Assessing Cloud Computing Sustainability

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***Abstract*— In this paper we deal with the issue of providing a suitable, comprehensive and efficient sustainability assessment framework for cloud computing technology, taking into consideration the multi-objectivity approach. We provide the comparison methodology for Sustainable Development Goals models, and apply it to the proposed multi-objective cloud computing sustainability assessment model and the general United Nations (UN) framework, taking into consideration the emerging issue of open data.**

I. INTRODUCTION

Cloud computing represents an innovative computing paradigm designed with an aim to provide various computing services to the private and corporate users. As it provides a wide range of usage possibilities to the users, along with the sustainability, it has become one of the most promising transformative trends in business and society. As such, this trend imposes the need of proposing a model for assessing cloud computing sustainability. The extensive reference research indicates that there were several attempts to proceed with this idea, but there is still no unified approach. The sustainability approach is a qualitative step forward when compared to other methodologies. Taking all this into consideration, we have proposed a new model which is still in the research phase. The basics of our concept are presented in [1].

The framework development becomes more challenging with taking into consideration the need of integrating the issue of open data to the framework proposal. The Open Data phenomenon is initiated by the Global Open Data Initiative (GODI) [2]. The goal is to present an idea of how governments should deal with the open data accessibility, raise awareness on open data, support the growth of the global open data society and collect, increase, and enlarge the databases for open data. Different countries started to gradually accept the idea of open data and are taking the initiative for the introduction of adequate legislation. The national and international laws related to the free access to information of public importance constitutionally guarantee human rights and freedom, and form an integral part of numerous international documents which set standards in this area. E.g. Serbian Government regulates the right to free access to information with a special law constituted in 2006. It constitutionally guarantees and regulates the right of access to information, and in addition to access to information of public importance held by public authorities, it includes the right to be truthfully, completely and timely informed on issues of public importance [3]. This law establishes the Commissioner for Information of Public Importance, as an autonomous state body which is independent in the operation of its jurisdiction.

The foundation idea of our framework is to encompass the four different aspects that are highly influenced by the trends in cloud computing development, and provide a comprehensive multi-objective (MO) model for assessing sustainability. Such a MO perspective is foreseen to take into account how cloud computing affects economy, business, ecology and society. This methodology provides flexibility in allowing all participants to support objectives that they found relevant for their needs, eliminating the necessity to find a way to fit to any of the existing constraints, which is typical for a pure sustainability approach [4]. The named areas are of the primary interest as the consumers are becoming heavy users of cloud computing services satisfying their needs for social communication, sensitive data exchange, or networking, all in compliance with the rights stated in Universal Declaration of Human Rights (UDHR) [5]. This trend also strongly influences the economical development, strengthens the business communities [6] and significantly raises the environmental awareness of the society [7].

The goal of this paper is to further elaborate proposed model, proceed with the comparison to the state of the art in this area, and positioning of our model. The research of the current state of the art in the area of cloud computing sustainability assessing models leads only to the United Nations (UN) general model, thus it will serve as the foundation for initial consideration and reference for comparison [4].

The UN model relies on the introduction of Sustainable Development Goals (SDG) defined by Inter-agency and Expert Group on SDG Indicators (IAEG-SDGs) which motivates international community to put additional attention to the indicator framework and associated monitoring systems. The first guidelines for SDG establishment were given in 2007 [8]. The named document provides the set of Indicators of Sustainable Development and presents recommendations on the procedures for adapting them at national level, in accordance to national priorities and needs. More recently, in 2015, UN report on "Indicators and a Monitoring Framework for the Sustainable Development Goals" was published as a response to the need for contribution in support of the SDGs implementation. It outlines a methodology of establishing a comprehensive indicator framework in a way to support the goals and targets proposed by the Open Working Group (OWG) on the SDGs [4].

The framework for the sustainability assessment heavily depends on the access to the open data, which should be available under no condition. Moreover, the availability of the data is the necessary condition for assessing the sustainability, as building a special, dedicated system for collecting such an amount of data is unprofitable. The Inter-agency and Expert Group on

SDGs (IAEG-SDGs) have organized a set of meetings in Bangkok, during October 2015, where the main topic was the development of an indicator framework which purpose is to monitor the goals and targets of the post-2015 development agenda. As it is emphasized in Global Policy Watch report, it was agreed that the UN framework in its final version is to be presented to UN Statistical Commission in March 2016 [9]. Until then, it is of importance to find a proper agreement on the suggested indicators for each defined goal, being aware that indicators alone cannot be sufficient for measuring the advancement of the development of the goal.

In this paper we first introduce the comparison methodology for SDG models. Then, we apply it to the UN and to the proposed MO cloud computing sustainability assessment model, taking into consideration the open data initiative principles. Finally, we conclude with some remarks related to the provided comparison.

II. CLOUD COMPUTING SUSTAINABILITY MODELS

The models for sustainability assessment can be classified as general and specific. Alternatively, the models can be territorially (geographically) classified as global, regional, local and national. For the needs of comparison and evaluation of the cloud computing sustainability, as a general model we chose the one proposed by UN, and compare it to the MO framework.

The UN framework relies on 100 sustainable development indicators defined in conjunction with 17 SDGs [4]. Our aim is to try to provide the mapping of sustainable development indicators to our MO framework. Figure 1 presents UN framework principles for global monitoring indicators.

Figure 1. Ten principles for Global Monitoring Indicators [4]

The UN framework SDGs are listed in Figure 2.

Taking into account defined goals and list of UN indicators [4] we provide a mapping of the indicators to the areas covered by the MO framework. It is performed taking into account the definition of the indicators, without a specific policy and rules for mapping. Figures 4, 5, 6, and 7 provide the corresponding mapping of the indicators (represented in form of the numbers, as they appear in [4]).

Goal 1. End poverty in all its forms everywhere
Goal 2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
Goal 3. Ensure healthy lives and promote well-being for all at all ages
Goal 4. Ensure inclusive and equitable quality education and promote life-long learning opportunities for all
Goal 5. Achieve gender equality and empower all women and girls
Goal 6. Ensure availability and sustainable management of water and sanitation for all
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10. Reduce inequality within and among countries
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12. Ensure sustainable consumption and production patterns
Goal 13. Take urgent action to combat climate change and its impacts
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17. Strengthen the means of implementation and revitalise the global partnership for sustainable development

Figure 2. Seventeen UN framework SDGs [10]

Figure 3 presents the general overview of the proposed MO Assessment Framework for cloud computing, showing the first two layers of the model. Each of the shown branches is further layered in accordance to specific area characteristics.

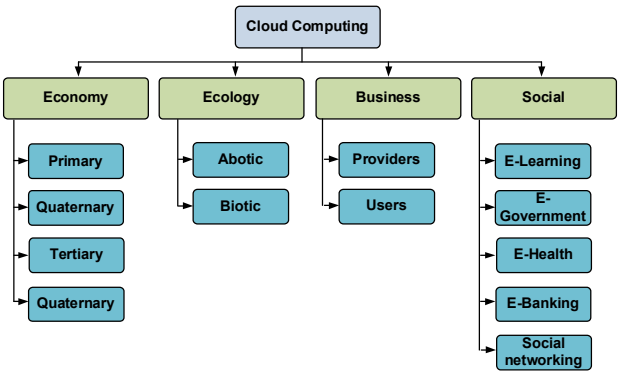

Figure 3. General overview of a proposed Multi-objective Assessment Framework for Cloud Computing

Figure 4 represents the mapping within the social aspects area. It covers the provisioning to the users the set of e-services, taking into consideration the fulfilment of rights claimed in Universal Declaration of Human Rights (UDHR) and legislative of certain country [5]. The set of e-services can be grouped into: e-Learning/e-Education, e-Government, e-Health, e-Banking, and social networking. These basic services can be further analysed through benefits and issues/risks. All of these subcategories have a set of common characteristics, and some of the most important are the privacy and security of the data which is shared among different user categories, and awareness that there is a need for developing services to help users with disabilities to efficiently satisfy their special needs.

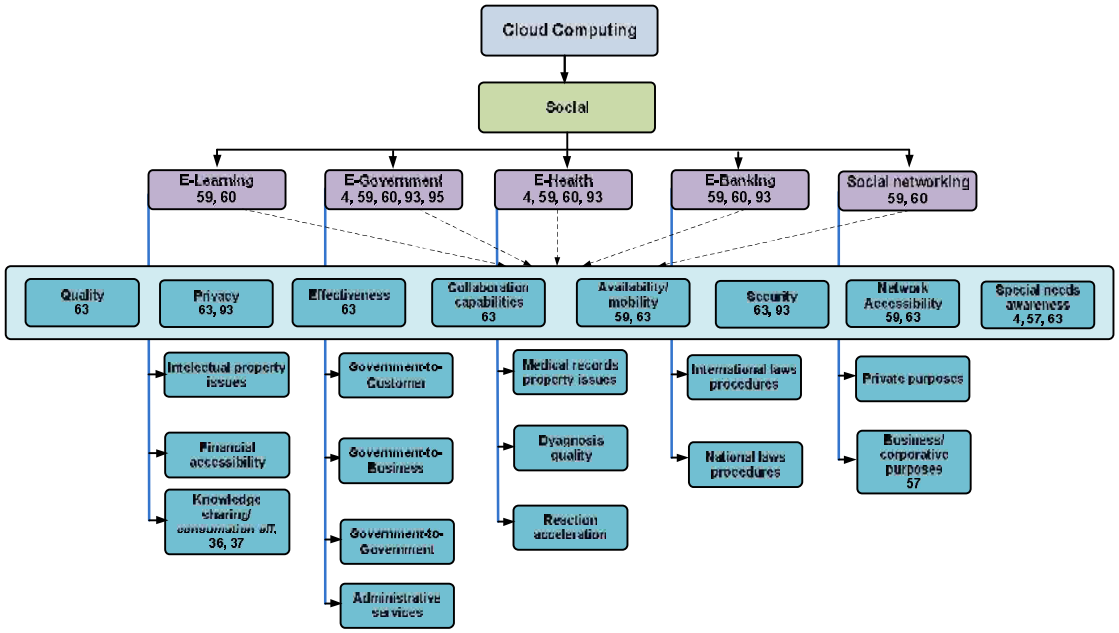

Figure 4. Social aspects for framework assessment

Figure 5 shows the ecology branch of the framework. Ecology objectives can be classified according to general ecology factors into abiotic and biotic [11]. The abiotic branch deals with the issue of pollution generated during the use of cloud computing resources in different life-cycle phases, and with carbon footprint that is typical for each cloud computing component. Biotic branch considers impact of cyber physical systems to the reestablishment of degraded homeostasis or to the process of keeping the existing homeostasis.

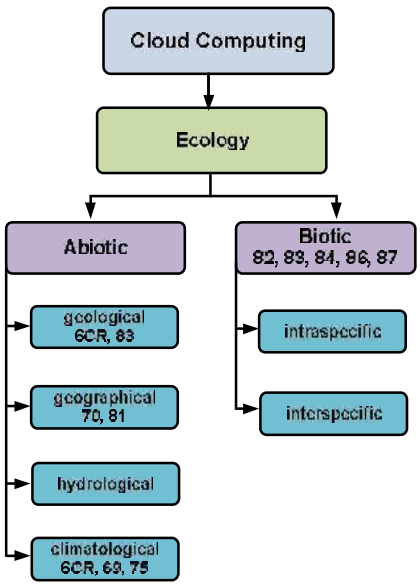

Figure 5. Ecology assessment framework

Figure 6 provides mapping within the economy area.

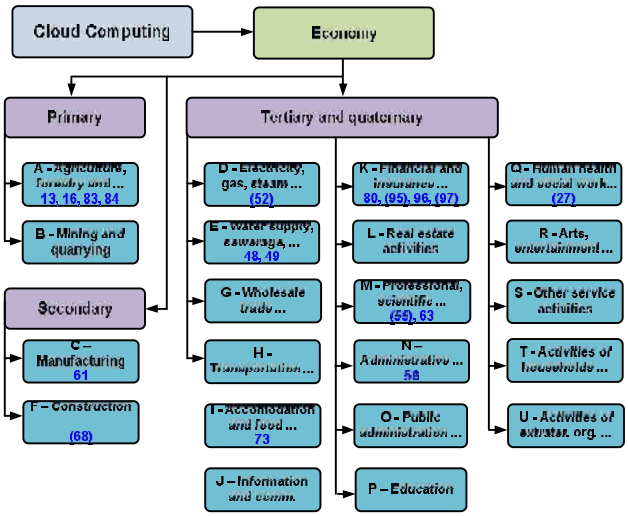

Figure 6. Economy aspects for framework assessment

The service economy (SE) concept [12] is analysed as the integrated part of Information and Communications Technologies (ICT) domain. As such, it fits well within the MO cloud computing framework [1]. Actually, the economy sector is treated based on the widely known concept of the four economic sectors – primary, secondary, tertiary and quaternary [13] and classification of economic activities is obtained from the UN International Standard Industrial Classification (ISIC) hierarchy with 21 categories of activities labelled with letters A to U [14].

Special effort is put into covering the business area, as that sector is not covered by UN model. The focus is on the business objectives related to the interests of cloud computing business users (Figure 7).

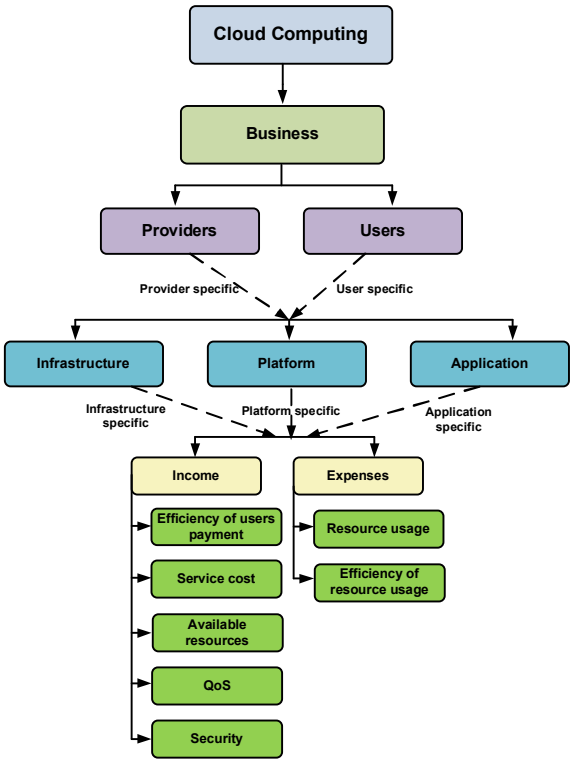

Figure 7. Business aspects for framework assessment

This area highly depends on Open Data initiative implementation as, for example, it can multiply educational and job opportunities and can help people achieve greater economic security.

We have put an effort into allocating all the UN indicators to the defined MO framework sectors. There are some sectors with no indicators assigned which shows that the UN framework for sustainability has not considered that all specified activities are equally important for sustainability. On the other hand, some of the indicators that we have previously identified as associated with e.g. some economic section (figure 6), latter could not be assigned to any ISIC section. The very same situation appears within other considered areas (figures 4 and 5), and especially for the business area (figure 7) as we could not find indicators that can cover it successfully. The frameworks are assessed based on following:

1. Control cycles phases defined for the chosen model
2. Choice of the target user
3. Principles for determining indicators and targets
4. Number of indicators
5. Readiness of the framework
6. Areas covered by sustainability assessment models

where this list of points is a cornerstone for further comparison procedure and evaluation.

III. METHODOLOGY

Cloud Computing is the concept designed with an aim to satisfy many different flavours, and it is tailored toward different users and companies. The main expectations of most cloud services are at least to allow self monitoring and self-healing, existence of the proper service level agreement, advanced automation, pay-per-used service, and high level of reliability and availability [15]. From the standpoint of control systems, an important role in this comparison plays the understanding of the purposes which have initiated the application of the sustainability assessment procedure. The theory of control systems relies on: control cycles, multi-objective optimization and dynamic control. Dynamic control theory is founded on the need for allowing a controlled transition from some specific state to the desired state of the system. The Multi-Objective Optimization (MOO) encompasses the formulation of the issue based on the vector of the objectives, as the approach relying on the single objective may not satisfactorily represent the considered problem. Dynamic control of the system should allow the most efficient combination of the MOO and adaptive control, in a way to keep transitions slight, without dislocating the system to the undesirable regions. The idea is to allow transition from the system state oriented assessment framework to the system control oriented framework, where it is important to provide dynamic MO control of the system and keep the homeostasis in desired state.

IV. COMPARISON

The comparison of the MO and UN frameworks is provided taking into consideration the aspects listed in previous chapter. When making MO framework comparison to the UN framework, several observations can be made.

1. When considering **the control phases**, both models provide a set of specific phases, where some of them coincide.

The UN framework does not rely on the real control cycle but on a set of phases: Monitoring, Data Processing, and Presentation. Unlike the UN framework, the proposed MO framework relies on the full control cycle. Figure 8 represents the comparative overview of the defined UN phases versus the MO framework cycle.

The **Monitoring phase - UN** relies on the list of Global Monitoring Indicators (GMI) whose progress is supervised on defined time basis taking into consideration local, national, regional, and global level of monitoring. MO framework considers this first phase as **Data Collecting - MO** phase, as it basically relies on that process. For the process of monitoring/data collection there is a need to cover a wide range of data types. The UN framework, with 100 indicators and a set of sub indicators targeting different levels (global, regional, local and national), requires an enormous monitoring system that would process the huge amount of collected data. As it is evident that creating such a system would be a time consuming and costly task, the monitoring/collection of data should rely on existing systems and in particular to those owned by the State. Therefore, the UN framework relies mostly on a national level data monitoring, while the idea of the MO is to collect open data and private data.

Data processing phase - UN is assumed to be realized by specialized UN agencies and other international organizations that are connected to national statistical offices (NSO), companies, business and civil society organizations. They put efforts into determining the standards and systems for collecting and processing data.

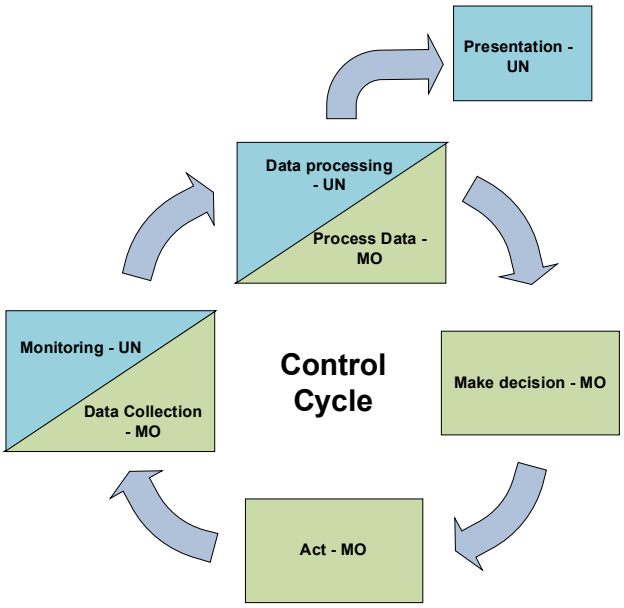

Figure 8. MO versus UN SDG framework

Presentation and analysis - UN is the final phase of the UN model. It is performed through generation of different reports, and organization of workshops and conferences. In contrast, the MO framework considers the **Process Data - MO** phase as the input for the **Make Decision - MO** phase. In this phase the decision makers are offered the possibility to use information generated based on the MO optimization in order to make the decisions. On the bases of the taken decisions it is further possible to proceed to the **Act - MO** phase which corresponds to the operational part of the MO framework.

2. The target user/group represents important difference between this two frameworks. The UN framework sees the final user as a target, while all the data are publicly available. In contrast, the MO framework is primarily designed for corporate users, who take part in managing the processes based on the specific technology. Based on the profound research related to this aspect, we have realized that there is a high need to raise the awareness of the necessity to incorporate to the framework the fact that the technology forms a great part in every day's life of personal and corporate users. We have noticed that the UN framework lacks the indicators/sub-indicators that would properly indicate the level of the exploitation of the latest technology trends.

3. The high level consideration is the adopted set of **principles for determining indicators and targets**. The UN model relies on 10 principles defined towards fulfilment of the idea of an integrated monitoring and indicator framework (Figure 1). The basic principle of MO framework is to provide a multi-objective dynamic control system. The indicators must give real time information, and it must be made available before the defined time limit.

4. When thinking about the **number of indicators**, UN framework encompasses 100 indicators and 17 groups of the goals (defined on global, regional, local and national levels), whereas MO model is still in development, and aims to encompass companies grouped by size (global, regional, local) and ownership structure (public, private, combined). It is noticed that there is a lack of proper indicators for the area of business sector. It is also of great importance to provide proper set of indicators that would cover technological development, science and academia.

5. The **readiness of the framework:** the UN framework is a long year's process documented by, so far, two editions. The third edition is expected to be shortly published, and it is foreseen that it will encompass the business aspects as well. On the other hand, the MO framework is still in research and development phase.

6. The main discussion topic is the **areas covered by sustainability assessment models.** The MO framework is dominant as it covers areas of economy, business, society, ecology, while the UN framework still lacks the business indicators. The UN framework claims the necessity of covering this area as well. The major contribution to this initiative is claimed to be on several stakeholders and organizations supporting sustainability development, whereas the ultimate goal is to align the business metrics to the defined SDG indicators. For guaranteeing the best possible mapping, it is important to identify the crucial business indicators which can successfully track the business factors and their relation to SDGs.

In MO framework we consider business area from the very start. We cover both the service providers and end users. The framework encompasses used infrastructure, platform type, and used applications. When considering the infrastructure provider objectives it is important to consider those related to income maximization (efficiency of users payment, service cost, available resources, quality of service (QoS), and security) and the other related to expense minimization (resource usage, efficiency of resource usage, etc.). QoS in cloud computing depends on performance, fault tolerance, availability, load-balancing, scalability, while security aspects can be analysed through the security at different levels, sensitivity of security systems, and determination of security systems. Security objectives are usually in divergence with performance and energy efficiency. Moreover, the open data would seem to be a necessary condition for the implementation of our framework at full capacity. The initiative for the opening of the government data has to deal with the need to provide transparency, participation of different interested sides, and to stimulate development of the new services related to the proper and safe data usage.

At the national level the data is often non accessible, thus there is a need for open data initiative. The UN framework considers the use of open public data while MO framework relies on the use of both open public data and private data (Figure 9). Although the UN framework has not launched the open data initiative it will use it for its functioning. MO framework also needs a huge amount of diverse data, mostly referring to the open data which is held by the state. The accessibility to it depends on the existence of the laws that regulate the open data concept. E.g. in Serbia it is regulated with the Law on Free Access to Information of Public Importance [3].

The open data combined with cloud computing can facilitate development of the innovative approaches, in a way that the companies are using open data to make use of market gaps and recognize prominent business opportunities, develop novel products and services and create new business models.

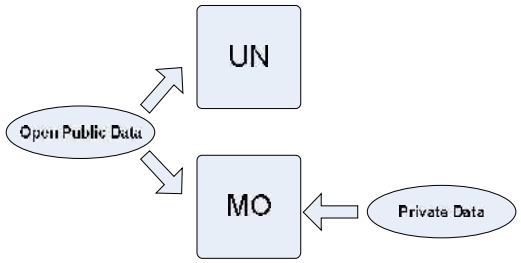

Figure 9. MO versus UN SDG framework control cycles

The publishment of the open data can increase the data supply, engage larger number of industrial and private users and allow business insight for government employees. Figure 10 shows an overview of cloud computing and Open Data relationship [16].

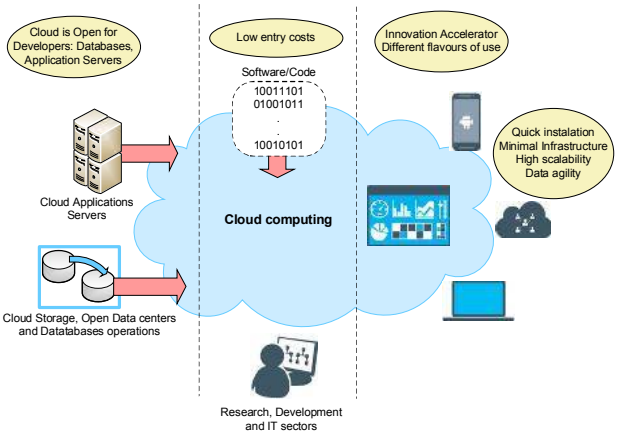

Figure 10. Cloud Computing and open data relationship

The open data is important part of overall government information architecture. It should be enabled to be meshed up with data from different sources (operational systems, external sources) in a way that is easy to be consumed by the citizens/companies with different access devices. Data in all formats should be also available for the use of the developers thus making them easier the process of developing new applications and services. The cloud computing platforms are ideal for encouraging and enabling the business value and business potential of open data. The government agencies are using this data and usually combine it with other data sources. Cloud enables new applications and services to be built on those datasets and enables data to be easily published by governments in very open way, independent of the used access device or software. Cloud allows high scalability for such use, as it can store huge amounts of data, process the millions of transactions and serve large number of users. Additionally, cloud computing infrastructure is driving down the cost of the development of the new applications and services, and is driving ability of access by different devices and software. Still, it is of great importance to consider the possibilities of integrating higher security and privacy concerns when dealing with the use of open data in cloud computing [17].

V. CONCLUSION

In this paper we first present two sustainability assessment frameworks, United Nations Sustainable Development Goals framework and our proprietary Multi-Objective model for assessing sustainability framework. We have explained the applied methodology and provided the qualitative frameworks comparison. It is clearly pointed out the necessity of having available the open data for both UN and MO frameworks. The general conclusion is that the research and development community still has to invest more time and resources into the development of the cloud computing applications that would help the efficient use of the data, improve services, and stimulate public and corporate innovations.

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