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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Optical fibre cables – Guidance and installation technique

Criteria for optical fibre cable installation with minimal existing infrastructure

Recommendation ITU-T L.163

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ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

OPTICAL FIBRE CABLES	
Cable structure and characteristics	L.100–L.124
Cable evaluation	L.125–L.149
Guidance and installation technique	**L.150–L.199**
OPTICAL INFRASTRUCTURES	
Infrastructure including node elements (except cables)	L.200–L.249
General aspects and network design	L.250–L.299
MAINTENANCE AND OPERATION	
Optical fibre cable maintenance	L.300–L.329
Infrastructure maintenance	L.330–L.349
Operation support and infrastructure management	L.350–L.379
Disaster management	L.380–L.399
PASSIVE OPTICAL DEVICES	L.400–L.429
MARINIZED TERRESTRIAL CABLES	L.430–L.449

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

Recommendation ITU-T L.163

Criteria for optical fibre cable installation with minimal existing infrastructure

Summary

Recommendation ITU-T L.163 describes criteria for the installation of optical fibre cables defined in Recommendation ITU-T L.110 in remote areas with lack of usual infrastructure for installation including the procedures of cable-route planning, cable selection, cable-installation scheme selection, cable tension and temperature consideration and the handling, bend protection and river/lake closing of the cable together with pilot tests and training for installation.

This Recommendation also describes how to mitigate the considerable risks and/or issues to which the optical fibre cable may be exposed when infrastructures are minimal during installation, maintenance and operation procedures.

History

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Best-effort reliability, closing the digital divide, developing countries, direct surface application, optical fibre cable installation, rural areas.

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FOREWORD

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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.

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Table of Contents

Page

Recommendation ITU-T L.163

Criteria for optical fibre cable installation with minimal existing infrastructure

1 Scope

This Recommendation describes criteria for optical fibre cable installation in situations with minimal existing infrastructure. This Recommendation also describes how to mitigate the considerable risks and/or issues to which the optical fibre cable may be exposed when infrastructures are insufficient during installation, maintenance and operation procedures. This Recommendation considers only point-to-point network architectures.

This Recommendation is equally applicable to the developing countries where creation of telecommunications infrastructure is underway to bridge the digital divide and can be extended to cover difficult rural areas comprising high altitudes, coasts, forest and similarly situated regions of the world. This Recommendation will be very helpful in quick restoration of telecom services that may be frequently interrupted by other developmental activities.

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 G.657] Recommendation ITU-T G.657 (2016), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable.*

[ITU-T L.110] Recommendation ITU-T L.110 (2017), *Optical fibre cables for direct surface application.*

[ITU-T L.150] Recommendation ITU-T L.150/L.35 (1998), *Installation of optical fibre cables in the access network.*

[ITU-T L.154] Recommendation ITU-T L.154/L.49 (2003), *Micro-trench installation technique.*

[ITU-T L.158] Recommendation ITU-T L.158/L.56 (2003), *Installation of optical fibre cables along railways.*

[ITU-T L.161] Recommendation ITU-T L.161/L.46 (2000), *Protection of telecommunication cables and plant from biological attack.*

[ITU-T L.201] Recommendation ITU-T L.201/L.13 (2003), *Performance requirements for passive optical nodes: Sealed closures for outdoor environments.*

[ITU-T L.261] Recommendation ITU-T L.261/L.89 (2012), *Design of suspension wires, telecommunication poles and guy-lines for optical access networks.*

[ITU-T L.302] Recommendations ITU-T L.302/L.40 (2000), *Optical fibre outside plant maintenance support, monitoring and testing system.*

[ITU-T L.430] Recommendation ITU-T L.430/L.28 (2002), *External additional protection for marinized terrestrial cables.*

[ITU-T L.1700] Recommendation ITU-T L.1700 (2016), *Requirement for low-cost sustainable telecommunications infrastructure for rural communications in developing countries.*

[IEC 60794-3-30] IEC 60794-3-30 (2008), *Outdoor cables – Family specification for optical telecommunication cables for lakes, river crossings and coastal application*.

3 Definitions

3.1 Terms defined elsewhere

For the purposes of this Recommendation, the definitions given in [ITU-T L.110] apply.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 DSA cable: Optical fibre cable for direct surface application as defined in [ITU-T L.110].

3.2.2 infrastructure for optical fibre cable installation: Physical structures to support the safety and security of optical fibre cables when installed such as underground pipes, utility poles, trenches, suspension wires and other cable protection and/or cable supporting mechanisms besides those built in as a part of cable structure.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CAPEX	Capital Expenditure
CNOC	Centralised Network Operation Centre
DIY	Do It Yourself
DSA	Direct Surface Application
FTTH	Fibre to the Home
GIS	Geographic Information System
IXP	Internet exchange Point
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
OF	Optical Fibre
OPEX	Operating Expense
OTDR	Optical Time Domain Reflectometry
PE	Polyethylene
RoW	Right of Way
VSAT	Very Small Aperture Terminal

5 Conventions

None.

6 Needs and goals

The ITU Connect 2020 Agenda for Global Telecommunication/Information and Communications Technology (ICT) Development has identified Goal 2 "Bridging the digital divide and providing broadband for all". Broadband brings education, healthcare, financial services, etc. into rural communities, but also brings distant cultures to advanced countries, cultures which have preserved values now forgotten by many modern societies. Thus, broadband benefits us all.

As a result of the massive costs of installing broadband connectivity, the rural-urban digital divide is often more pronounced in developing countries.

[ITU-T L.1700] recently identified ultimate affordability with best-effort reliability as the priority requirement for telecommunications infrastructure for rural communications. The installation cost of conventional optical fibre cables has been typically 70-80% of the entire capital expenditure (CAPEX) of the network.

[ITU-T L.110] specified direct surface application (DSA) cable as the key to the realization of ultimately affordable rural connectivity. The DSA cable can be affordably installed on the ground surface while eliminating the need for ducts, underground pipes, poles, heavy machinery as well as skilled human resources. However, the local community should continually secure the cable by optimizing its location, placement and environment to address potential natural/unnatural disturbances and local convenience.

The objective of this Recommendation is to describe the criteria for the installation of the DSA cable with a view to ultimate affordability with best reliability with respect to [ITU-T L.1700].

7 Installation general requirements

Key requirements for the installation of DSA cables are:

– Ultimate affordability with best-effort reliability;
– Target availability of 99%.

Affordability and reliability should consider CAPEX/OPEX and mean time between failures / mean time to repair (MTBF/MTTR), respectively as defined in clause 6.1 of [ITU-T L.1700]. Compared with no service at all, a meaningful target of availability would be 99% based upon the assumption that a communication failure in a rural location may occur once a year and be repaired in approximately three to four days.

For example, an Asian developing country allows MTBF and MTTR of 7-9 months and 2-4 weeks, respectively as noted in Appendix I.5 of [ITU-T L.1700]. Other requirements defined in [ITU-T L.1700] for rural connectivity are high data rate, upgradability, flexibility, scalability, energy efficiency and environmentally friendly life cycle.

8 Prior to installation

8.1 Requirements for infrastructure for DSA cable installation

To achieve ultimate affordability with best reliability, the DSA cable can be placed directly on the ground surface with minimal infrastructure in a do it yourself (DIY) manner.

In remote areas cable laying directly on the ground surface is possible and will speed up the deployment process.

However, a length of the cable may be submerged, aerially suspended or buried underground without splices. Here, the use of minimal physical infrastructure is necessary, together with local experiences, wisdom and non-professional human resources as intangible infrastructure.

See clause 4.8 of [b-IEC TR 62691] for more on installation in special cases.

8.1.1 Cable installation on the ground surface

When optical fibre cables are exposed on the ground surface across rural areas, they may face many kinds of natural and unnatural attacks. In fact, clause 4.4 of [ITU-T L.161] suggests that steel wire armouring works well against pests. But imperfect splicing, mechanical damage or corrosion may lead to discontinuity in the armour thus leading to damage from beetles and larvae.

The DSA cable with metal core tube construction with a welded seam (welded core tube) could be used on the ground surface for the better protection. Additional use of steel wire armour increases the cable durability. Installing the DSA cables with welded core tube on the ground surface demands minimal basic infrastructure. Other types of cables discussed in [ITU-T L.110] may also be used.

a) Along the road or walking trail

Since no large-scale land slide, rock falls, floods or mudflows might be expected along a road or walking trail, no specific infrastructure may be needed here for the DSA cables.

NOTE – Clause 5.3.2 of [b-ITU-T L.107] states that metallic barriers such as steel tape or wire armouring can provide suitable and effective protection against rodent attacks. The DSA cables with welded core tube described in Appendix I.1 of [ITU-T L.110] are extremely robust against fire, crushing, rodents and vibration as shown in Figures 6-9 of [b-ITU-T L-Suppl.22].

b) Through original forest or unexplored land

A walking trail should be created as infrastructure by cutting trees and branches or removing obstacles for cable installation and later maintenance. The cable may be laid by moving the cable drum with a backpack carrier or a handy cart, or by manually pulling the cable end with the drum position fixed.

NOTE 1 – The weight of typical DSA cables with welded core tube shown in Appendix I.1 of [ITU-T L.110] is 180-200 kg/km, 85 kg/km or 20 kg/km.

NOTE 2 – Rollers or quadrant brocks may be needed to keep the tension and bend radius of the cable safe when employing the end-pull method.

c) Steep terrain or vertical routes

It is necessary to fix the DSA cable using suitable fittings or clamps and/or cable loops to avoid excessive fibre strain and movement, when the cable is placed on the surface of steep terrain or vertical routes.

d) Theft and vandalism

Cost-effective safeguarding of the cable can be accomplished by using the following measures as appropriate:

– bury the cable to hide it using, for example, hand picks, e.g., a few cm;
– patrol by the local community;
– display short cable pieces at some intervals to show that a no value material is used;
– post a notice indicating that a "no-value material is used" and "significant social loss if cable if damaged".

e) Optical fibre cable visibility

To avoid on-surface cables being damaged during civil works for example, the optical fibre cable may be made noticeable by using a shiny-colour outside jacket of the cable. However, such a cable may have a higher risk of theft/vandalism. Shiny-colour polyethylene (PE) sheath could have a shorter life than black. Another option is to use black PE sheath with a distinctive stripe. The cable visibility issue may need to be decided at each community.

8.1.2 Cable shallow burial

The DSA cable may be directly buried in a shallow simple trench or groove to protect landscape, avoid theft/vandalism and mitigate environmental impacts.

a) Trench width and depth

Due to the robustness of the DSA cable, the depth of the trench or groove can be less than 0.5 m. The depth should be determined upon terrain, cost, construction speed, security, trust ability and longevity.

NOTE – Clause 4.7.2 of [b-IEC TR 62691] suggests the minimum installation depths (to the bottom of the trench) as 0.8 m, 0.6 m and 0.5 m for data rates of heavy concentration (trunk), medium (distribution) and low (service/drop), respectively. It further states the cables should be provided with special protection (e.g., by means of cable duct) if the depths are less. Since the welded core tube in DSA cable is a "special protection", less-than 0.5 m burial should basically be acceptable.

Using optic fibre cable with minimum criteria such as DSA cables as defined in [ITU-T L.110], trenching and backfilling can be avoided, hence the initial costs for civil works can be reduced significantly. The trench depth in remote locations can be between 0.1 m to 0.2 m at some points due to protection reasons.

b) Bottom of trench

Where threatening pressure is expected to be applied to the in-trench cable, the bottom of the trench should be made flat by using backfill soil which should not contain cable-damaging obstacles.

c) For stony or rocky areas

For stony or rocky areas where cable burial is not always possible, any on-surface part of the cable can be covered by sand and/or soil.

d) Micro-trenching

Installing the DSA cable on an asphalt road or concrete pavement should be avoided if vehicles can tread over the cable because hard gravel could lie between the cable and the road surface that could easily damage the cable.

To avoid vehicles running over the DSA cable, the micro-trench installation technique identified in [ITU-T L.154] should be applied. It suggests that the cutting depth of a groove in the asphalt should be no less than 7 cm but avoid cutting entirely through the asphalt. It states that groove width may vary (e.g., 10-15 mm).

NOTE – For micro-trenching, clause 2 of [ITU-T L.154] requires that the cable have crush resistance and temperature resistance against hot bitumen during the sealing operation (between 100°C to 170°C).

8.1.3 Cable aerially suspended

The DSA cable may be aerially suspended for a short length to cross a river, valley or road, or to avoid a potential flood, landslide, avalanche or moving glacier. Here, the cable may depend on the cable's self-supporting capability, or the cable is lashed to a suspension wire.

The use of a stable rock or tree could be more cost-effective for anchoring than building utility poles. Suitable wire, metal fixtures or cable clamps should be appropriately used with trees considering that the growth in height and thickness of trees varies depending on the tree species, age, sun/shade, rain, temperature and other factors. The smallest suspension wire with a satisfactory strength should be used because the effect of wind and ice loading increase with enlarged suspension wire.

As suggested in clause 4.5.3 of [b-IEC TR 62691], unless the DSA cable is constructed to withstand the lashing to pre-tensioned support wire, it is recommended to attach hanger rings or similar to a pre-provided suspension wire for hanging the DSA cable. Most DSA cable designs which are sufficiently rugged to address the other criteria will be able to withstand lashing.

Tilting or collapsing trees, or unstable rock should not be used. Cable aerial span length should be determined by considering that the maximum tension will depend on the span length, sag, level change, wind force, ice formation and temperature change.

To suppress vibration, rotation and jumping of the aerial cable due to wind and/or snow, counter weight(s) can be used; this cancels the cable-rotating wind force from a frozen snow-wall piled on the cable.

See clause 8 of [ITU-T L.261] for design of suspension wires.

8.1.4 Cable submerging

Clause 7.3.13 of [ITU-T L.110] states that "DSA cables with welded metallic core tube under the lake, pond or shore, may be placed for water depths up to 100 m". Other types of DSA cables may be used in shallower depths. For the cable in Appendix I of [ITU-T L.110], Table I.1 suggests increased durability. Cable movement from water movement should be restricted using simple infrastructure.

Selection of overhead or underwater should depend on the water movement throughout the year, in addition to affordability and reliability: underwater trenching, sandbags or cable external protection demand excessive cost. Places used for fishing or ship anchoring should be avoided.

A warning, publicity and bulletin board may also be needed to minimize human disturbances.

Underwater cable joints should be avoided and the gradient of the cable route along the river bed or lake shore should be selected so that the gradient is as gentle as possible.

[ITU-T L.430] and clause 4.8.3 of [b-IEC TR 62691] describe this aspect.

8.2 Installation planning

8.2.1 Cable route consideration

a) Cable and installation criteria

The following criteria for the cable and installation should be considered for the route of the DSA cable:

– Low cost and ease of installation (on-land to water to air) in a DIY manner by non-skilled local people;
– Acceptable MTBF, MTTR and availability;
– Moisture/water block capability, water pressure resistance (when submerged);
– Temperature range;
– Bending durability (minimum radius);

  NOTE 1 – [ITU-T G.657] fibre with improved bend characteristics is to be considered to avoid maintenance of induced losses due to sharp bends leading to additional joints (to rectify high loss points) on the optical fibre cable link which may be a frequent scenario, post installation in DSA.

– Tensile strength;
– Crush strength;

  NOTE 2 – The optical fibre cable should be crush resistant so that should a road construction machine hit the cable, it would not break at the first contact. Which may allow the driver to notice the cable and put it aside.

– Rodent /animal resistant;
– Vibration resistant;
– Fire resistant;

– Accessibility to the cable.

NOTE 3 – It is imperative that the laid fibre cable be as accessible as possible in order to provide a quick maintenance and repair.

b) Cable route

For cable installation works, the use of a vehicle road or walking trail is not always possible or cost effective. In order to take advantage of the lightweight and robust nature of the DSA cable, short-cut routes not following already existing roads or trails could be considered where empirical knowledge by the local community about the geography, climate and weather rooted in the region is critically important.

i) The route along the road or walking trail

The moving drum method to lay the cable can generally keep the cable tension minimum, but routes where cable drum jerking could happen should be avoided to avoid cable tension increases because of the drum inertia.

The moving drum method may not allow the cable to go beyond tall obstacles near the roadside such as poles and trees. The cable also cannot go beneath fixed covers or plates on the existing trench or groove.

The cable end-pull method can install the cable not only along the road but flexibly a little away from potential danger such as traffic, rock falls from a road-side cliff, road construction and maintenance, etc.

ii) The route through unexplored land

It is necessary for the local community to jointly conduct a route survey through unexplored land. The cable route should be selected where a walking trail can be created by cutting trees and branches and removing obstacles.

Using the cable end-pull method into unexplored land, it is important to consider how and where to cross the valley, river or other geographical barriers. When a long steep route is inevitable where cable could slide, the route should include some short horizontal loops or slack on the cable at intervals to absorb cable tension caused by the cable slides.

To avoid the cable sliding, the optical fibre cable may be buried at less than 5 cm depth.

Collaboration with local administration and with other infrastructure maintenance teams, such as National Highways authorities, Railway authorities, etc., may lead to minimizing cable maintenance of these routes, which will result in improving the MTTR.

Clause 3.2 of [b-IEC TR 62691] describes general considerations on optical fibre cable routes.

8.2.2 Selection of the cable and installation schemes

a) Selection of DSA cables

For use in the cable route selected, suitable DSA cable should be selected by considering the following points with a view to meeting the criteria described in clause 8.2.1, a):

– terrain and landform;
– landslide, avalanche, tectonic movement, dune movement;
– extreme climate and weather, e.g., heat/cold wave, heavy rain, heavy snow, icing, flash flood, storm, wild fire;
– vibration caused by vehicle or, strong wind when suspended;
– attacks by flora and fauna;
– hitting the cable by a road construction machine;

NOTE 1 – DSA cables should be crush resistant to withstand at least one impact by a road construction machine.

– human error, theft/vandalism;
– economic resources and human resources (skill and manpower) available;
– local civil work capability: experiences, local practices and achievement record;
– tools/machinery available for cable transporting, cable handling and trenching;
– transport of the cable drum to where cable laying starts, including human, cow, cart, wagon, vehicle and helicopter transport.

NOTE 2 – Table I.1 shows performance of the DSA cable described in Appendix I.1 of [ITU-T L.110].

NOTE 3 – Icing of the cable increases cable tension and wind loads.

NOTE 4 – Cable vibration may be caused by vehicles or strong wind when suspended.

b) Cable installation schemes

Laying the cable over land, under water or in the air should be selected by considering the terrain and landform, the ground surface conditions, climate, weather, flora and fauna, cable specification, pros and cons of each cable installation scheme and local capabilities to help install and maintain the cable. Other than laying the DSA cable on the ground surface, three schemes can be selected for a long cable without cable splicing.

i) Direct burying

For protecting the landscape, avoiding theft/vandalism and mitigating extreme environmental impacts, cable burial is effective to an appropriate depth (see clause 8.1.2 for trench/groove depth).

ii) Aerial suspension

For the cable to be aerially suspended over a limited length in a DIY manner, a shorter suspension length is desirable as suggested in clause 3.2 of [b-IEC TR 62691]. During installation, the cable is, first placed on the ground level and aerially suspended as the second step, it should be carefully handled so as not to excessively bend the cable. A cable-bend protector should be used as appropriate for this purpose, Figure 2 in clause 9.2.2 shows a bend protector concept for safe handling of DSA cable.

NOTE 1 – Appendix I.4 of [ITU-T L.150] shows examples of mean length and maximum length between poles as 25 m-80 m and 50 m-200 m, respectively, for aerial installation of conventional cables.

NOTE 2 – The suspension span of 240 m for the cable in Appendix I.1 of [ITU-T L.110] is in operation since 2011 in the Tokachi river crossing in Hokkaido Japan, where suspension wire is used for lashing.

iii) Submerging

Although clause 7.3.13 of [ITU-T L.110] generally states that "DSA cables with welded metallic core tube under a lake, pond or shore, may be placed for water depths of up to 100 m", the cable shown in Figure I.1 of [ITU-T L.110] can go well beyond 100 m. Other DSA cables may be appropriate for shallower depths. See Table I.1 for more information.

See clause 4.8.3 of [b-IEC TR 62691] and [IEC 60794-3-30] for guidance for cables for lakes, river crossings and coastal applications.

8.2.3 Cable segment and cable length considerations

a) Cable segment layout

Within a point to point cable route, fibres are dropped or a cable is branched. Specific cable length for each cable segment between the start point, drop points (or branch points) and end point should include additional length of, e.g., 10% or 100 m of the route length measured with a GPS device or other means that should cover unexpected needs for cable-route changes and avoid additional cable splicing.

The cable joint boxes (closures) installation locations could be flexibly selected on site if the cable includes additional length. For cable jointing and for fibre dropping, extra cable length of at least 10 m should be included at each cable end for fibre splicing. See clause 8.2.3 b).

The length of the optical cable segment: the cable should be longer than the "point to point" length so that while displacing it (when cultivating, etc.), the tension will not disconnect or make vulnerable the splicing.

$$L > l + 10 \text{ m}$$

where:

L: cable length

l: distance between two cable-joint closures

The length of the optical fibre cable wound onto the cable drum should be determined by considering the above cable segment length, ease of cable handling, drum transportation and the drum weight (drum + cable) for using the drum moving method. The drum should carry the cable length covering as many segments as possible so that the residual cable is efficiently available from multiple-segment length without cable splicing.

The cable on the drum should be long enough to avoid unnecessary splicing when laying the cable for a long distance.

b) Cable joint closure strength

The joint closure for the optical fibre cable should be strong enough or protected in order to avoid damaging it; otherwise, the network will be vulnerable despite having a suitable fibre cable.

Sealing requirement for pole and underground mounted joint closures for DSA applications should meet [ITU-T L.201].

c) Required cable length to allow cable jointing

When installing the DSA cable, an extra length of cable should be needed for use in cable jointing and branching. The extra cable length required is a minimum of 10 m, depending on the cable splice practices.

A minimum 10 m length of extra cable is typically needed for correct and safe splicing as suggested in clause 4.5.1 of [ITU-T L.158]. The cable length to be stored is determined by the characteristics and dimensions of the cable closure and distance from a convenient splicing location. Cable splicing should take place while respecting cable bending limits set by the cable manufacturer.

8.2.4 Cable tension consideration

When installing DSA cables, the maximum cable tension must stay within the limit of the cable tensile strength. With the cable-drum position fixed for installation, the use of rollers or quadrant brocks can minimize the tension of the cable while being pulled and keep the cable bend radius safe. With the cable drum position moving, cable tension can be generally kept low. Manual pulling from the moving drum may be used to minimize cable tension. Care should be taken not to cause jerking of the cable drum because of the drum inertia.

When a cable is aerially suspended, its tension can be minimized if the cable is lashed or clipped to a suspension wire.

When shallow buried after trenching or ploughing, the cable tension is generally much lower than its rated tension, clauses 3.3-3.5 of [b-IEC TR 62691] describe this aspect.

8.2.5 Installation temperature

Ambient temperature when undertaking installation should be within the limits set by the cable manufacturer. Although cables with polyethylene sheath are usually rated for storage and operating temperature between −40°C to +70°C, it is recommended that the installation temperature range be −15°C to +50°C.

Installation above the temperature limit may result in softening of the polyethylene sheath material, thus increasing friction and inviting physical damage. Installation below the temperature limit will cause the cable to become very stiff, which will make handling very difficult and can cause permanent damage to the cable. Either may have a negative impact on the installation. Cables should be stored in the ambient temperature within the specified installation temperature range for 12 hours before installation starts.

The cable should be installed where ambient temperature throughout the year does not exceed the cable operating range set by the cable manufacturer.

8.3 Pilot test of a DSA cable installation

8.3.1 Introduction

Before installing a long DSA cable in a region, a set of pilot tests could be useful using short cable pieces, e.g., 50 to 100 m each and exposing them to combinations of multiple disturbances at several representative terrains/landforms and the natural/societal environment in the region and using local personnel. Real disturbances are available only in the field but are not reproducible in test laboratories. The cable should be installed realistically with help from non-skilled local people based on their knowledge, daily practices and familiar hand tools.

Throughout this pilot testing, problems, issues and remedies will be identified and experiences acquired that will contribute to successful cable installation and yet it will help local communities, equipment providers and administration to unite with each other and become prepared. The cable implementation unit will be, for example, administrated by the government, cable manufacturers, equipment vendors and civil work leaders of the local communities.

8.3.2 Test plans

Changes in optical losses should be measured before and after for simplicity, or periodically if incremental optical loss changes are expected. Key information of cable location, its installation condition, environmental aspects such as terrain, landform, weather, temperature and other physical disturbances, if any, should be periodically recorded during the test.

a) Cable durability tests

Various cable installation schemes should be tested, such as shallow burial, aerial wiring typically using suspension wire (with hanger rings), fixed to poles, trees, building walls or rocks, etc., submerging and other schemes that should be chosen by considering landforms, terrain and environment such as wet land, dry land, mountains, forests, rocky fields, peat, pampas, cold area, hot area, etc.

Multiple disturbances such as crushing, tension, bends, vibrations, twists, etc. may be applied to the cable, by wind, rain, flooding, snow, avalanches, land slides, wildfires, grassfires, biological attacks, tree falls, UV exposure or even tectonic movement and dune movement.

b) Cable installation/restoration test

The cable installation can be fast, cost-effective and yet highly reliable if the proposed cable is robust and is laid on the surface of the ground from vehicles or even from a helicopter, if an access road is not available and the terrain is difficult to approach. The cable is shallow buried, aerially suspended or relocated helped by the local people using hand pickaxes or light tools but not using heavy machinery. It is useful to try such cable deployment prior to the real deployment even for short pieces of cable over different terrain and landforms and, thus, identify problems and remedies.

c) Cable slack (surplus) vs tension increase

The effectiveness of providing cable slack of an appropriate amount to suppress increases in cable tension caused by tectonic movement, dune movement or slope-slipping effects of the cable can be tested while the cable is expected to be exposed to multiple other disturbances at the same time.

d) Cable attenuation vs. very high/low temperature

Where extremes of low and high temperatures are expected, it is important to test the effects with other disturbances at the same time.

e) Burial depth vs hazards (temperature buffering effect)

This test may be useful if ambient temperature is extremely high or low, say, less than minus −50°C and/or higher than +70°C while other multiple disturbances are expected to be simultaneously applied.

8.4 Training of installation crews

The installation crews should be trained not only for installing optical fibre cable in a cost-effective DIY manner but also for sensitizing the local community to proactively protect and maintain the cable as the important lifeline it is for, e.g., health, education and businesses. The training should also cover potential changes on site, if any, of the pre-determined cable route and installation scheme (on-land, water and air).

The installation crew therefore should appropriately understand the cable durability, pros and cons of cable installation schemes and installation key points including the use of jigs and tools such as bend protectors (see clause 9.2.2), metal fittings, suspension wire and even a PET-bottle rockets (see clause 9.2.3).

Such training should be developed planned and given in cooperation with cable manufacturers, administration (central or local) and leadership of the cable installation crews prior to, during and even after the installation. Cable installation crews should also cover maintenance and repair of the cable, which can enable them to understand the threat perceptions and carry out preventive maintenance.

The training should be safe and cost-effective covering difficult landforms, terrain and region-specific disturbances. This leads to minimizing of the OPEX and MTTR. Self-motivated careful maintenance and prioritized fault-preventive measures based on the knowledge and experiences of the local community greatly extends the MTBF of the cable lifeline.

Imparting some basic skill sets in cable construction will prove extremely handy in the case of optical fibre cable installation projects or for restoration of cable faults. Simple video based and/or pictorial training skill sets in local language can be a very effective training technique.

NOTE – [ITU-T L.1700], advises "Affordability (CAPEX and OPEX) would be improved if installation, operation, maintenance and repair of the infrastructure were supported by the local community in a do-it-yourself manner."

Clause 3.7 of [b-IEC TR 62691], addresses information and training under installation planning.

9 Installation methods

9.1 General considerations

As discussed in the following clauses, the DSA cables utilize a cable design which is sufficiently robust for DIY installation. Several such designs are discussed in [ITU-T L.110].

One of several options is a metal tube construction with a welded seam as identified in clause 8.2.3 of [ITU-T L.110]. Here, a thick radial sheath and multiple layers of wire armouring are not necessary even for direct surface application.

Such a cable is sufficiently lightweight, thin and robust so that local people can easily handle it, thus not only a direct surface installation, but a length of shallow burial, aerial wiring and under water submerging can be best selected on site. However, the relatively low bending durability of small-diameter cable must be carefully handled.

9.2 Installation procedure and cable handling

9.2.1 Cable installation from a drum

a) Drum positioning

The cable drums should be brought into the place where the cable installation starts and where the cable is branched and/or jointed with cable closures. The drum location should be selected where access, cable handling, equipment accommodation and operation can be easy and safe when installing, repairing, upgrading, and testing the cable. The drum can be carried into the place where manual DIY installation should start by using trucks or other vehicles, or a helicopter as a last resort. The use of animal cart or manual transport should also be considered as appropriate.

b) Moving drum method

The moving drum method is easy and quick to lay a long cable if a vehicle is used. However, once the cable is laid along the drum trail, it is difficult to place it over tall obstacles such as poles, trees and other structures and it is also difficult to go through a tunnel or to go under a bridge. Moreover, it is difficult for the moving drum to cross a river, a steep valley, rough ground, wet land, jungle, or unexplored land with obstacles. In some cases, light and small drums could be manually moved across difficult terrain using methods such as a backpack carrier or a hand cart.

c) Single end-pull method

Since the DSA cable is generally lightweight, it can be laid manually over a distance using a single end-pull method even where there is no vehicle road nor walking trail. Local people should carry the cable in a synchronous manner at intervals of for example every 100 m, depending on the cable weight, terrain, landform and route length.

Speed-controlled cable winching equipment may be used if affordability permits. In such cases, a sock-type grip with a rotary shackle with a fused (breakable) link to prevent excess strain may be fitted to the pulling end of the cable as shown in Figure 1.

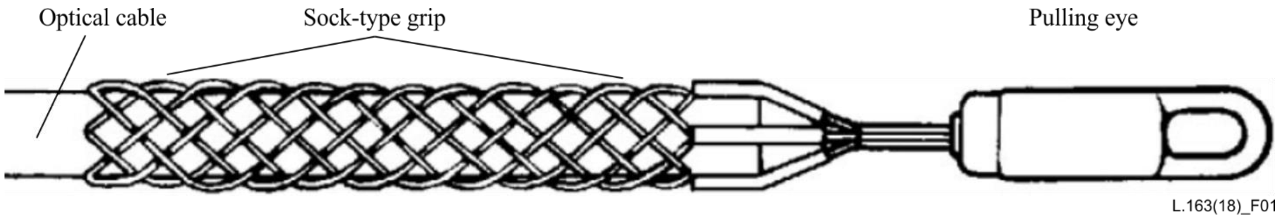

Figure 1 – An example of sock-type cable grip (see Figure 5 of [b-IEC TR 62691])

NOTE – Clause 4.5.5 of [b-IEC TR 62691] details the use of winches and states "Pulling speed can be gradually increased up to the maximum speed of 75 m/min".

d) Midpoint drum method

When the moving drum method is not possible because of difficult terrain and, when single end-pull installation is also difficult due to the load limitation or interference, the midpoint-drum method with "the figure-of-eight pattern" should be employed.

Here the cable drum is placed at a midpoint and, after the end-pull method used in one direction, the remaining cable is removed from the drum and laid on the ground in a figure-of-eight pattern to avoid twisting the cable. The end-pull method is then used in the opposite direction, for more detailed information refer to clause 4.5.7 of [b-IEC TR 62691].

9.2.2 Cable bend protection

When moving the cable in a different direction from the cable axis with bare hands, particularly by non-professional local people, care must be taken to avoid excessive bending or cable kinking. As the cable becomes smaller, this problem becomes more severe. Particularly compact DSA cables may be prone to kinking. For very small DSA cables, a bend protector should be always used so that the minimum bending diameter should not be exceeded.

As shown in Figure 2, the bend protector should have a cable guide groove with, e.g., half or quarter circular shape, with a circular radius larger than the cable bend limit. All the local people who help in the cable installation should always carry bend protectors and use them whenever necessary.

NOTE – Clause 4.5.4 of [b-IEC TR 62691] notes "In general, a minimum bending diameter of around 20 times the cable diameter is considered appropriate but when installed under tension, it is suggested that this ratio may be doubled".

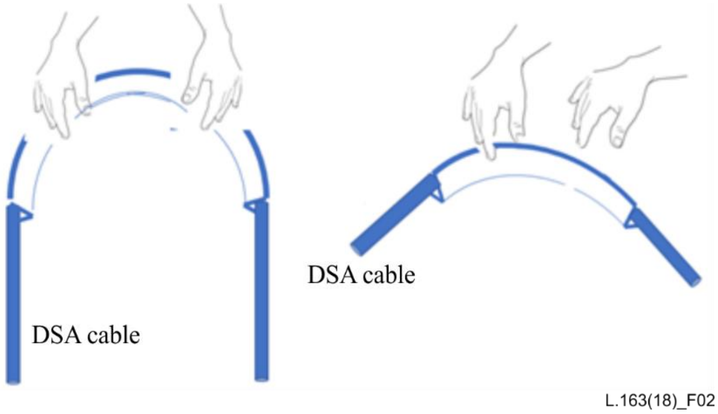

Figure 2 – A bend protector concept for safe handling of the DSA cable

It is important for the DSA cable that the minimum bending diameter of the cable set by the manufacturer be known. Most DSA cables have small minimum bend specifications. In fact, the minimum bending diameter set by the manufacturer for the φ11-mm DSA cable with wire armour shown in Appendix I.1 of [ITU-T L.110] is 110 mm during installation and 220 mm after installation (for many years of operation) as shown in Table I.1 of Appendix I.

9.2.3 Passing the cable to the other side of a river, lake or valley

To span the cable over a river, lake or valley, first use a lightweight lead rope to cross the river or lake using a drone, PET-bottle water rocket or other means. The 2nd or 3rd higher-tension rope should then pull the cable across the river, lake or valley. During this operation, the tensile rating of the DSA cable should not be exceeded. The cable end grip may be used as described in clause 9.2.1. For more information see clause 4.5.5 of [b-IEC TR 62691].

10 Risks with insufficient infrastructure and remedies

10.1 Risks

[ITU-T L.1700] identifies "ultimate affordability" as the top-priority requirement followed by the best-effort reliability toward avoiding digital exclusion and bridging the digital divide.

The DSA cable exposed on the ground's surface will sooner or later be covered by soil, sand, snow or flooding or occasionally lifted from the ground after a flood, change of landforms or tree growth as noted in clause 6 of [ITU-T L.110].

Biological attacks to the DSA cable may include not only mammals, insects, birds and micro-organisms as addressed in [ITU-T L.161], but also reptiles, amphibians and even fish. Unnatural disturbances may include near-by construction, civil works and theft/vandalism.

The DSA cable shallowly buried, partially suspended or submerged will also be exposed to such disturbances.

10.2 Remedies

To cope with such difficulties, robust cable structure, safe cable routes, an appropriate cable installation scheme and physical safe guarding measures of the cable should be properly selected and applied by making the best use of the knowledge and experiences of the local community. The help of local communities is the key particularly in rural areas (see clause 8.4).

Requirements for DSA cables are identified in [ITU-T L.110]. [ITU-T L.430] describes the external protection devices that can be utilized during/after the installation and cable restoration when partially marinized.

Remedies against risks common to conventional optical fibre cable systems are generally acceptable if the affordability permits. [ITU-T L.302] addresses equipment alarms, ring topology and protection switching. Signal-degradation detection could reduce the time to locate faults and thus reduce the time of connectivity outages and so reduce the MTTR.

When early failure takes place, or a threat emerges, the cable may need to be replaced, relocated, buried, suspended or submerged by the help of local people. The system availability and affordability throughout its life cycle would be maximized by the following actions:

– patrol monitoring, danger preventing/removing and maintaining the cable particularly at an early stage after installation;
– careful and detailed manual/physical safeguarding of the cable and of the cable's surrounding environment including the use of optical time domain reflectometry (OTDR) and use of surveillance and crime prevention camera systems including the use of drone technologies;
– quick fault detection and quick restoration;
– quick fault diagnosis and application of fault preventive measures;
– building of a cooperative support team among neighbouring local administrations, local communities, and cable/equipment manufacturers where spare equipment and spare DSA cables with cable-joint tool kits should be maintained in common for quick and affordable recovery minimizing MTTR;
– avoid laying underground DSA cables in areas where continuous excavation is taking place such as coal mining and hilly terrains;
– planning aerial cable routes with standard grounding of armoured cables.

For efficient replacement and repair of the cable, depots should be created to store the consumables for maintenance of the cable route, at feasible locations or as designated by the local administration to improve the MTTR and to avoid the inconveniences of material transportation. As-build records along with video recording with optical fibre of the cable route co-ordinates (latitudes and longitudes) should be recorded, preferably in a geographic information system (GIS) will help from a centralised network operation centre (CNOC) team to guide the local maintenance team to reach the spot of outage with ease.

These as-build records and their updates during the life cycle of the optical fibre cable route will help local government/authorities in the providing the right of way (RoW) permissions for new optical fibre cable laying and thus enable them to decide whether or not to allow duplication of the network and so monetise the DSA asset, subject to suitability of new requirements.

Since the optical fibre cable will be laid directly on the ground, the population nearby must be informed, sensitized and educated in order to protect the infrastructure. Publicity and education for the local community and visiting people are important, particularly with the following public awareness context:

– the optical fibre cable carries an enormous amount of information vital to the community;
– the optical fibre cable has no valuable materials to be sold such as copper or aluminium;
– local communities need to develop the ability to protect/restore the cable as much as possible.

Objectives of the sponsors of such an infrastructure build should also include welfare schemes for local populations which may include providing education, imparting skills to improve the local professions, entertainment, etc., which can convince and enable the local population of the importance of safeguarding the DSA network.

Chapter III of [b-ITU-T TR-OFCS] addresses various aspects of optical fibre cable installation.

Appendix I

Japanese experience: example of DSA cable performance

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

Table I.1 describes the performance of the DSA cable described in Appendix I.1 of [ITU-T L.110].

Table I.1 – Performance of the DSA cable

Criteria	Values	Comments
Ease of installation (on-land to water to air) in a DIY manner by non-skilled local people	– Cable diameter 11 mm, 8 mm, 3.5 mm – Cable weight 180-200 kg, 85 kg, 20 kg – Cable length Max. 15 km	Cable manufacturer confirms through 20-year, 20 000-km experiences in Japan.
Moisture/water block capability	100% (without any through-hole)	Pin-hole test is conducted during production by manufacturer.
Bending durability (minimum radius)*	110 mm (during installation) 220 mm (after installation)	Cable manufacturer confirms.
Temperature range	– 30°C ~ +60°C (during installation) – 50°C ~ +70°C (after installation)	The acceptable range could be further expanded, subject to specific multiple disturbances that should be confirmed by pilot testing (see clause 8.3).
Tensile strength	3 500 N	Cable manufacturer confirms.
Crush strength*	5 000 N/100 mm	Cable manufacturer confirms (No optical loss increase was observed up to 20,000 N/100mm)*.
Water pressure resistance*	100 m and beyond	Clause 7.3.13 of [ITU-T L.110] states "up to 100 m", and un-uniform load of 2 000 kg/100 mm was acceptable as seen in Figure 7 of [b-ITU-T L-Suppl.22]. Un-uniform load of 2,000 kg/100 mm may be severer for the cable than uniform water pressure at 2 000 m depth (200 kg/cm2).
Rodent resistance*	No damages observed to the welded core tube	After Exposed to four brown Rats and roof rats for 6 days.
Vibration resistance*	No damage observed	After simulated cable vibration of 10^6, 10 Hz, 5 mm(p-p) using a shaker set at 1 m cable-span centre, both ends cramped.
Fire resistance*	Optical loss increases of < 0.03 dB	After one-spot heating by gas torch flame for 15 minutes at 1 180°C.
***** The test results are included in [b-ITU-T L-Suppl.22].		

Appendix II

Japanese experience: a temperature test of an example DSA cable

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

Figure II.1 shows optical loss changes for 20 heat cycles (−50°C ~ 70°C) for a 4800 m optical fibre accommodated in 200 m, 24 fibre core DSA cable with welded core tube plus wire armour. The 24 optical fibres in the core tube were spliced at each end of the 200 m cable. The optical loss change was <0.06 dB/km at each cycle, and the residual loss was −0.001 dB/km after the test, Thus, the temperature durability of the DSA cable after installation was confirmed under the conditions tested.

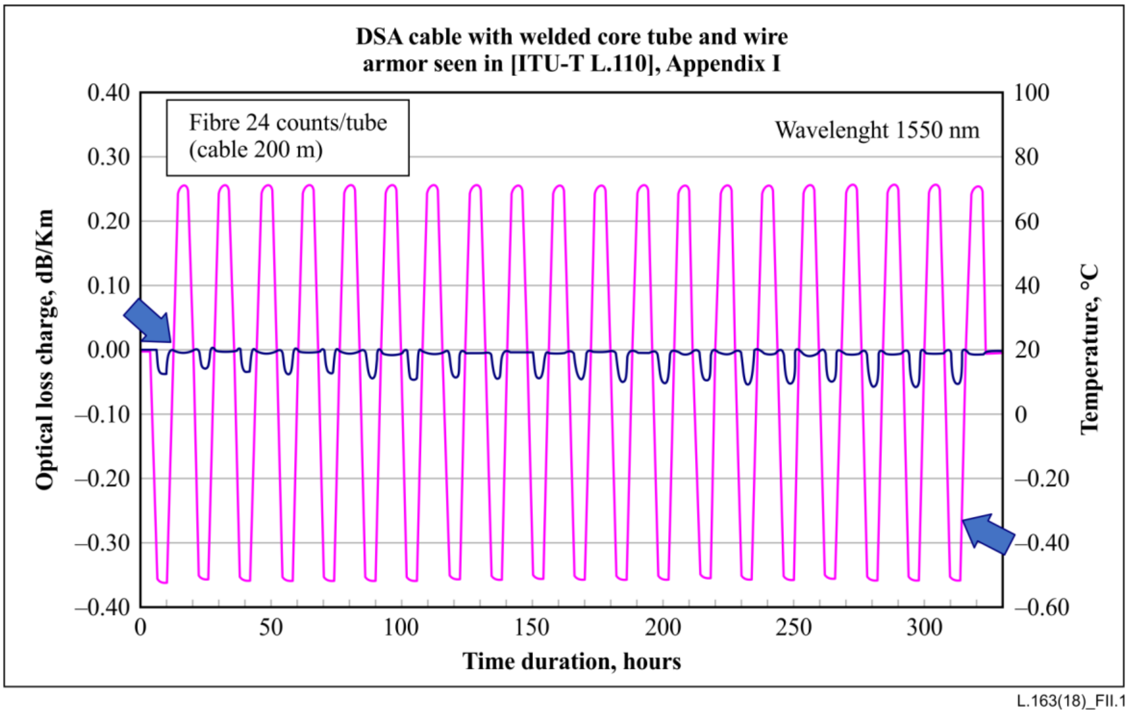

Figure II.1 – Example of optical loss changes of a DSA cable against heat cycle

Appendix III

Tanzania experience

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

III.1 Introduction

Tanzania undertook various efforts to bridge the digital divide by implementing the National ICT Broadband Backbone (NICTBB), creating an enabling environment for investment in optic fibre cable infrastructure such as the East African Submarine Cable System (EASSY) and South East Asia Commonwealth Cable (SEACOM); establishment of the Universal Communication Services Access Fund (UCSAF) to facilitate ICT investment in underserved areas (rural and urban) and development of Internet exchange points (IXPs) for localization of Internet services.

The integration of the NICTBB to the landing points of submarine cables has connected Tanzania to the rest of the world. The results of this are the availability of broadband services at high speed, high capacity and low costs. The primary objective of the NICTBB is to provide broadband connectivity to Tanzanians at all levels including the national, regional, district, municipal, village and the household levels at low cost. The landlocked countries neighbouring Tanzania; namely Uganda, Rwanda, Burundi, Malawi, Zambia and DRC were also linked to the NICTBB and submarine landing points.

However, in spite of the above efforts, lack of right of ways, lack of business viability, lack of ICT infrastructure deployment guidelines and procedures; high cost for civil works, the unreliability and the absence of electricity are among the challenges that exist in Tanzania when deploying the ICT infrastructure (optic fibre networks) in remote areas.

Since 2010 the optic fibre backbone has been deployed and has connected the major towns of Tanzania such as Dar es Salaam, Morogoro, Mbeya, Dodoma, Arusha, Shinyanga, Tanga, Singida, Iringa, Songea, Rukwa and Sumbawanga. The backbone passes through towns and districts covering a distance of more than 15,000 km. The NICTBB aimed at connecting among others hospitals, institutions, telecentres, business centres and schools to benefit from broadband Internet via optic fibre cable networks.

III.2 Optic fibre trench

Depending on the topology, the normal trench between manholes (MH-MH) or manhole and handhole (MH-HH) of the existing NICTBB in Tanzania is laid down at a depth of 1.5 m below the surface of the soil and concreting at depth between 0.2 m-0.4 m at rock soil. This contributes to high costs for the civil works (trenching and backfilling) during cable deployment. Using the optic fibre cable with minimum criteria such as direct surface application (DSA) cables as defined in [ITU-T L.110] the trenching and backfilling can be avoided, hence reducing significantly the initial costs for civil works. The trench depth to some points may be allowed for protection reasons in remote locations and can be done between 0.1 m-0.2 m.

III.3 Optic fibre cable laying

The existing optic fibre cable crossing rocky soil may be managed by pouring heavy concrete along the desired path or fixing cable onto rock with special accessories at a certain intervals. This will ensure the cable does not slip or zig zag on the rocks. In the context of utilizing minimum infrastructure DSA cables in Tanzania's remote areas will reduce the initial cost of the project.

In remote areas cable lying directly on the ground surface is possible and will speed up the deployment process. The fibre cable may be submerged when crossing a river, lake, pond, or wet land or aerially suspended to cross over roads, railways, valleys, rocky outcrops and at the same time take consideration of multiple splices along the cable route.

III.4 Cable maintenance

Putting demarcations along the optical fibre cable route is a procedure used to allow quick identification of the routes along the roads during maintenance of the cable route. The existing optic fibre cable route along the major roads in Tanzania is demarcated using concrete pillars of heights of between 0.5m-0.8m above the ground. The average span between the pillars is 50 m. Using direct surface application cable (DSA) avoids these costs and reduces the operation costs of operating the optic fibre network.

III.5 Length of the cable

The optic fibre cable length deployed in the NICTBB has a length of 2 km-4 km coiled in the drum. Depending on the environment of the local area in Tanzania, the cable length between manholes or hand holes (HH) may vary depending on the planned cable route. Heavy cables make it difficult to be deployed in remote areas where there is no infrastructure to support transportation. Light weight fibre cables need to be considered for easy carriage by people during installation.

III.6 Cable crossing roads and bridges

Normally, the existing optic fibre cable crossing roads and bridges considers an overhead installation at a height of least 4.5 m to allow free passage of motor vehicles. Optic fibre cable crossing the bridges can be attached along with bridge accessories at intervals of 10 m. The same scenario can be considered in remote areas with fibre cable crossing roads or bridges. Using optic fibre cable for direct surface application will require minimum infrastructure to be supported and will reduce the initial cost of the project.

III.7 Optic fibre cable crossing water or dam

In various parts of Tanzania the optic fibre cables crossing water and dam areas were laid down beneath the water surface or overhead (above 2.5 m) to allow passage of boats, logs, etc. This method can be used to optimize the available infrastructure without going against natural/unnatural disturbances or community inconveniences. Other issues for considerations include the following:

– **Optical fibre cable visibility**: The optical fibre cable should be easily visible so that persons engaged in other activities such as civil works on roads, construction, bridges or house building should be able to notice the cable at first sight.
– **Protection of the optic fibre cable**: The optic fibre cable should be durable enough so that when a road construction machine hits the cable it will not break at the first contact. Physical considerations during installation are important. The installer should access the environment and consider the probability of the risks that may occur to ensure that the cable is safe from damage.
– **Joint closure**: The joint closure for the optical fibre cable should be strong enough or protected enough to avoid damage to it; otherwise, the network will be vulnerable despite having a suitable fibre cable.
– **Optical fibre cable accessibility**: Even if the optical fibre cable is strong, resistant to weather conditions and rodents, which makes it suitable for direct surface application, it is imperative that the laid fibre cable be as accessible as possible in order to enable quick maintenance and repair.
– **Public awareness**: Since the optical fibre cable will be laid directly on the ground or pass just below the surface, it is necessary that the surrounding population be informed, sensitized and educated for the sake of protecting the infrastructure.

Appendix IV

Rwanda experience

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

IV.1 Introduction

Bridging the digital divide and provide broadband to all citizens for any country is essential. In Rwanda the country laid a fibre backbone up to the district level completing a distance of 4 732 km. The exercise was done in line of providing broadband access to all citizens disseminated around the country. In the neighbouring areas of all districts there are several business activities such hospitals, telecentres, schools, small companies, etc. which benefit from broadband Internet via optical fibre.

Meanwhile, there are several places within the districts, which are remote areas, ranging from 15 km, up to 50 km distance with a difficult terrain. To provide broadband connectivity via fibre to these places become too expensive and generally they must employ very small aperture terminals (VSATs) in a satellite network as a solution which is relatively expensive and not stable.

To maximize the benefit of fibre with [ITU-T L.110] characteristics, a clear installation method or in other words set criteria needs to be identified. The criteria should tackle the installation, the maintenance and accessibility in general.

IV.2 The criteria for optical fibre cable installation with minimal existing infrastructure

In order to maximize the throughput as well as the network availability using the [ITU-T L.110] standard cable, the following criteria need to be considered:

– **Length of the optical fibre cable**: The optical fibre cable should be longer than "point to point" connection so that while displacing it (when cultivating, etc.), the cable tension will not disconnect or make the splicing vulnerable.

$$L > l + 10 \text{ m}$$

where:

L: cable length

l: distance between two joint closures

– **Optical fibre cable visibility**: The optical fibre cable should be noticeable so that when entities other than the fibre owner are carrying out other activities such as civil works on roads, construction, bridges or house building the cable is clearly visible. (The outside jacket of the cable should be a shiny colour).

– **Protection of the optical fibre cable**: The optical fibre cable should be thick and long enough so that when a road construction machine hits the cable it will not break at the first contact. This may allow the driver to notice the cable and put it aside.

– **Joint closure**: The joint closure for the optical fibre cable should be strong enough or protected enough to avoid damaging it; otherwise, the network will be vulnerable despite having a suitable fibre cable. (Made with a resistant material).

– **Optical fibre cable accessibility**: Even if the optical fibre cable is strong, resistant to weather conditions and rodents, which makes it suitable for direct surface application, it is imperative that the laid fibre cable be as accessible as possible in order to enable quick maintenance and repair.

– **Public awareness**: Since the optical fibre cable will be laid directly on the ground, it is necessary that the surrounding population be informed, sensitized and educated for the sake of protecting the infrastructure.

– **Cable drum**: The cable drum should be long enough to avoid a lot of splicing over long distances taking into consideration the signal attenuation.
– **Cable sliding**: To avoid cable sliding, the fibre cable should be buried at less than 5 cm depth.

Appendix V

Japanese experiences on the DSA cable installation

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

The cables used here are those presented in Figure I.1 of Appendix I of [ITU-T L.110].

V.1 Successful use of Japanese DSA cables under difficult environment

1) In Japan

Conventional optical fibre cables in remote/rural areas have to resist damage from wildlife including birds and animals as well as from shotgun pellets when shooting of birds on the cable if the cable is suspended.

To cope with such difficulties, DSA cables have been introduced over the last >20 years in Japan as shown in Figure V.1. These cables have successfully avoided fatal damage from woodpeckers, rabbits, crows, rats, raccoons, dogs, ants, flying squirrels and shotgun pellets when shooting birds on the cable.

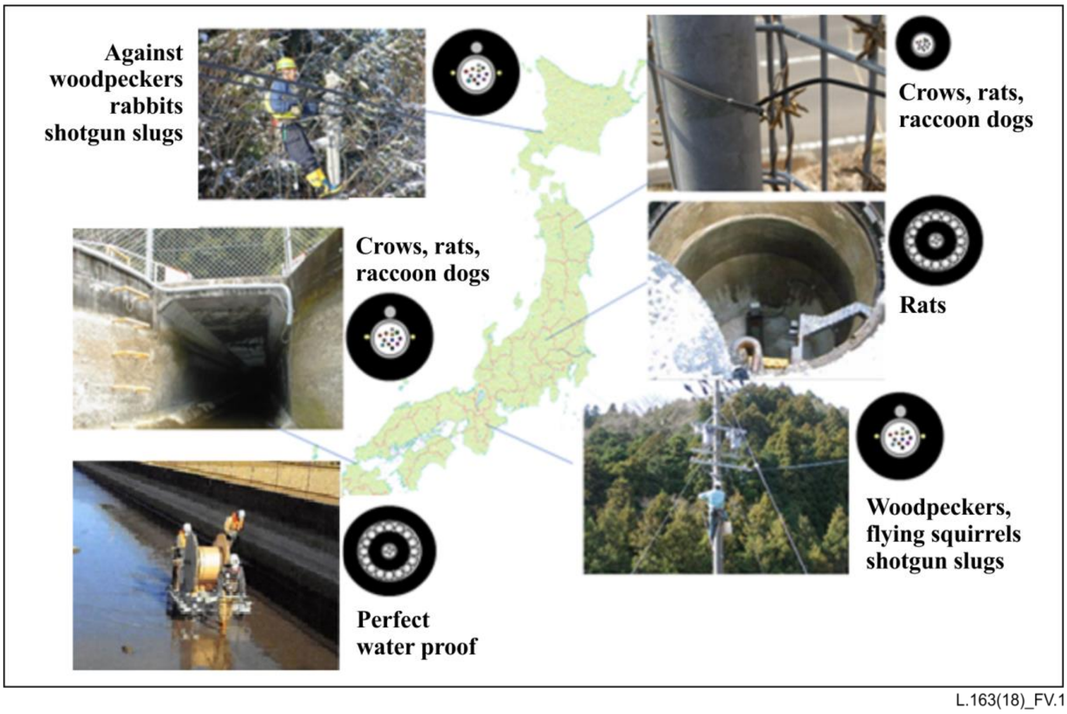

Figure V.1 – DSA cables implemented in Japan between 2000-2016

2) In rural areas in Bhutan supported by APT J3 Project

March 2013, a 1.2 km DSA cable was installed in a rural/remote area in Bhutan after four days of construction. This was conducted as an APT J3 project (ICT Pilot Projects for Rural Areas).

NOTE – The objective of the ICT Pilot Projects for Rural Areas is to narrow the digital divide in the Asia-Pacific region by ensuring ICT access to in rural areas, funded by the extra budgetary contribution from the Government of Japan.

The Internet was made available at a local government office, a school and a hospital (see (1) in Figure VI.2. A DSA cable was suspended on the tree (2), by the local people (3), a 15-cm shallow trench to bury the cable (4) was dug using hand picks (5). To date no problems have been reported after 5 years of successful operation, while to date a wireless connectivity system installed simultaneously very near this cable site has not been working for several years.

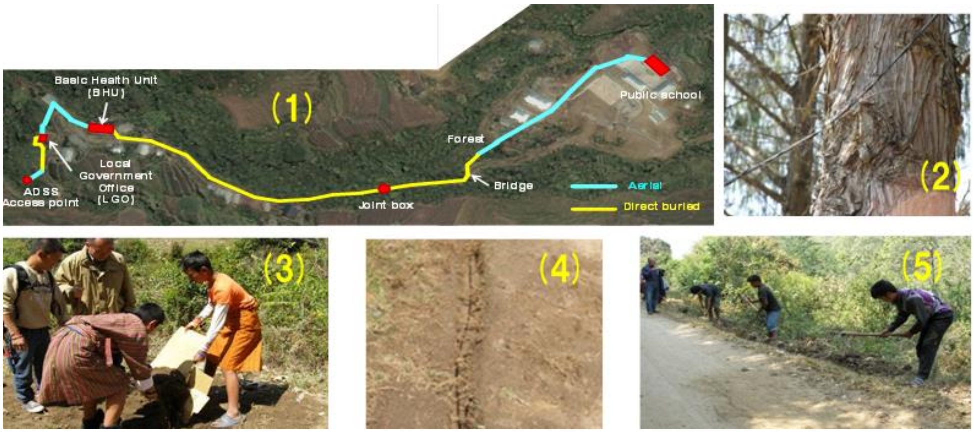

Figure V.2 – DSA cable implemented in Bhutan in 2013

V.2 Underwater

Figure V.3 shows a 35 km DSA cable with welded core tube, as shown in Appendix I.1 of [ITU-T L.110], that was deployed underwater at Tokuyama Dam Lake having the largest water volume in Japan with a max. length 20 km and a max. depth 120 m. The DSA cable was selected for its perfect water-proof capability, long length laying (max.12 km) and because of the ease and cost effectiveness of cable laying using a small boat.

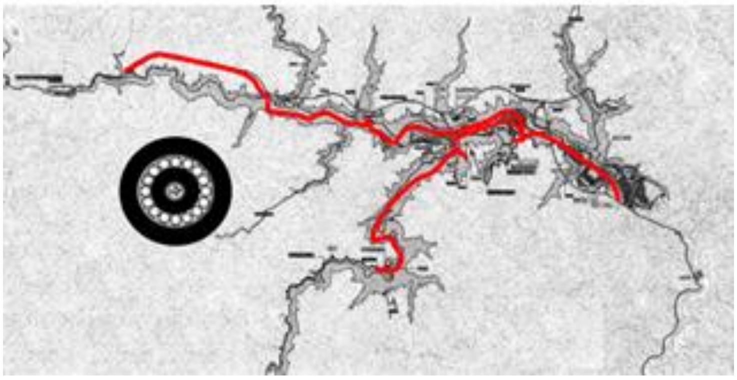

Figure V.3 – DSA cable under Tokuyama Dam Lake

V.3 Fire resistance

When a cable TV operator's office caught fire, the optical signal through the optical fibre was protected by the metal core tube of a DSA cable and survived while the conventional cable signal was immediately blocked. The fire proof testing of a DSA cable with the metal core tube is shown in Figure V.4 where optical loss increase was <0.03 dB during 15 minutes of exposure to a 1 180°C flame of a gas burner.

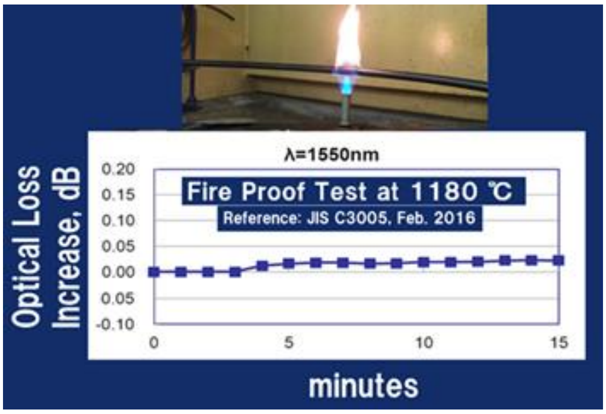

Figure V.4 – Fire proof test of a DSA cable

V.4 Portable DSA cable package for quick installation/recovery

A 5-kg portable cable package is commercially available with a 100-m long, φ4 mm, 30 g/m DSA cable coiled with a light-weight reel. Cable tensile strength is 300 N. Connectors can be pre-attached at both ends of the reeled cable.

The cable is sent out from the reel and manually laid directly on the ground surface, directly buried, suspended in the air or submerged underwater so that the cable-laying construction can be extremely safe, easy and quick. The cable is laid and recovered repeatedly. The cable can be made longer than 100 m. Such a cable reel package has been used in Japan for quick disaster recovery missions or for temporary (few days) outdoor events at remote places for broadband connectivity for Wi-Fi stations, for example.

V.5 Conclusion

DSA cables in compliance with [ITU-T L.110] have been successfully used in remote/rural areas from the ground surface to air to water across Japan for more than 20 years with a total length of 20 000 km. Bhutan also implemented a short-length of a DSA cable with the help of the local community (supported by Japan). No fatal damages to the cables have been reported to date.

Appendix VI

Indian experience

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

VI.1 Introduction

In rural, hilly and inaccessible areas of the country, a massive optical fibre (OF) cable construction project is underway in which about 800 thousand kilometres is planned to be laid by 2020. Of this planned cable project about 300 thousand kilometres have been laid so far. In hilly areas, especially during rains and earthquakes, optical fibre cables can snap leading to disruption of telecommunication services.

For quick restoration of snapped optical fibre cables, aerial and DSA alignments are prevalent. It is important to save the capital and operational costs in the early completion of cable construction projects, optical fibre infrastructure projects and restoration of telecom services during natural disasters.

VI.2 Climatic considerations

There is remarkable climatic variation in different inhabited parts of the country where average temperature varies from −7°C (Leh, India) to +50°C (Alwar, Rajasthan). Icing impact on cable installations is less than 10% and therefore it would be appropriate to use a suitable cable specification for such specific installations and different specifications for the remaining 90% of installations. This practice will result in less capital and operational expenditures, which will finally result in affordable telecom services, especially for the marginalized masses of the developing country.

VI.3 MTBF and MTTR

In most of the rural parts of the country, the network topology is "linear" and average achievable network availability is about 95%. Rural and hilly area network availability of 99% can be achieved when network topology is changed from "Linear" to "Ring".

In India, as utility corridors for telecom services are under development, the cable cuts per 1000 km per month range from 5 to 15 in national intercity cable networks and MTTR of 4 to 12 hours is used by various telecom operators. MTTR of Bharatnet (Rural Digital India Project) is 15 to 20 hours (excluding night hours) and availability of network, which is mostly a linear network, is 95%. MTBF of one month for linear topology and four months for ring topology are acceptable norms. Similarly, MTTR of 8 and 16 hours is proposed for urban and rural networks respectively. The proposed figures of MTBF and MTTR can be considered for a period of another five years. Video based skill sets in local languages, for optical fibre cable installation and maintenance, are being effectively utilised by many telecom infrastructure providers in India to improve MTBF and MTTR.

Appendix VII

Democratic Republic of the Congo experience

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

VII.1 Introduction

Africa remains a continent where Internet access is both uncommon and expensive and this is attributable in part to the continent's lagging social, technological and scientific development. The Democratic Republic of the Congo (DRC) is no exception. There is no denying that the shocking state of the country's communication infrastructure weighs heavily on development and the fight against poverty. Broadband connections are made by satellite and are extremely expensive. The need to create a national backbone infrastructure is not unique to DRC.

Many international and regional organizations and forums recognize that optical fibre networks will make it possible to reduce the digital divide between the well-off and everyone else. A whole range of international, regional and national initiatives are focused primarily on enabling people to be part of the information society through connectivity.

A national backbone would help to improve communications in DRC, a country four times the size of France and still home to several very isolated regions. Despite the political crises devastating the country since its independence and its weak economy, the ICT sector has confounded all pessimistic expectations and expanded. Thousands of jobs have been created and sector revenue has helped to place the country on the path of economic growth.

Sector growth has been driven by the infrastructure of GSM mobile phone operators, connecting the country's main centres.

The absence of broadband is the main obstacle to ICT expansion. The strategic position of DRC at the heart of Africa has implications for the development of both Central Africa and the whole continent. The country bears a responsibility to Africa, requiring it to establish links with international transmission networks, such as SAT-3, the West African Festoon System (WAFS) and the West Africa submarine cable system.

The construction of an Internet backbone in DRC will undoubtedly generate economic synergies that can help to combat poverty, promote national unity and relaunch the national economy. Internationally, the project is integral to the development of a global information society.

VII.2 The local broadband network in the Democratic Republic of the Congo

Transmission media like copper wiring and radio-relay links are approaching their bit rate limits. Expecting rapid developments in customer uses and the need for greater simultaneity and quality, optical fibre has been chosen as it offers very large bandwidths, low signal attenuation and very high rates.

Indeed, optical fibre can have an incredible impact on the communication system. It will allow the high-speed transfer of information over greater distances and with fewer repeaters.

Consequently, only optical fibre, deployed near users, will sustainably provide the very high bit rates required for new users, the multiplication of simultaneous use in the same location and the increasing number of connected devices (multimedia and other smart devices, such as domestic appliances, sensors, connected televisions and so on). Fibre to the home (FTTH) will thus also contribute to developing services and enhancing their quality.

The development of optical fibre is one of the great challenges of the coming decade, given its capacity to drive growth and industrial innovation and create value, jobs and services nationwide. The operational implementation of optical fibre in the country, and in Kinshasa in particular, requires the creation of the optimum conditions for a large-scale industrial roll-out.

The deployment of very high-speed optical fibre networks can contribute significantly to economic development, by boosting competitiveness among companies and to social progress, by creating a more democratic society in terms of access to NICTBBs in the country.

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