive on the Protection of Personal Data (95/46/EG). 4. City follows all the relevant national and European regulations/laws related to data privacy and protection. If personal/private data is collected from citizens, proper authorisations with written agreements are made. 5. Relevant national and European regulations on data protection and privacy are followed and written agreements are made for use of citizens' private/personal data. All the collected personal/private data, especially sensitive personal data, is accessed only by agreed persons and is heavily protected from others (e.g. locked or database on internal server with firewalls and restricted access).	Quality of Life Dimension

(Table6: Suggested Input Indicators)

On the other hand, process indicators are these indicators refer to indicators to measure whether planned activities took place. Examples include holding meetings, the conduct of training courses, distribution of smart meters (Bosch et al., 2017). Below are suggested process indicators:

Indicators	Description	Calculation Methodology	Pilot City Aspect
Adoption of monitoring and evaluation framework	The extent to which the progress towards a smart city and compliance with requirements is being monitored and reported	Likert scale no continued monitoring – 1 — 2 — 3 — 4 — 5 — Extensive monitoring 1. No monitoring & reporting: No monitoring and reporting at all was used to verify the progress of policies/strategies/projects. 2. Little monitoring & reporting: there is a basic monitoring scheme in place: a basic set of indicators assessed at irregular time intervals. 3. Some monitoring & reporting: there is a city-wide monitoring scheme in place with an elaborate set of indicators measurement intervals, backed by well-defined (SMARTY) goals of the smart city strategy. 4. Very much monitoring & reporting: there is a city-wide monitoring scheme in place with an elaborate set of indicators and measurement intervals, the findings of which are yearly reported upon. 5. Extensive monitoring & reporting: there is a city-wide monitoring scheme in place addressing all stages of the process, the findings of which are yearly reported upon and published transparently online	Governance Dimension
Distribution of smart electricity	Proportion of distribution of smart electricity meters	(number of buildings with smart electricity meters / total number of buildings)*100	Environment Dimension
Distribution of smart water meters	Proportion of distribution of smart water meters	(number of buildings with smart water meters / total number of buildings)*100	Environment Dimension
Distribution of air quality monitoring	Proportion of distribution of air quality monitoring	Number of air quality meters used per 500 m	Environment Dimension

Distribution of street lighting remotely managed by a light management system	Proportion of distribution of street lighting remotely managed by a light management system	(number of street lights with smart electricity meters / total number of street light)*100	Environment Dimension
Distribution of the digital surveillance cameras	Proportion of distribution of the digital surveillance cameras	Number of digital surveillance cameras distributed per 500 m	Quality of life Dimension
Proportion of public parking spaces	Proportion of public parking spaces connected to the parking management system	(Public parking spaces connected to the PMS/ Parking spaces available in KOM)*100	Quality of life Dimension
Access to public transport	Share of population with access to a public transport stop within 500m	(Number of inhabitants with a transportation stop <500m/total population)*100%	Quality of life Dimension

(Table7: Suggested Process Indicators)

Remarks

With adding and considering the 15 input and process indicators on the selected indicators, the total number of selected indicators increased from 31 to 46 with the following significant changes.

Dimension	# of indicators	%	# of indicators	%
	(Before)		(After)	
Environment Dimension	14	45%	18	39%
Quality of life Dimension	11	36%	15	32%
Urban Mobility Dimension	6	19%	6	13%
Economy Dimension	0	0%	4	9%
Governance Dimension	0	0%	3	7%

(Table8: Indicators Distribution by City Sector after Adding Input and Process Indicators)

39% of the indicators are covering the environment dimension, 32% quality of life dimension, and 13% urban mobility. Both economy and governance dimensions are not covering one of the pilot

frameworks (environment dimension, quality of life dimension, and infrastructure dimension). However, it has significant importance for the evaluation process. 9% of the indicators are covering the economy dimension, and 7% indicators are covering the Governance dimension.

Sub - Dimension	Input	Process	Output	Outcome	Impact	Total
Air Quality	0	1	2	0	0	3
Energy	0	2	4	1	0	7
Waste	0	1	1	2	0	4
Water	0	1	0	3	0	4
Security and Safety	1	2	2	1	0	6
Transportation	0	1	1	5	1	8
Urban Mobility	0	1	1	4	1	7
Economy	4	0	0	0	0	4
Governance	2	1	0	0	0	3
Total	7	10	11	16	2	46
%	15%	22%	24%	35%	4%	100%

(Table9: Indicators Typology Distribution by City Aspect after Adding Input and Process Indicators)

6. Conclusion

This report developed the most significant and suitable smart city indicators for the Smart City Pilot project and explained the process of how the indicators were chosen. The pilot project is being implemented in Knowledge Oasis Muscat (KOM) due to the challenges the area is suffering and as it is a suitable place for a proper benchmarking for other entities after having the real data which will reflect the benefits of going smart. The outcome indicators will help decision-makers in setting future targets, provide recommendations for improvement, and making critical decisions for the pilot. The selection of the indicators was based on the needs of the pilot and its strategic objectives. As mentioned before, the report reviewed 410 indicators in seven standards published by international and regional organizations for measuring the performance of the city in terms of smart city implementation. Each standard covers several city aspects where the report removed the indicators to reflect only the ones consistent with the pilot project. Around 236 indicators cover the environment, quality of life, and infrastructure dimensions.

The urban focus of the pilot was critical for the selection process. Out of the 236 indicators, only 88 indicators focus on achieving sustainability and smartness objectives. Therefore, the report scored those indicators based on the eight selected criteria, and ended up with having 31 indicators. These indicators cover the urban focus, are aligned with the pilot project city dimensions and comply with all eight selection criteria.

Based on what the study achieved, and due to the lack of input and process indicators, the report suggested to add some inputs and process indicators to create the balance needed for the developed indicators and achieve its objective from assessing the pilot. A total of fifteen inputs and process indicators suggested: seven input indicators and eight process indicators (section 5). Those indicators

are essential for the pilot as they will support ITA to know what are the resources needed for implementing the pilot including financial resources, human recourses, materials, and check whether the planned activities took place to get an accurate result.

Overall, the result of the study fulfills the purpose of this report, and we are expecting that the indicators will support ITA in strengthening the project's strategic planning and measure its progress. However, the one remaining concern is the uncertainty about data availability. This needs to be assessed with the project team. Therefore, the study is still on-going, and improvements to the indicators list is expected to develop a good assessment framework.

This report will be proper guidance for other entities and industrial estates in Oman in developing their assessment indicators for their own smart cities projects and initiatives. As Oman is calling for becoming smart, several smart cities projects will implement in the upcoming days and having the perfect indicators from the early stage is essential. This report provides an approach that can be followed by others to end up having the most suitable indicators to understand the specification and requirements needed. However, the adoption of this approach depends on some specific facts that the city should consider as mentioned in the report.

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8. Appendices

Appendix A

Most Suitable Indicators for Smart City Pilot

Sub-Dimension	Standard	#	Indicator	Urban Focus	Indicator Type
Air Quality	ISO 37122	1	Number of real-time remote air quality monitoring stations per square kilometre (km2)	Sustainability & Smartness	Output
		2	Percentage of public buildings equipped for monitoring indoor air quality	Sustainability & Smartness	Output
Energy	ISO 37122	3	Percentage of street lighting remotely managed by a light management system	Sustainability & Smartness	Output
		4	Percentage of street lighting that has been refurbished	Sustainability & Smartness	Output
		5	Percentage of buildings in the city with smart energy meters	Sustainability & Smartness	Output
		6	Number of electric vehicle charging stations per registered electric vehicle	Sustainability & Smartness	Output
	ITU 4903	7	Availability of smart electricity meters	Sustainability and Smartness	Outcome
Waste	ISO 37122	8	Percentage of waste drop-off centres (containers) equipped with telemetering	Sustainability & Smartness	Output
		9	Percentage of the city population that has a door-to-door garbage collection with an individual telemetering of household waste quantities	Sustainability & Smartness	Outcome
		10	Percentage of the wastewater pipeline network monitored by a real-time data tracking sensor system	Sustainability & Smartness	Outcome
	ITU 4903	11	Resilience plans	Sustainability and Smartness	Process
Water	ISO 37122	12	Percentage of the city's water distribution network monitored by a smart water system	Sustainability & Smartness	Outcome
		13	Percentage of buildings in the city with smart water meters	Sustainability & Smartness	Outcome
		14	Percentage of the wastewater pipeline network monitored by a real-time data tracking sensor system	Sustainability & Smartness	Outcome

Sub-Dimension	Standard	#	Indicator	Urban Focus	Indicator Type
Security and Safety	ISO 37122	15	Percentage of the city area covered by digital surveillance cameras	Sustainability & Smartness	Outcome
	ISO 37120	16	Response time for emergency response services from initial call	Sustainability & Smartness	Output
	ITU 4903	17	Resilience plans	Sustainability and Smartness	Process
		18	Emergency Service Response Time	Sustainability and Smartness	Output
Transport	ISO 37122	19	Number of users of sharing economy transportation per 100 000 population	Sustainability & Smartness	Outcome
		20	Percentage of public transport lines equipped with a real-time system	Sustainability & Smartness	Outcome
	ISO 37120	21	Percentage of public parking spaces equipped with real-time availability systems	Sustainability & Smartness	Outcome
	ETSI	22	Access to vehicle sharing solutions for city travel	Sustainability and smartness	Outcome
		23	Congestion	Sustainability and smartness	Impact
	ITU 4903	24	Road traffic efficiency	Sustainability and Smartness	Outcome
		25	Real-time public transport information	Sustainability and Smartness	Output
Urban Mobility	ISO 37122	26	Number of users of sharing economy transportation per 100 000 population	Sustainability & Smartness	Outcome
		27	Percentage of public transport lines equipped with a real-time system	Sustainability & Smartness	Outcome
	ETSI	28	Access to vehicle sharing solutions for city travel	Sustainability and smartness	Outcome
		29	Congestion	Sustainability and smartness	Impact
	ITU 4903	30	Road traffic efficiency	Sustainability and Smartness	Outcome
		31	Real-time public transport information	Sustainability and Smartness	Output

Appendix B

Indicators Analysis & Scoring .xlsx

Appendix C

Suggested Input & Process Indicators

Input and Process Indicators Analysis &

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