

International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Y.4906

(07/2019)

SERIES Y: GLOBAL INFORMATION
INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS,
NEXT-GENERATION NETWORKS, INTERNET OF
THINGS AND SMART CITIES

Internet of things and smart cities and communities –
Evaluation and assessment

**Assessment framework for digital
transformation of sectors in smart cities**

Recommendation ITU-T Y.4906

ITU-T



ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	Y.1300–Y.1399
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
IPTV over NGN	Y.1900–Y.1999
NEXT GENERATION NETWORKS	
Frameworks and functional architecture models	Y.2000–Y.2099
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Enhancements to NGN	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Network control architectures and protocols	Y.2500–Y.2599
Packet-based Networks	Y.2600–Y.2699
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899
Carrier grade open environment	Y.2900–Y.2999
FUTURE NETWORKS	Y.3000–Y.3499
CLOUD COMPUTING	Y.3500–Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	
General	Y.4000–Y.4049
Definitions and terminologies	Y.4050–Y.4099
Requirements and use cases	Y.4100–Y.4249
Infrastructure, connectivity and networks	Y.4250–Y.4399
Frameworks, architectures and protocols	Y.4400–Y.4549
Services, applications, computation and data processing	Y.4550–Y.4699
Management, control and performance	Y.4700–Y.4799
Identification and security	Y.4800–Y.4899
Evaluation and assessment	Y.4900–Y.4999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T Y.4906

Assessment framework for digital transformation of sectors in smart cities

Summary

The ultimate objective of this Recommendation is to enhance the sustainability of identified priority sectors in smart cities, in order to optimise economic, environmental and social benefits.

Cities will decide on their digital transformation priorities. For example, cities might also want to encourage collaboration to deliver desired outcomes.

This kind of engagement based on the assessment framework can incentivize industry engagement and investment.

Recommendation ITU-T Y.4906 contains the following:

- 1) Introduction of the assessment framework and its components
- 2) Identification of indicators – Examples of categories of indicators to assist in this objective for the assessment frameworks include:
 - Digital infrastructure;
 - Digital transformation initiatives for sectors;
 - Collaboration efforts on digital transformation;
 - Economic, environmental and social benefits according to sector digital transformation.
- 3) Sector assessment and analysis

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.4906	2019-07-07	20	11.1002/1000/13922

Keywords

Assessment, digital transformation, smart sustainable cities.

* To access the Recommendation, type the URL <http://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID. For example, <http://handle.itu.int/11.1002/1000/11830-en>.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at <http://www.itu.int/ITU-T/ipr/>.

© ITU 2019

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without the prior written permission of ITU.

Table of Contents

	Page
1 Scope.....	1
2 References.....	1
3 Definitions	2
3.1 Terms defined elsewhere	2
3.2 Terms defined in this Recommendation	2
4 Abbreviations and acronyms	2
5 Conventions	2
6 High-level objectives for digital transformation of sectors in SSC.....	3
7 Assessment framework for digital transformation of sectors in SSC.....	3
7.1 Overview of the assessment framework.....	3
7.2 Introduction to the assessment indicator system of sectors' digital transformation.....	6
7.3 Description of assessment indicator set for sectors' digital transformation in SSC.....	6
8 Guidance on the sectors' digital transformation assessment in SSC	7
8.1 Data collection of sector's digital transformation in SSC.....	8
8.2 Data calculation of sector's digital transformation in SSC.....	8
8.3 Data analysis of sector's digital transformation in SSC.....	9
Appendix I – Assessment indicators	10
I.1 Basis and support.....	10
I.2 Domain application	14
I.3 Integration and interaction.....	16
I.4 Innovation and disruption.....	19
I.5 Digital competitiveness	21
I.6 Economic, environmental and social impacts	23
Bibliography.....	24

Recommendation ITU-T Y.4906

Assessment framework for digital transformation of sectors in smart cities

1 Scope

This Recommendation formulates an assessment framework for digital transformation of sectors in smart sustainable cities (SSCs). This assessment framework specifically provides the assessment indicator system, assessment indicator set and assessment method. Assessments based on this framework can help SSCs as well as their stakeholders to identify the priorities of sectors' digital transformation, investigate the current states of selected sectors' digital transformation, and then explore the suitable paths and measures to promote the digital transformation in these sectors.

This assessment framework will:

- Help cities identify their priority sectors for digital transformation;
- Provide indicators (examples of the indicators are included in the Summary) that may help cities identify what is needed to assist in promoting digital transformation of the identified priority sectors;
- Help cities assess sector development.

This framework is intended to reinforce dialogue between cities and the solution providers on identified digital transformation priorities.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T Y.4900] Recommendation ITU-T Y.4900/L.1600 (2016), *Overview of key performance indicators in smart sustainable cities*.
- [ITU-T Y.4901] Recommendation ITU-T Y.4901/L.1601 (2016), *Key performance indicators related to the use of information and communication technology in smart sustainable cities*.
- [ITU-T Y.4903] Recommendation ITU-T Y.4903/L.1603 (2016), *Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals*.
- [ITU-T Y.4905] Recommendation ITU-T Y.4905/L.1605 (2019), *Smart sustainable city impact assessment*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 smart sustainable city [ITU-T Y.4900]: A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental, as well as cultural aspects.

3.1.2 sector [b-ISIC Rev.4]: Sector is a category of companies that are related based on their primary business activities. A single sector is often named after its principal product.

3.1.3 integration of informatization and industrialization [ITU-T Y-Sup.52]: The integration of informatization and industrialization (III) is an interaction, converging and merging process of informatization development course and industrialization development course, and is also the evolution path of transformation from industrial society to information society. Focusing on building new competitiveness in all areas of economy and society, the III emphasizes the interactive innovation and systematic transformation of productivity and production relationship enabled by the in-depth application of emerging ICTs, during which the data resources gradually become a new driven factor.

3.1.4 spillover effect [b-E CPNRE]: Spillover effect is the cost or benefit that affects a party who did not choose to incur that cost or benefits during economic activities.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 sectors' digital transformation: A process during which, by advanced applications of ICTs in sectors' business activities such as R&D, production, services, etc., the sectors' business activities are optimized, reconstructed and integrated, and sectors' development modes are disruptively reformed and innovated. The digital transformation is vitally useful for sectors to optimize resource configuration, improve operational efficiency and innovation capability, and hence realize sectors' sustainable development.

3.2.2 smart sustainability city (SSC) manager: An executive in charge of the administration of a smart sustainable city's government. SSC manager is sometimes referred to as the municipal administrator, governor or the chief executive of a smart sustainable city.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
SSC	Smart Sustainable City
III	Integration of Informatization and Industrialization
ICTs	Information and Communication Technologies
GDP	Gross Domestic Product
R&D	Research and Development

5 Conventions

None.

6 High-level objectives for digital transformation of sectors in SSC

In the context of rapid development of digital economy, concentrating on achieving the sustainable development goals, SSC should enhance business integration and interaction, and accelerate reformation of sectors' development pattern based on the advanced applications of digital technologies in all areas of sectors. These efforts will promote sector's competitiveness, improve the economic, environmental and social benefits, and achieve the sustainable development of SSC.

Effective and efficient achievement of sector's digital transformation should be in alignment with the following core concepts:

- **Innovation driving:** Sector's digital transformation should attach great importance to the innovations of product, service, technology, management, and business processes based on ICTs applications, and subsequently boost the sector's sustainable development.
- **Seamless data sharing:** Sector's digital transformation should emphatically promote communication, interoperability and sharing of data among equipment and facilities, information systems, users, etc., to achieve efficient circulation and optimized allocation of production factors.
- **Coordinated development:** Sector's digital transformation should fully consider the resource endowment and vision of a smart city, promote business collaborations among entities in the supply chains, to achieve coordination and alignment with smart city development.
- **Value creation:** Sector's digital transformation should consider value creation as the ultimate goal, continually promote the sector's core competitiveness to enhance sector's productivity and economic value creation.

7 Assessment framework for digital transformation of sectors in SSC

7.1 Overview of the assessment framework

The assessment framework for digital transformation of sectors in SSC contains three components. These are the component to help SSC to determine the catalogue of sectors to be assessed, the component to clarify the assessment indicator system, and the component to implement the assessment and analyses. The overview of the assessment framework is shown in Figure 1.

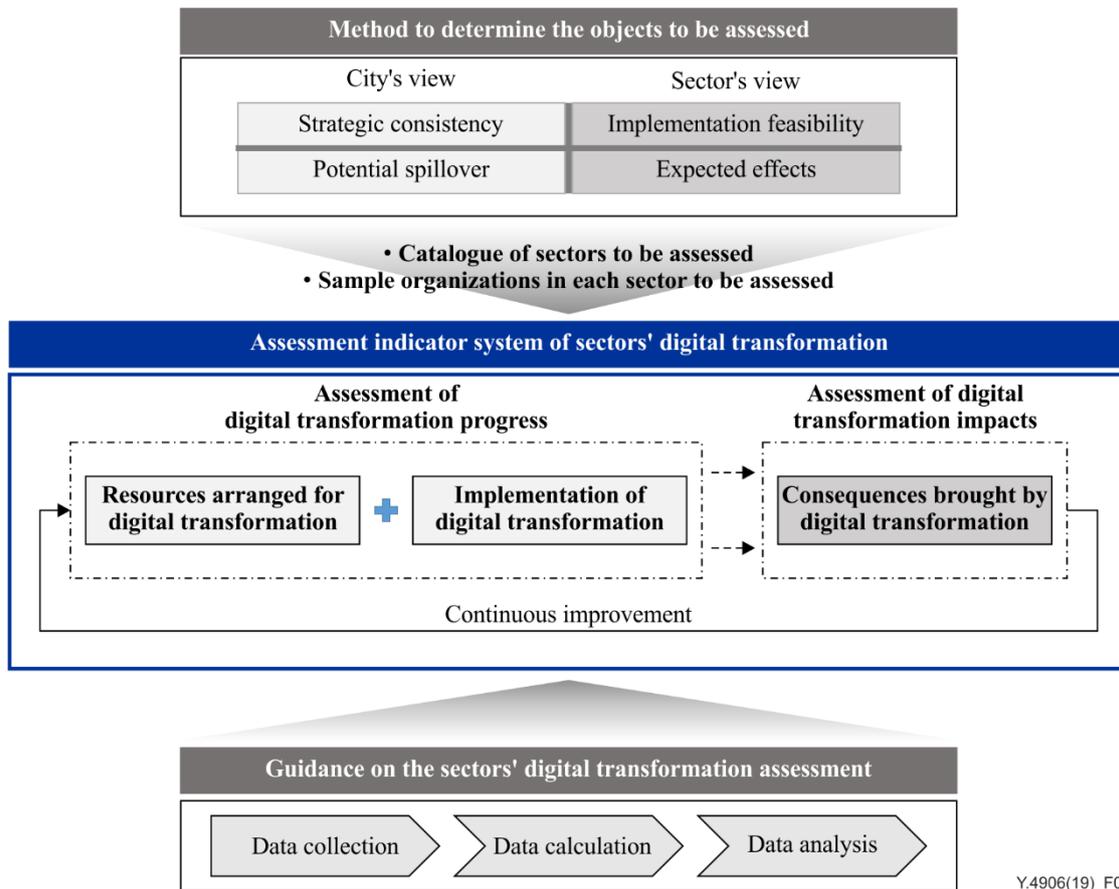
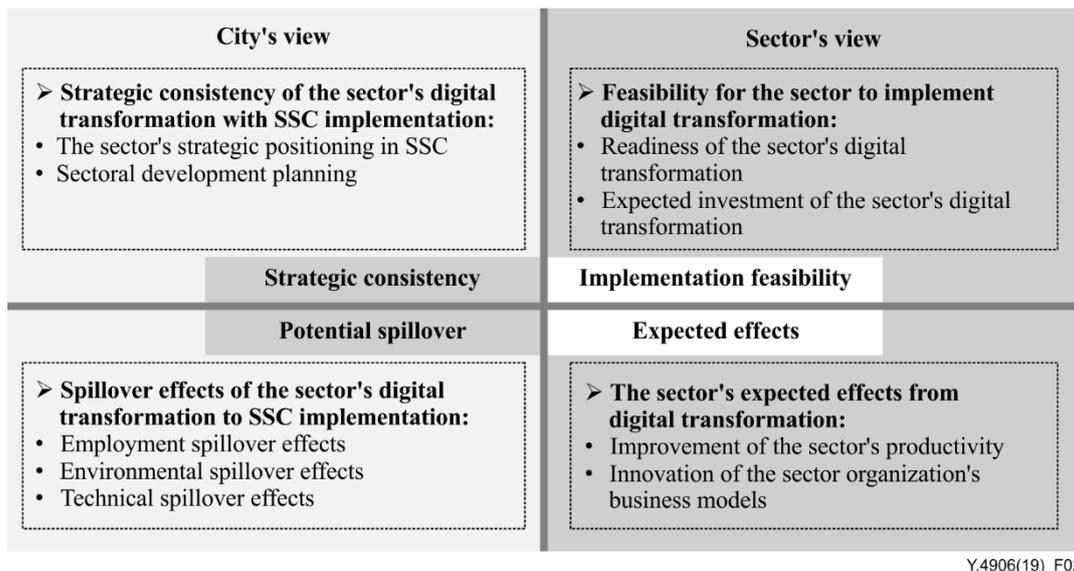


Figure 1 – Overview of the assessment framework for digital transformation of sectors in SSC

The SSC, intending to conduct sectors' digital transformation assessment based on this framework, should begin with determining the catalogue of sectors to be assessed.

To generate the catalogue of sectors, the SSC can do a preliminary qualitative research on the concerned sectors, according to the research model in Figure 2. This model proposes four aspects which the SSC should consider when it determines whether a sector's digital transformation should be promoted or not. These four aspects are the strategic consistency, implementation feasibility, expected effects, and the potential spillover. This research model will also help to clarify which sample organizations of these sectors will be assessed within a city.



Y.4906(19)_F02

Figure 2 – Research model to determine the catalogue of sectors to be assessed

The meanings and details of these four aspects are as follows:

- **Strategic consistency:** The strategic consistency of the sector's digital transformation with SSC implementation.
 - The sector's strategic positioning in SSC – Mainly analyses the sector's proportion of gross domestic product (GDP) in SSC, promoting the effect of sector's digital transformation to SSC's development level, etc.
 - Sectoral development planning – Mainly analyses the effect and value of digital transformation to the implementation of sector's development planning and the realization of sector's development goals, etc.
- **Implementation feasibility:** The feasibility for the sector to implement digital transformation.
 - Readiness of the sector's digital transformation – Mainly analyses the sector's technical reserves and fundamental conditions for ICTs application, the sector's talent pool for digital transformation, etc.
 - Expected investment of the sector's digital transformation – Mainly analyses the total amount and subsequent amounts of needed capital investments for the sector's digital transformation, etc.
- **Expected effects:** The sector's expected effects from digital transformation.
 - Improvement of the sector's productivity – Mainly analyses the expected degree of contribution of the digital transformation to the improvement of sector's productivity, etc.
 - Innovation of the sector organizations' business models – Mainly analyses the effect and expected value of digital transformation to the business model innovation in the sector, etc.
- **Potential spillover:** The spillover effects of the sector's digital transformation to SSC implementation. It should be noted that, spillover effects of sector's digital transformation from aspects of employment, environment and technology are most commonly seen.
 - Employment spillover effects – Mainly analyse the employment opportunities brought about by sector's digital transformation, the adjustment effect of sector's digital transformation to SSC's employment structure, etc.

- Environmental spillover effects – Mainly analyse the promotion effect of sector's digital transformation to SSC's resources utilization efficiency, the effect of sector's digital transformation to SSC's ecological environment, etc.
- Technical spillover effects – Mainly analyse the stimulating effect of sector's digital transformation to SSC's innovation investments, the promoting effect of sector's digital transformation to SSC's innovation efficiency, etc.

When using this research model, the SSC should first classify the sample organizations into small, medium and large (e.g., by number of employees, revenue). Then for the concerned sector, the organizations being assessed should include all different sizes, and the size distribution of organizations should be selected to reflect an appropriate representation of the sector.

7.2 Introduction to the assessment indicator system of sectors' digital transformation

The assessment of sectors' digital transformation can be considered in two parts, namely, the progress and the impacts of sectors' digital transformation. Specific business activities in the value chain of organizations form the foundation for digital transformation. Therefore, the assessment of the digital transformation progress should focus on the changes and improvements brought by ICTs application to business activities. The assessment indicators of digital transformation progress should be selected from the following four aspects:

- Basis and support for digital transformation;
- ICTs application in sectors' specific domains;
- Integration across different domains or links in value chains;
- Sectors' development through innovation and disruption based on ICTs application.

The digital transformation progress from the four aspects above can directly induce the enhancement of sectors' competitiveness, and further bring economic, environmental and social impacts indirectly. Accordingly, the digital transformation impacts can be assessed from two aspects, that is, digital competitiveness, and economic, environmental and social impacts.

In conclusion, the assessment framework for digital transformation of sectors in SSC includes two parts, one is the assessment of digital transformation progress, and the other one is the assessment of digital transformation impacts, as shown in Figure 3.

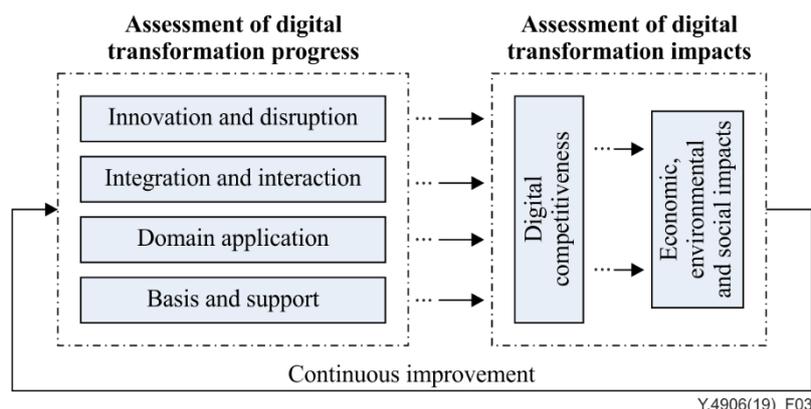


Figure 3 – Assessment indicator system of sectors' digital transformation in SSC

7.3 Description of assessment indicator set for sectors' digital transformation in SSC

Assessment indicator set for sectors' digital transformation is provided in a hierarchical structure with three layers. More specifically, there are different aspects in the first layer, several key areas of digital transformation in the second layer, and various assessment indicators in the third layer.

In the first layer, there are 6 aspects corresponding to the 6 parts shown in the solid frames of Figure 3. These aspects are described in clauses 7.3.1 to 7.3.6.

In the second layer, each aspect is decomposed to several key areas of digital transformation. In total, there are 25 key areas, which are also specified in clauses 7.3.1 to 7.3.6 according to the aspects to which they belong.

In the third layer, each key area is further decomposed to several assessment indicators. The referential assessment indicators are provided in Appendix I.

7.3.1 Basis and support

Mainly assesses the infrastructures and support required by sectors' digital transformation, covering seven key areas of basis and support for digital transformation; namely, strategy planning, organizations and talents, capital investment, physical infrastructure, ICTs infrastructure, data resources, and information security. The specific indicators of this assessment aspect are shown in Table I.1 of Appendix I.

7.3.2 Domain application

Mainly assesses the application of digital technology in specific domain of sectors or individual links in value chains, covering five key areas of domain application; namely, digital technology's application in customer's requirement definition, research and development (R&D), production, delivery, and service. The specific indicators of this assessment aspect are shown in Table I.2 of Appendix I.

7.3.3 Integration and interaction

Mainly assesses the business integration and interaction across sector's domains or links in value chains through digital transformation. It covers three key areas of integration and interaction; namely, integration and interaction of the product life cycle, horizontal integration and interaction of supply chain, and vertical integration and interaction among multi levels from decision making to execution. The specific indicators of this assessment aspect are shown in Table I.3 of Appendix I.

7.3.4 Innovation and disruption

Mainly assesses the reformation and reconstruction of sectors' traditional business processes through digital transformation, covering three key areas of innovation and disruption; namely, production, service and business processes. The specific indicators of this assessment aspect are shown in Table I.4 of Appendix I.

7.3.5 Digital competitiveness

Mainly assesses the sectors' digital competitiveness building and enhancement through digital transformation, covering four key areas of digital competitiveness; namely, innovation, operational, customer experience, and new market penetration capabilities. The specific indicators of this assessment aspect are shown in Table I.5 of Appendix I.

7.3.6 Economic, environmental and social impacts

Mainly assesses the overall economic, environmental and social impacts through sectors' digital transformation, covering three key areas, namely; economic impacts, environmental impacts, and social impacts. The specific indicators of this assessment aspect are shown in Table I.6 of Appendix I.

8 Guidance on the sectors' digital transformation assessment in SSC

SSC manager(s), should define the responsibilities and authorities of stakeholders engaged in the sectors' digital transformation assessment activities.

SSC manager(s) should first determine the sectors and sample organizations within them to be assessed and list a catalogue referring to the research model shown in Figure 2.

Third-party, including consulting service firms, industrial associations or industrial alliances, etc. could help SSC manager(s) with practical implementation of the assessment, and provide the necessary awareness and trainings to the sample organizations according to the needs of SSC manager(s).

8.1 Data collection of sector's digital transformation in SSC

SSC manager(s) could conduct the assessment of sector's digital transformation through a questionnaire based survey. The questionnaire could involve the referential assessment indicators listed in Appendix I. When conducting assessments for different sectors, the selection of assessment indicators in the questionnaire can be done by each city via adjusting and expanding its list of indicators according to the characteristics and needs of its individual sectors.

It should be noted that, SSC manager(s) could select indicators referring to the series of Recommendations on assessment in SSC, including [ITU-T Y.4901], [ITU-T Y.4903] and [ITU-T Y.4905].

SSC manager(s) should develop a detailed instruction for assessed organizations and other relevant participants. The instruction should cover several aspects, including but not limited to, how to accurately comprehend the indicators and their measurements in the questionnaire, clarifying the criterion of filling in the questionnaire, and other sector-specific considerations. The instruction would help assessed organizations reflect their actual situation of digital transformation in the survey.

SSC manager(s) should set up a standardized procedure for data collection and management for further analysis. The procedure should clarify several issues, including the processes of organizing the data collection activities, the requirements of data quality verification and data cleansing, the responsible persons for each process of collecting and recording the data, etc.

SSC manager(s) should establish an effective mechanism to ensure the authenticity, integrity and confidentiality of collected data, and clarify the intellectual property rights of data and relevant analyses results. The mechanism should be documented as agreed policies and made known to all the participants.

8.2 Data calculation of sector's digital transformation in SSC

In order to effectively conduct the assessment of sectors' digital transformation in SSC based on the assessment indicator system provided in clause 7.2, the scoring method for all the indicators, key areas and aspects are as follows:

(1) Setting of weights

Before the scoring of assessment indicators, SSC manager(s) should determine the weights of all the aspects, key areas and indicators. The weights can be used to reflect their degree of importance to the sectors' digital transformation.

SSC manager(s) could invite experienced experts to discuss the assessment indicator system and the questionnaire, then to determine the indicators' weights which should be in line with the actual situation and future development plan of the sector's digital transformation in SSC. Methods such as Delphi method [b-DMAW], analytic hierarchy process (AHP) [b-AHP] and analytic network process (ANP) [b-ANP] can be used to set the weight of each indicator.

(2) Scoring for indicators of each sample organization

Considering the characteristic of each indicator, there are mainly three methods for data collection; namely, numerical question, single-choice question, and checklist question.

The scoring for each kind of data collection method can be conducted as follows:

- For numerical questions, the scoring can be calculated by the formula:

$$X_i = \frac{V_i - V_{min}}{V_{max} - V_{min}} \times 100.$$

Where, the X_i is the i th indicator's score, which has the value range of [0,100], the V_i is the actual value of the i th indicator's collected data, of which the minimum and maximum thresholds are denoted respectively as V_{min} and V_{max} .

- For single choice questions, the scoring can be calculated as follows:
 - (i) All the available options should be assigned with certain scores, which should be distributed in the value range of [0,100].
 - (ii) The score of the indicators should be the corresponding score of the selected option.
- For checklist questions, the scoring can be calculated as follows:
 - (i) All the available options should be assigned with certain scores, which should be distributed in the value range of [0,100], and the options' total scores should be 100.
 - (ii) The score of the indicators should be the sum of the selected options' scores.

(3) **Weighted scoring for the key areas and aspects of each sample organization**

For each sample organization, scores of the 25 key areas of digital transformation and the 6 aspects can be calculated by the weighted average of their sub-indicators' scores, and the total score can be calculated by weighted average of the 6 aspects' scores.

For a given indicator, let n be the number of sub-indicators, $\{X_i | i = 1, 2, \dots, n\}$ be the scores of its sub-indicators, and the W_i be the weight of the i th sub-indicator, while $0 < W_i \leq 1$ and the constraint $\sum_{i=1}^n W_i = 1$ should be satisfied. And the score of this indicator can be calculated by the following formula:

$$Y = \frac{\sum_{i=1}^n X_i \times W_i}{\sum_{i=1}^n W_i} \quad (i = 1, 2, \dots, n)$$

(4) **Scoring for indicators, key areas and aspects of each sector**

For a given sector, the scores of the assessment indicators, 25 key areas of digital transformation, 6 aspects and the total score can be calculated by the arithmetic average of corresponding scores of indicators, key areas, aspects, and also the total scores of all the samples in this sector.

8.3 **Data analysis of sector's digital transformation in SSC**

SSC manager(s) can further conduct in-depth data mining by using various kinds of data analyses methods based on the collected data and the above scoring results. According to the actual needs, SSC manager(s) can do comparative analysis and correlation analysis among different sectors in the SSC, or within the same sector in other SSCs, or among different indicators of certain sectors, etc. The results of the analyses can be used to help SSC managers to precisely find out the current states, key points, problems and trends of the assessed sectors' digital transformation. Furthermore, SSC manager(s) can determine the priorities of sectors' digital transformation, and then provide suitable paths and corresponding measures to promote these sectors' digital transformation.

Appendix I

Assessment indicators

(This appendix does not form an integral part of this Recommendation.)

This appendix lists potential assessment indicators, among others, that SSC manager(s) can select according to their own needs and requirements for sectors' digital transformation. Each indicator is labelled (*Ix.y.z*), where:

- (i) *x* denotes the 6 aspects of the assessment indicator system for digital transformation; namely, basis and support, domain application, integration and interaction, innovation and disruption, digital competitiveness, and economic, environmental and social impacts;
- (ii) *y* denotes the 25 key areas of digital transformation decomposed from the above mentioned 6 assessment aspects;
- (iii) *z* denotes corresponding indicators after further decomposition of the 25 key areas for the assessment of digital transformation.

I.1 Basis and support

There are seven key areas of digital transformation in this aspect, which can be further decomposed to several assessment indicators including strategy planning related to digital transformation, implementation control of strategy planning related to digital transformation, organizational setting related to digital transformation, professional personnel engaged in digital transformation, empowering employees through digital transformation, etc. The referential indicators and their descriptions in the above seven key areas are shown in Table I.1.

Table I.1 – Names and descriptions of assessment indicators in the aspect of basis and support

Area	Indicator name	Description	Data collection method
I1.1 Strategy planning	I1.1.1 Strategy planning related to digital transformation	Level and range of the company's strategic planning for digital transformation. NOTE – Checklist: a) There is no strategic planning for digital transformation; b) Partial strategic planning is formulated considering the single business's needs for digital transformation; c) Company-level strategic planning for digital transformation is formulated.	Single-choice question
	I1.1.2 Implementation control of strategy planning related to digital transformation	Measures for effective management and control towards the implementation of digital transformation strategy. NOTE – Checklist: a) Specific quantitative objectives of digital transformation strategy are defined; b) The implementation of digital transformation strategy is tracked and monitored; c) The implementation of digital transformation strategy is evaluated.	Checklist question
I1.2 Organizations and talents	I1.2.1 Organizational setting related to digital transformation	Realization of the collaboration among relevant business functions and organizational levels of the organization/company for the promotion of digital transformation. NOTE – Checklist: a) The leader in the decision level presides over the overall promotion of digital transformation; b) The departments or employees responsible for related activities of digital transformation are assigned with functions and duties of optimizing business processes and organizational structures; c) All the business departments take an active part in digital transformation; d) Good communication and coordination mechanism is established among business departments and organizational levels which are related to digital transformation.	Checklist question
	I1.2.2 Professional personnel engaged in digital transformation	Proportion of the employees whose full-time job is the promotion of digital transformation.	Numerical question

Table I.1 – Names and descriptions of assessment indicators in the aspect of basis and support

Area	Indicator name	Description	Data collection method
	I1.2.3 Empowering employees through digital transformation	Digital measures adoption for empowering employees to achieve the matching between the employees' capability and the organization's/company's development. NOTE – Checklist: a) The data resource is open and sharable to employees whose needs for improving knowledge and capability can be satisfied; b) There exists Internet-based transformation in the relationship between employees and managers, which helps to realize the self-organization of employees; c) Employees are provided with entrepreneurial resources and innovation resources based on the platform, which promotes the coordinated development between employees and the company.	Checklist question
I1.3 Capital investment	I1.3.1 Investment in construction, operation and maintenance of automation equipment and facilities, etc.	Expenditure ratio of construction, operation and maintenance of automatic devices and facilities to the revenue of main business in the recent three years.	Numerical question
	I1.3.2 Investment in construction, operation and maintenance of IT equipment, software and information systems	Expenditure ratio of construction, operation and maintenance of IT equipment, software and information system to the revenue of main business in the recent three years.	Numerical question
I1.4 Physical infrastructure	I1.4.1 Digital control of physical infrastructure	Proportion of digital controlled devices and facilities.	Numerical question
	I1.4.2 Networking of physical infrastructure	Proportion of networked devices and facilities.	Numerical question
I1.5 ICTs infrastructure	I1.5.1 Possession of IT equipment (e.g., computers, servers, intelligent terminals)	Possession of IT equipment per 100 persons. NOTE – Calculated as: Possession of IT equipment per 100 persons = Total number of IT equipment×100/Total number of employees.	Numerical question
	I1.5.2 Network infrastructure construction (e.g., network environment)	Backbone network coverage of the organization/company. NOTE – Checklist: a) Absence of backbone network of the organization/company; b) Establishment of backbone network of the organization/ company;	Single-choice question

Table I.1 – Names and descriptions of assessment indicators in the aspect of basis and support

Area	Indicator name	Description	Data collection method
		c) More than 50% area of the organization/company is covered by the backbone network; d) More than 80% area of the organization/company is covered by the backbone network.	
I1.6 Data resources	I1.6.1 Standardization of data resources	The extent of standard management of data resources. NOTE – Checklist: a) Absence of the classification coding of data resources; b) Realization of classification coding separately for each kind of data resource; c) Realization of department-level unified classification coding for the data resources; d) Realization of enterprise-level unified classification coding for the data resources.	Single-choice question
	I1.6.2 Collection, storage and management of data resources	Realization of collection, storage, accumulation, integration, etc. of data resources. NOTE – Checklist: a) Automatic collection of primary data of the production operations; b) Hierarchical storage of data resources; c) Establishment of enterprise-level data dictionary; d) Integration of multi-source heterogeneous data; e) Gathering and management of historical data; f) Implementation of data mining to meet business needs.	Checklist question

Table I.1 – Names and descriptions of assessment indicators in the aspect of basis and support

Area	Indicator name	Description	Data collection method
I1.7 Information security	I1.7.1 Information security	Adoption of management measures for information security. NOTE – Checklist: a) Establishment of management organization specially designed for information security; b) Establishment of management regulations for information security; c) Adoption of professional products and services for information security; d) Regular tracking and assessment of information security.	Checklist question

I.2 Domain application

There are five key areas of digital transformation in this aspect, which can be further decomposed to several assessment indicators including customer's requirements gathering, customer's requirements analysis, translation and identification, digitalization of products design, digitalization of process planning, digitalization of production management, digitalization of production management, etc. The referential indicators and their descriptions in the above five key areas are shown in Table I.2.

Table I.2 – Names and descriptions of assessment indicators in the aspect of domain application

Area	Indicator name	Description	Data collection method
I2.1 Customer's requirement definition	I2.1.1 Customer's requirements gathering	Realization of automatic collection of customer's requirements. NOTE – Checklist: a) The customer's requirements can be collected automatically; b) The customer's requirements cannot be collected automatically.	Single-choice question
	I2.1.2 Customer's requirements analysis, translation and identification	Realization of online analysis, translation and identification of customer's requirements. NOTE – Checklist: a) The customer's requirements can be analysed, translated and identified online;	Single-choice question

Table I.2 – Names and descriptions of assessment indicators in the aspect of domain application

Area	Indicator name	Description	Data collection method
		b) The customer's requirements cannot be analysed, translated and identified online.	
I2.2 R&D	I2.2.1 Digitalization of products design	Proportion of the types of products which are developed with the establishment of digital models and then get their functions and performances verified using digital technologies.	Numerical question
	I2.2.2 Digitalization of technological process planning	Proportion of types of products which are developed through computer aided technological process planning and simulation and optimization. NOTE – Technological process planning is concerned with determining the sequence of individual manufacturing operations needed to produce a given part or product, and also refers to the planning of use of blanks, spare parts, packaging material, user instructions (manuals), etc.	Numerical question
I2.3 Production	I2.3.1 Digitalization of production management	Implementation of production planning and scheduling using digital technologies. NOTE – Checklist: a) Automatic generation of production plan; b) Automatic generation of materials requirement plan; c) Automatic generation of external cooperative production plan; d) Real-time tracking of production plan's implementation; f) Dynamic adjustment of production plan as needed.	Checklist question
	I2.3.2 Digitalization of production process management and control	Proportion of key production processes which are automatically controlled using digital technologies.	Numerical question
I2.4 Delivery	I2.4.1 Digitalization of transaction process	Implementation of transaction process management using digital technologies. NOTE – Checklist: a) Online management towards the procurements' planning, supplier sourcing, schedule and cost; b) Online processing and real-time tracking of sales orders; c) Online payment and online charging.	Checklist question
	I2.4.2 Digitalization of logistics distribution	Management of logistics distribution using digital technologies. NOTE – Checklist: a) Automatic generation of logistics distribution plan; b) Dynamic planning of logistics distribution route and delivery timetable;	Checklist question

Table I.2 – Names and descriptions of assessment indicators in the aspect of domain application

Area	Indicator name	Description	Data collection method
		c) Whole-process dynamic tracking of logistics distribution information.	
I2.5 Service	I2.5.1 Digitalization of after-sales service	Implementation of after-sales service using digital technologies. NOTE – Checklist: a) Online feedback and processing of after-sales problems; b) Dynamic allocation and automatic flow of after-sales services' work order; c) Online tracking of after-sales service process.	Checklist question
	I2.5.2 Digitalization of customer relationship management	Implementation of customer relationship management using digital technologies. NOTE – Checklist: a) Management of customer' basic information; b) Online collection of customers' behaviour data; c) Provision of personalized customer interaction and service based on analysis of customers' characteristics and value.	Checklist question

I.3 Integration and interaction

There are three key areas of digital transformation in this aspect, which can be further decomposed to several assessment indicators including life cycle associated maintenance and management of product data, business integration and associated optimization between R&D and production, business integration and associated optimization between R&D and service, business integration and associated optimization of production, supply and sales, whole process tracking management of customer orders, etc. The referential indicators and their descriptions in the above three key areas are shown in Table I.3.

Table I.3 – Names and descriptions of assessment indicators in the aspect of integration and interaction

Area	Indicator name	Description	Data collection method
I3.1 Integration and interaction of the product life cycle	I3.1.1 Associated maintenance and management of product data in the entire life cycle of products	Implementation of automatic transmission, associated maintenance and consistency management of data among key stages of the product life cycle, such as R&D, production and service. NOTE – Checklist: a) Establishment of unified product data model; b) Automatic transmission of product data among all the stages of the product life cycle; c) Associated maintenance and consistency management of product data among all the stages of the product life cycle.	Checklist question
	I3.1.2 Business integration and associated optimization between R&D and production	Implementation of integration and associated optimization among product R&D and design, manufacturing, production management, etc. NOTE – Checklist: a) Automatic generation of technological process scheme according to product's design; b) Fast optimization of product's R&D scheme based on practical needs of production; c) Parallel processing of R&D and production.	Checklist question
	I3.1.3 Business integration and associated optimization between R&D and service	Implementation of integration and associated optimization among related business activities of product R&D and after-sales service. NOTE – Checklist: a) Users' participation in product design using information systems; b) Automatic collection of user service's data and optimization of product design accordingly.	Checklist question
I3.2 Horizontal integration and interaction of supply chain	I3.2.1 Business integration and associated optimization of production, supply and sales	Implementation of integration and associated optimization among production, supply, sales, etc., along a supply chain. NOTE – Checklist: a) Provided with precise supply in designated time at particular place from the suppliers; b) Production's automatic scheduling and dynamic dispatching according to customers' orders; c) Accurate delivery according to customers' requirements.	Checklist question

Table I.3 – Names and descriptions of assessment indicators in the aspect of integration and interaction

Area	Indicator name	Description	Data collection method
	I3.2.2 Whole process tracking management of customer orders	<p>The coverage extent of whole-process tracking management of customers' orders using digital technologies.</p> <p>NOTE 1 – Checklist:</p> <ul style="list-style-type: none"> a) Product delivery and all the subsequent stages of the whole process; b) Production and all the subsequent stages of the whole process; c) R&D, design and all the subsequent stages of the whole process. <p>NOTE 2 – The whole process of customer orders management includes but not limited to the aspects of R&D and design, production and product delivery, which are implemented in order.</p>	Checklist question
I3.3 Vertical integration and interaction among multi levels from decision making to execution	I3.3.1 Data interconnection and business integration between decision making level and management level	<p>Implementation of data interconnection and business integration between decision-making level and management level based on information systems.</p> <ul style="list-style-type: none"> a) Automatic conveying of instructions from the decision-support system to the business management system; b) Automatic uploading of operation information from the operation management system to the decision-support system. 	Checklist question
	I3.3.2 Data interconnection and business integration between management level and execution level	<p>Implementation of data interconnection and business integration between operation management level and production execution level based on information systems.</p> <p>NOTE – Checklist:</p> <ul style="list-style-type: none"> a) Automatic conveying of instructions from the operation management system to the production execution system; b) Automatic uploading of information from the production execution system to the operation management system. 	Checklist question
	I3.3.3 Level of intelligent decision making	<p>Implementation of optimal decision-making of production and business management problems using information technologies (especially using big data technology or artificial intelligence technology).</p> <p>NOTE – Checklist:</p> <ul style="list-style-type: none"> a) Timely tracking and online collection of internal and external information needed for decision-making; b) Comprehensive optimization of decision-making results with the assistance of information technologies; 	Checklist question

Table I.3 – Names and descriptions of assessment indicators in the aspect of integration and interaction

Area	Indicator name	Description	Data collection method
		c) Automatic optimization of decision-making results and forecasting and early warning using new generation of information technologies, such as artificial intelligence and big data technologies.	

I.4 Innovation and disruption

There are three key areas of digital transformation in this aspect, which can be further decomposed into several assessment indicators including networked collaborative R&D and production, customization, remote service, real-time service, sharing service, cloud platform-based operation, industrial internet and supply chain finance. The referential indicators and their descriptions in the above three key areas are shown in Table I.4.

Table I.4 – Names and descriptions of assessment indicators in the aspect of innovation and disruption

Area	Indicator name	Description	Data collection method
I4.1 Production processes	I4.1.1 Networked collaborative R&D and production	Realization of concurrent and collaborative design and manufacturing of products in the context of distributed collaborative environment based on the Internet. NOTE – Checklist: a) Realization of networked collaborative R&D and production among multiple R&D or manufacturing centres in the organization/company; b) Realization of networked collaborative R&D and production among organization/company and their upstream and downstream companies; c) Realization of networked collaborative R&D and production between organization/company and their end-users.	Checklist question
	I4.1.2 Customization	Realization of customization and on-demand manufacturing based on dynamic perception and quick response to customers' needs. NOTE – Checklist: a) Accurate collection of customers' needs through online one-to-one marketing; b) Provision of customer-oriented platform for collaborative design; c) Support for the customer-defined products configuration using the module design method;	Checklist question

Table I.4 – Names and descriptions of assessment indicators in the aspect of innovation and disruption

Area	Indicator name	Description	Data collection method
		d) Quick arrangement of production scheduling and dynamic dispatching adapting to the changes of products' types and lot sizes.	
I4.2 Service processes	I4.2.1 Remote service	Realization of online and remote provision of services for products' end-users. NOTE – Checklist: a) Remote support for installation and usage of sold-out products; b) Remote monitoring of sold-out products' running state; c) Remote diagnosis of sold-out products' operational fault; d) Pushing of personalized value-added service based on data mining of customers' behaviour.	Checklist question
	I4.2.2 Real-time service	Implementation of real-time services using digital technologies in order to meet the customers' demands of fast and on-time delivery. NOTE – Checklist: a) Real-time matching among related entities of orders; b) Real-time delivery of products; c) Real-time tracking of orders; d) Real-time compensation for overtime orders.	Checklist question
	I4.2.3 Sharing service	Realization of sharing resources and capabilities between organization/company and their relevant parties based on platforms. NOTE – Checklist: a) Realization of sharing design resources and providing design services based on platforms; b) Realization of sharing equipment's production capability and providing production services based on platforms; c) Realization of sharing logistics system and providing the third-party logistics services based on platforms.	Checklist question
I4.3 Business processes	I4.3.1 Cloud platform-based operation	Implementation of business operation based on Internet platforms. NOTE – Checklist: a) Business operation based on the third-party Internet platform, which is beneficial to the cost reduction and efficiency improvement;	Checklist question

Table I.4 – Names and descriptions of assessment indicators in the aspect of innovation and disruption

Area	Indicator name	Description	Data collection method
		b) Realization of self-built Internet platform, which can facilitate the aggregation of resources for all the production factors and help to realize the socialized production operation.	
	I4.3.2 Industrial internet	Realization of manufacturing resources' networked and dynamic allocation based on the construction of industrial Internet. NOTE – Checklist: a) Wide interconnection of devices and facilities; b) Online deployment of manufacturing resources; c) Online transaction of manufacturing capabilities.	Checklist question
	I4.3.3 Supply chain finance	Development of products and services of supply chain finance based on big data, etc. through Internet platform-based cooperation with financial institutions. NOTE – Checklist: a) Credit loan; b) Financial leasing; c) Hypothecation guarantee; d) Insurance.	Checklist question

I.5 Digital competitiveness

There are four key areas of digital transformation in this aspect, which can be further decomposed to several assessment indicators including quality of R&D, efficiency of R&D, cost of R&D, capacity utilisation, speed of capital turnover, customer satisfaction, customer loyalty, new product/service, new marketing channel, and new user group. The referential indicators and their descriptions in the above four key areas are shown in Table I.5.

Table I.5 – Names and descriptions of assessment indicators in the aspect of digital competitiveness

Area	Indicator name	Description	Data collection method
I5.1 Innovation capability	I5.1.1 Quality of R&D	Proportion of the new products which is successfully manufactured in their first trial-production.	Numerical question
	I5.1.2 Efficiency of R&D	Development cycle time of new product.	Numerical question
	I5.1.3 Cost of R&D	Ratio of expenditure of R&D to total revenue in the recent three years.	Numerical question
I5.2 Operational capability	I5.2.1 Capacity utilisation	Capacity utilisation rate. NOTE – Calculated as: Capacity utilisation rate = Actual capacity/designed capacity×100%.	Numerical question
	I5.2.2 Speed of capital turnover	Inventory Turnover Ratio. NOTE – Calculated as: Inventory Turnover Ratio = Yearly total cost of product sales/average capital balance of inventory.	Numerical question
I5.3 Customer experience capability	I5.3.1 Customer satisfaction	Average increasing rate of numbers of customers who show their satisfaction to the organization/company and their products in the customers' survey of the recent three years.	Numerical question
	I5.3.2 Customer loyalty	Average increasing rate of numbers of loyal customers in the recent three years. NOTE – Loyal customers are those who repurchase the organization's/ company's products or services in a long term.	Numerical question
I5.4 New market penetration capability	I5.4.1 New product/service	Proportion of sales of new products.	Numerical question
	I5.4.2 New marketing channel	Proportion of sales from new marketing channels in the recent year. NOTE – New marketing channels refers to ways of transferring products or services to end-users using digital technologies, mainly on the Internet, but also including mobile phones, online advertising, and any other digital medium.	Numerical question
	I5.4.3 New user group	Average number of new users per month.	Numerical question

I.6 Economic, environmental and social impacts

There are three key areas of digital transformation in this aspect, which can be further decomposed to several assessment indicators including labour productivity, profit margin per person, energy consumption, carbon dioxide emission and technical contribution. The referential indicators and their descriptions in the above three key areas are shown in Table I.6.

Table I.6 – Names and descriptions of assessment indicators in the aspect of economic, environmental and social impacts

Area	Indicator name	Description	Data collection method
I6.1 Economic benefits	I6.1.1 Labour productivity	Overall labour productivity.	Numerical question
	I6.1.2 Profit margin per person	Ratio of total profit to the total number of employees.	Numerical question
I6.2 Environmental benefits	I6.2.1 Energy consumption	Energy consumption per unit of output value. NOTE –Energy consumption is commonly calculated by measuring the consumption of standard coal.	Numerical question
	I6.2.2 Carbon dioxide emission	Carbon dioxide emissions per unit of output value.	Numerical question
I6.3 Social benefits	I6.3.1 Technical contribution (e.g., patents)	Number of patents per 100 employees of the organization/company. NOTE – Calculated as: Number of patents per 100 employees = (Number of granted patents×100)/ Total number of employees in the organization/company at the end of the year	Numerical question

Bibliography

- [b-ITU-T Y-Sup.52] Recommendation ITU-T Y-series – Supplement 52 (2018), *Methodology for building digital capabilities during enterprises' digital transformation*.
- [b-ISIC Rev.4] International standard industrial classification of all economic activities (ISIC), Rev.4.
https://unstats.un.org/unsd/publication/seriesM/seriesm_4rev4e.pdf
- [b-E CPNRE] Classic papers in natural resource economics, *Externality*.
https://link.springer.com/chapter/10.1057/9780230523210_7
- [b-DMAW] MA: Addison-Wesley, *the Delphi Method*.
https://www.researchgate.net/profile/Maria_Joao_Teixeira/post/What_are_the_Likert_scales_used_in_Delphi_study/attachment/59d620c279197b807797f38d/AS:292381292285964@1446720541026/download/The+Delphi+Method.pdf
- [b-AHP] Encyclopedia of operations research and management science, *Analytic hierarchy process*.
http://iors.ir/journal/files/site1/user_files_ba3acb/mehdi_ghotboddini-A-10-6-2-f082faa.pdf.2019)
- [b-ANP] Decision Making with the Analytic Network Process, *The Analytic Network Process*.
http://iors.ir/journal/files/site1/user_files_ba3acb/mehdi_ghotboddini-A-10-6-2-f082faa.pdf

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	Tariff and accounting principles and international telecommunication/ICT economic and policy issues
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling, and associated measurements and tests
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities
Series Z	Languages and general software aspects for telecommunication systems