# On the Sustainability of Mobile Telecommunications Systems

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## ABSTRACT

It is widely acknowledged that human society is transcending through the era of Society 5.0 which is powered by the rapidly evolving technologies of the fourth industrial revolution. The era is characterized by unprecedented volatility, uncertainty, complexity, and ambiguity in a highly globalised world. There is also a general understanding that sustainability is the paramount paradigm for the Society 5.0 era. Subsequently, and due to increasing concerns about the effects of climate change, the predominant context has been the environmental dimension of the sustainability paradigm. However, in recent times, economic, business, technology and even socio-political aspects have emerged as other dimensions to study and operationalize the sustainability paradigm. This preliminary paper arises from an on-going examination of the technological dimension of the sustainability paradigm. The study focuses on the sustainability of mobile telecommunications systems, especially given the significance of these systems as highlighted by the impacts of the on-going Covid-19 pandemic.

**Key words:** Sustainability, Technological Sustainability, Mobile Telecommunications Sustainability

## INTRODUCTION

Human civilization is transcending through an era of Society 5.0. Coined by the government of Japan, "Society 5.0" was launched in April 2016 as the vision for the fifth stage of society to meet the world's present and future needs, following the earlier hunting, agrarian, industrial and information societal stages (Fukuda, 2020). Under Society 5.0, characterized by unprecedented levels of volatility, uncertainty, complexity, and ambiguity (VUCA), rapidly evolving technologies of the fourth industrial revolution(4IR) are integrated more deeply within the ethos of 'human-centredness' (Matthew, 2019).

The sustainability paradigm has gained more prominence following the adoption of the UN Sustainable Development Goals (UN-SDG) together with heightened concerns about climate change effects. In this regard, much discourse on the sustainability paradigm has tended to emphasise the "environmental" aspect, albeit, that triple bottom line accounting also includes social and economic dimensions. Intriguingly, the triple bottom line accounting framework does not highlight a technology dimension for the sustainability paradigm. However, in an uncanny sense, the Covid-19 pandemic has exposed the significance of the technology dimension of the sustainability paradigm as telecommunications systems enabled essential industry during the widespread lockdowns.

While playing a crucial role in supporting other socio-economic systems during global catastrophes, such as the ongoing Covid-19 pandemic, the telecommunications sector itself has been affected by an increasingly challenging global environment and many other prevailing factors. According to the ITU Windsor Place Consulting report (Minehane, 2020), mobile network operators reported massive demand for network bandwidth due to increased reliance on tele-remote services. In addition to the scarcity of spectrum and instabilities in the global supply chain system that delayed network rollouts (Karmaker et al., 2021; Belhadi et al., 2021), mobile telecommunications systems firms in different parts of the world are dealing with network capacity and network resilience concerns. With the increasing instances of VUCA events and stressors, there are correspondingly increasing concerns about the sustainability of global system for mobile communications (GSM) networks among various stakeholders including such as governments, regulators, investors, operators, equipment vendors, systems integrators, and society. In an era where hyper-interactions between VUCA events and technological systems have become critical for human activities, this raises the question as to how to sustainably manage mobile telecommunications systems (MTS).

This paper arises from an ongoing research investigation into the sustainable management of mobile telecommunications systems (MTS). This paper includes a brief review of the sustainability paradigm with emphasis on the technology dimension. Because the MTS comprises both engineering (or technical) and business structures, the discourse articulates life stages of mobile telecommunications systems and outlines the value chain of mobile telecommunications business as two aspects of a conceptual framework for the sustainable management of mobile telecommunications systems.

## SUSTAINABILITY PARADIGM: THE TECHNOLOGY DIMENSION

According to Chandler and Munday (2011), the verb “sustain” means “to keep in existence” or to “maintain” or “to cause to continue in a certain state for an extended period or without interruption”. The Oxford Dictionary states that to “sustain” is to maintain in good condition or working order, or to “to provide for the upkeep, running or general maintenance of”. That which is sustainable is “capable of being sustained or maintained at length without interruption or weakening” (Merriam-Webster, 2004) or at a certain rate or level (Chandler and Munday, 2011). It is noteworthy that the term was originally coined in German as “Nachhaltigkeit” by a Saxon bureaucrat who sought to describe “the practice of harvesting timber continuously from the same forest” (Caradonna, 2014). These definitions suggest that sustainability (with synonyms as durability, endurance, permanence, fixity, serviceability according to Pharos-Online Dictionaries (2014)), concerns three main aspects: existence, duration and performance. In its simplest form, sustainability is about “constant existence at desired performance”.

In the Brundtland Report (WCED, 1987), sustainability is defined in the context of development “that meets the needs of the present without compromising the ability of future generations to meet their own needs”. The WCED definition of sustainable development is generally discussed in terms of environmental, social and economic dimensions and triple bottom line (TBL) accounting of sustainability (Sala, 2020; Gimenez et al., 2012; Neri et al., 2021). The environmental dimension focuses on efforts undertaken by society and firms to reduce the impact on the environment and ecology. The social dimension concerns the management of “intangible resources” such as social values, people’s skills, and relationships. The economic dimension refers to the production systems of firms, together with their business and financial performance to ensure return on investment. This economic dimension is sometimes referred to as business sustainability emphasising the achievement of revenue growth and capital profitability (D'Heur, 2015).

The antecedents that promote the sustainability of social and environmental systems have been examined vastly in scientific and policy research (Costanza et al., 2006). Acknowledging the inherent interconnectedness between humans and technological systems (Denton, 2014), UN-SGD 9 focuses on building sustainable and resilient infrastructure and developing technological capabilities to support socio-economic development. This implies that there is a technology dimension to the sustainability paradigm; hence, the remainder of the paper explores this technology dimension in the context of mobile telecommunications systems.

## MOBILE TELECOMMUNICATIONS SYSTEMS

Mobile telecommunications systems (MTS) enable "the transmission or exchange of information over a distance using electrical, radio, optical, or other electromagnetic signals, as by telegraph, telephone, radio, television, (in later use) the internet and so forth" (Oxford, 2019). Mobile telecommunications systems are comprised of a set of interconnected radio access, transport and core networks that allow the use of portable cellular devices such as mobile phones "for connecting to a telecommunications network in order to transmit and receive voice, video, or other data" (Encyclopaedia Britannica, 2005).

*Table 1: Comparison of Mobile Cellular Generations, Source: (Ahmed et al., 2015)*

| Technology | 1G | 2G | 3G | 4G | 5G |
|---|---|---|---|---|---|
| Design Began | 1970 | 1980 | 1990 | 2000 | |
| Implementation | 1981 | 1991 | 2001 | 2010 | 2020 |
| Services | Analog voice | Digital voice, short messages | Higher capacity data services | Higher capacity, completely IP-oriented, multimedia data services | Higher capacity, low latency and massive access, IP-oriented, multimedia data services |
| Standards | AMPS, ETACS, NMT etc | TDMA, CDMA, GSM | WCDMA, CDMA-2000, UMTS | Single standard (LTE) | |
| Data Rate | N/A | 14,4 kbps | 2 Mbps | >200Mbps | >10 Gbps |
| Multiplexing | FDMA | TDMA, CDMA | CDMA | OFDM | |
| Core Network | PSTN | PSTN | Packet Network | Evolved Packet Core Network | 5G-Core Network |

The cellular mobile telecommunication system has rapidly evolved following the invention of the transistor in 1947 (Kularatna and Dias, 2004). Advances in micro- and nano-electronics coupled with other fourth industrial revolution (4IR) technologies continue to fuel the evolution of MTS. Table 1 shows a comparison of the different cellular generations of networks in terms of their supported services, standards, and architectures.

**MTS Life Stages**

The ISO/IEC 15288 defines the system life stages as follows: "conceptualization of a need for the system, its realization, utilization, evolution and disposal" (Software et al., 2008). This model has been so often used and applied to define the life stages of different technological systems. Thus, it is plausible to consider four life stages for cellular mobile telecommunications systems as: conceptualize, implement (establish), utilize and retire. Value creation in the telecommunications industry takes into consideration these life stages (Ryan, 2014).

Conceptualization is probably the most important life stage of an MTS because it determines how the succeeding life stages will be managed. It is paramount to understand what "problems" the MTS will solve. Value and the addressable market must be defined, ab initio. Investors and other stakeholders need to understand what products and services the corporate and individual customers require, and how delivering these will return value (in the form of ROI and profits) to investors, and this is achieved during the conceptualization phase. The outcome of this life stage informs decision-makers on what technologies to deploy, where and how to build, which suppliers to use, partnership agreements, technical and business risks, constraints, budgets, the total cost of ownership (TCO) that includes both the capital and operational expenditures for a given period of time desired for payback.

During the establish stage, the effort is to acquire the resources; and for mobile telecommunications the most strategic resource is spectrum (Freyens and Yerokhin, 2011), followed by the physical infrastructure. As part of establishing the cyber physical system, a firm must acquire the necessary operating licenses from the relevant authorities. The establishment process includes engaging suppliers for detailed technical solutions, designs and network plans, the installation, commissioning, testing and service acceptance of the MTS.

During the utilize stage, all stakeholders pay close attention to their respective interests. For example, shareholders tend to be more interested in revenue and return on investment. Within the MTS firm, the engineering teams focus on cost effective operations and maintenance of infrastructure, other functions within the business structure of the firm work in consonance to ensure continuity of service and customer satisfaction. The customer experience and MTS business performance during the utilization stage could either reinforce or discredit decisions made during the conceptualization stage. The net promoter score (NPS) is often used to gauge customer loyalty, modify business strategy, and to persuade investors for further investments (Gerpott et al., 2001; Joshi, 2014; Saroha and Diwan, 2020; Tong et al., 2017). A higher NPS score means the customer perceived value of the MTS is good, and could contribute to the sustainability of the MTS.

The retirement stage entails the termination of use, decommissioning or disposal of the MTS infrastructure or any of its subsystems. The overall MTS may not necessarily be retired. However, physical subsystems and components would certainly be retired due to product end-of-life support because of advancements in technologies. A typical example would be to change the core network switching subsystem from bare-metal hardware to virtualized cloud core, while keeping the transport and base station subsystem part of the network the same. Another example would be to discontinue 2G services, and therefore to change this part of the base station subsystem and replace it with 4G or 5G networks. For instance, an MTS firm that wishes to focus on infrastructure-as-a-service, may decide to decommission all bare-metal servers and have them replaced with cloud servers that will support the new business model. Other MTS firms may be forced into this stage due to poor business performance, leading to divestiture or a merger and acquisition of the MTS firm or its assets (Ryan, 2014).

**MTS Business Structure**

The value chain is the structuring of a business in terms of value-adding activities that result in increased efficiency, better product(s) or service(s) (Olla and Patel, 2002; Slavica et al., 2015). Table 2 illustrates a value chain for MTS business. The physical layer or cyber physical infrastructure comprises of the tower sites, the data centres, the power and cooling systems, fibre and ethernet cabling, the spectrum, and the network equipment, which comprises of both the hardware and the software. The network or connectivity layer defines the specific technology per domain (radio, transport of core). The main players in this part of the value chain are the operators and vendors of the network equipment, who may both supply and configure the equipment in the network, if the MTS firm chooses to outsource such services. In some cases, the vendors may also be contracted to maintain the network equipment and configurations through managed services or outsourcing agreements (Marshall et al., 2007; Patil and Patil, 2014). The services layer is the most complex layer in the mobile telecommunications value chain, as it is where the MTS firm differentiates itself from competitors. Traditionally, MTS firms offered only voice and simple data services. Later, during the 2G era, value-added services such as missed call alerts, voicemail boxes or mobile advertising were developed. With the introduction of 3G and 4G technologies, video services were added, and over 5G networks MTS firms anticipate there will be an explosion of new innovative services across. The application or content layer encompasses numerous players. In most markets, MTS firms have joint partnerships with entertainment and television firms to deliver entertainment services. In the 5G era, this layer also includes IoT applications.

The application layer seeks to address the opportunities in the content space. And as such, there are two types of players in the MTS value chain viz: (i) content creators and (ii) content enablers (Sabat, 2002). Content creators for mobile wireless services include not only the operators and their third-party partners but also, the mobile consumers of the technology. Content enablers include application delivery providers and network infrastructure providers. Application delivery providers further aggregate consumer applications and enterprise applications, service bureaus, wireless portals, mobile virtual network operators (MVNOs), verticals such as financial, education services, middleware and content delivery application platforms, billing services, content management, corporate data access, network monitoring, optimization services, security services, system integrators and consultants. Network infrastructure providers include manufacturers, installation and maintenance services providers for the core network equipment such as the routers, the mobile switching centre servers, wireless gateways; the radio access components such as the base stations, microwave radios and the base station controllers; the hosting services such as the wireless network hardware; and the transport network, tower and cell site, and the handset supply chain.

*Table 2: Mobile Telecommunications Business Structure*

| LAYER | REMARKS | PLAYERS |
|---|---|---|
| PHYSICAL | Towers, data centres, network equipment and software fall under this category. | Content Enablers: Network Infrastructure Providers |

| LAYER | REMARKS | PLAYERS |
|---|---|---|
| NETWORK/CONNECTIVITY | This layer is where the networks are built, maintained, and operated. | Content Enablers: Network Infrastructure Providers |
| SERVICES | This is where voice, data, video, and value-added services are configured and delivered to the end-users. | Content Enablers: Application Delivery Providers |
| APPLICATION/CONTENT | This new layer is a result of the renewed focus that MNOs have on creating and delivering "content", as an additional revenue stream. Other verticals, such as entertainment providers, financial institutions and mobile network virtual operators may take part in this layer. | Content Creators |

**A CONCEPTUAL FRAMEWORK FOR SUSTAINABLE MANAGEMENT OF MTS**

Figure 1 illustrates a proposed conceptual framework for sustainable management of the mobile telecommunications systems. The framework combines the life stage view of MTS infrastructure with the value chain view of MTS business as the basis for examining the technology dimension of sustainability. The main proposition is that the sustainability of the MTS should be founded on concurrent management of both the technology (i.e., cyber physical infrastructure) and business structure (value-chain).

The mobile telecommunications business includes many firms with flexible and sophisticated business structures that operate at different life stages of the increasingly complex cyber physical infrastructure (Li and Whalley, 2002). MTS business is extremely competitive, thus, innovation and strategic alliances (Ryu, 2018) are key to an organization's ability to sustain its operations by capturing and offering value throughout the life stages of the mobile telecommunications cyber physical system.

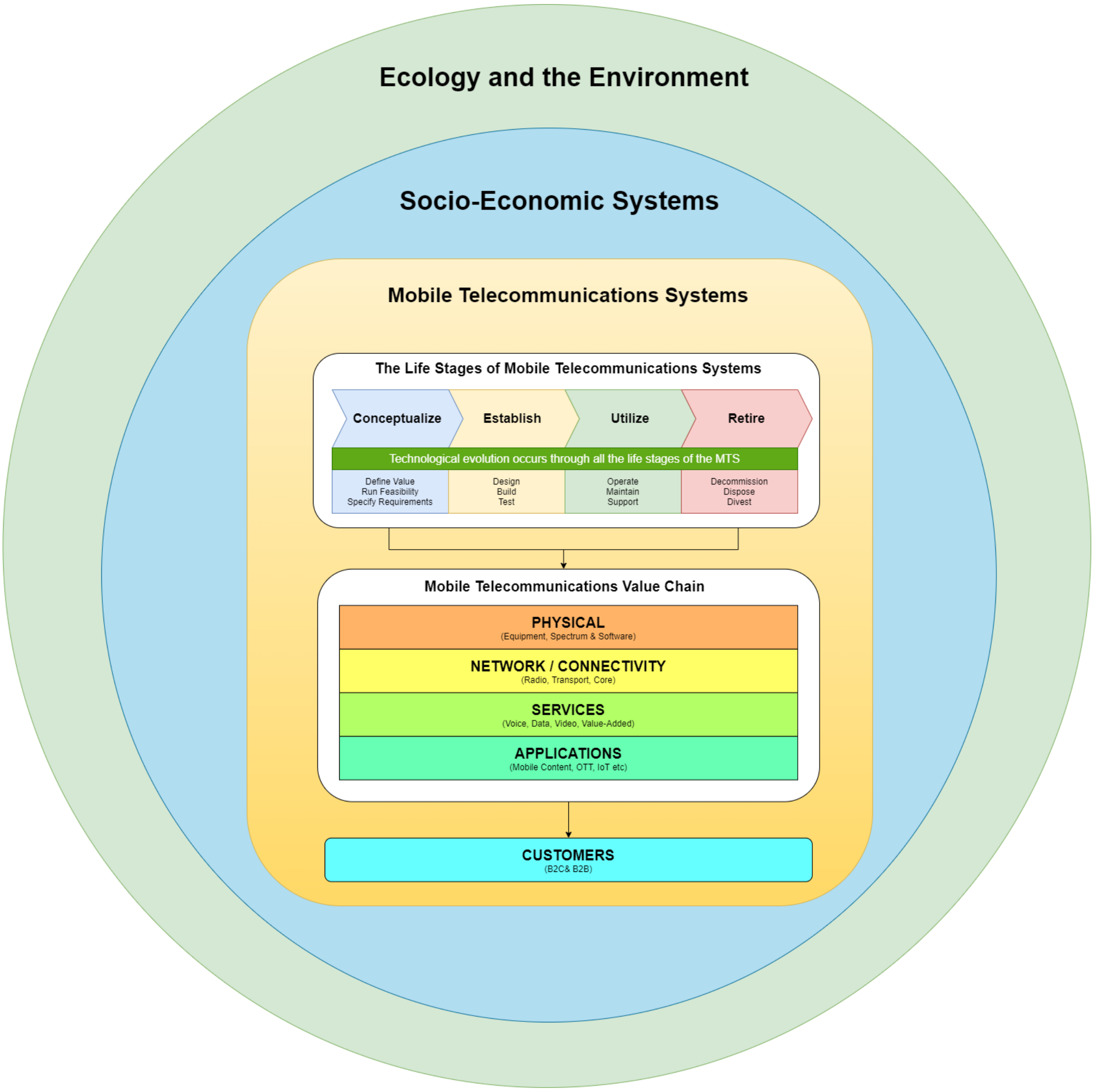


*Figure 1: A Conceptual Framework for Sustainable Management of Mobile Telecommunications Systems*

Notwithstanding the technology dimension outlined in terms of the conceptual framework, the sustainability of mobile telecommunications systems demands the holistic incorporation of economic, environmental and socio-political dimensions (Bocken and Geradts, 2019; Lüdeke-Freund et al., 2016; Jahanbakht and Mostafa, 2019). The MTS does not operate in an island. The MTS physical infrastructure and the MTS firm's business models operate within the socio-economic systems, even as the socio-economic systems operate within the ecology and the environment.

As may be deduced from the conceptual framework in Figure 1, stressors on the MTS may originate from within the MTS, or from external socio-economic systems or from the wider environment and ecology. Exogenous stresses from either the environment and/or socio-economic behaviour have as much significance to the sustainability of the technologies and business models encapsulated within the MTS. Climate change effects, earthquakes, and the Covid-19 pandemic, violent civil disturbances, and financial shocks are typical examples of exogenous sources of stressors on the MTS. For instance, the telecommunications industry is not exempted from the mounting global pressure to support the reduction of carbon emissions during both the manufacturing and operation of telecom equipment. Development of next generation technologies such as 5G considers new architectures for 5G networks that should improve energy efficiencies, and support green communication Gandotra and Jha (2017), thus illustrating how exogenous stressors from the environment and ecology influence the way the MTS physical layer is conceptualized and established.

Changes in socio-economic systems that may also create stressors on the MTS that include, but are not limited to: changes in regulatory, political and tax regimes (Moshi and Mwakatumbula, 2017) and changes in the global or national economy (Maitland et al., 2002). Certain MTS firms may operate within multiple socio-economic systems. European multinationals with local operations in Africa, for instance, may be required to comply with certain laws and regulations from one country and others from different countries, adding to the complexity of managing MTS business models. This conceptual framework, therefore, highlights the interrelatedness and interdependencies between the different sustainability dimensions.

## CONCLUDING REMARKS

The conceptual framework proposed in this paper provides the basis for the ongoing study on sustainable management of MTS. The framework facilitates better understanding of strategies for managing both the cyber physical infrastructure and business structures of MTS. The framework is currently being used to distinguish where and how MTS firms fail or succeed.

Although there is extensive discourse on the environmental dimension of the sustainability paradigm, however, triple bottom line accounting and the sustainable development goals highlight the need to study sustainability from other dimensions. This paper briefly describes an ongoing research that focuses on the technology dimension of sustainability using mobile telecommunication systems as the unit of study.

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