Sustainable Green Service Level Agreement (GSLA) Framework Development for IT and ICT Based Industries

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ABSTRACT

Nowadays, when most of the business are moving forward to sustainability by providing or getting different services from different vendors, Service Level Agreement (SLA) becomes very important for both the business providers/vendors and as well as for users/customers. There are many ways to inform users/customers about various services with its inherent execution functionalities and even non-functional/Quality of Services (QoS) aspects through negotiating, evaluating or monitoring SLAs. However, these traditional SLA actually do not cover eco-efficient green issues or IT ethics issues for sustainability. That is why green SLA (GSLA) should come into play. GSLA is a formal agreement incorporating all the traditional commitments as well as green issues and ethics issues in IT business sectors. GSLA research would survey on different traditional SLA parameters for various services like as network, compute, storage and multimedia in IT business areas. At the same time, this survey could focus on finding the gaps and incorporation of these traditional SLA parameters with green issues for all these mentioned services. This research is mainly points on integration of green parameters in existing SLAs, defining GSLA with new green performance indicators and their measurable units. Finally, a GSLA template could define compiling all the green indicators such as recycling, radio-wave, toxic material usage, obsolescence indication, ICT product life cycles, energy cost etc for sustainable development. Moreover, people's interaction and IT ethics issues such as security and privacy, user satisfaction, intellectual property right, user reliability, confidentiality etc could also need to add for proposing a new GSLA. However, integration of new and existing performance indicators in the proposed GSLA for sustainable development could be difficult for ICT engineers. Therefore, this research also discovers the management complexity of proposed green SLA through designing a general informational model and analyses of all the relationships, dependencies and effects between various newly identified services under sustainability pillars. However, sustainability could only be achieved through proper implementation of newly proposed

GSLA, which largely depends on monitoring the performance of the green indicators. Therefore, this research focuses on monitoring and evaluating phase of GSLA indicators through the interactions with traditional basic SLA indicators, which would help to achieve proper implementation of future GSLA. Finally, this newly proposed GSLA informational model and monitoring aspects could definitely help different service providers/vendors to design their future business strategy in this new transitional sustainable society. Additionally, this research adds new layer of green services from the informational model of GSLA framework. The overall framework is validated by using the Bayesian network model (BNM) among the data collected from various IT and ICT based industries in different countries. The validation of using BNM is done with the feedback of 44 different IT and ICT based companies from Japan, India and Bangladesh. The average accuracy of using BNM for validating sustainable GSLA model is 68% while considering all sample data sets. Moreover, while the proposed BNM have higher confidence with entropy calculation, then the accuracy is almost 100% for most of the companies' feedback. The proposed idea of using BNM for evaluating and validating sustainable GSLA model would definitely help the ICT engineer to design and develop future green services in their industries.

Keywords: SLA, Green SLA, Green IT, Sustainability, IT ethics, Green Computing, Informational model, Green Services, Bayesian Network.

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Finally, I beg pardon for my unintentional errors and omissions if any.

Japan, March 2018.

Iqbal Ahmed

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LIST OF SYMBOLS AND ABBREVIATIONS

ACSI	American Customer Satisfaction Index
BPEL	Business Process Execution Language
BNM	Bayesian Network Model
CSI	Customer Satisfaction Index
GHG	Green House Gas
GSLA	Green Service Level Agreement
IaaS	Infrastructure as a Service
ICT	Information Communication Technology
IT	Information Technology
KPI	Key Performance Indicator
LAN	Local Area Network
MOS	Mean Opinion Score
MTTR	Mean Time to Reparation
PaaS	Platform as a Service
PAQ	Perception of Affective Quality
PLR	Packet Loss Ratio
QoS	Quality of Service
RTE	Réseau de Transport d'Électricité
SaaS	Software as a Service
SLA	Service Level Agreement
SLI	Service Level Indicator
SLM	Service Level Management
SLO	Service Level Objective
SLS	Service Level Specification
SOA	Service Oriented Architecture
SPEC	Standard Performance Evaluation Corporation
TGG	The Green Grid Consortium
TTR	Time To Respond
VoIP	Voice over Internet Protocol
WAN	Wide Area Network

CHAPTER ONE

1 INTRODUCTION

The most of the IT and ICT industries are moving forward to sustainability through conducting different level of commitment towards their customer with providing new services. At the same time, service level agreement (SLA) becomes very familiar and plays significant roles in response to this field. SLA might be the only way to understand whether the companies underlying sustainability practicing aspects and their inherent execution functionalities of provided services in recent days. Green SLA (GSLA) is almost similar non-technical and formal document mentioning traditional commitments of provided services as well as green aspects and ethical concern in IT business area. Therefore, GSLA research could be the most promising field to understand sustainability scopes by taking consideration of Ecological, Economical and Ethical parameters in the industry. This chapter basically focuses on some background study about traditional SLA and their setting process. Moreover, it also includes the definition of new green SLA and the motivation of this research under sustainability lens. Finally, the chapter ends with GSLA research goals and also stating some of its limitation. The whole organization of GSLA research also includes briefly at the end of this chapter.

1.1 Background

Service Provider: hi! Here is my service; it's available, reliable and green!
Customer: ...come on! How is it green! How much energy I consume or how do I know it's reliable?

Look at this conversation. This day might not too long to come when customers would ask organizations to provide a kind of service level agreement or terms of usage, where green issues plays much attention. Many people might think that, Service level Agreement (SLA) might be an informal term in Information Technology (IT) and Information and Communication Technology (ICT) worlds, but actually it's not true at all. Nowadays, when most of the business are moving forward to the world of service oriented architecture to provide or get services from different vendors, it becomes important day by day for both the business providers/vendors and as well as for users/customers. In a short sentence *SLA is a formal document between an IT service provider and one or more customer outlining Service Commitment***.** The main issue is that, there are many ways to inform customers about various services with its inherent execution functionalities and non-functional properties/Quality of Services (QoS) through negotiating, evaluating or monitoring SLAs. However, these traditional SLA actually do not cover eco-efficient green issues. SLAs have been used since late 1980s by fixed line telecom operators as part of their contracts with their corporate customers [1]. This practice has spread such that now it is common for a customer to engage a service provider by including a service level agreement in a wide range of service contracts in practically all industries and markets.

Service level agreements are, by their nature, output based – the result of the service as received by the customer is the subject of the agreement. The service provider can demonstrate their value by organizing themselves with ingenuity, capability, and knowledge to deliver the service required, perhaps in an innovative way. Organizations can also specify the way the service is to be delivered, through a specification (a service level specification (SLS)) and using subordinate "objectives" other than those related to the level of service [2]. This type of agreement is known as an input SLA. Service level agreements are also defined by different areas of IT. Next Table shows some definitions of SLA.

Table 1. Definition of SLA based on different areas and different sources

Area	Definition	Source
Web Services	*“SLA is an agreement used to guarantee web service delivery. It defines the understanding and expectations from service provider and service consumer”.*	HP Lab [3]
Network	*“An SLA is a contract between a network service provider and a customer that specifies, usually in measurable terms, what services the network service provider will supply and what penalties will assess if the service provider cannot meet the established goals”.*	Research Project [4]
Internet	*“SLA constructed the legal foundation for the service delivery. All parties involved are users of SLA. Service consumer uses SLA as a legally binding description of what provider promised to provide. The service provider uses it to have a definite, binding record of what is to be delivered”.*	Internet NG [5]

DataCenter Management	*"SLA is a formal agreement to promise what is possible to provide and provide what is promised".*	Sun Microsystems Internet DataCenter group [6]

Currently, cloud & grid computing and various data centers acts as most promising service providers. This computing industry provides different services in compare to traditional computing with some scalability benefits. At the same, some cloud services are offered in various levels: Infrastructure, Platform and Software as a Service [7]. At each level, they maintain a SLA with respect to their parties. Therefore, this shows the growth rate of SLA in recent times.

1.2 Defining SLA and GSLA

SLA or traditional SLA is an agreement between two or more partners, where one partner might be the customer and the others are service providers who provide services and all the service commitments are outlined in human readable form. This can be a legally binding formal or an informal contract/relationship. Contracts between the service provider and other third parties are often incorrectly called SLAs – because the level of service has been set by the customer, there can be no "agreement" between third parties or resource suppliers; these agreements are simply "contracts." Fig. 1 also refers the main idea of SLAs with consumers. Consumers are interacting with service providers through SLA setting and SLA contains information regarding the performance, connectivity and timing issues of networking and communicating equipments. There might be another confusing term like Operational-level Agreements or OLAs with SLAs [2]. This OLAs might be used by internal groups to support their SLAs. In the most cases, Customers and Service providers negotiate the key issues, such as how the service will be available to him or how services are much green and/or better than others etc. However, all these key facts presented either in terms of usage or in service level agreements (SLAs).

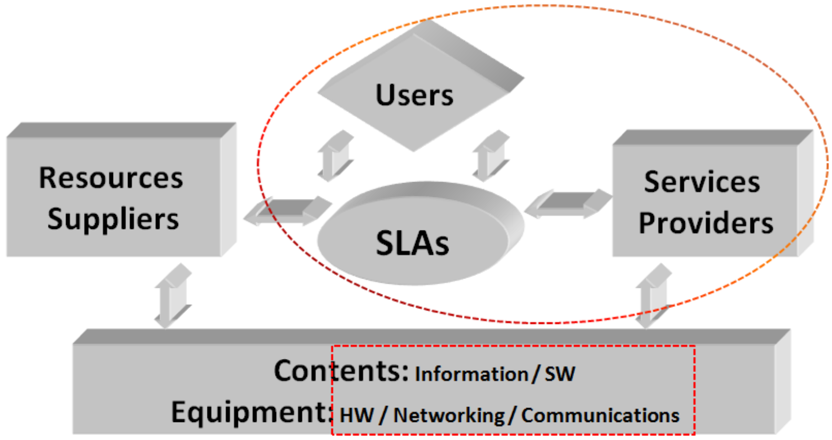

Fig.1. General View of SLA

A traditional basic SLA commonly includes different segments to address: a definition of services, performance measurement, problem management, customer duties, warranties, disaster recovery, and termination of agreement. As an example, SLA defines percentage of service being available in some time period. If the agreement is not met by service provider, they usually give some kind of compensation. In order to ensure that SLAs are consistently met, these agreements are often designed with specific lines of demarcation and the parties involved are required to meet regularly to create an open forum for communication. Contract enforcement (rewards and penalties) should be rigidly enforced, but most SLAs also leave room for annual revalidation so that it is possible to make changes based on new information. However, currently all these traditional/basic SLA do not attach green issues regarding their services as well as how the green parameter could incorporate in their commitment. Most of the performance indicators in basic SLAs are concentrated only on service availability, timing, and bandwidth capacity issues. Therefore, the Green SLA (GSLA) terminology starts journey here. Green SLAs are defined as SLAs that induce a more eco-efficient operation and their monitoring indicators compared to traditional performance-based SLAs. Such kinds of GSLA need to relax traditional SLA's parameter in some extent.

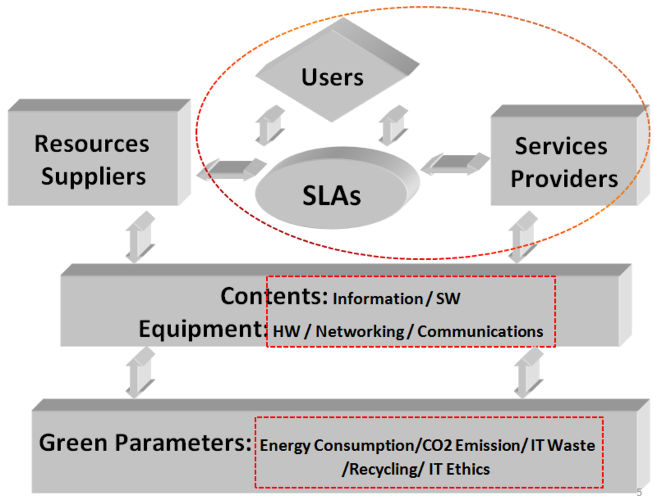

Fig.2. General View of GSLA

Fig. 2 also depicts GSLA briefly. There is relationship between users and service providers with much more eco-efficient services. All their provided services are embodies with green parameters and these parameters should state in their SLAs.

1.3 General Basic SLA Process

Service Level Agreement (SLA) is a formal negotiated agreement between a service provider and a customer/ client. When a customer orders a service from a service provider, an SLA is negotiated and then a contract is established. In the SLA contract, QoS parameters that specify the quality of service that the service provider would guarantee are included. The service provider must perform SLA monitoring to verify whether the offered service is meeting the QoS parameters specified in SLA. Thus, most of the service providers introduce some key performance indicators and their measurable units for monitoring their services and they put all this information in a common human readable format.

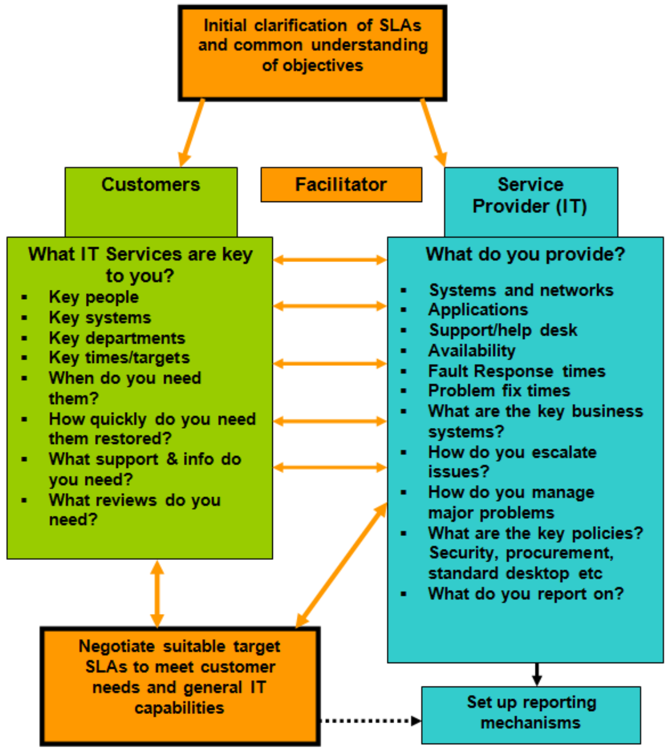

Fig.3. Traditional SLA Setting Process [8]

The above figure showed some traditional SLA setting process, where an SLA creates a relationship between some customer and IT service provider [8]. At first, there must be some initial understanding and common objectives between them. However, in the actual service provision case, those initial SLA could be negotiated and changed. In addition, there is also some evaluating or reporting process for SLA through measuring key indicators for their negotiated services. There could be a third party to evaluate the SLA to observe that either the desired QoS capable services are met or not. Most of the traditional SLA is using some common measurement metric to maintain their SLA in real time. Some commonly used basic SLA metrics are shown in next Table 2. *MTBF, MTBSI, MTRS, TAT, NOS, NOF* etc. defines the conditions when the services are considered to be unavailable/limited, availability targets, reliability targets, time-to-restore services, connectivity testing and maintenance downtime for the service providers. These parameters are mostly performance and timing based information. They are easy to evaluate and monitor in traditional SLA process.

Table 2. Common used metric in a SLA.

Service Availability (MTBF) (Mean Time Between Failures)
Service Reliability (MTBSI) (Mean Time Between Service Incidents)
Maintainability (MTRS) (Mean Time to Restore Service)
Service Completibility (TAT) (Turn Around Time)
Congestion (NOS, NOF) (Number of Successful attempt, Number of Failure attempt)
Service Utilization (%) (Percentage)

Though these traditional or basic SLAs are well defined for some paid and free service, they are always overlooked the green and eco-efficient issues and their representation in SLA. There are many entities in the context of SLAs, such as *Purpose and Scope,* which hold a description of requested service, *Service level Objectives (SLO)* model the QoS or non-functional properties that both customer and provider agreed and *Service level Indicator (SLI),* provides the means to monitor the actual performance of a service. SLO introduce the definition of key performance indicators for services whereas SLI mention the measuring unit and the way of representation for those SLO in a basic SLA.

1.4 Motivation of GSLA Research

Green ICT is a rising topics in recent time. It constitutes a new term in the science of information that describes the utilization of informatics through providing and interacting various services in the interest of the natural environment and the natural resources regarding sustainability and sustainable development. Presently, ICT has introduced the convergence of services with broadband network infrastructure, wireless technologies and mobile devices. The revolution of ICTs introduction in daily average life has also resulted in the increase of Green House Gas (GHG), since the “carbon footprint’’ is continually increasing. At 2007, the ICT sector produced as much GHG as the aero industry and is projected to grow rapidly [1]. Presently, data centres and cloud computing industry around the world provide various levels of services and at the same time, they produce huge amount of carbon. As estimated in 2008 that world-wide data centres emit 116 million metric tons of carbon, more than entire country of Nigeria [1] and according to SMART 2020 report share of data centers in the production of GHG emission is rising (2002 – 14%, 2020 – 18%) [9]. Green SLA research would help to show that most of existing green SLAs are mainly focused on energy/ power, carbon footprint, green energy, recycling issues. Additionally, several existing green SLA also demonstrated their productivity issues with necessary monitoring unit and all these existing green SLA work are based on cloud computing industry. Most of the recent days green SLAs are provided by some well know data center around the world for their services. The main motive of these data centers is to make profit. It will be worth to introduce new green SLA in these data centers with compromising some QoS parameters and profit. If ICT has a negative impact on environment, it can be used for greening the other human activities (logistic, city, industry etc) in the society. Indeed, the dimensions of Green ICT contribution are: the reduction of energy consumption, the rise of environmental awareness, the effective communication for environmental issues and the environmental monitoring and surveillance systems, as a means to protect and restore natural ecosystems potential [10]. Currently, many IT companies or service providers think about their business scope in the light of green perspective. Therefore, with the increased attention that green informatics is playing within our society it is timely to not only conduct service level agreements for traditional computing performance metrics, but also to relate the effort of conducting green agreements.

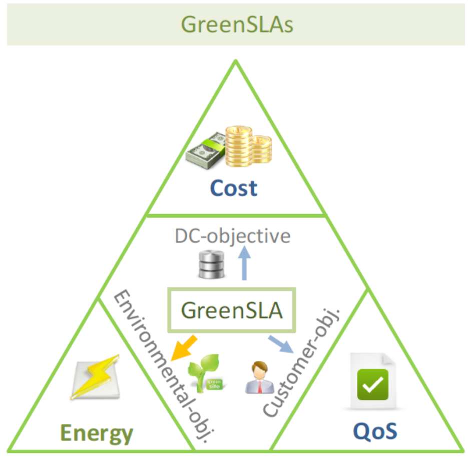

Fig.4. Impact of GSLA in Data Centre

Here, Fig. 4 shows the impact of GSLA in data center. The main objective of this computing industry is to gain more profit and at the same time their customer asked for quality of their services. Again for sustainable development there is a commitment to reduce energy consumption, carbon emission etc. Therefore, the GSLA could play vital role to understand the underlying trade-off between all the parameters for sustainable future.

1.5 Goals and Delimitations

The main goals of GSLA research are summarized below:

- Find out the most commonly used basic SLA parameters for Network, Compute, Storage and Multimedia services in IT industry
- Survey on existing GSLA in the distributed computing industry under traditional green computing practice
- Find out the gap and incorporation of existing GSLA for achieving sustainability in future
- Introduce some measurable eco-efficient green performance indicator and their measurable units for existing GSLA and propose a new GSLA for the business through sustainability lens
- To help ICT engineers to define the new proposed GSLA under three pillars of sustainability using some informational model

- To improve the understanding and working relationships between existing and new performance indicators in proposed GSLA for satisfying business requirement in ICT fields
- To discover the management complexity and inter-dependencies among ecological, economical and ethics pillar's indicators using the informational model
- Identifying new services through defining GSLA for sustainable development in future
- Designing a new GSLA tool for the IT industries
- Discussing monitoring and evaluation of future GSLA parameter for achieving proper implementation
- Validate the informational model by using Bayesian Network model through conducting survey among the various IT and ICT based industries in Japan, India and Bangladesh
- To create awareness, knowledge for the customer/clients/service requestor for making a sustainable future in the light of green computing practice

The main challenges to achieve these goals are stated below.

- ➢ To get proper and common format of agreement from some well reputed service providers
- ➢ Some eco-efficient green parameters and IT ethics program need to authorize by some concern authority. However, there is no standard alliance to look after this issue
- ➢ There are no open standard or global alliances responsible for designing and defining green agreement templates and their indicators
- ➢ Even providers and customers point of view sustainable awareness is still an important issue

1.6 Organization of Thesis

Organization of this research work is divided into five chapters and is as follows:

Chapter 1, entitled, "Introduction", presents Green Service Level Agreement's background, definition of SLA and GSLA, the motivation of this research, the goals & delimitations of this research and organization of the thesis.

Chapter 2, entitled, "Literature Review", provides the general literature review of basic SLA in different environment, finding out the motivation of Green SLA, impact of ICT for achieving sustainability, some green and eco-efficient metric and their measuring unit in SLAs, green computing practice and IT ethics issues.

Chapter 3, entitled, "Research direction", describes the research methods and service level indicator for basic SLA and existing Green SLA for various services. This chapter classifies various services into four main branches – Network, Compute, Storage and Multimedia. Therefore, it needs some survey from various service providers and as well as from service consumer. In addition, this chapter also presents some existing green eco-efficient performance indicators and their measurable units from distributed computing industry under green SLA practice.

Chapter 4, entitled, "Results and Contributions", deals with proposing new Green SLA indicators with respect to ecological, economical and ethical point of view to achieve sustainability. Results section found all the missing performance indicators and also their measuring unit from reviewing empirical work on green IT and sustainability. All the missing indicators are organized in a tabular form under three pillars of sustainability. Finally, a general global informational model is proposed for defining new green SLA and then discusses all the relationships and dependencies within the missing and existing indicators. Using the general informational model, more new services could be identified for sustainability achievement. The implementation and validation part helps to automate future green SLA for the industry. Moreover, the monitoring and evaluating section gives new idea to implement future green SLA through incorporating basic SLA parameters to respect new green parameters. In addition, the informational model validation using Bayesian Network model is done in this chapter.

Chapter 5, entitled, "Conclusion", represents the conclusion and the future work of this proposed Green SLA.

Finally, the thesis ends with citing references.

CHAPTER TWO

2 LITERATURE REVIEW

There were several works on basic SLA and green SLA for different services. Most of the researches regarding SLA were survey based focusing only one or two services. Some work has been done on modeling, monitoring or automating basic SLAs. There were very few specific works found only on Green SLA. Some specific works were found regarding performance metric for distributed computing industry (cloud and grid computing). Some researcher focused only the importance of adopting Green issues including IT ethics in ICT field. The main objective of this section is to gather all the information regarding basic SLA and green SLA for further research in this field. All the references could be organized by following criteria: reference related to methodology, information, services, monitoring, assessment and implementation of SLAs for various services. Some basic SLA papers could also be categorized as interesting to reuse for green SLA work.

2.1 Papers on Basic SLA

Jani Lankinen *et al.* surveyed on security profiles of existing cloud services provided by varieties providers [7]. Their selected services were analyzed based on the security principles presented in provider's terms of usages and also in SLA. They attached a comparison of services targeted for private use and for company use as well as for paid and free usages. They did not find available SLAs for free services and there were very little concrete promises concerning security issues regarding their promised services. Actually, in cloud computing SLAs were not monitored and evaluated properly and thus, even for data security the users have no choice to argue with providers. However, this paper gives some idea to develop some survey concerning Green SLA from different cloud service providers like Amazon, Apple iCloud, DropBox, Microsoft Office 365, Google Apps for Business, Box etc.

In [11], Salman A. Baset gave an idea of the present and future SLA for different cloud service providers. In his paper, he showed the variability in the SLAs of cloud providers lead a common a question of how to compare and monitor those SLAs and actually most of the cloud providers did not provide any performance guarantee for their services. He tried to provide a future guideline for traditional SLA with some common metrics. He found a common anatomy of typical SLA that consist of service guarantee, service guarantee with time period, service guarantee granularity & exclusions, service credit and service violation measurement & reports. He surveyed on some well known public IaaS providers and finally indicated that none of the IaaS providers offer any performance based SLAs for compute services. Moreover, all cloud providers leave the burden of providing evidence for SLA violation on the customer. However, his paper helped in clarifying and defining SLAs of existing and future cloud based services.

L. Jin *et al.* presented a novel approach to model and understand the relationships between customers and some web service providers [12].They attached a clear and concise definition of SLA in a highly competitive business environment where service providers are interested in gaining a good understanding of the relationship between what they could promise in an SLA and what their IT infrastructure is capable of delivering. This paper also mentioned some components of SLA such as *purpose, parties, validity period, scope, SLA objectives, penalties, optional services, exclusions and administration.* Finally, their research ends up with some web service composition with SLA modeling. Furthermore, they focused on information collection and analysis at the creation stages of SLAs and their result suggested that having information of impact of various service levels on business process would give SLA negotiators, human managers or automatic components, a clear picture of pros and cons of various SLOs in an SLA. This paper also introduced Dynamic service ranking concepts, which means that service providers rank its services based on customer's real time needs. Also this ranking is done and available only for the customer who needs to sort out a web service from same service provider.

C. Raibulet *et al.* introduced adaptation in service oriented architecture through defining and managing SLA at run-time environment. Adaptation claimed for representation and monitoring of several non-functional issues related to the quality of service itself (e.g. service level indicators) and the quality of provisioning/delivery process (e.g. restrictions to ensure the requested quality) of the services [13]. Their proposed architecture mainly aimed to provide support to exploit services which meet the quality features indicated and expected by users through SLA. Finally, they summarized their research to conclude that, the service level adaptation requires SLA to be modified in two different ways- *modification of SLA and Cancellation of SLA*. Modification of SLA means that the provider of the service remains the same, but QoS specified in the SLA are re-negotiated. Cancellation means creating a new SLA while avoiding old one at run-time. However, objective of their work is mainly focused on obtaining adaptation in SOA, but the creation of one separate functional module (e.g. SLA manager) leads some clear idea of generating a new form of service level agreement.

In [14], H. Lee *et al.* proposed a formal mapping mechanism between QoS parameters in SLA and the network performance metrics for service level management system to verify whether the specified QoS parameters are being met. They offered a general SLA monitoring system architecture that could be used to monitor service levels for different services provided by some network, Internet and application service providers. Their work showed much clear idea of finding some QoS parameters, measurement metrics, monitoring and evaluating SLA for different service providers.

SLA Monitoring is an integrated functionality in any traditional SLA life cycle [15]. When a customer orders a service with some specific QoS parameters from a service provider, then an SLA is negotiated and at the same time a contract is create between two parties (customers and providers). It is the responsibility of the service provider to perform SLA monitoring to verify whether the offered service is meeting QoS parameters specified in the SLA. In order to verify the offered service, the service provider's system must gather performance data from their underlying network performance monitoring system and map such data to the QoS parameter. In this situation, Hyo-Jin Lee *et al.* proposed a formal mapping mechanism between QoS parameters in SLA and the network performance metrics by taking consideration of some network access services (example, leased-line services, xDSL services, VPN services) [18]. In addition, they introduced a general SLA Monitoring system architecture that could be used to monitor service levels for different services offered by Network, Internet & Application service providers. However, they did not focus on any eco-efficient green parameters of these services.

In [16], V. Stantchev *et al.* described an approach for mapping SLA and QoS requirements of business processes to some emerging grid and cloud computing infrastructure. They discovered that most of the grid and cloud computing environments, SLAs are typically provided for basic platform services. However, from SOA point of view, enterprise Business Processes typically expect service levels for the technical services they integrate while providing services. In this paper, to accomplish this integration, they proposed *translucent parallelization* of service processing and *service replication* to improve service levels regarding response time, transaction time, through put and availability. In addition, this research also contributes to the way of representing and controlling some non-functional properties (QoS) at the technical level of services in order to satisfy the SLAs of a business processes in various cloud & grid computing environment. However, they did not put much effort on SLAs in their work. They just tried to show the importance of mapping and formalization of Business processes and technical infrastructure of some cloud providers with the help of negotiating and enforcing SLAs and QoS. The way of representing some QoS parameter and measurement metrics would definitely help to proceed on Green SLA research.

Through-out the IT business sector, one of the biggest and important challenges in both traditional SLA and GSLA could be the specification ambiguities and difficulties for predicting & monitoring SLA compliances. N.J. Dingle *et al.* proposed the use of the *Performance Tree* formalism for the specification and monitoring of Service Level Agreements (SLAs) in their research [17]. Specifically, they showed how the basic *Performance Tree* formalism could be adapted to provide an accessible and expressive means to specify common SLA metrics. In addition, using established performance analysis tools that support *Performance Trees*, they proved that their proposed method allows system designers to check SLA compliance on formal models of their system before implementation. Though they did not put any effort for Green issues in their work, but their research could be helpful for creating new Green SLA metrics and its implementation without involving any third-party for monitoring Green SLA.

T. Unger *et al.*, in their paper defined a method of aggregating SLAs of the individual services within a business process (specified in BPEL) [18]. This aggregation provides a service provider with the capability to annotate the service that the business process implements with an appropriate SLA. They also introduced a framework to carry out the

SLA aggregation within business process. In this framework, one part consisted of creating a formal SLA model. In addition they showed the concept of SLA aggregation in the framework. Moreover, their flexible framework to describe SLAs could be applied to some domain-specific QoS properties. Therefore, the domain-specific issues could eventually lead the idea of Green SLAs within business process.

The white paper of service level agreement for Voice and Internet Service presented some performance based SLAs covering Jitter, Mean Opinion Score (MOS), Network Availability and Time To Respond (TTR) by some Green cloud providers [19]. These SLAs are provided to Green Cloud VoIP customers, who use Green cloud's Bandwidth service. In addition, this paper stated some credit process to the customers for each performance the provider promised them to provide.

E. Marilly *et al.* presented some of the main SLA related issues in the field of multimedia services over Internet [20]. They showed the actors involved in SLA negotiation, the technical specifications of SLAs and the mapping of SLAs to some specific service classes. In addition, their research discovered the *service level specifications (SLS)*, which is the precise technical specification directly related to the SLA. Moreover these SLS parameters are important for the classification of services, defining services, which eventually lead to an end to end SLA/QoS management for multimedia service providers. At the same time, their research states one of the most important Green SLA parameters such as *Service Reliability* issue and its corresponding measuring metrics *(MDT-Mean Downtime, MTBF-Mean Time Between Failure, MTTR-Mean Time To Repair)*.

T. Onali [21], did her doctoral thesis for finding the quality of service technologies for next generation network's multimedia application. In first chapter, she gave a brief table about some key performance indicators (KPI) for existing multimedia services. These KPI would lead us to understand basic SLA as well as GSLA indicators for different types of multimedia services such as audio, video, web-browsing, e- transaction etc. The author's thesis also talked about MOS (Mean Opinion Score) metrics for audio and video application at different network environment. In addition, she also discussed briefly some important basic SLA parameters for Internet services such as IPPM (IP Performance

Metrics) for measuring network connectivity and for measuring performance, one-way, RTT delay.

A. Paschke *et al.* contributed to a systematic categorization of traditional SLA contents with a particular focus on SLA metrics in IT industry [22]. In addition, their intention supported the design and implementation of automated SLAs based on efficient metrics. They categorized five basic IT object classes: *Hardware, Software, Network, Storage and Service Desk (Help Desk).* Even though this research did not focus on Green issues and their metrics, their categorization scheme might help to design an automated Green SLA. The followings figures showed their categorization of basic IT object classes in SLA. The class "Hardware" subsumes different physical resources e.g., servers or workstations, processors or simply computing power. The most important metric is instructions per second. Fig.5 depicts the metrics for hardware class.

No	Description	Object	Unit
1	Availability	Hardware	Time hour, percent
2	Maximum down-time	Hardware	Hours or percent
3	Failure frequency	Hardware	Number
4	Response time	Hardware	Duration in minutes/seconds
5	Periods of operation	Hardware	Time
6	Service times	Hardware	Time
7	Accessibility in case of problems	Hardware	Yes/no
8	Backup	Hardware	Time
9	Processor time	Hardware	Seconds
10	Instructions per second	Hardware	Number per second
11	Number of workstations	Hardware	Number

Fig.5. Hardware Performance metrics, adopted from [22]

Network services provide the technical infrastructure to communicate and work in a distributed environment. The most important metrics are availability and throughput Typical SLA metrics are shown in Fig.6. Software class comprises applications such as ERP solutions and application management services (Fig. 8). Storage services are used to make data or information persistent. The main SLA parameters are storage volume and bytes per second which states how fast data is transferred from or to the storage. In fig. 7 basic SLA metric for storage services are shown.

No	Description	Object	Unit
1	WAN period of operation	Network	Time
2	WAN Service times	Network	Time
3	LAN period of operation	Network	Time
4	LAN Service times	Network	Time
5	Solution times	Network	Minutes
6	Availability WAN	Network	Percent
7	Availability LAN	Network	Percent
8	Access Internet across Firewall	Network	Yes/no
9	Access RAS	Network	Yes/no
10	Latency times	Network	Ms

Fig.6. Network Performance metrics, adopted from [22]

No	Description	Object	Unit
1	Availability	Storage	Time hour, percent
2	Maximum down-time	Storage	Hours or percent
3	Failure frequency	Storage	Number
4	Response time	Storage	Duration in minutes/seconds
5	Periods of operation	Storage	Time
6	Service times	Storage	Time
7	Accessibility in the case of problem	Storage	Yes/no
8	Backup	Storage	Time
9	Bytes per second	Storage	Number per second
10	Memory size	Storage	Number in bytes

Fig.7. Storage Performance metrics, adopted from [22]

No	Description	Object	Unit
1	Service times	Software	Time
2	Response times	Software	Minutes
3	Availability	Software	Time
4	Solution times	Software	Minutes
5	Number of licences	Software	Number

Fig.8. Software Performance metrics, adopted from [22]

The interface to the service customer is referred to as "service desk" (according to ITIL) or "help desk". Service times and the self solution rate are most important for this object type. Fig. 9 illustrates the help desk SLA metrics.

No	Description	Object	Unit
1	Self solution rate (not with 2nd level support)	User Help Desk	Percent
2	Service times	User Help Desk	Time
3	Availability	User Help Desk	Time
4	Failure forwarding degree	User Help Desk	Percent
5	Failure categorization degree	User Help Desk	Percent
6	Availability with phone	User Help Desk	Hours
7	Availability with Email	User Help Desk	Hours
8	Response time	User Help Desk	Hours, minutes
9	Language variety	User Help Desk	Number of languages

Fig.9. Help Desk (Service Desk) metrics, adopted from [22]

In [23], H. Ludwig *et al*. proposed a language for service level agreements for various dynamic and spontaneous electronic services. This paper gave a direction to deliver a machine-readable format for SLAs, which is an emerging topic with respect to sustainability practice in a cross-organizational environment. The SLA language described in their research aimed at providing the needed flexibility by means of XML-based representation and a run-time system for SLAs. Using this language, clients for different services could describe many points in their SLAs, such as how parameters are measured, computed from metrics, the guarantees they want with respect to those parameters. However, the research did not show any idea of green parameters, metrics regarding their services. The proposed language definition would be more helpful for designing Green SLA templates.

P. Hasselmeyer *et al.* described a framework to discover and negotiate SLAs automatically, focusing primarily on the protocols & the components needed [24]. The negotiation and establishment of SLAs is a viable solution for electronic contracting. In addition, such automation is a crucial factor in the future adoption of SLAs in e-business environment and proliferation of electronic service ecosystems. Therefore, their proposed framework would be an important solution for generating Green SLAs templates in this e-business era. However, their research did not show any new parameters or measurement metrics for Green SLA. They just tried to retrieve more insight in the usages of traditional SLAs in e-business through implementing automated SLA negotiation framework such as discovery of service providers, selection of providers that offer the required services, SLA templates retrievals, visualization and establishment of an actual SLA.

In the white paper of *Dimension Data* [25], writers evaluated the importance of service level agreements for every buyer of cloud computing services. This paper compared some performance-sensitive applications of different cloud providers with respect to *availability* and *downtime* measurement. In addition, it also provided the details of how service providers define their SLA measures and penalties with their clients.

E. Wustenhoff, in his paper tried to show some performance monitoring metrics for Data Centre in order to maintain a viable SLA [26]. In addition, this paper introduced the influence of service level management (SLM) for composing SLA. Finally, his research ended with some suggestion to assure the generation of good SLAs in data centre.

In [27] white paper, the author gives the guideline for designing a standard cloud service level agreement. In February 2013, the European Commission, DG CONNECT set up the Cloud Select Industry Group- Subgroup on SLA (C-SIG-SLA) to work for the standardization guidelines for cloud computing SLAs. The author showed that this guideline actually helped to the professional cloud service customers and providers with respect to the protection of hosted data in the cloud industry. In addition, this paper discussed about some qualitative parameters in cloud service SLA such as security, authentication & authorization, logging & monitoring, vulnerability management, service change notification, reliability, reversibility and the termination process etc which could be very much important for proposing GSLA for achieving sustainability in this arena.

2.1.1 Remarks on Basic SLA

Most of the paper found on basic SLA discussed performance based indicators for various services in recent ICT arena. Some empirical work found on SLA implementation, management, automation, template design and assessment in the context of business requirement. Very few scientific works found on interesting aspects such as security and privacy issues on traditional SLA, which could be important for green SLA research under IT ethics concept. Table 3 shows the brief idea of basic SLA work through some interesting criteria of SLAs as column subheads. The cell identified with "X" symbol means that, the authors mentioned and worked on that criteria of basic SLAs.

Table 3. Analysis of Basic SLA papers

Author Lists	**Analysis Criteria**						
	Services	*Information*	*Methodology*	*Implementation*	*Assessment*	*Monitoring*	*Reuse to Green SLA*
Jani Lankinen *et al.* [7]	X	X			X		X
Salman A. Baset [11]	X		X	X		X	
L. Jin *et al.* [12]	X	X	X	X			
C. Raibulet *et al.* [13]				X	X		
H. Lee *et al.* [14, 15]	X	X		X	X	X	
V. Stantchev *et al.* [16]		X	X				X

N.J. Dingle *et al.* [17]		X				X	X
T. Unger *et al.* [18]		X	X				
Anonymous [19]	X	X					X
E. Marilly *et al.* [20]	X	X		X		X	
T. Onali [21]	X	X		X			
A. Paschke *et al.* [22]		X	X		X		
H. Ludwig *et al*. [23]	X			X			X
P. Hasselmeyer *et al.* [24]	X			X	X	X	
Anonymous [25]		X	X				
E. Wustenhoff [26]						X	
Anonymous [27]		X					X

2.2 Papers on Green SLA (GSLA)

In [4], Linlin Wu *et al.* presented the definitions of service level agreement from various IT areas and they defined all the essential components of SLA life cycle. In addition, their research focused on diverse survey about the *Customer Satisfaction* issues in grid & cloud computing which would be an important direction in designing Green SLA from IT ethics point of view.

Z. S. Andreopoulou's works are mainly on the impact of ICT in our natural environment and natural resources [10]. He showed how ICT plays vital role in getting sustainable world. He proposed a model *ICT for Green and Sustainability.* This paper also includes ICT's Key role to attain future EU strategy to a low carbon European society by 2050.However, the author thought green behavior is still critical in this transition.

In [28], N. Agarwal *et al.* conducted research with the possible reasons of environment degradation due to IT industry; the challenges and steps towards going green; and various initiatives taken by different countries, practitioners and industry towards greenness. Their work actually helped to understand the importance of Green IT in recent time. In addition, it motivates to perform research in the field of Green SLAs, where both customer and providers (various IT industries) could know their responsibilities more clearly towards a transition of sustainable society.

The Open Data Center Alliance recognized the growing requirement to indicate the carbon footprint of services and products [29]. However, the report also found some IT services are delivered as a "black box" from the cloud, or even just outsourced from other third parties, making carbon footprint assessment difficult. In addition, these could be difficult to put this assessment value in SLA. The report also introduced "The Usage Model" which is designed to ensure organizations can predict CO_2 emissions and track actual emissions through technical capabilities instituted by providers of cloud services. This report eventually shows the impact of carbon footprint in service oriented architecture. Finally, it would help to determine how put carbon footprint in newly developed Green SLA.

In [30], Klingert *et al.* introduced the notion of Green SLAs. However, their work focused on identifying known hardware and software techniques for reducing energy consumption and integrating green energy, and how applications might specify preferences/requirements for these techniques. They did not propose a specific type of Green SLAs and did not explore approaches for satisfying Green SLAs.

Li *et al.* focused mainly on Data Centre's resource optimization to satisfy customers while providing services [31]. They proposed a static partitioning of data centre into separate green and brown parts, and migration of virtual machines between two parts to maximize use of green energy while minimizing performance overheads. In addition, their wok also did not propose any Green SLAs.

G. von Laszewski *et al.* invented a framework towards the inclusion of Green IT metrics as part of service level agreements for grids and cloud computing environment [32]. While they were introducing this framework, they made an effort to revisit some Green IT metrics and a proxy, which was eventually, considered optimizing against in order to develop GreenIT as a Service (GaaS). Their research also showed that, GaaS could be reused as part of Software as a Service (SaaS) and Infrastructure as a Service (IaaS) framework. They utilized some Green IT metrics, such as Data Center Infrastructure Efficiency (DCiE), Power Usages Effectiveness (PUE), Data Center energy Productivity (DCeP), Space Watts and Performance (SWaP), storage, network and server utilization. This paper also mentioned that, Green IT metrics should not only consider for just runtime. Furthermore, these metrics should also be consider as a life time metrics that include creation, recycling and disposing of a resource or a system that generates energy to operate a resource. Finally, their research concluded by proposing SLA specification efforts on integrating GreenIT as a part of it.

In [33], Md. E. Haque *et al.* provided direction to some High Performance Computing Cloud providers to offer a new class of green services in response of practicing explicit sustainability goals in their fields. In addition, this new class would also introduce a new form of explicit SLA (Green SLA) for their clients. They proposed a power distribution and control infrastructure for various HPC providers, together with an optimization-based scheduling framework and policies and finally incorporate as a Green SLA service. Their research work was evaluated extensively using simulations and their evaluated result showed that, the choice of optimization-based policy could be useful for HPC provider to attract environmentally conscious clients through maintaining Green SLAs.

Kien Le *et al.* introduced a general, optimization-based framework and several request distribution policies that enable multi-data-centre services to manage their brown energy consumption and leveraged green energy, while respecting their service level agreements (SLAs) and minimizing energy cost [34]. Though their work showed that, this optimization based framework must be important for business point of view, they did not put much effort on SLAs. However, their research contributes some guidelines to determine service user satisfaction metrics.

M. Nichollas, in his report applied an effort to find out the insight of *User Satisfaction* role in some current SLAs [35]. He pointed out that, most of the IT service providers tried to introduce Green SLAs in their service provisioning. However, all these SLAs are almost based around technology measurements, such as availability, response time and so on. While creating SLAs, these service providers always overlooked one of the most important topics regarding their services – *Customers/Users Satisfaction.* Therefore, it becomes necessary for the service providers to incorporate user satisfaction factors in their current traditional SLAs. This report would be an important source for researching on Green SLAs.

It also shows direction how to imbed *user satisfaction level* and *user satisfaction level representation* while generating Green SLA templates.

In [36], Robert R. Harmon *et al.* offered a review of current thinking and suggested factors for a sustainable IT strategy in various enterprise levels IT organization. They defined the term *Green Computing* as the practice of maximizing the efficient use of computing resources to minimize environmental impact. Therefore, they discovered that, sustainable IT services require the integration of *Green Computing* practices such as power management, virtualization, improving cooling technology, recycling, electronic waste disposal and optimization of the IT infrastructure to meet required sustainability requirement. In addition, this paper studied on some green IT parameters and its corresponding metrics. Their research must be helpful to design new green IT services as well as generating Green SLAs in various level of IT enterprise.

Next Figure.10 summarizes the most widely used benchmarks in green computing industry in the transition of sustainability in various domain of IT industry.

Benchmark	Metric	Level	Domain
Total Power Consumption	$ cost of power consumed Kilowatts used	Data center	Enterprise
Green Grid PUE	Ratio of facility power to It equipment power	Data center	Enterprise
Green Grid DCiE	Percent of power that reaches IT equipment	Data center	Enterprise
Green Grid DCPE	Work done/total facility power	Data center	Enterprise
Analysis tool	Performance per watt	Any	Any
EnergyBench	Throughput per Joule	Processor	Embedded
SWaP	Performance/(space x watts)	System(s)	Enterprise
Energy Star: Workstations	Certify if "typical" power is less than 35% of "maximum" power	System	Enterprise
Energy Star: Other systems	Certify if below a predefined threshold for the system class	System	Mobile, desktop, small server
SPECPower and Performance	Power consumption per server on Java graduated workload	System	Enterprise
JouleSort	Records sorted per Joule	System	Mobile, desktop, enterprise
Carbon footprint Environmental Impact	Amount of carbon dioxide emissions per product, service, process, facility, or organization	Any	Any

Fig.10. Green computing benchmark and their metrics, adopted from [36]

A. P Bianzino *et al.* [37] did a survey on recent green networking research and they presented a more precise definition of "Green" attributes in networking field. They viewed green networking as a way to find the way to reduce energy consumption while at the same time maintains the same performance level. This tutorial also showed four main stem branches where energy wastage became an important factor, namely (i) Adaptive Link Rate (ii) Interface Proxing (iii) Energy-aware infrastructures and (iv) Energy-aware applications. The authors also illustrated a few key paradigms that the network infrastructure could exploit to reach green objectives, such as resource consolidation, virtualization, selective connectedness and proportional computing. Though their work did not say much about Service level agreement or Green Performance metrics, but it gives very nice and solid direction to organize a survey based research work.

In [38], A. Atrey *et al.* did some research on Green Cloud Computing. Their main work were mainly based on some survey of existing research to find out the way of reducing energy consumption and CO_2 emission in cloud computing area. They gave some discussion on green metrics which are currently using in SLA's of many data centers. These metrics will lead us to design our Green SLA in some point. The authors also introduced some existing green scheduling algorithms to reduce energy consumption and CO_2 emission in current existing system. At the end of their research, they showed some architecture of future green cloud which will make greener environment with respect to energy. Actually, their collective broad discussion regarding green metrics would definitely help us to propose and design Green SLA for both service consumers and providers.

A. Orgerie [39] did some survey and found solution to improve energy efficiency for computing and networking resources in his work. He discussed on methods to evaluate existing energy consumption model that operate at a distributed system level and also tried to improve few aspects such as resource allocation, scheduling and network traffic management. Moreover, the author showed the importance of energy efficiency in large scale computing area and gave some idea how to make network and computing resource more efficient. The survey directed us to foster our research on Green SLA (GSLA) by providing real time data of energy efficiency for networking and computing services.

Fritz H. Grupe *et al.* [40] discussed one of the most important concepts of green SLA issues for IT industry in their research- IT Ethics Program. They put the necessity of designing ethics program very nicely in IT unit of any industry. In addition, the authors showed the concepts of organizing ethics program in IT organization and also mention some selected ethical bases for IT decision making such as legalism, professionalism, client/customer choice, equity, competition, comparison, impartiality, objectivity, openness/full disclosure, confidentiality, trustworthiness/honesty, evidentiary guidance etc. In their work, they also gave the idea of adopting the designed ethics program, responsibility of this program to evaluate and analyze it in any organization. Finally, we believe this research paper might be very interesting and informative source for our work. Here, we found some ethical attributes/bases which could be used for proposing our Green SLA for achieving sustainability in IT industry. The authors also mentioned that the IT ethics program should be handled explicitly by some properly trained and authorized personnel in the organization because in most case maintaining the ethics program might be more important than just establishing it in an IT organization.

In the article [41], the author wrote down the computer ethics history very briefly and also showed the impact of ethics in today's IT industry. The writer introduced some basis for establishing computer ethics program such as job security, computer crime, privacy & anonymity, intellectual property right, professional responsibility & globalization etc. These entire bases were actually originated from Terrell Bynum's research. In addition, the article also discussed about common computer ethics fallacies from Peter S. Tippetti named as the computer game, the law-abiding citizen, the shatterproof, the candy-from-a-baby, the hacker and the free information fallacies. Moreover, the article covered some controversial discussion about hacker ethics; which might be very interesting while establishing ethics program in an organization. Finally, at the end, the author described five ethical principles that could apply for processing information in the workplace. All these principle derived from Donn B. Parker and we believe that these could be useful for our Green SLA (GSLA) proposal from ethical point of view.

2.2.1 Remarks on GSLA

The existing scientific work on green SLA is mainly based on cloud and grid computing environment. Some work have been found on green services and operation in the data center, few work done on green performance indicators for designing SLA. The next table 4 will demonstrates the analysis of exiting green SLA works with some criteria, such as green services and operations, greening practice, green metrics, framework development and monitoring. Here some papers also discussed IT ethics issues briefly. Therefore, IT ethics need to include here as an important analyzing criteria in the table.

Table 4. Analysis of green SLA papers

Author Lists	Analysis Criteria					
	Green Services & Operations	*Greening Computing Practice*	*Metrics Information*	*Framework/ Implementation*	*Assessment*	*IT Ethics issue*
Linlin Wu *et al.* [4]		X				X
Z. S. Andreopoulou [10]		X				X
N. Agarwal *et al.* [28]	X	X				
Anonymous [29]		X		X	X	
Klingert *et al.* [30]	X	X				
Li *et al.* [31]		X		X		
G. von Laszewski *et al.* [32]	X	X	X	X		
Md. E. Haque *et al.* [33]				X	X	
Kien Le *et al.* [34]				X		
M. Nichollas [35]						X
Robert R. Harmon *et al.* [36]	X	X	X			
A. P Bianzino *et al.* [37]	X	X		X		
A. Atrey *et al.* [38]		X	X	X		
A. Orgerie [39]	X	X				
Fritz H. Grupe *et al.* [40]				X		X
R. Herold [41]						X

2.3 Conclusion

In this chapter, the main objective is to collect information from different scientific work in order to create general basic SLA and green SLA. The most of the papers did not provide any specific type of green SLAs and also did not explore approaches for satisfying green SLAs. However, the theory and empirical work on basic SLA and green SLA shows new direction and thinking to discover new green SLA's performance indicators and their measurable units through the sustainability lens in this research. Additionally, all these reviewed scientific work could be helpful to design future green SLA templates. Moreover, this chapter's collective broad discussion regarding green metrics under green computing practice could definitely help to propose and design future green SLA. This would also help to finding the management complexity of incorporating basic SLA parameter and existing green SLA parameter for sustainable development in ICT business sector. This chapter actually played as guideline coach for GSLA research.

CHAPTER THREE

3 RESEARCH DIRECTION

3.1 Background

The overall research direction of sustainable GSLA is performed using the following block diagram.

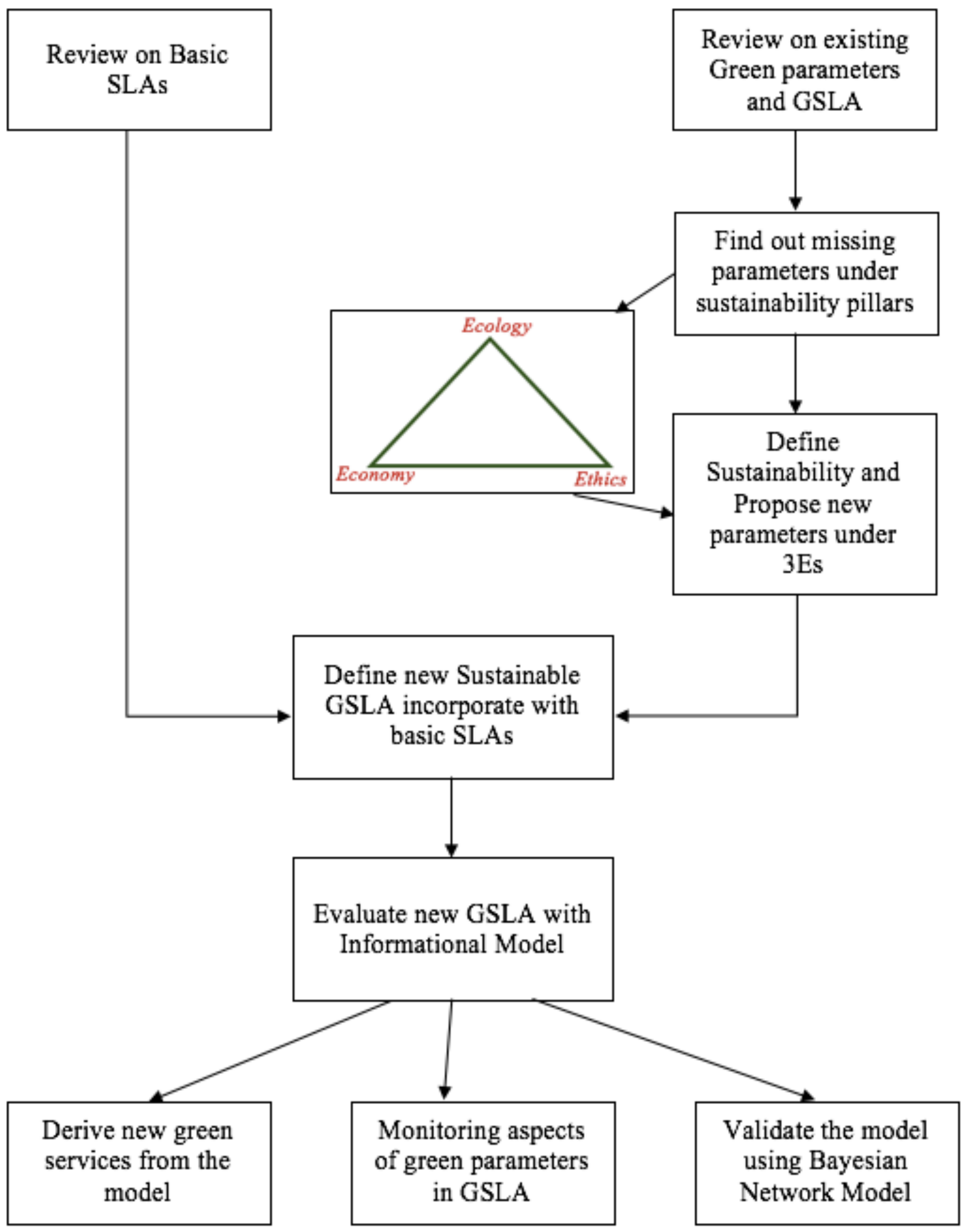

Fig.11. The overall research direction of sustainable GSLA

The GSLA research did rigorous literature review and survey based on existing work in the field of SLA, green SLA, green computing, energy optimization in IT industry, impact of ICT on environment and natural resource, IT ethics issues, IT for Sustainability etc. The major research questions are, - *What are the important missing parameters in green SLA concerning sustainability practice in IT industry?* And *How could ICT engineer respect all newly identified green parameters in future?* To answer these questions, the first approach is literature review and analysis of existing basic SLA work and green SLA work in current IT field. Then, it is easy to find out the gap or missing parameters for achieving sustainability in the concerned field. This GSLA research did systematic review and meta-analysis of the empirical work on basic SLA, green SLA, green IT and sustainability aspects. The most important challenge here is that, there is no common or standard template to receive most of the existing SLA parameter from related field. The meta-analysis so far is quite difficult as there is no proper authority to cross-check the information. Most of the well known service provider did not provide their SLAs for free services and even sometimes for the paid services too. The questionnaire could be an interesting in future green SLA work. In the finding, the work is classifying according to Basic SLA and then Green SLA for four different types of services as Network, Compute, Storage and Multimedia services [42].

According to above figure, the review of basic SLAs for network, storage, compute and multimedia services are completed at first stage of this research. At the same time, the existing GSLA and green parameters are also reviewed under distributed cloud computing industry. This GSLA research did systematic review and meta-analysis of the empirical work on basic SLA, green SLA, green IT and sustainability aspects. The most important challenge here is that, there is no common or standard template to receive most of the existing SLA parameter from related field. The meta-analysis so far is quite difficult as there is no proper authority to cross-check the information. Later, the research finds out the missing parameters for achieving sustainability in existing GSLAs from various ICT industries. Then, the research contributes to define sustainability under ecological, economical and ethical pillars and also proposed new parameters and their metrics in the scope. Finally, an overall new sustainable GSLA is defined. The evaluation of new GSLA is formulated using an informational model, which might be very helpful for the future ICT engineer in the industries. Later in this research, new green services are identified from the proposed informational model. In addition, the overall model is validated by using Bayesian network model with the help of questionnaires generation and their feedback analysis. The monitoring and implementation aspects of few green parameters are also explored from the informational model.

3.2 Basic SLA

In the basic SLA section findings are divided into four main services as network, compute, storage and multimedia services. Most of the performance indicators in basic SLA sections are quantitative parameters and they are simple to evaluate, control and monitor. They do not cover any parameters related with environmental factors, energy/power issues, human's interaction. The next tables show the result with following headings. *Performance Indicator Name* is the notion which could be used in their SLAs, their definition from different providers as *Description,* and their measurable unit as *Unit* column.

3.2.1 SLA for Network Services

Usually network services include connectivity and switching as well as advanced network systems and management functions for well known network service providers. The basic SLA for network specifies service level commitments which are applied to measure and evaluate network performance and give proper support for their clients. Usually, from different network service provider, the following performance indicators [14, 19, 22, 32] found in their SLAs are- *Network Availability, Delay, Latency, Packet Delivery Ratio, Jitter, Congestion, Flow Completion time, Response time, Bandwidth, Utilization, MTBF (Mean Time Between Failure), MTRS (Mean Time to Restore Services), Solution time, Resolution time, LAN/WAN period of operation, LAN/WAN Service Time, Internet access across Firewall, RAS (Remote access Services).* Among these performance indicators, only *Internet access across Firewall* and *RAS* are informative- there is no standard indicator to evaluate or calculate these indicators. Some indicators like *Bandwidth, Utilization, and Congestion* are related to link capacity whereas *Availability*, *Delay, Jitter, Response Time* etc. associated with time related information for different network service providers. Table 5 demonstrates the performance indicator and their measurable unit.

Table 5. Basic SLA for Network Services

Sl.No.	Performance Indicator Name		Description	Unit
1.	Network Availability	Connectivity (IPPM)	Consider for everyday operations so that user accessing services achieving the best connectivity and performance. "connectivity test to IP devices [CISCO]"	% (Percentage)
		Functionality		
2.	Delay	One way delay	How long it takes for a data packet across the network from one node to another.	Time in Milliseconds
		RTT delay (Round Trip Time)		
3.	Latency		The time it takes for a data packet to reach from one designated point to another.	Time in Milliseconds
4.	Packet Delivery Ratio(PDR) or Packet Loss Ratio(PLR)		When a data packet in a network discarded at a given moment because of device is overloaded and unable to receive incoming data.	% (Percentage)
5.	Jitter		Variance of inter-packet delays; sometimes derived from just delay metric.	Time in Milliseconds
6.	Congestion		Ratio between number of successful attempts to get connectivity and number of failures. (NOS/NOS+NOF)	% (Percentage)
7.	Flow Completion Time (FCT)		Time required to get one successful service from servers e.g. to download a web-page.	Time in Milliseconds/ Seconds
8.	Response Time		Time to get initial response from network servers.	Time in Milliseconds
9.	Bandwidth		Total capacity of the link to get network services.	Hertz (Hz)
10.	Utilization		Percentage of the link to be used while services are reached to users.	% (Percentage)
11.	LAN/WAN period of Operation		Time to complete the operation to be carried for certain services either on LAN or WAN e.g. including restarting even a switch.	Time in Milliseconds/ Seconds
12.	LAN/WAN Service Time		Time to get services in any LAN or WAN system.	Time in Milliseconds
13.	MTBF (Mean Time between Failure)		Predicted elapsed time between inherent failures of LAN or WAN system; it could be on either full system or part of the systems.	Time in Milliseconds
14.	MTRS (Mean Time to Restore Services)		The average time taken to restore an item or IT services after a failure.	Time in Milliseconds
15.	Solution Times		The time taken for an IT desk to solve any problem; usually used in internet service provider's SLA.	Time in Seconds/Minutes/ Hours

16.	Internet access across Firewall	Either to access through firewall or not; usually used in internet service provider's SLA.	YES/NO
17.	RAS (Remote Access Service)	Combination of Hardware and Software to enable the remote access tools or information that typically reside on network IT devices [Wikipedia]	YES/NO
18.	Resolution Time (TTR)	Amount of time to resolve customer issues in computing services; closely related with customer satisfaction	Time

3.2.2 SLA for Compute Services

Most the cloud, grid service provider provides computing service to their consumers. In recent time, the Service Oriented Architecture (SOA) also comes into the computing field. The main point is that there is research on building middleware SLA infrastructure for computing services. Some of the current work: the European Union–funded Framework 7 research project, SLA@SOI, which is research on aspects of multi-level, multi-provider SLAs within service-oriented infrastructure and cloud computing [43]. In next Table 6, we showed traditional SLA parameter for computing services. The traditional SLA parameters [19, 22, 32, 27] for computing services are,-: *Broad Network Accessibility, Multi-tenancy, Rapid Elasticity, Scalability, Resource Pooling Time, Solution Time, Response Time, Availability (MTBF & MTTR), Capacity, Virtualization, Delay, Resolution Time and Logging & Monitoring.* Here, *Broad Network Accessibility, Multi-tenancy* and *Logging & Monitoring* are informative indicators presented in their SLAs.

Table 6. Basic SLA for Compute Services

Sl.No.	Performance Indicator Name	Description	Unit
1.	Broad Network Accessibility	Measuring the computing resources in large scale which involves deploying groups of remote servers and software networks e.g. allowing centralized data storage and online access to computer services or resources	% (Percentage) Or YES/NO
2.	Multi-tenancy	Possibility of sharing the same resources for serving multiple users at a time	YES/NO
3.	Rapid Elasticity	Ability to provide scalable computing services	% (Percentage)
4.	Scalability	Showing how scalable a computing system in order to meet demand on specific time	% (Percentage)
5.	Resource Pooling Time	Amount of time needed to provide services to multiple users with their provisional and scalable services	Time in Milliseconds Or Seconds

6.	Solution Time		The time taken to solve any problem after getting feedback from users	Time in Seconds/Minutes/ Hours
7.	Response Time		Measuring computing resource response time to do a task/process e.g. CPU time	Time in Milliseconds Or Microseconds
8.	Availability	MTBF	predicted elapsed time between inherent failures of a system during an operation and it is related to MTTR (failed system to be repaired)	Time in Milliseconds Or Seconds
		MTTR		
9.	Capacity		Minimum number of specified operation that can be processed in a stated time period	Number Or Request per Minutes
10.	Virtualization		Percentage of virtualized resource to be employed for successfully completing an operation	% (Percentage)
11.	Delay		Time to get delayed operation	Time in Milliseconds
12.	Service Time		Amount of time to compute one service	Time
13.	Logging & Monitoring		Either to get into logged in the computing system and keep tracking on it or not	YES/NO
14.	Resolution Time (TTR)		Amount of time to resolve customer issues in computing services; closely related with customer satisfaction	Time

3.2.3 SLA for Storage Services

The storage services are typically handled by cloud storage provider. Interestingly, today's cloud storage SLAs just ensure uptime guarantee but not data availability and data protection. In some case, traditional SLAs just mention about data storage security and backup but there is no proper authority or standard to check their commitments. Table 7 provide basic SLA performance indicator for storage services. Some common basic SLA performance indicator [14, 19, 22] for storage services are as follows-: *Availability, Response Time, Maximum Down Time, Uptime, Failure Frequency, Period of Operation, Service Time, Accessibility, Backup, Physical Storage Backup, Transportation for Backup, Size, Data Accessibility, Security.* Among all these parameters, some of them are just informative and subjective such as *Accessibility, Backup, Physical Storage Backup, Transportation for Backup,* and *Security.* These parameters might vary according to human perspective too.

Table 7. Basic SLA for Storage Services

Sl.No.	Performance Indicator Name	Description	Unit
1.	Availability	Percentage of connectivity with storage service provider in order to get optimum accessibility	% (Percentage) per time
2.	Response time	Measuring the time to get response from storage service provider e.g. retrieve data from database	Time in Milliseconds
3.	Maximum down time	Amount of maximum tolerable error rate from database side; closely related with Up time	Time Or % (Percentage)
4.	Failure Frequency	Chance of database failure in given time period	% (Percentage)
5.	Periods of Operation	Total operational database access time including remote access through network and as well as database retrieval	Time in Milliseconds/ Seconds
6.	Service Time	Average service time in a given interval e.g. 6 days in a week	Time in Hours/Day
7.	Accessibility	In case of any problem, either to access the stored data in some other way	YES/NO
8.	Back up	Data back up opportunities for storage service provider	YES/NO
9.	Physical Storage Back up	Either to have physical storage back up possibilities or not	YES/NO
10.	Transportation of Back up	If there is physical storage back up then policy of transportation	YES/NO
11.	Size	Amount of storage capabilities	Number in Bytes
12.	Data accessibility	Rate of data accessibility from database	Number per seconds
13.	Security	Policy of data security for both paid and free storage services	YES/NO

3.2.4 SLA for Multimedia Services

Here in multimedia service, the findings classified into three broad application areas- Audio, Video and Data. It is challenging to monitor and evaluate some qualitative indicator such as *Mean Opinion Score (MOS)* and *Lip Synchronization* for one way video, conferencing or in videophone. These could vary among different consumers at the same time. Most of the SLA indicators for multimedia services for different applications are *Information Loss (PLR), Jitter, One way Delay, MOS, Lip Synchronization, and Security Policy* [21]. The next Table 8 demonstrates SLA indicators for multimedia services.

Table 8. Basic SLA for Multimedia Services

Sl. No.	Media	Application Name	Performance Indicator Name	Unit
1.	Audio	Conversational Voice	Information Loss (Packet Loss Ratio)	% (Percentage)
			One way Delay	Time in Milliseconds
			Delay Variation (Jitter)	Time in Milliseconds
		Voice Messaging	Information Loss (Packet Loss Ratio)	% (Percentage)
			One way Delay	Time in Milliseconds
			Delay Variation (Jitter)	Time in Milliseconds
2.	Video	One way Video	Information Loss (Packet Loss Ratio)	% (Percentage)
			One way Delay	Time in Milliseconds
			Mean Opinion Score (MOS)	Number (0 to 5)
		Videophone	Information Loss (Packet Loss Ratio)	% (Percentage)
			One way Delay	Time in Milliseconds
			Mean Opinion Score (MOS)	Number (0 to 5)
			Lip Synchronization	Time in Milliseconds
3.	Data	Still Images	One way Delay	Preferred or Acceptable
			Information Loss (Packet Loss Ratio)	% (Percentage)
		Interactive Game	Information Loss (Packet Loss Ratio)	% (Percentage)
			One way Delay	Time in Milliseconds
		E-mail	Information Loss (Packet Loss Ratio)	% (Percentage)
			One way Delay	Time in Milliseconds
		Web-browsing	One way Delay	Preferred or Acceptable
			Information Loss (Packet Loss Ratio)	% (Percentage)
		Transaction Services e.g. e-commerce, ATM	Information Loss (Packet Loss Ratio)	% (Percentage)
			One way Delay	Time in Milliseconds
			Security Policy	YES/NO

3.3 Existing Green SLA (GSLA) for various Services

Most of the green SLA performance indicator corresponds to traditional high performance distributed computing environment such as grid and cloud computing industry. Currently, several IT industries and businesses provide their SLA with green computing practice. Green SLA survey shows that most of their green SLAs are mainly focused on energy/ power, carbon footprint, green energy, recycling issues. Additionally, several existing green SLA also demonstrates their productivity issues with necessary monitoring unit. The next Table 9 depicts existing green SLA survey with several headings. *Green Computing Domain* mentions the category of green computing practices in IT industry; *Performance Indicator Name* is the notion which used as an evaluating, monitoring metric for defining performance in green SLAs, and then the definition of the indicators as *Description* and finally the measurable unit as *Unit* column. All these performance indicators helps various service providers and consumers either to design or to choose services mainly with respect to energy consumption, renewable energy usages, carbon emission issues, productivity issues in recent days. Here, some data centers performance evaluating metrics are also presented. *Data Centre Productivity* (*DCP)* [38], *Data Centre Energy Productivity* (*DCeP)* [32, 38] and *Heating, Ventilation, Air-conditioning* (*HVAC)* [44] effectiveness indicators are still difficult to assess and control in some data centre's SLAs as they do not have any measuring units. The *Analysis Tool* and *EnergyBench* [45] used to inform about productivity in grid computing also do not have any measuring unit to evaluate or monitor in their SLAs. In some cases, *Carbon Usage Effectiveness* (*CUE)* [38] and *Green Energy Co-efficient (GEC)* [38] consider only on usages stages but these indicators are closely associated with some other indicators such as *Recycling* [42, 46]*, e-Wastage* [44], *Energy Cost* [36]*, and Total Power Consumption* [36, 45]. Some of these performance indicators in existing green SLA need to be defined newly and precisely and should state in their green SLAs according to government laws and standard. Some indicators could not be generalized as traditional green computing practices. Therefore, they just categorize as "others" in the tables. Next Table 9 demonstrated the performance indicators and their unit for different services considering green computing practices.

The following next section discussed briefly most of the performance indicators mentioned on the table.

Total Power Consumption- This indicator is important for assessing total electric power as well as renewable power or energy required to support and cooling in the data center. It is essential metric in planning for the development of a facility that will meet the end user's availability expectations for desired services [36, 45]. *Total Power Consumption* includes total electric power needed for lighting purpose, battery and Uninterrupted Power Supply (UPS) charging, cooling facility supporting, supporting electronic services and standby generator estimation. The measurable unit of this indicator is kilowatt per hour (kW-h) in existing green SLAs.

Power Usages Effectiveness (PUE) - PUE is a measurement of how efficiently a data center uses energy or how much energy is used by the computing equipment. Generally *PUE* is the ratio of total amount of energy used by a computer data center facility to the energy delivered to computing equipment [38, 44]. This indicator was developed by a consortium called The Green Grid (TGG). It is also the inverse of *Data Center Infrastructure Efficiency (DCiE)* [32, 43, 44]. Most of the cases, *PUE* is used as a marketing tool for companies. According to [44], accuracy of calculating IT load is the major factors affecting the measurement of *PUE* metric, as utilization of the server has an important effect on IT energy consumption and hence the overall *PUE* value. *PUE* is generally ranges from 1.0 to infinity, whereas an ideal value is 1.0.

Data Center Infrastructure Efficiency (DCiE) - This metric is used to calculate the energy efficiency of a data center and it is the ratio between IT equipment energy to the total energy data center energy usages. The total data center energy usages is the sum of electrical energy for IT, HVAC system, Power distribution, lighting and any other form of energy use such as steam or chilled water [44]. This indicator presented in most of the data center's SLA as "DCiE value" and the typical practice of this value is 0.5 and 0.7.

Compute Power Efficiency (CPE) - CPE helps to determine the total amount of power is truly used for computing purpose. This indicator could be calculated as the ratio between IT equipment utilization energy to the *Power Usages Effectiveness (PUE)* [38]. Usually the measurable unit for *CPE* is watts.

SPECPower- This is the first industry standard benchmark that evaluates the power and performance characteristics of volume server class computers [38, 47]. *SPECPower_ssj2008* [47] is the Standard Performance Evaluation Corporation (SPEC)'s first attempt for defining server's power measurement standards. This indicator usually measures the rate of computation for every watt of power consumed for a single server.

Energy Efficiency Benchmark- There is some alternate approach to monitor energy efficiency at data center levels. Some of this benchmark used to find energy efficiency into the initial design of components & systems and to adaptively manage system power consumption in response to changes in workload and environment [45]. The *Analysis Tool, EnergyBench, SWaP* and *JouelSort* [45] are commonly used benchmark in this area.

Water Usages Effectiveness (WUE) - WUE is the calculation of yearly water used by any data center such as for cooling purpose, energy production etc. It is the ratio between annual usages of water to the total energy used by IT equipment [38] and the monitoring unit is Liter per Kilowatt-hour. According to TGG, Source and Site based *WUE* metrics [48] need to monitor and both are beneficial for green computing practice. WUE_{source} ,a source based metric that includes water usages on-site and water usages off-site for the production of energy used on-site [48]. On the other hand *WUE,* a site based metric used to assess the water used on-site for operation of the data center. This includes water used for humidification and water evaporated on-site for energy production or cooling and its support systems in the data center [48]. However, general *WUE* provides a way to determine trade-offs in energy efficiency strategies by comparing other metrics such as *PUE and CUE* under various usages scenarios, operating conditions etc.

Thermal Design Power (TDP) - TDP metric was proposed by TGG consortium. This performance indicator helps to determine the maximum amount of heat generated from the whole facility for which a cooling system is required. The measurable unit of this indicator in SLAs is watts.

Energy Reuse Factor (ERF) - ERF is a metric that identifies the portion of energy that is exported for reuse outside of the data center. For example, reuse energy includes energy that is exported outside of the data center to another area within a mixed use building or to another facility. It is computed as reuse energy divided by total energy consumed by the data center [38]. *ERF* value ranges from 0.0 to 1.0, while 0.0 means no energy is reused or exported from the data center and 1.0 means all the energy brought into the data center is reused outside of it.

Energy Reuse Effectiveness (ERE) - This metric is only used when energy is being reused outside of a data center. This indicator is calculated as *ERE= (1-ERF) x PUE* [38]. The *ERE* value range defines from 0 to infinity. An *ERE* of 0 means that 100% of the energy brought into the data center is reused elsewhere. *ERE* and *ERF* alternatively used in existing green SLAs.

Green Energy Co-efficient (GEC) - GEC is a metric that quantifies the portion of a facility's energy that comes from green source. It is computed as the green energy consumed by the data center divided by total energy consumed by the data center [38]. Here green energy is defined as any form of renewable energy for which the data center owns the right to get green energy certificate or renewable energy certificate as defined by local/regional authority or government [49]. In *GEC* metric, complexity arises because there are regional or local differences in the definition of renewable/green energy. In SLAs, *GEC* indicator is simple to assess: the percentages energy that is green. It could be ranges from 0 to 1 where 0 indicates no green energy or renewable energy is used.

Carbon Usage Effectiveness (CUE) - One of the most important indicators that enables an assessment of total green house gas (GHG) emission such as CO_2, CH_4 in atmosphere, relative to its IT energy consumption. *CUE* is computed as total CO_2 emission equivalents from the energy consumption of the data center facility divided by total IT energy consumption. To completely find out the total GHG emission, a data center must include emission from all energy sources such as electricity, district heat, primary energy source (natural gas, diesel, bio-gas etc), and renewable energy produced on-site. Generally, for any data center with electricity as the only energy source, the equation for *CUE* is: *CUE=CEF x PUE;* where *CEF* is the carbon emission factor (kgCO_2eq/kWh) of the site [49]. This carbon factor is varied according to the country's environmental laws and regulation. *CUE* has an ideal value of 0.0 indicating that no carbon is associated with the data center's operations. This indicator has no theoretical upper boundary [49].

IT Equipment Energy Efficiency (ITEE) - This metric helps to install IT equipment with less energy consumption in any data center facility. *ITEE* is calculated by summing all the IT equipment rated with capacity divided by all rated power consumption of IT equipment

[50]. This indicator usually presented in SLAs as sub-metric of *DPPE (DataCenter Performance Per Energy)* metric [50] and showing the efforts to procure energy saving for IT equipments. In some case, *ITEE* alone also represents energy efficiency of all the IT equipments in whole data center.

IT Equipment Utilization (ITEU) - This is also a sub-metrics of *DPPE* [50] to promote reduction in energy consumption by improving utilization rate of IT equipment and reduce of surplus equipment investment.

DataCenter Performance Per Energy (DPPE) - It means work production per carbon energy in the data center [50]. IT is possible to calculate with four other sub-metrics- *ITEU, ITEE* [50]*, PUE* [36, 44] and *GEC* [38] using following equation [50].

$$DPPE = ITEUxITEEx\frac{1}{PUE}x\frac{1}{1-GEC}$$

The purpose of expressing *DPPE* as a product of each sub-metrics is to calculate data center capacity per non-green power. *DPPE* might become infinite when *GEC* is 1. Therefore, the maximum value for *GEC* should be limited to 0.8 when calculating it [50].

Heating, Ventilation, Air-conditioning (HVAC) Effectiveness – This performance indicator is the ratio of the IT equipment energy to HVAC system energy. The HVAC system energy is the sum of electrical energy for cooling, fan movement and any other HVAC energy use like steam or chilled water [44]. It is a dimensionless metric and provides a measure of the overall efficiency potential for HVAC systems in which the higher values relative to the peer group suggest higher potential to reduce HVAC energy use. The HVAC energy use can be reduced by using strategies such as "free-cooling" with air economizer and geographically site-selection for building date center etc.

Cooling System Efficiency- This metric characterizes the overall efficiency of the cooling system (including chillers, pumps and cooling towers) in terms of energy input per unit of cooling output at the data center. It is the average value showing average power of the cooling system with respect to the cooling load in the data center facility [44] and the measurable unit is kw/ton. However, there are many efficiency actions that could be used to improve the overall efficiency of any chiller plant such as modularization, high efficiency chillers, premium efficiency motors, water-side economizer etc. [44].

eWastage – According to e-waste guide this term is used as a generic term embracing all types of waste containing electrically powered components. e-Waste contains both valuable materials as well as hazardous materials which require special handling and recycling methods. ORDEE from Swiss and WEEE directive from EU demonstrate guidelines and categorization of e-wastage in recent days. In some green SLA, e-wastage means the total amount of IT wastages produced at a certain period of time in any facility and the smallest measurable unit is gram (gm).

Recycling- According to [42, 46], the percentages of IT equipment to be recycled at a given specified time period in IT industry. The Recyclability Rate (RR) [42] could the most appropriate metrics to evaluate or monitor in green SLA. The RR of an item of IT equipment ranges from 0 to 1, where 1 corresponds to 100% recyclability and it means that the item of an IT equipment is fully reusable as resource in other applications [42]. However, carbon emission and energy consumption issues need to be considered while recycling an IT equipment. Therefore, this indicator might become difficult to assess in future green SLA for achieving sustainability.

Data Center Productivity (DCP) - DCP is used to assess the productivity of data center by calculating the amount of useful work done in the data center [38]. There is no standard measurable unit for this metric. Thus, it could be evaluated and monitor by third party or some common governing authority.

Data Center Energy Productivity (DCeP)- DCeP is the ratio between total useful work done by total energy use to do this work whereas *DCP* is the ratio of total useful work done by total resource used to complete this work [38]. Therefore, this productivity metric is more related with energy usages issue though in the table it is shown as productivity information in the light of green computing practice. *DCeP* measurement unit is still unknown.

Server Compute Efficiency (ScE) - ScE finds out the specific server health and measurement in percentages [38].

Space, Wattage and Performance (SWaP) - This is a three dimensional metric that provides a more comprehensive and realistic way to assess any server in recent days. This indicator is the ratio between performance and space x power in the data center. *SwaP* was developed by Sun Microsystem and they believe that traditional metric like *ScE* are only good for calculating throughput but it does not consider the power and space demands in their calculation. Here, space is also calculated by measuring the height of the server in rack units (RUs) and power is measured in watts.

Air Management Metric- This metric is composed of four other sub-metrics in any data center- *Temperature Range, Humidity Range, Return Temperature Index and Airflow Efficiency* [44]. The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) guidelines provide a range of allowable and recommended supply temperature and humidity at the inlet to the IT equipment [44]. Although, this indicator is composed of other four important sub-metrics, in some green SLAs only the temperature range is shown as *Air Management Metric.* Usually, this is a dimensionless indicator and sometimes it shows Fahrenheit (F) as measurable unit while consider only temperature range.

UPS System Efficiency- This indicator is the ratio of the UPS output power to the UPS input power [44]. The UPS efficiency varies depending on its load factor and its measurable unit is % (Percentage). At UPS load factor below 40%, the system usually is highly inefficient due to no load losses [44]. UPS manufacturer claim that improved efficiencies are available today but still when selecting UPS it is very much important to evaluate performance over the expected loading range for the IT industry. This indicator is important from the companies' perspective; users usually overlooked this kind of indicators in their SLAs.

Energy/Power Cost- It is an economic assessment in existing green SLAs in recent time. The cost is typically given per kilowatt-hour or megawatt-hour according to government rules and regulation [45]. This costing information also includes renewable energy/green energy cost and also the cost due to some safety investment for using some renewable energy. For example, The French authority adds 04 euro per megawatt-hour (MWh) for the safety investment in their nuclear plant. There are many sources of renewable energy in recent days such as tidal power, wave power, wind power, solar, radiant energy, geothermal, nuclear and biomass etc. Among these, the solar power is the most expensive source to produce electricity but it has some long term advantages such reducing production cost and less environmental impacts. The costing information for power or energy usages stated in some existing green SLAs.

Mean Opinion Score (MOS) - MOS indicators usually used in multimedia service SLAs for monitoring the quality of audio and video applications over the network [51]. This metric is very much subjective, as it is based from what is perceived by people during test. *MOS* is expressed in number, from 1 to 5, where 1 being the worst quality and 5 is the best [42, 51].

User Satisfaction- This kind of information is used in some SLAs without any measurable unit. It is just an informative indicator and very much subjective to those who participate to find out the satisfaction level of any services in IT industry. This indicator is quite complex to assess and monitor. User satisfaction could be rated from 0 to 5, where 0 indicates worst level of satisfaction and 5 is the preferred level.

Reliability- It means whether the service deliver to the intended user without any kind of interruption and closely related with some other basic SLA's indicators such as *Mean Time Between Failure (MTBF), Mean Time to Restore (MTTR), Availability, Delay, Bandwidth* etc. According to Cronbach's Alpha or coefficient alpha, user reliability ranges from 0.0 to 1.0.

Risk Assessment- In some green SLA, providers put the information about their system's security threat as *Risk Assessment.* They just mention how many percentages of their system might vulnerable to attack in some consequences of user's activity. For example, while an authentic user trying to get access his/her database with wrong id and password (by mistake) and at the same time hackers might took that chance to attack the 40% of that company's database at certain location.

Table 9. Performance Indicator for different services considering green SLA

Sl. No.	Green Computing Domain	Performance Indicator Name	Description	Unit
1.		Total Power Consumption [36,45]	Amount of total energy consumed while providing services;	kW-h (Kilowatt-hour)
2.		PUE (Power Usages Effectiveness) [32,38,42,44]	Fraction of total energy consumed by the service of a data centre to the total energy consumed by IT equipments;	Number (1.0 to ∞) Or Dimensionless
3.		DCiE (Data Center Infrastructure Efficiency) [32,43,44]	To calculate the energy efficiency of a data centre;	% (Percentage)

4.	Energy/ Power	CPE (Compute Power Efficiency) [38]	Total amount of power needed for computing;	Watts
5.		SPECPower [32, 38]	Power consumption per server on a given workload to complete;	Watt
6.		WUE (Water Usages Effectiveness) [38]	Ratio of the annual water usages to the IT equipment energy;	Liter/kW-h
7.		TDP (Thermal Design Power) [38,44]	Maximum amount of heat generated for which the cooling system is required;	Watts
8.		ERF (Energy Reuse Factor) [38]	Amount of reusable energy like hydro, solar, wind power etc used outside of a data center;	Number [0.0 to 1.0]
9.		ERE (Energy Reuse Effectiveness) [38]	Measuring the profit of reusing energy from a data center;	Number [0 to ∞]
10.		GEC (Green Energy Co-efficient) [38]	Amount of green energy used to provide services in green grid computing usually on usage stages;	Number [0.0 to 1.0]
11.		ITEE (IT Equipment Energy Efficiency) [50]	Ratio between IT equipment used and their energy consumption;	% (Percentage)
12.		ITEU (IT Equipment Utilization) [50]	Ratio between total energy (kWh) of all IT equipment and their total energy specification (Power rating in kWh);	Number
13.		HVAC (Heating, Ventilation, Air-conditioning) Effectiveness [44]	Ratio between the IT equipment energy to the HVAC system energy;	Dimensionless
14.		Cooling System Efficiency [44]	Characterizes the overall efficiency of the cooling system (including chillers, pumps, and cooling towers) in terms of energy input per unit of cooling output;	kW/ton (kilowatt per ton)
1.	Energy Efficiency Benchmark	JouleSort [45]	Amount of energy required to sort different size of records in data centre;	kW/J (Kilowatt per Joule)
2.		Analysis Tool[45]	Performance per watt in green grid computing;	Not Known
3.		EnergyBench [45]	Throughput of work per Joule for computing;	Numeral Rating
4.		SWaP (Space, Wattage and Performance) [32, 38,45]	Ratio between performance and space x watts;	Not Available
1.	Carbon footprint	CUE(Carbon Usages Effectiveness) [38]	calculation of green house gases (CO2, CH4) release in atmosphere usually on usage level;	KgCO2 per kW-h OR [0.0 to 1.0]
2.		DPPE (Data Center Performance Per Energy)[50]	Ratio between Data center's throughput (work) by carbon energy;	Number [0 to 1]

1.	Recycling	e-Wastage Or IT Wastage [44]	Amount of IT wastages per product, services, process, facility or even the whole industry;	Gm (Gram)
2.		Recycling [42, 46]	Percentages of IT equipment to be recycled at a given specified time period;	% (Percentage)
1.	Productivity	DCP (Data Center Productivity) [38]	To calculate the amount of useful work done by data centre;	Not Available
2.		DCeP (Data Center Energy Productivity) [32, 38]	Quantifies useful work compared to the energy it requires; It can be calculated for an individual IT device or a cluster of computing equipment;	Not Available
3.		ScE (Server Compute Efficiency) [38]	To find the specific server's computing efficiency (Server Health);	% (Percentage)
1.	Costing Information	Energy Cost/Power Cost [45]	Cost of power consumed per kilowatts hour used including renewable energy cost;	Currency [according to law]
1.	Others	User Satisfaction [19, 32]	Satisfaction level of an user while getting services;	Number [0 to 5]
2.		Mean Opinion Score (MOS) [19,32,51]	Human's view for measuring the quality of a network; specially for audio and video;	Number [1 to 5]
3.		Reliability [32]	Service delivery to the intended user without interruption;	Number [0.0 to 1.0]
4.		Air Management Metric [44]	Finding the difference between the supply and return air temperature in the data centre;	F (Fahrenheit)
5.		UPS System Efficiency [44]	Ratio of the UPS output power to the UPS input power;	% (Percentage)
6.		Risk Assessment [19, 32]	Percentage of systems are involved in security threat; very few SLA mentioned it;	% (Percentage)

3.4 Discussion

In this chapter, the rigorous theoretical and empirical work on existing basic SLA and as well as existing Green SLA are showed in a tabular format. Table 5 to Table 8 lists all performance indicators and their measurable units for Network, Compute, Storage and Multimedia services. Here, most of these performance indicators are quantitative parameter; some are qualitative, informative and subjective parameter such as *MOS, Lip synchronization* and *Security policy* for multimedia service SLA. These qualitative and informative parameters might vary and difficult to evaluate and monitor. Mathematical model and robot simulation might helps to standardize these parameters in future. Most of the performance indicators in basic SLA are related with service availability and timing concern and they did not focus on energy consumption, carbon footprint issues. Table 9 demonstrated the performance indicators and their unit for all the mentioned services considering green computing practices. Here, most of the parameter usually used in data center, cloud and grid computing infrastructure. All these parameter is well established in recent green SLAs and easily monitored and controlled. They focused energy consumption issues and productivity issues through the greening lens. Very few indicators were found on carbon footprint and recycling issues. In most of the recent green SLAs over looked many parameters for achieving full sustainable development such as IT ethics, economical issues and ecological issues. Additionally, some performance indicator such as *CUE (Carbon Usage Effectiveness), GEC (Green Energy Co-efficient), Total Power Consumption, Recycling, HVAC* needs more precise calculations for evaluating because these parameter has association with other parameters for making SLA greener in future. As an example, while considering recycling IT equipment, is also directly associated with carbon issues, energy consumption issues. Additionally, in table 9, some parameters such as, *MOS, User Satisfaction, Reliability* and *Risk Assessment* used as an informative statement in some existing green SLA. These parameters did not cover any green computing practice field. Therefore, these indicators might need to assess and evaluate more standard way to include future green SLA. In present studies, there is no specific standard or common format to design and evaluate existing green SLA. Therefore, most of the parameters indicated in existing green SLA were very much difficult to understand and evaluate in GSLA research.

CHAPTER FOUR

4 RESULTS AND CONTRIBUTIONS

Results and contribution section discusses the most important missing performance indicators from existing green SLA through the sustainability lens. A new green SLA is propose here after accumulating all these existing green indicators and also need to add new indicators, which are demonstrates in the next following tables. In order to achieve sustainability, the ICT engineers from different service providers need to add all performance indicators in their future green SLA with respect to ecology, economy and ethics point of view. At the same time, it might be very complex and difficult task for the ICT engineer to incorporate all parameters and their interrelationship in green SLA. Moreover, this research also contributes to propose an informational model to define proposed green SLA as well as mitigate the problem of incorporating a new green SLA in IT industry. Finally, the proposed informational model is validated by using Bayesian Network Model (BNM).

4.1 Green SLA (GSLA) Proposal

In existing green SLAs, most of the performance indicators mainly focus on energy consumption issues and productivity concern in cloud and grid computing industry (Table 9). Most of them do not consider recycling, radio wave, toxic material usage, noise, light, sight pollution for sustainable development. Moreover, people's interaction and IT ethics issues, such as user satisfaction, intellectual property right, user reliability, confidentiality etc are also missing in recent days green SLA. Next section discusses the proposed new performance indicators of green SLA for achieving sustainability from 3Es perspectives (Ecological, Economical and Ethical). Fig. 12 shows the concepts of 3Es relationship, that IT engineer can use as a guideline to respect all the facets of sustainable development. The following tables explain each of the performance indicators and their measurable unit for proposing new green SLA.

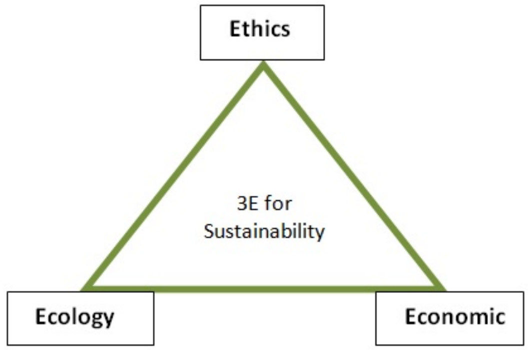

Fig.12. 3Es for Sustainability

The sustainability is not only expressed in term of longevity of solutions [42] but it also needs to care about economical aspects and ecological or environmental aspects as well as ethical point of view. The more energy or power is needed, the more money spent; at the same time the more renewable energy source needed. Again, burning energy will produce more GHG emission to the environment. Additionally, people are getting much more dependent of IT and ICT industry day by day. Therefore, people's awareness from either consumer sides or industry sides is also playing more vital role for sustainable development. Thinking about this ethical point, the ethics parameter must plays important role here. In the next following section discusses some of the missing parameters for making SLA greener, which are usually not used in recent times green SLA.

4.1.1 GSLA indicators from Ecological point of view

Recycling- The recycling of ICT equipment impose into their whole life cycle. This is a very complex indicator and need to be sub divide as reuse, refurbish, sub-cycling and up cycling. According to [42, 46], the Recyclability Rate of an equipment ranges from 0 to 1. Again, at each stage of recycling, it needs to be considers the *CUE, GEC, Energy Cost* (Table 9) because recyclability includes energy consumption and carbon emission simultaneously. Recycling has direct relationship with eWastage and pollution as it helps to reduce global magnitude of e-waste. On the other hand, if recycling procedure is not well managed then it could pollute air, water and soil. Recycling information should put into green SLA according to government laws, directives such as Waste Electrical and Electronic Equipment (WEEE) Directive (2012/19/EU) by European Union (EU). There are also some voluntary recycler standards in US like *e-Steward and Responsible Recycling (R2) Practices*.

Toxic Material Information- Electric and Electronic products contain several toxic materials such as Beryllium, Cadmium, Lead, and Mercury etc. These chemical elements and their compound both cause serious health hazards and also make environment polluted. Beryllium is used in manufacturing computer motherboard and is acutely & chronically toxic to humans mainly affecting their lungs [52]. Cadmium and its compounds is used in some switches, many laptop's batteries and in some older CRTs monitor as phosphor coating. These materials and its compounds are also toxic to human, which affects kidneys in the long run [52]. Lead is usually used for primary electric solder on printed circuit boards. Lead could damage to the nervous system and blood system in human body [52] and also causes severe air pollution. In some switching devices and batteries, mercury could be used which is highly toxic. Mercury has a high level impact on human nervous system [52]. Additionally, Polyvinyl Chloride (PVC) is a chlorinated plastic incorporated into some electrical and electronic products, including as insulation on wires and cables in networking facility [53]. Both the production of PVC and its disposal by incineration can result in the generation of chlorinated dioxins and furans [52]. These chemicals are highly persistent in the environment, able to bio accumulate and many are toxic to humans, animals and plants. All of these mentioned toxic material used in IT industry should have a safety limit and needs to be defined or restricted by third party or governing body such as Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (2002/95/EC) from EU commonly known as RoHS Directive. The information about the usage of these toxic materials in IT and ICT field should be stated clearly for making SLA greener.

Obsolescence Indication- The services, process, product or technology used or produced by a company for profit will become obsolete after certain period. Therefore, it is a matter of urgency in ICT industry to indicate or label product's life time with obsolescence indicators [54] according to product's raw materials scarcity, demands, usages limit etc at different stage of product's life cycle. These indicators should be stated in a proposed green

SLA to create awareness for both customer levels and company levels for achieving sustainability. It might be complex to indicate or determine the obsolescence of ICT equipment because it depends on different variables associated with equipment's production cost, raw material scarcity, energy issues and user's interaction. Additionally, *Optimum Obsolescence* [55] indication would help to decide when a product to be reused, recycled or land filled of any ICT equipment. There is no standard to indicate this parameter in SLAs till now but it might be related with product life cycle costing, recyclability rate indicators as well.

Radio Wave Information- The electromagnetic radiation emitted by electronic equipment in IT industry, is a controversial topic in scientific community. The health effects of radio waves were also studied and most of these studies found that the EMF (electromagnetic field) effects on the human body are not only depends on their field level but on their frequency ranges and energy [42, 46]. All studies claim that the unique non controversial effect of non ionizing EMF is thermal [46]. In some cases, these radiations might cause severe health hazards such as brain cancer, heart diseases and even leukemia. To avoid this electromagnetic effect, the government of each country defines maximum level of EMF generated by wireless antenna and their maximum *Specific Absorption Rate (SAR)* value [42]. According to SCANTECH, Australia [56], for measuring the EMF levels and safety the following units are used. *Gauss (G), Tesla (T)* for EMF values; *Gray (Gy)* and *Sievert (Sv)* for measuring radiation effects on human tissues. These radio waves information should state in green SLA according to government's defined level clearly and precisely.

Noise Pollution- The network engineer who works in Data Centre might need guidelines and regulations to control noise pollution in his/her workplace. The noise generated from data centre causes hearing loss permanently [57]. OSHA and NIOSH- these two US government agencies look after the limit of noise level in work places. The noise pollution level might be stated on green SLA using decibel (dB) measuring unit. Moreover, the noise created by ICT equipment such as Ringtone of a cell phone might also responsible for some sort of pollution as it become disturbing and irritating for other peoples. This type of pollution might be subjective and easily prevented by increasing awareness among the cell phone users.

Visual Pollution- The aesthetic aspects of ICT industry, for example- installing an antenna in a beautiful landscape or on a roof top. This could create hypersensitivity affect [42] and these might be very much subjective to human being such as Perception of Affective Quality (PAQ) [58] is an individual's perception of an object's ability to change his/her neurophysiological states as feeling either good or bad.

Light Pollution- Computer Screen generates light pollution affecting health [42]. According to American Optometric Association, Computer Vision Syndrome (CVS) causes headache, blur, dry eye, watery eye, eyestrain, sleep disorder, redness, double vision etc [59, 60]. Moreover, the lighting in workplace might also create health hazards. Many individuals who worked under uncomfortable light in his/her office for long time might have some problems such as ocular discomfort, muscular strain and stress [61]. The safe computing practice and awareness might help to decrease CVS and as well as there should be some level of standard to look after the lighting comfort in workplaces. However, there is still no standard or measurable unit for light pollution level and its environmental impact but it should be mentioned in proposed green SLA.

The next Table 10 demonstrates the proposed green SLA from ecological point of view and their proposed measurable units.

Table 10. Green SLA proposal consider Ecology pillar for sustainability

Sl. NO.	Performance Indicator Name		Description	Domain	Unit
1.	Recycling Rate (RR)	Reuse	Amount of ICT product reuse/ percentage of ICT equipment refurbished/ percentage of IT equipment sub cycled or up cycling;	Network, Multimedia, Compute, Storage	gm (gram) OR % (Percentage) OR RR[0~1] [40]
		Refurbish			
		Recycle			
2.	Toxic material limit/ Toxic material Usage Level		Information about using toxic material in ICT product and their limit level;	Network, Multimedia, Compute, Storage	Preferred/ Acceptable

Sl. NO.	Performance Indicator Name	Description	Domain	Unit
3.	Obsolescence Indication	Indication about the perfect time to change an ICT equipment;	Network, Compute, Storage,	Labeling according to laws
4.	EMF Level/ Radiation Effect Level	Amount of electromagnetic energy radiation; usually the strength is measured by frequency;	Network, Multimedia, Compute, Storage	T (Tesla) / G (Gauss) OR Sv (Sievert) / Gy (Gray)
5.	Noise Pollution Level	The noise emitted from ICT equipment e.g. Ringtone of Cell phone, noise in data centre;	Network, Multimedia, Compute, Storage	µdB/dB (micro decibels)
6.	Light Pollution Level	The light pollution generated by ICT equipment e.g. Computer Screen;	Network, Multimedia, Compute, Storage	Subjective
7.	Visual Pollution Level	The aesthetic aspect of ICT industry e.g. installing an antenna in a beautiful landscape or roof top;	Network, Multimedia, Compute, Storage	Subjective OR *PAQ* [54]

4.1.2 GSLA indicators from Economic point of view

Carbon taxation- A number of countries has implemented carbon taxes [62] or energy taxes and *Cap and Trade System* [63] that is very much effective to reduce Green House Gas (GHG) emissions while stimulating technological innovation and economic growth. The taxation may create political or social unrest in some countries, therefore might be complex to impose. In 1990s, a carbon/energy tax was proposed at the EU level but failed due to industrial lobbying but in 2010, the European Commission implemented a pan-European minimum tax on pollution under the European Union Greenhouse Gas Emissions Trading Scheme (EU ETS) [62]. According to this new plan, 4 to 30 euro would be charged per ton of carbon emission. On the other hand, in US the Cap and Trade gave more assurance to decline GHG emission and also has some political advantages [63]. Therefore, according to different country's economic, social or political culture, carbon taxation or *Cap and Trade* policy should need to be established and this information need to put in a green SLA.

Civil Engineering Cost- The cost of civil engineering includes building cost, antenna setup cost, digging tranches for cabling etc. The building costing also need to consider designing cost, manufacturing cost, renovation cost and finally dismantling cost of an IT facility or data centre. All these costing information should come into proposed GSLA. The cost of building design indicator is also associated with carbon emission indicators in each step. It is important to note here that, the new green datacenter have an environmental impact in their lifespan. For example, most of the green datacenter uses natural resources (air, water) for cooling purpose but also at the same time it dissipates heat directly to the atmosphere, which might create imbalance in the surrounding eco-system of that datacenter.

Cooling Cost- The cooling system costing information need to be mentioned in the proposed green SLA. It includes energy (electric power, renewable energy) costing, infrastructure (humidity, temperature monitoring) and transportation costing for cooling the whole site. This indicator becomes complicated because of *HVAC, Air Management Metric* and *Cooling System Efficiency* indicators in existing green SLA (Table 9) and these might need to define newly. Moreover, carbon emissions also need to assess regarding transportation of cooling equipment for the sites.

ICT Product Life Cost- ICT product life costing consider the whole life cycle of a product cost including mainly manufacturing from raw materials, purchasing, delivery, operational and end of life. Operational cost has association with utility cost such as energy and maintenance costing and end of life costing also has association with recycle or refurbishment costing. Again, the life cycle assessment (LCA) [32] need to be considered in this parameter. ICT Product life cost indicators, thus become very complex to assess and monitor in GSLA. Table 11 showed the economic performance indicators and their measuring unit for evaluating proposed GSLA.

Table 11 shows the economic performance indicators and their measuring unit for evaluating proposed green SLA.

Table 11. Green SLA proposal consider Economic pillar for sustainability

<table>
<tr><th>Sl. NO.</th><th colspan="2">Performance Indicator Name</th><th>Description</th><th>Domain</th><th>Unit</th></tr>
<tr><td>1.</td><td colspan="2">Carbon Tax</td><td>Tax for carbon content on fuel in most case; this should be charged according to government laws;</td><td>Network, Multimedia, Compute, Storage</td><td>Currency (euro)</td></tr>
<tr><td>2.</td><td colspan="2">Cooling Cost</td><td>Amount of cooling cost in a data center or percentages of renewable energy usage for cooling;</td><td>Network, Multimedia, Compute, Storage</td><td>Currency (euro)</td></tr>
<tr><td rowspan="5">3.</td><td rowspan="5">ICT Product Life Cost</td><td>Manufacturing</td><td rowspan="5">Considering the whole life cycle of an ICT product and their costing; LCA assessment need to consider here;</td><td rowspan="5">Network, Multimedia, Compute, Storage</td><td rowspan="5">Currency (euro)</td></tr>
<tr><td>Purchasing</td></tr>
<tr><td>Delivery</td></tr>
<tr><td>Operational</td></tr>
<tr><td>End of Life</td></tr>
<tr><td>4.</td><td colspan="2">Civil Engineering Cost</td><td>Information about costing related building, antenna installation, digging for cabling etc.; Also, in building costing includes energy efficient building infrastructure and their costing including dismantling;</td><td>Network, Multimedia, Compute, Storage</td><td>Currency (euro)</td></tr>
</table>

4.1.3 GSLA from Ethics point of view

Mostly, the green computing practice focuses on the ecological, economical point but usually neglect human's interaction and ethical aspects [42]. The use of ethics in IT and ICT field covers many indicators such as *Satisfaction level, Intellectual Property Right, Reliability, Confidentiality, Security and Privacy, Gender/Salary/Productivity Information.* All of these indicators are usually subjective metrics, thus making green SLA assessment difficult. The ICT Company should analyze social responsibilities towards *Customers, Employee and Community* [42, 65]. Table 12 gives the idea of these responsibilities as performance indicators with respect to ethics for greening SLA to achieving sustainability. In addition, the natural resources are decreasing day by day because of green energy, renewable energy usages are increasing. *Earth Resource Depletion* issues also need to consider here. Almost 07 billion people around the world consume the natural resources like water, gas, oil and forests in their everyday life. The social economic sustainable development will be impossible in this limited resource based planet. Therefore, at present social responsibilities and awareness is very much important while consuming natural resources both in business as well as in daily life living.

Table 12. Green SLA proposal consider Ethics pillar for sustainability

<table>
<tr><th>Sl. NO.</th><th colspan="2">Performance Indicator Name</th><th>Description</th><th>Domain</th><th>Unit</th></tr>
<tr><td>1.</td><td colspan="2">Satisfaction level [Customer, Employee, Community]</td><td>Whether the customer, employee and community are satisfied with; [usually defined by third party or community]</td><td>Network, Compute, Storage</td><td>Rating OR CSI [66]</td></tr>
<tr><td>2.</td><td colspan="2">Intellectual Property Right [Customer, Employee, Community]</td><td>IPR means copyright, patents of user’s data; no hacking; royalty etc. ;</td><td>Network, Multimedia, Compute, Storage</td><td>YES/NO</td></tr>
<tr><td>3.</td><td colspan="2">User Reliability</td><td>Whether customer reliability preserved by the company ; reliability between employee and company;</td><td>Network, Multimedia, Compute, Storage</td><td>Test based Rating</td></tr>
<tr><td>4.</td><td colspan="2">Confidentiality</td><td>Information should be kept confidentially and also available for customer, employee or for community;</td><td>Network, Multimedia, Compute, Storage</td><td>Test based Rating</td></tr>
<tr><td rowspan="7">5.</td><td rowspan="7">Security & Privacy</td><td>Authentication & Authorization</td><td rowspan="7">Rules regarding security and privacy should clearly state and defined or not; usually it could be defined third party or government law.</td><td rowspan="7">Network, Multimedia, Compute, Storage</td><td rowspan="7">High / Medium / Low

OR
Preferred/ Acceptable</td></tr>
<tr><td>Access Control & Privilege Management</td></tr>
<tr><td>Data Geographic</td></tr>
<tr><td>Data Integrity</td></tr>
<tr><td>Transparency</td></tr>
<tr><td>Physical Security</td></tr>
<tr><td>Termination Management</td></tr>
<tr><td>6.</td><td colspan="2">Gender Balance Information</td><td>The information about gender balance in an organization;</td><td>Network, Compute, Storage</td><td>YES/NO</td></tr>
<tr><td>7.</td><td colspan="2">Salary Balance Information</td><td>The salary balance of an organization in IT industry;</td><td>Network, Compute, Storage</td><td>YES/NO</td></tr>
</table>

4.2 Defining proposed green SLA using Informational Model

Sustainability is not only expressed in terms of longevity, productivity, energy consumption issues of various services in IT industry. Current trends in the developed society shows that people much more concern about other factors of sustainable development such as carbon taxation, green house gas (GHG) emission, ICT pollution, recycling and ethical aspects etc. Moreover, human's interaction is playing a vital role through SLA or green SLA in IT business arena. However, the recent trends of green SLAs are focusing only on energy/power consumption and productivity issues. Very few data center put carbon/Green House Gas (GHG) emission and recycling information in their existing green SLAs. The economical aspects, such as building cost, cooling cost, ICT product cost etc. always overlook in most of the cases though it is one of the important variables for sustainable development in future. In the previous contribution section, this research finds most of the important performance indicators with respect to three pillars of sustainability and this will definitely help ICT and IT service providers to develop and design their existing green SLA more greener for achieving sustainability as well as making more profit in their businesses. However, ICT engineer would face some challenges to incorporate, manage and finding the relationship between all new performance indicators for green SLA under three pillars of sustainability in future.

This GSLA research tries to help ICT engineers to define their green SLA using an informational model language and found Unified Modeling Language (UML)' s class diagram [67] is the best suitable. This UML model would try to find out the interrelationships, interdependencies and complexity of managing all the new performance indicators with respect to three pillars of sustainability- Ecology, Economy and Ethics. The general global view of GSLA indicators with respect to three pillars are shown in Fig. 14 and then the relationships, interdependencies and management complexity among the new indicators and existing indicators are depicted with discovering some important new services under sustainability lens and explained them briefly with necessary figures and relationship tables.

Here, it is important to indicate that, the *ICT Product Life Cycle* must need to include at the first level of GSLA model as this entity and its sub-entities (manufacturing, transportation, usage and dismantling) have direct relationship to calculate existing ecological, economical and ethical indicators, such as carbon emission, energy consumption, recycling, energy cost etc. Again, to achieve sustainability the proposed *GSLA* entity should aggregate and satisfy all three entities in general model- *Ecology Pillar, Economy Pillar, Ethics Pillar*. In general, the ICT product life cycle and its relationships with sustainability pillars coexist while developing future GSLA. Therefore, the interaction between *ICT Product Life Cycle* and GSLA are shown first (Fig. 13) and then the general global model of future GSLA is proposed next (Fig. 14).

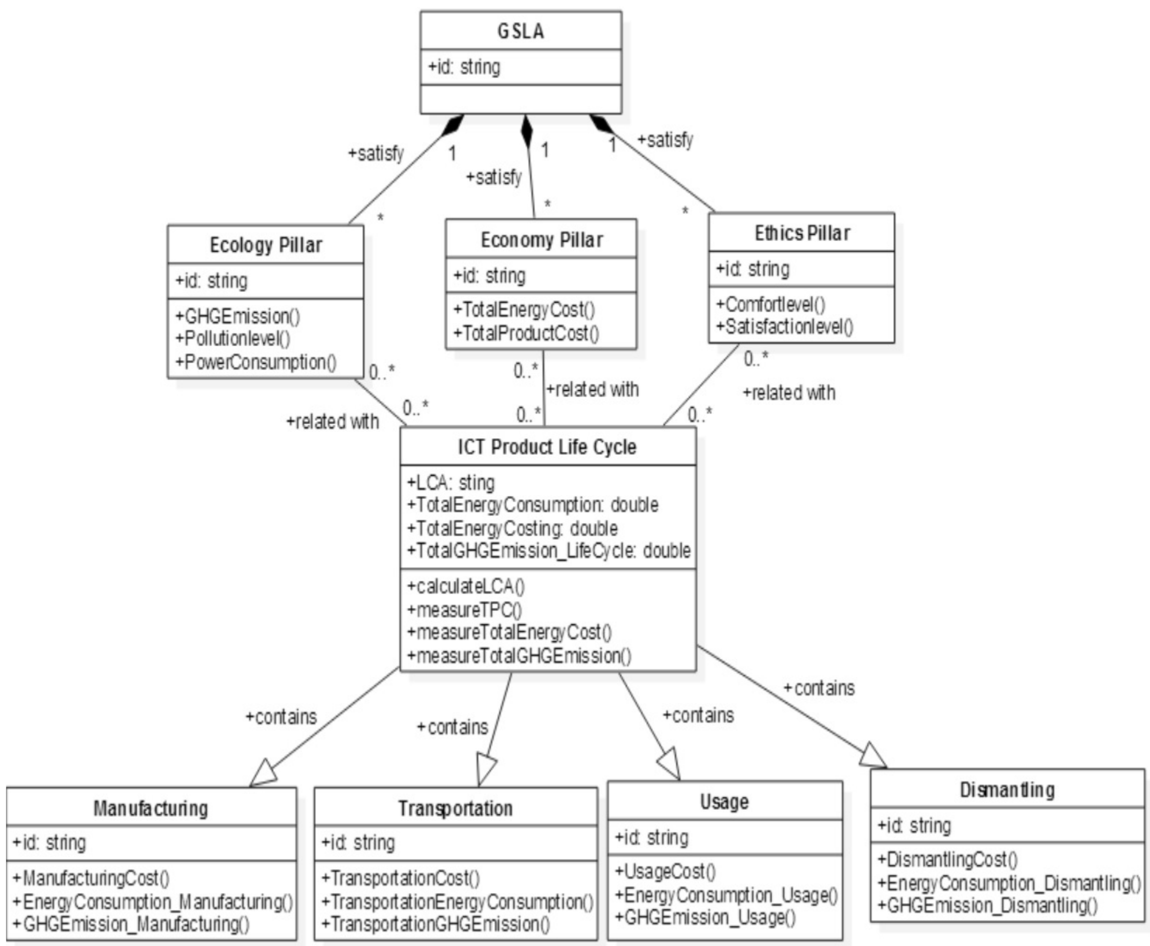

Fig.13. Relationship between GSLA and ICT Product Life Cycle

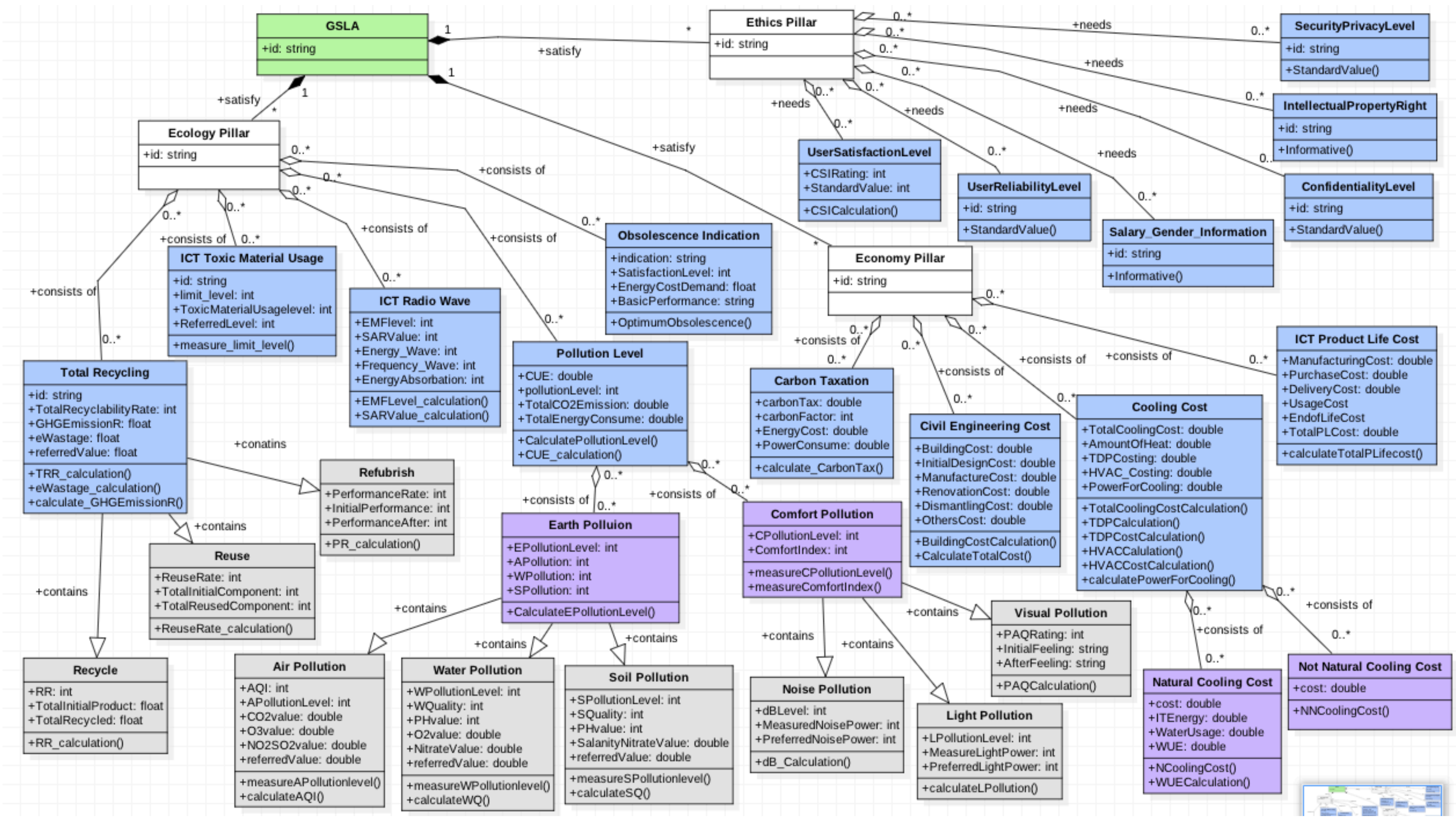

Fig.14. General UML model to define proposed green SLA indicators

4.2.1 Discussion about the General Model

1. To achieve sustainability, the proposed *GSLA* entity should aggregate and satisfy all three entities in general model- *Ecology Pillar, Economy Pillar, Ethics Pillar*.

2. It is important to indicate that, the *ICT Product Life Cycle* must need to include at the first level of GSLA model as this entity and its sub-entities (manufacturing, transportation, usage and dismantling) have direct relationship to calculate existing ecological, economical and ethical indicators (Fig. 13), such as Total Power Consumption, Total Energy/Power Cost, GHG emission etc.

3. *Ecology Pillar* entity is consisting of following missing indicators from existing green SLAs, *Total Recycling, ICT Toxic Material Usage, ICT Radio Wave, Pollution level* and *Obsolescence Indication.*
   Total Recycling is a complex indicator and it could compose of three other sub metrics- reuse, refurbish or recycling of an ICT product or equipment. However, for simplicity, it depicts as one entity in UML model. Total recycling entity has direct relation with existing green indicators from Table 9, such as *e-Wastage* and *Recycling* under green computing domain. Again, in the general model, *Pollution level* consists of two other sub-entities, - *Earth Pollution,* which have direct impact on environment and composed of three other entities (air, water and soil) and *Comfort Pollution* have direct relations with people's comfort (noise, light and visual pollution entity).

4. *Economy Pillar* entity for sustainable green SLA is composing of *Carbon Taxation, Civil Engineering Cost, Cooling Cost* and *ICT Product Life Cost* entities. The cooling cost entity is an important indicator in data center and these costing could be calculated either on natural cooling facility (water, air) or not natural cooling facility. Moreover, *Cooling Cost* entity need to evaluate and defined accurately with the help of existing indicators from Table 9, such as *TDP, HVAC Effectiveness, Cooling system efficiency* etc. In this proposed model, *Cooling Cost* entity is actually consists of two types of entities, - *Natural Cooling Cost* and *Not Natural*

Cooling Cost. In addition, *Natural Cooling Cost* helps to derive existing *WUE* in the model as *WUE* indicator is the ratio between annual usage of water for cooling and the total energy used by IT equipment.

5. *Ethics Pillar* entity could be one of the important parameter for sustainable green SLA development model as it has direct relationship with people and society. IT ethics needs following parameters to be associated in proposed model, *User Satisfaction Level, User Reliability Level, Confidentiality Level, Intellectual Property Right, Security Privacy Level, Salary and Gender Balance Information.* Here, most of the entities under ethics pillar are very much subjective and these could be the most challenging part for ICT engineers to monitor, manage and assess these indicators in future. Moreover, still there is no standard authority or third party to evaluate these ethical entities.

   User Satisfaction Level could be measured and evaluated by using standard method of survey or model design (ACSI model) for specific services and then possible to calculate standard Customer Satisfaction Index (CSI) [66,68] for that services. *Security Privacy Level, Intellectual Property Right* could be monitored by third party using government defined rules and regulation. Third party could monitor and update information periodically regarding *User Reliability Level, Confidentiality Level, and Salary & Gender Information* in future green SLA. In UML model, salary and gender balance information represents as one entity for simplicity and they might carry same type informative attributes.

4.2.2 Identification of new services for future GSLA

Figure 14 shows the general view of proposed GSLA definition and now the complexity of managing this proposed GSLA explains by taking some of the important services from sustainability pillars and existing green computing practice. All these central entities have direct and indirect relationships for evaluating and assessing all existing performance indicators of the proposed global GSLA model. Additionally, choosing central entities might also help the ICT designer to view and design new services for the users. Moreover, these new services actually cover all the dependencies and respect all other existing and new indicators under three pillars of sustainability (Fig. 12) and traditional green computing practice in IT industry. The rest of the work organizes all these services showing their direct relationships and indirect important and small effects with other entities from the general global model.

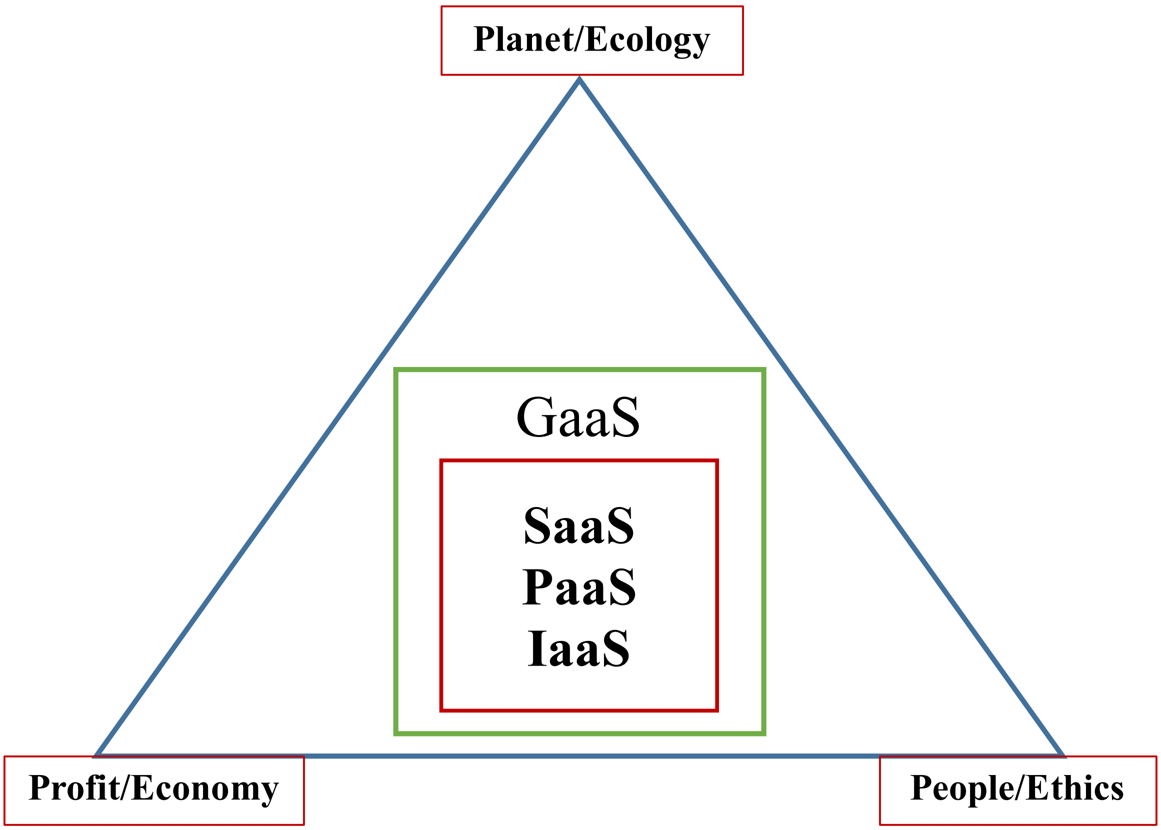

Fig.15. GaaS (Green IT as a Service) over current grid and cloud computing

Fig. 15 illustrates the Green IT as a Service (GaaS) over the current grid and cloud computing paradigm. All these GaaS derive from general global informational GSLA model (Fig.14). Therefore, this research identifies following central entities as new services in future GSLA, - *Total Recycling, Obsolescence Indication, GHG Emission, Energy Consumption, Pollution level, ICT Product Life Cycle* and *Energy Cost*. Among these, *GHG Emission, Energy Consumption* and *Energy Cost* are already defined services in exiting GSLA work. Therefore, the graphical notations of these three services are not shown in the proposed general model (Fig. 14). However, these existing three services included in future GSLA work because these has different level of relationships, dependencies with newly identified GSLA parameters under 3Es pillar of sustainability. The graphical notations of all new services are shown next Fig. 16 to Fig. 22 and the relationships are organized in a tabular form (Table 13).

Total Recycling Service:

Total Recycling service depicts using following UML notation (Fig.16) for further decomposition of proposed GSLA model. *Total Recycling* has interrelationships with other existing and new indicators in the model. While recycling an item or ICT product, it could emit GHG directly into the atmosphere. Moreover, it has direct impact and relation with *Earth Pollution* entities (Air, water and soil). For example, Cathode Ray Tube (CRT) used in computer monitors could emit lead, barium and other heavy metals into the ground water and release toxic phosphor into the air [69]. Again, computer and networking wires could also be recycled for extracting copper using open burning and stripping method, which creates hydrocarbon ashes released into the air, water and soil in the environment [69]. The *Air Pollution* entity is directly related with *GHG Emission* in proposed model.

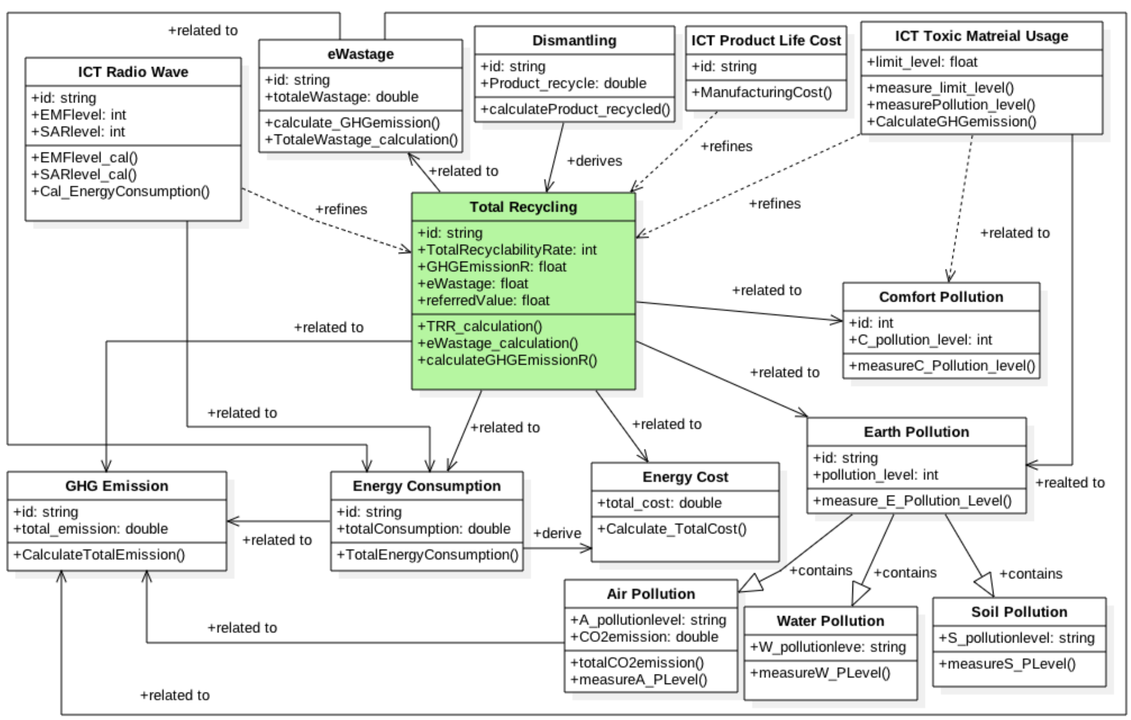

Fig.16. UML notations for Total Recycling Service

Total Recycling has direct relationship with eWastage entity. Recycling helps to reduce global magnitude of e-waste as metals, plastics, glass and other materials could be recovered from ICT product through recycling procedure. *eWastage* entity has direct impact on *GHG Emission* and *Energy Consumption* entity in this model. Moreover, to recycle a product or equipment, it needs to consume energy or power and cost of energy need to consider. *Total Recycling* has direct relations to calculate existing *Energy Consumption, Energy Cost* indicators. *ICT Toxic Material Usage* makes recycling indicator more complex. Most of the toxic materials used in ICT industry have indirect important effects to the *Comfort Pollution* entity because the dumping or recycling procedure might irritate people's comfort through noise or visual pollution and also responsible for health hazards. For example, in fluorescent tubes, flat screen monitors etc. mercury and its compound is used. This toxic material affects human health including sensory impairment, dermatitis, memory-loss and muscle weakness [69]. Sulphur and lead are also commonly used in lead-acid batteries, might responsible for sever health problems such as liver, kidney, heart damage, behavioural disturbances, attention deficits and lower IQ [69]. Besides all these comfort level pollution, toxic material usages also have direct relation with other earth pollution entity. Earth pollution of mercury and its substance affects plants, trees by reducing soil's fertility rate and thus slower their growth and development [69]. Also, when sulphur released, it could create sulphur dioxide, which is responsible for acid rain [69]. *ICT Radio Wave* could measure and monitor through standard value of EMF (Electromagnetic Frequency) or SAR (Specific Absorption Rate) value for some specific domain such as network or internet etc. SAR is a measure of rate at which energy is absorbed by human body when exposed to radio frequency; SAR also define as power absorbed per mass tissue and has units of Watts per kilogram (W/Kg) [70]. In addition, *ICT Radio Wave* have direct relation with *Energy Consumption,* as to reduce to the power of wave, it also requires to install more antenna; which consume more energy and thus more money for that consumed energy and at the same time more antenna increase the problem of equipment recycling. *Total Recycling* service have impact on *Economic Pillar* of sustainability as the more product will be recycled, the more money could gain. However, the cost of energy and other necessary cost to recycle ICT product also need to consider here. The *Dismantling* entity from *ICT Product Life Cycle* has direct relations with recycles, reuse or refurbish entity (Figure 13). Additionally, *Manufacturing* entity of ICT product life refines total recycling entity as recycling helps to avoid extracting new earth resources as well as minimizes production cost to some extent. The main challenges to define this new *Total Recycling* services is to gather all necessary information and monitoring their effect. Most of non-technical parameters under sustainability pillars in this service need some laws and directives to derive exact information for the users. There are some standards available for recycling services in US (*Responsible Recycling (R2) Practices*, *e-Steward*) and also some directives such as *WEEE or D3E* from European Union.

Obsolescence Indication Service:

Obsolescence Indication could be another service in the ecological pillar of proposed GSLA. Minimum optimum obsolescence could be calculated using some mathematical model design for an ICT product or for the raw materials to produce that product [55, 71, 72]. Additionally, obsolescence Management could also be used to find out the optimum indication for a product to be obsolete [72, 73]. However, obsolescence is relative information estimated from other useful existing criteria. It could calculate from cost of energy, carbon/GHG emission, ICT product life cycle assessment and or pollution level. There is an interesting relation between obsolescence and people. Therefore, *Obsolescence Indication* entity has indirect relationship with *Ethics Pillar* entity in proposed GSLA model. There is an interesting relationship between existing *User Satisfaction* indicator with this entity. For example, people often change their mobile phone frequently because it might become old fashioned to use it. Moreover, to find out the optimum obsolescence of ICT equipment, the performance of that equipment should need to monitor and evaluate using classical SLA parameters (availability, connectivity, bandwidth capacity, memory, and uptime etc. for a switch). That's why, obsolescence indication entity need to incorporate the ICT equipment basic performance metric. The next Fig. 17 shows the graphical notation of obsolescence indication service in the proposed GSLA. There is still no available standard to define obsolescence indication. Obsolescence management of an

ICT product could define according to design some regulatory lever, education/training for user behaviors and recycling practice in the society.

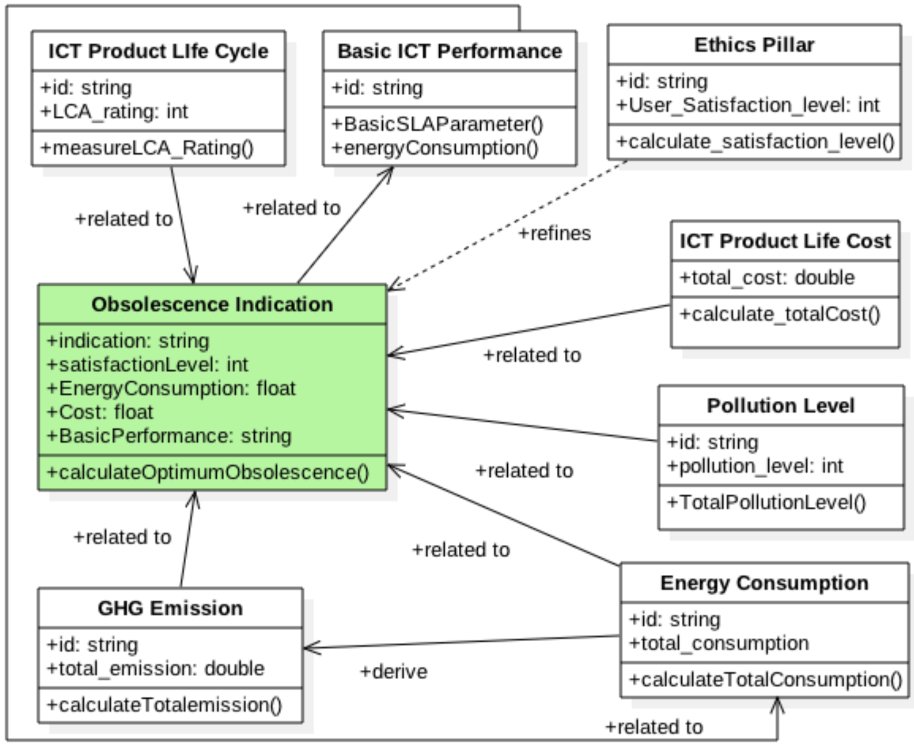

Fig.17. UML notation for Obsolescence Indication Service

GHG Emission Service:

Currently, Green House Gas (GHG) emission parameter exists in some previously defined GSLA for IT industry. This global service has direct impact on environment through sustainability lens. Fig. 18 gives the idea of interrelationships and dependency of *GHG Emission* service in the proposed GSLA. *Air Pollution* entity from ecological pillar has direct relationship with *GHG Emission* in the proposed model as the more air is polluted; the more carbon is emitted in the atmosphere. Additionally, the air is polluted because of carbon emission and this emission is also directly depending on energy consumption issues. Generally, there are two types of energy currently used most industries, - renewable energy and non-renewable energy. Non-renewable energy such as coal, oil and natural gas is more responsible for producing GHG emission whereas renewable energy (Solar, Wind, Tidal, Nuclear etc.) has negligible effects on GHG emission. Therefore, the *GHG Emission* entity has direct relationship with non-renewable energy type in the proposed model. The *Comfort Pollution* entity has an indirect small effect on GHG emission. The ICT product which is responsible for creating noise, light or visual pollution under comfort pollution level, might also emits carbon in the atmosphere. Moreover, GHG emission entity has direct relations on an economic entity in GSLA- Carbon taxation. *Carbon Taxation* is derived after measuring total carbon emission and carbon factor in any facility/industry. Though, carbon factor is varying according to different country's government rules and regulation, it plays an important role to calculate carbon tax. Additionally, total recycling, ICT toxic material usage, dismantling an ICT product has direct relation on *GHG Emission* service whereas obsolescence indication has indirect important effects on it.

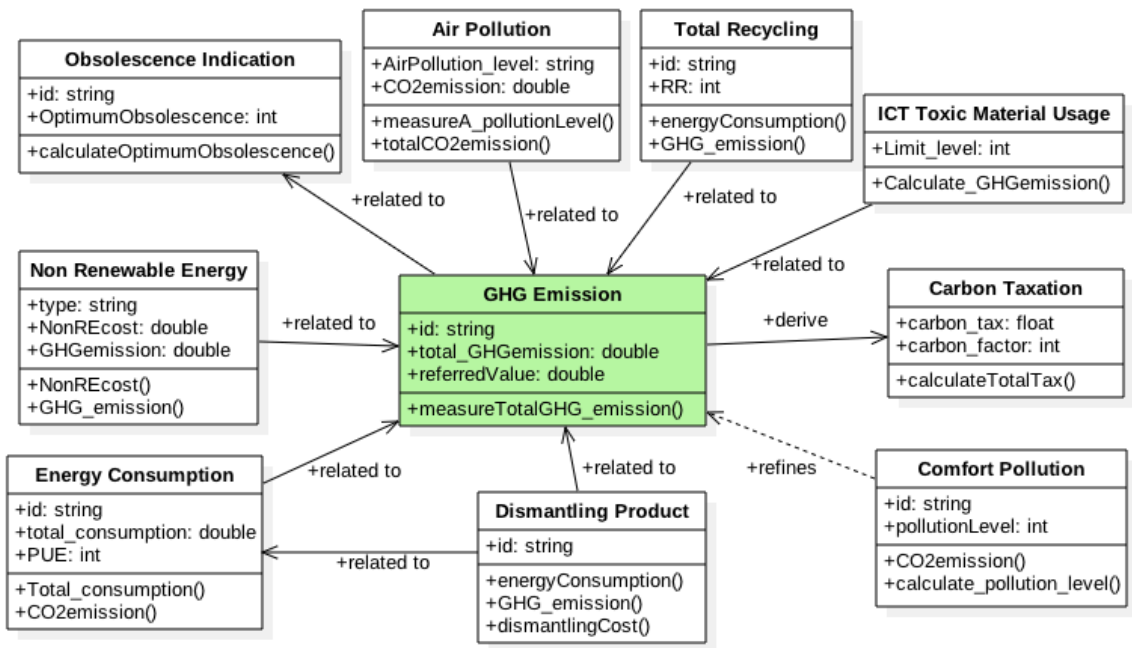

Fig.18. UML notation for GHG Emission Service

Energy Consumption Service:

Fig.19 is demonstrating energy consumption service under green computing domain for the proposed GSLA model. This service has close relationships and dependencies to derive some existing indicators. For example, *Power Usage Effectiveness (PUE)* derived as the ratio between total energy consumption and IT energy consumption and to completely find out total energy consumption, the *Energy Consumption* service is relating with all other entities in the model. Moreover, *ITEE, ITEU* and *Green Energy Coefficient* (*GEC)* indicators help to find *Data centre Performance Per Energy* (*DPPE*) in existing green SLAs. *GEC* is calculated from renewable energy source entity in the proposed model.

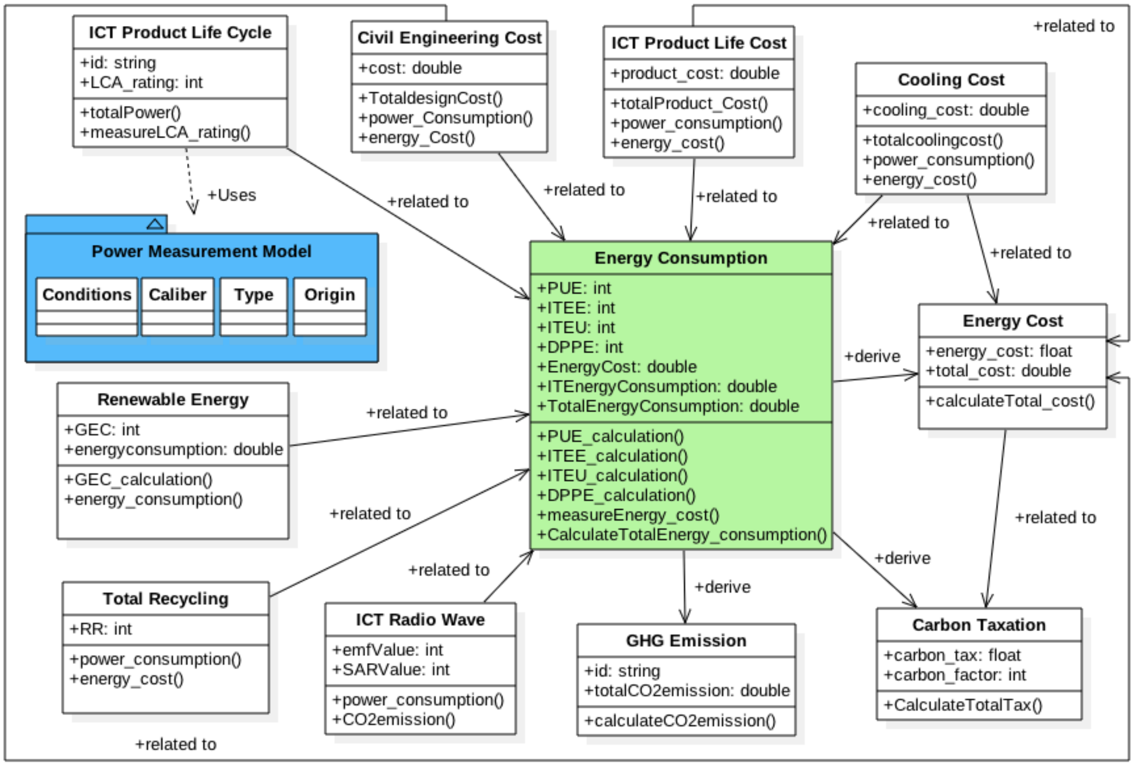

Fig.19. UML notation for Energy Consumption Service

Additionally, *ICT Product Life Cycle* is an important entity for GSLA with respect to energy consumption issues in the model. The manufacturing, transportation, usage and dismantling entity an ICT product requires energy in each stage. There are some EnergyWise standard ICT product from CISCO, which already used in many industries. The network engineer could easily monitor the real time energy consumption of devices compatible with this EnergyWise [42] standard. Again, either for recycling, reusing or refurbishing procedure of an ICT product or equipment also needs energy. Therefore, *ICT Product Life Cycle* and *Total Recycling* services have direct and continuous dependencies for calculating energy consumption services in future GSLA. The more energy consumed; the more carbon emitted. The real time energy consumption and carbon emission correlation observed during PERCCOM air quality project [42]. Thus, *GHG Emission* also has direct relationship with *Energy Consumption* entity. *ICT Radio Wave* has an indirect important effect because to reduce the power of radio, more antenna and other equipments are required which also consume more energy. Moreover, *Energy Cost* and *Carbon Taxation,* both economic entities have direct impact on energy consumption in IT industry. *Civil Engineering Cost, ICT Product Life Cost* and *Cooling Cost* have indirect important effects on this entity. In each stage of building or infrastructure design, it requires energy/power and also for installing ICT product in any facility needs energy too. In addition, the cooling techniques demand more energy than their IT equipment in some IT industry. All these economic entities depend on calculation of energy consumption first and then their measurement according to different countries energy/power regulations.

Pollution Level Service:

Pollution level service is important from ecological aspects in proposed GSLA. *ICT Product Life Cycle, ICT Toxic Material Usage, Total Recycling* and *GHG Emission* have direct relationship with pollution level service whereas *ICT Radio Wave* and *Obsolescence Indication* entities have indirect important effects on both earth and comfort pollution. There is an interesting relationship between *Comfort Pollution* entities with ethics pillar in proposed GSLA as ethical pollution is mostly concerned with people's comfort in their daily life. *Noise Pollution*, *Light Pollution* and *Visual Pollution* are the most three important comfort level pollution entities. *Noise Pollution* should need to calculate the standard level of noise in decibels (according to E-OSHA standard); *Light Pollution* might create Computer Vision Syndrome (CVS) [59, 60, 61] on human body and this indicator should need some guideline and modeling to control CVS. *Visual Pollution* could monitor and control according to PAQ (Perception of Affective Quality) rating. However, PAQ rating is very much subjective [58] and it needs further mathematical model or robot simulation to simulate this kind of pollution and define standard rating. The earth pollution level entity consists of three other entities in general model, - Air, Water and Soil pollution and *Air Pollution* is directly responsible for *GHG Emission* in the atmosphere (Figure 13). Air, water and soil pollution have direct relations with recycling, ICT toxic material usages and ICT radio wave entity. Pollution level central entity and its relationships are shown next Fig. 20. Additionally, existing *Carbon Usage Effectiveness* (*CUE*) indicator is computed here as total carbon emission equivalent from the total energy consumption for any facility. Therefore, this entity has relation to derive *CUE* using the formula, $CUE=CEF\,X\,PUE$; whereas *CEF* is the carbon emission factor, which could vary according to different countries government rules and regulation [42].

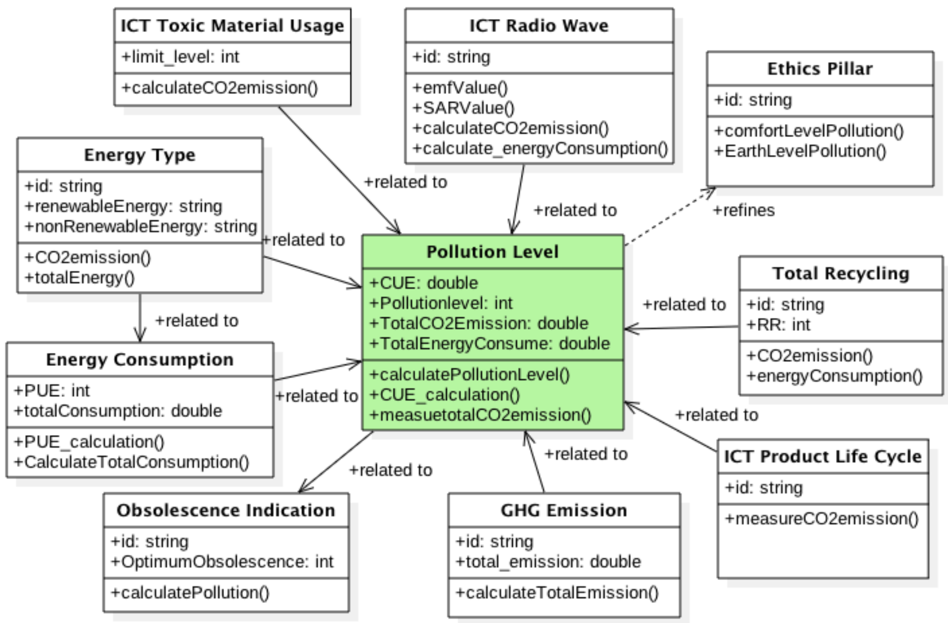

Fig.20. UML notation for Pollution Level Service

ICT Product Life Cycle Service:

The whole life cycle of an ICT product consists of following entities, - manufacturing, transportation, usage and dismantling entities. All these entities should directly connect to *GreenSLA* entity to respect global analysis of proposed model. The total GHG emission, total energy consumption and total costing of energy could not be estimated without considering all these product life cycle entities. Therefore, *GHG Emission, Energy Consumption, Pollution Level, Total Recycling* entities of ecological pillar and *Energy Cost* of economic pillar has direct relations with *ICT Product Life Cycle* service. Moreover, *ICT Product Life Cost,* which usually consider the production, usage level costs and initial setup costing; have also an indirect important effect on life cycle's entity. Fig. 21 depicts this central service and shows its corresponding relationship with other entities. Again, there is also an interesting relation between dismantling entity of ICT product life cycle and *ICT Product Life Cost* as dismantling could be refined either with recycle, reuse or refurbish entity and the production cost will be reduced. For example, gold could retrieve after reusing old ICT equipment, which helps to reduce the production cost of new ICT product and also there might be no need to explore more earth resources. Therefore, *Dismantling* entity in ICT product life cycle has direct relationship with *ICT Product Life Cost* in proposed GSLA model.

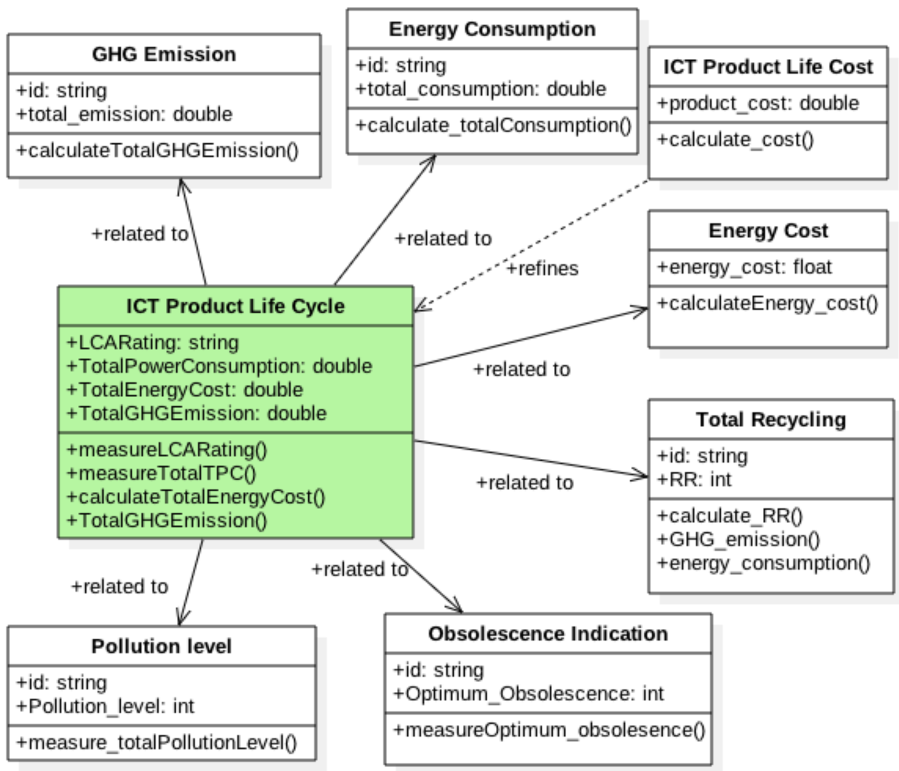

Fig.21. UML notation for ICT Product Life Cycle Service

Energy Cost Service:

This entity could another main service in the proposed GSLA model. Fig. 22 demonstrates the analysis of this service. *Energy Cost* service has direct relations with *ICT Product Life Cycle, Energy Consumption, Carbon Taxation* and *Energy Type.* There are two types of energy is considered in the model, renewable and non-renewable energy. The costing of energy depends on the types of energy sources used in the IT facility. However, different types of energy costing actually depend on different countries government rules and regulations and their economic conditions. Again, carbon tax is calculated after retrieving energy cost according to government rules and regulation. At each stage of life cycle for an ICT product, it demands energy and thus costing of these energy need to consider. Recycling procedure also requires energy and money but also money could gain after reusing a recycled material for further use. Therefore, *Total Recycling* service also has direct relation with energy cost entity in proposed GSLA.

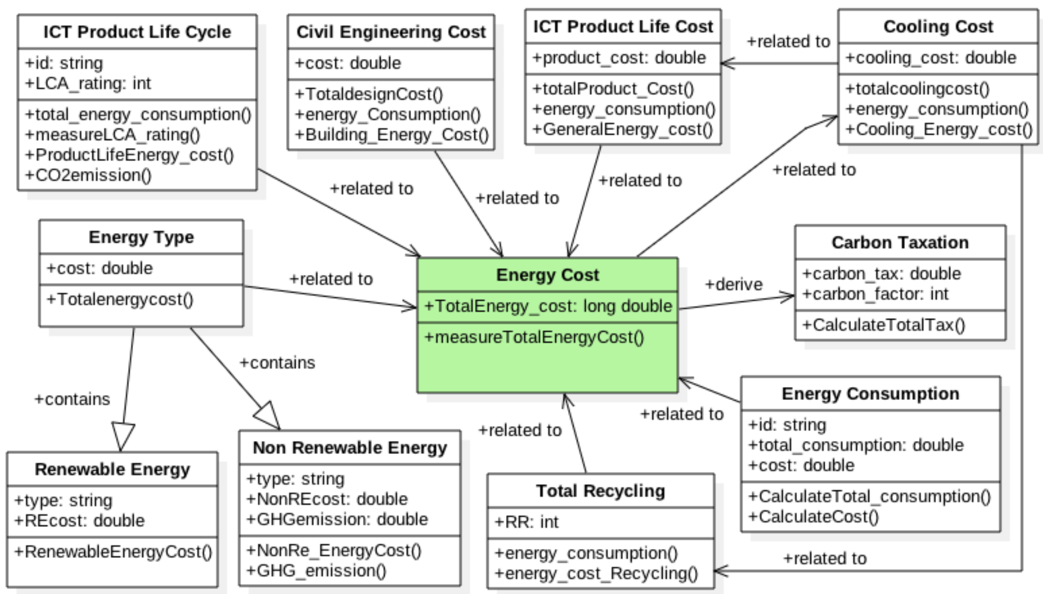

Fig.22. UML Notation for Energy Cost Service

Moreover, *ICT Product Life Cost*, *Cooling Cost* and *Civil Engineering Cost* have indirect important effects on energy costing issues. In future, cost of depollution should need to consider here. *Cooling Cost* entity has important and interesting relations with recycling and ICT product cost issues. Currently, huge amount of money spent on data centre cooling facility, which actually motivate from the work on temperature management [74]. In some case, the idea to reduce the cooling cost is to increase the threshold of temperature acceptable for a server in the data centre. However, temperature threshold has negative impacts on server reliability and performance [74]. The consequence of this scenario is that, it needs to change the server and other equipment prematurely in any data centre facility. Therefore, the cooling cost entity might have negative effects on ICT product cost entity of economic pillar as it needs more money to buy and install a new server. At the same time, prematurely damaged servers and other equipments could be recycled for further use. Thus, cooling cost entity has direct relationships with the recycling service under ecological pillar in proposed GSLA model. Additionally, the two types of cooling facility also need to consider (Fig. 14) for evaluating energy cost service in the model. For example, in data centre, natural cooling facility might more cost-effective and environment friendly than not natural cooling facility.

The above figures depict the complexity of managing all the performance indicators to define new services for GSLA. All these central services have different levels of relationships and interactions with other entities belonging to three sustainability pillars. The ICT engineers in the industry could analyze a cascade of effects in defining different levels of interactions between all these entities using the next tabular format. Again at the same time, the ICT engineer needs to hide the complexity from the user side to evaluate and monitor new services in future. From service provider side, regarding green computing and sustainability concern, the ICT industry needs to incorporate and trade-off between all newly identified parameters/services with their traditional performance based SLA parameters. The traditional parameters are mostly technical and easy to monitor but green parameters are not always technical; therefore, it might need to rethink how to do these incorporations for automating GSLA in future.

Table 13. Relationship between all services defined from the informational model

Central Entity/ Services	**Cascade of Relationships**		
	Direct	***Indirect Important Effects***	***Indirect Small Effects***
Total Recycling	ICT Product Life Cycle; eWastage; Earth Pollution; Energy Consumption; GHG Emission; Energy Cost; Dismantling ICT Product.	ICT Radio Wave; ICT Toxic Material Usage; Manufacturing	Comfort Pollution
Obsolescence Indication	ICT Product Life Cycle; ICT Performance; ICT Product Life Cost.	Pollution Level; Energy Consumption; GHG Emission	Ethics Pillar
GHG Emission	Total Recycling; Air Pollution; Non-renewable Energy; Carbon Taxation; Dismantling ICT Product; Energy Consumption.	Obsolescence Indication; ICT Toxic Material Usage	Comfort Pollution

Energy Consumption	Total Recycling; ICT Product Life Cycle; ICT Product Life Cost; Energy Cost; Carbon Taxation; GHG Emission; Renewable Energy; ICT Radio Wave.	Obsolescence Indication; Cooling Cost	Civil Engineering Cost
Pollution Level	ICT Product Life Cycle; Total Recycling; ICT Radio Wave; GHG Emission; Energy Type.	ICT Toxic Material; Obsolescence Indication; Energy Consumption.	Ethics Pillar
ICT Product Life Cycle	Energy Consumption; ICT Product Life Cost; Pollution Level; Obsolescence Indication; Total Recycling; Energy Cost.	GHG Emission	
Energy Cost	Energy Type; ICT Product Life Cycle; ICT Product Life Cost; Carbon Taxation; Energy Consumption; Total Recycling.	Cooling Cost	Civil Engineering Cost

4.3 Implementation of GSLA for green services

Previously, the informational model of all newly identified services for future GSLA discovers different level of interrelationships among them. It is important to mention that, all the relationships regarding newly identified services (Table 13) are important to respect future GSLA. The ICT engineer should analyze their future GSLA services by generating some questionnaires and then it's possible to evaluate their GSLA using proposed informational model. This is small step to the way of automation of proposed future GSLA model. The questionnaire is generated using Java (Eclipse Tool), following the general model of GSLA. In future, this simple validation of GSLA for Total Recycling services could be done elaborately in real time and context through using this tool. Practically, this simple tool helps to identify different level of relationships for designing a new and sustainable green service within the ICT industry. Therefore, the ICT engineer could easily compare their findings with GSLA theoretical research findings. The ICT companies could use this kind of tools to validate their slogan of sustainability practice. Next figure give some snapshot of simple GSLA tool.

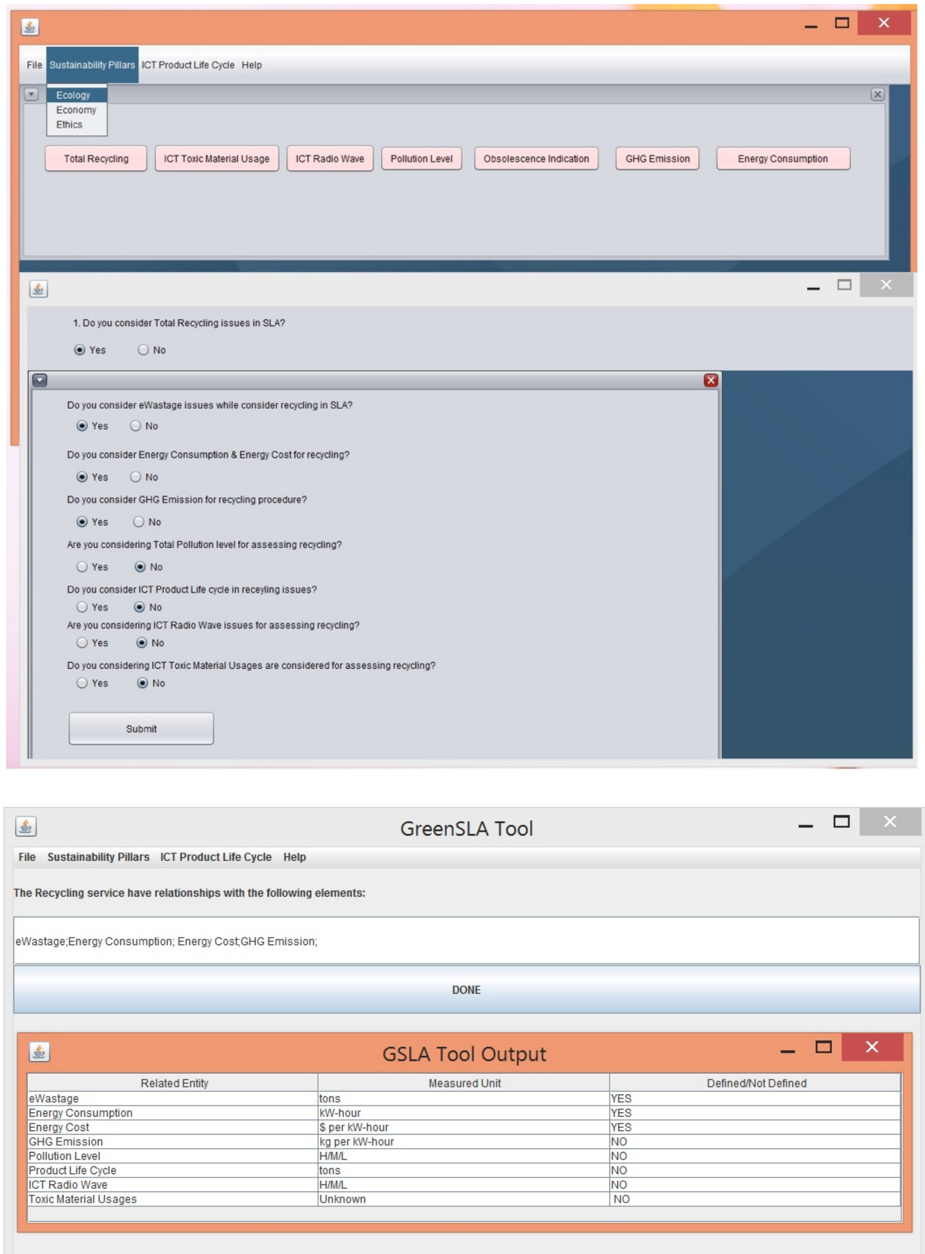

Fig.23. Snapshots of GSLA tool

The above questionnaires tool develops only for recycling services in real time context. The Total Recycling green services have been considering for 20 new startup industries in Japan and Bangladesh. The analytical results for this green services is done using JMP analytical tool, SAS Corporation, USA. The generation of automated questionnaires represents in Fig.23. These questionnaires sent to 20 different ICT companies and as well as other companies in Bangladesh and Japan, who respect recyclability and sustainability in their business scope. Most of these industries are varied in sizes, - Large, Medium, Small; and their response to the questionnaires were completely unbiased. Among the 20 industries, 15 ICT based industries delivered their answers for further analysis. The feedback of these industries is then analyzed using SAS analytical tool (JMP 12.2.0) and represented in Fig. 24 and 25.

Fig.24. Analysis of recycling services in different sized industries

The analysis revealed, most of this ICT-based industries taking consideration of recycling services while designing, developing, implementing or providing services/product to their customers. Fig.24 shows the feedback analysis of 15 industries and among them 66% medium (red color) and large sized industries respect recycling services under sustainability. The small sized (green color) industries are usually using the slogan of sustainability but they are far behind of considering the proposed green services. In contrary, most of the large size industries (blue color) are practicing recyclability though they are not pretending to be a sustainable industry due to the lack of knowledge to design new green services in their scope.

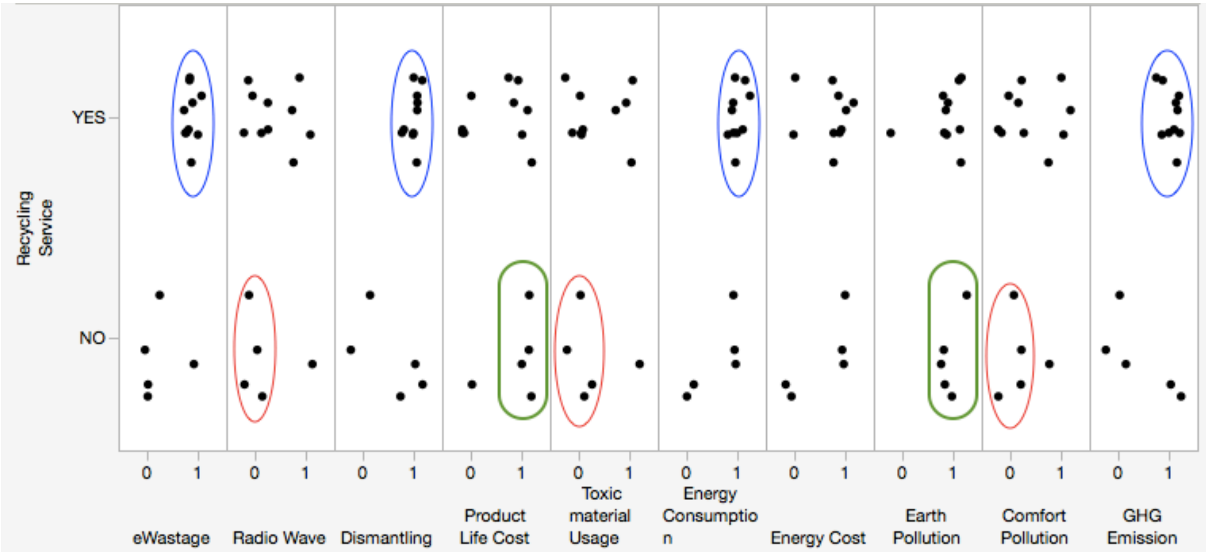

Fig.25. Analysis of all entities of recycling services

However, these industries are unware of designing their recycling services with the proposed designed model (Fig.16). It is evident from the fig. 25 that, these companies are just consider the interaction of *eWastage, energy consumption, energy cost, dismantling and GHG entities* in their scope while ignoring *Radio wave information, Toxic material, Comfort pollution* entities. It is noticeable that, very few industries (only 01 company) are justifying all entities and their different levels of interactions (Table 13) in compare to the proposed designed *Total Recycling Services* (Fig.16). The interesting fact is that, most of these industries concentrate on *earth pollution* and *product life costing* while not considering recycling services in their business scope. It shows the importance and awareness of practicing sustainability in businesses to some extent.

4.4 Monitoring and evaluating of GSLA indicators

In the previous section, this research defined a general informational model of future GSLA and identified some services from that model to explain the interrelationship among all the indicators. However, sustainability could only be achieved through proper implementation of GSLA, which largely depends on monitoring and evaluating the performance of the indicators [75]. This research also focuses on monitoring the indicators and evaluating them for better performance and validation.

The importance of real-time monitoring can easily be understood from the existing network monitoring systems of any data center or IT system. Basic SLA defines the parameters of any ICT architecture and these parameters are monitored in order to ensure QoS and performance [75]. Similarly, ecological and economical performances should also be monitored to ensure that GSLA is respected by the concerned parties. Once monitoring of the parameters is possible, further analysis of the indicators and their impact can also be performed.

Another important perspective about monitoring is - ICT engineers should be able to monitor and analyze about both ICT performances (e.g., delay, jitter, uptime etc.) and ecological performances (e.g., energy consumption, GHG emission, recycling etc.) simultaneously. This particular idea leads this research to establish a relationship between basic SLA and GSLA. Indeed, basic SLA is currently monitored and if the relationships between ICT performance indicators and green performance indicators are identified, then the monitoring of GSLA will be simplified. *DCeP* indicator is a good example of this interaction but this indicator is not clearly defined [38]. In order to show the interrelations among the ICT performance indicators and green indicators, this research review on following three indicators as examples: energy consumption of a switch, carbon emission and ICT lifetime costs. The rest of the section illustrates these indicators:

1) Power Consumption of a Switch (Usage Phase): The power consumption measurement of the whole network is very complex due to the diverse and dynamic nature of the network. There are several research works on modeling network power consumption. The power consumption measurement of a switch is based on three basic ICT parameters – bandwidth, number of PC connected and link load [76]. The research considers the switch architecture (CISCO 2960 EnergyWise) at the usage level to show the relationship between basic ICT performance parameter and power usage [76]. The following equation [76] is proposed by

the authors and this equation could be scaled for a network to measure the power consumption of the whole network.

$$Power = 33.2708 - 0.000318\ Bandwidth + 0.05156\ PC\ Connected - 0.001329\ Link\ Load + 0.000253\ Bandwidth * PC\ Connected + 0.000006\ Bandwidth * Link\ Load + 0.000477\ PC\ Connected * Link\ Load$$

These three basic ICT parameters mentioned by authors are currently monitored in any network monitoring system. Hence, such a relationship established through the above equation can easily be included in any monitoring tool to monitor the power consumption of a switch during usage phase.

There is another interesting dimension of such monitoring model of GSLA. The energy consumption of the network architecture can be obtained both directly by EnergyWise and indirectly by using the equation [76]. The interest of this approach is to compare real measures (EnergyWise) with indirect measures (equation). If there is a deviation between these two measures, it can be assumed that there are anomalies (e.g., disconnection of PCs, links) in the system. From this approach, such relationship defined by the equation not only develops a system for monitoring energy consumption, but also enables smart monitoring system for basic SLA indicator. Also, in many cases, anomalies cannot be detected correctly by the monitoring tool of basic SLA. In such cases, a system of cross validation derived from GSLA monitoring can be very effective and opens scopes for further analysis.

2) Carbon Emission (Usage Phase): The carbon emission is one of the most important concern regarding green IT and sustainability till now. Carbon emission is estimated from the measurement of energy consumed by ICT architecture and from the CO_2 factor (per kWh) provided in real time by RTE, France (*Réseau de Transport d'Électricité*) and also from the Internet [42]. The next figure depicts a real time scenario of carbon emission and energy consumption correlation during PERCCOM air quality project [42]. The carbon emission and power consumption could also be correlated using previous work [76]. Thus, carbon emission can be obtained from the basic SLA indicators as well.

Fig.26. Monitoring ICT energy consumption and Carbon Emission, adopted from [42]

3) ICT Product Life Time: The ICT product life is one of the most important services to monitor in future GSLA. The maximum allowable life time could be decreased in accordance with the relations of traditional SLA parameter such as MTTR (Mean Time To Reparation) costs and power saving parameter of the ICT devices. The following equation is derived to show this interrelation [77].

maximum allowable life time decrease — energy saving — energy saving — reparation costs

$$MaxLD_{10\%} = \frac{10\%.P_{eq}.C_{kWh}}{10\%.P_{eq}.C_{kWh} + \frac{FR}{10^6}.(MTTR.Pers.C_m + C_{eq})}$$

Fig.27. Equation for ICT product life time with MTTR costs and power savings, adopted from [77]

Fig. 28 shows the interrelations of basic SLA parameters with proposed GSLA using UML notation with respect to above mentioned three examples for any typical network architecture. This UML shows high level abstraction of the basic SLA parameter, defined by four general ICT network performance indicators. It is obvious from the UML that monitoring GSLA indicators is possible from the basic SLA indicators also.

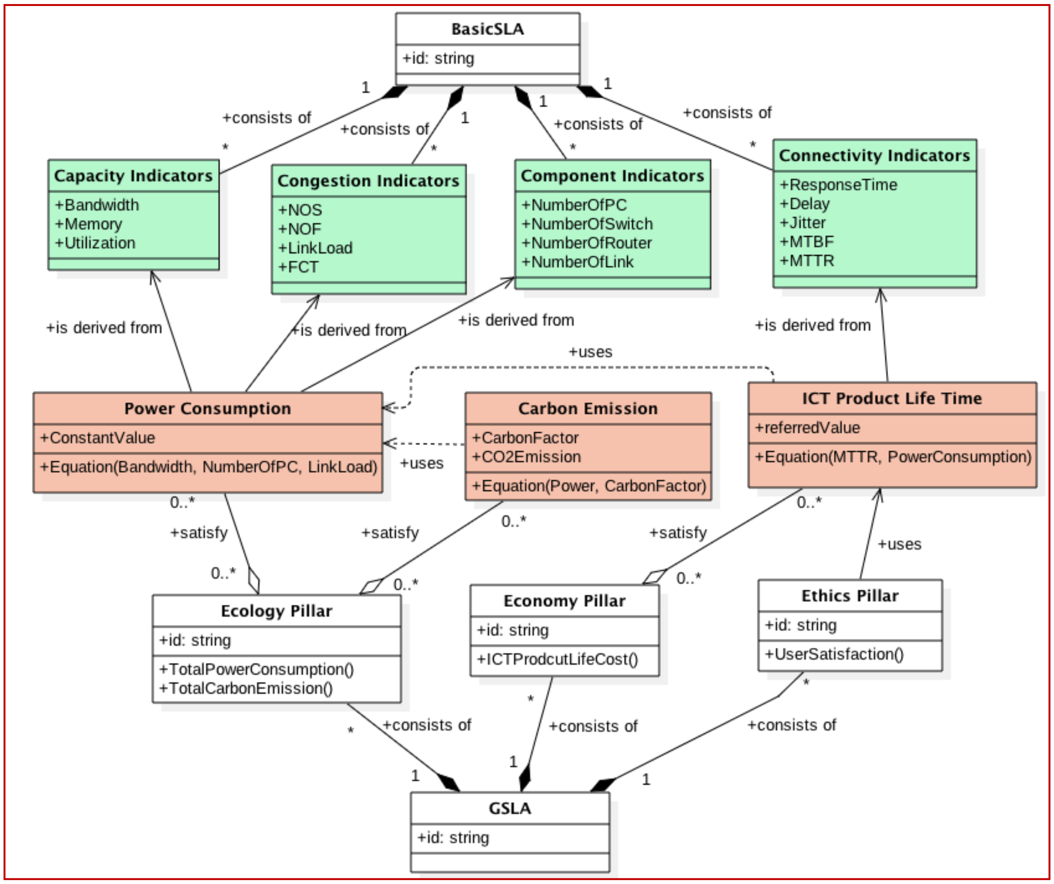

Fig.28. Basic SLA and GSLA relationship model for monitoring

This section identifies the scope of monitoring and evaluating some of the GSLA indicators by defining their interrelations with traditional basic SLA indicators. However, most of the green and sustainable indicators discussed in this research are not directly measurable. They are non-technical and depend on human interaction. On the other hand, basic SLA ICT indicators are easily measurable and monitored. Hence, it is not easy to establish such interrelationships for most of the GSLA indicators. As a result, the monitoring of all of the green indicators still remains a challenge under sustainability achievement.

4.5 Sustainable GSLA model validation using Bayesian Network

This research includes all parameters of sustainable GSLA model (Fig.14) using Bayesian network model (BNM) and thereby, analysis the output of BNM and validate the informational model for IT and ICT industries. The BNM takes into the consideration of 50 different IT and ICT based companies' feedback from Japan, India and Bangladesh. The finding of BNM would definitely assists the ICT engineer to develop a viable sustainable GSLA for their company in future. The analytical accuracy of BNM also helps us to validate the proposed sustainable GSLA information model. The findings of practicing sustainability around these 50 different companies is analyzed also with JMP analytical tool by SAS Corporation, USA. The main aim of using BNM for sustainability achievement by using questionnaires from all these companies were completely unbiased. The next section will introduce the details of BNM for validating sustainability model and then followed by analytical results and discussion.

Create a BNM to evaluate/implement the general global informational model of sustainable GSLA parameters in different industries in the society, which varies according to industry size and business type. BNM model helps to evaluate the proposed GSLA model with high confidence. Moreover, Bayesian network model helped to visualize the changes of posterior probability as the evidence/sample increases and thus assists to improve the accurate evaluation of GSLA with other methods. Fig. 29 shows the proposed BNM tree structure for validating sustainable GSLA model.

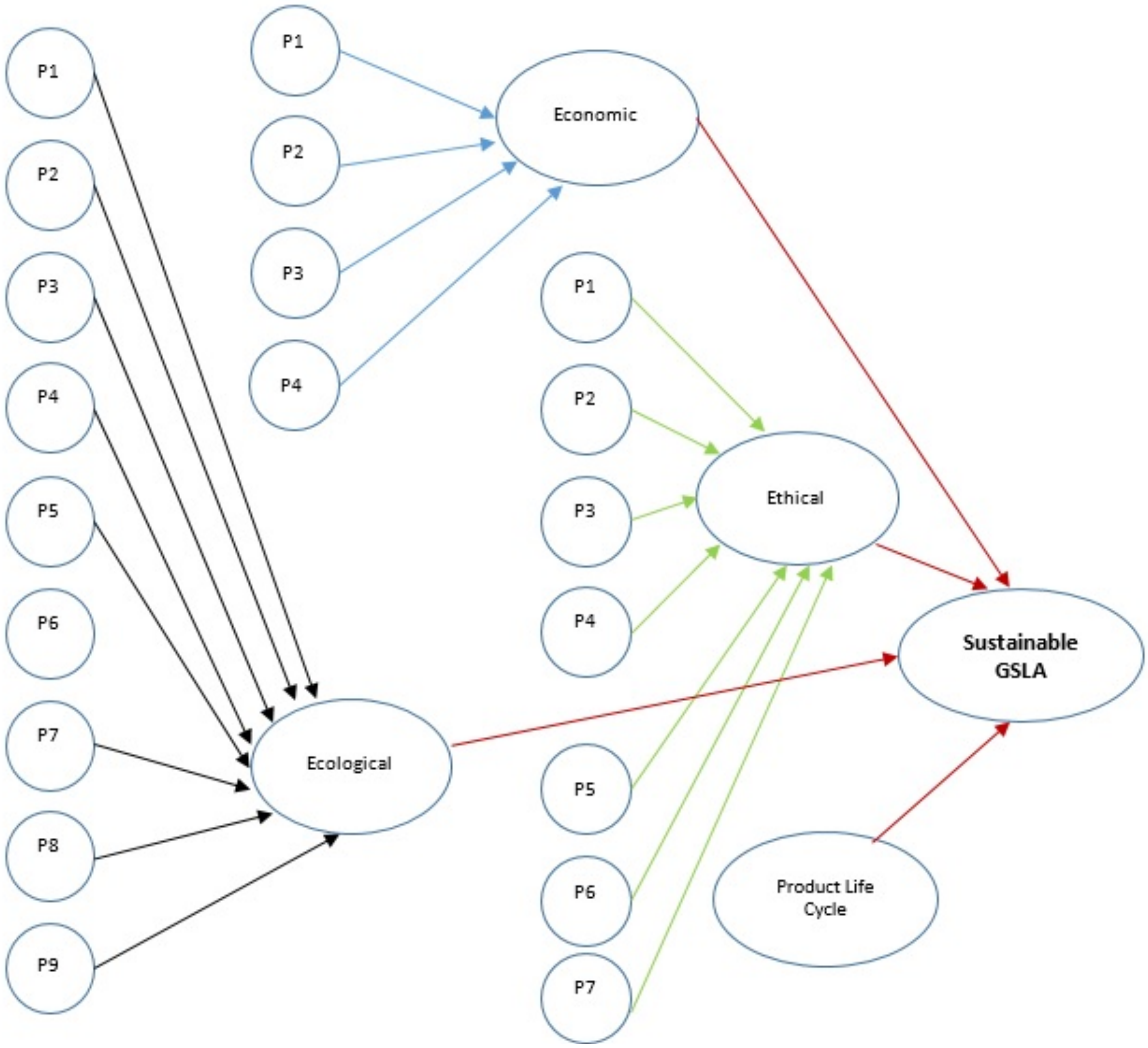

Fig.29. The proposed Bayesian network tree structure for sustainable GSLA model

The model takes into account 9 parameters under ecological pillars, 4 parameters from economical pillars and 7 parameters from ethical parameters to achieve sustainability. In total, 50 different industries are taken into consideration in this evaluation according to 20 parameters under 3Es. It is evident from their data that, still all of these industries are far away from the establishment of sustainable GSLA in their scope. However, all this prior information could be used in the designed BNM to get posterior information. Therefore, the BNM model actually shows the accurate importance of parameters to work out for achieving sustainability. The next Table 14 represents all the parameters under three pillars of sustainability (3Es) in the proposed tree structure of Bayesian network (Fig.29).

Table 14. All parameters for designing Bayesian network model

Ecological	***Economic***	***Ethical***
P1-Recycling P2-eWastage P3-Energy Consumption P4-Carbon Emission P5-Earth Pollution P6-Comfort Pollution P7-Obsolescence Indication P8-Radio Wave Information P9-Toxic Material Information	P1-Energy Cost P2-Carbon Taxation P3-Cooling Cost P4-Civil Engineering Cost	P1-Satisfaction level P2-Gender Balance P3-Salary Balance P4-Product Security P5-Product reliability P6-Patent/IPR P7-Product Performance

4.5.1 Flow graph of using Bayesian Network Model (BNM) for sustainable GSLA

The following figure represents the stepwise GSLA model evaluation using BNM with the help of Bayonet-6 software Tool, developed by AIST, Tosu, Japan. The output of the BNM is also analyzed using JMP software, developed by SAS cooperation, USA.

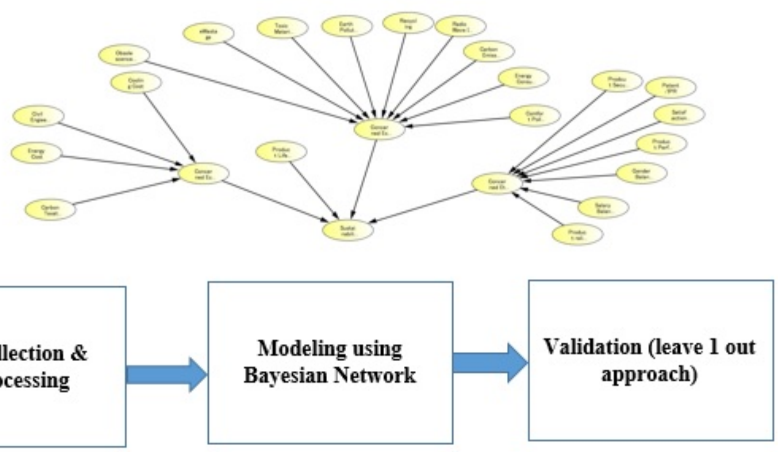

Fig.30. The overall evaluation method using BNM

Questionnaires Generation and Dispatch:

The proposed sustainable GSLA informational model is usually designed theoretically through rigorous literature review and their analysis. The evaluation of this informational model could be done by designing questionnaires regarding that model. Therefore, initially questionnaires created and then dispatched these questions to various IT and ICT industries in Japan and around other countries. In total, 55 questions asked under three pillars

(Ecology, Economy and Ethics). The feedback of all these questions are collected in hard copy format from 50 various industries in Japan, India and Bangladesh. Most of these industries are chosen in the field of ICT and varies in different size (small, medium and large size companies).

Data Collection and Preprocessing:

The feedback of all questionnaires are collected in regular Microsoft-Excel program and processed for using Bayonet Tool as the tool accept only .csv format files. In total, 50 industries return back their feedbacks regarding the sustainability practice in the scope of GSLA. All these feedbacks are completely unbiased and asked to the responsible person of the companies. Though most of these companies still having lack of green expert CEO or management in some perspectives.

Modeling using Bayonet Tool:

The feedback from various industries are then analyzed using Bayesian Network Model(BNM). BNM is carried out using Bayonet-6 software tool. The following picture shows the snapshots of Bayonet tool. BNM helped to visualize the changes of posterior probability as the evidence/sample increases in the provided feedbacks and thus assists to improve the accurate evaluation of proposed GSLA informational model.

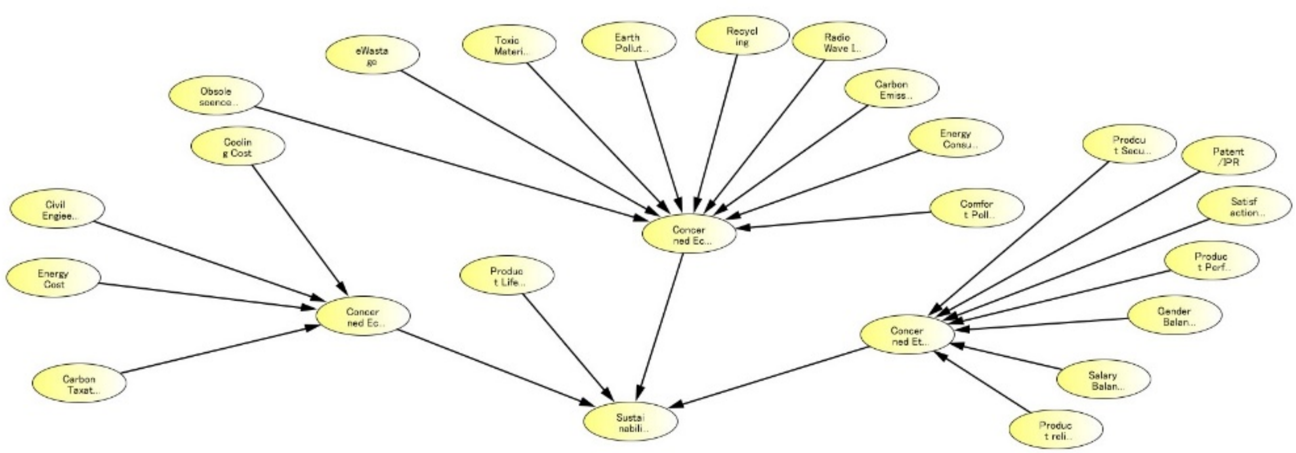

Fig.31. Screen shots of Bayonet 6 Software Tool

4.5.2 Results and Discussion of BNM:

The feedback of all 44 companies analyzed to validate sustainable GSLA model using JMP analytical tool (SAS Corporation, USA) and Bayonet Tool (AIST, Japan). Among the 50 companies, 6 companies feedback could not be accepted due to the lack of proper information according to designed questionnaires. In general, most the industries concerned about three pillars of sustainability (Ecology, Economy and Ethics). According to the next distribution figure, almost 23 companies concern about sustainability practice. However, Fig. 32 also demonstrates that, most of these companies are mainly concerned about ecology and economy than their ethical point of view. Interestingly, most companies are mainly concerned about the economic aspects (profit) in their scope. Later, the research reveals some other interesting facts about all three sustainability pillars.

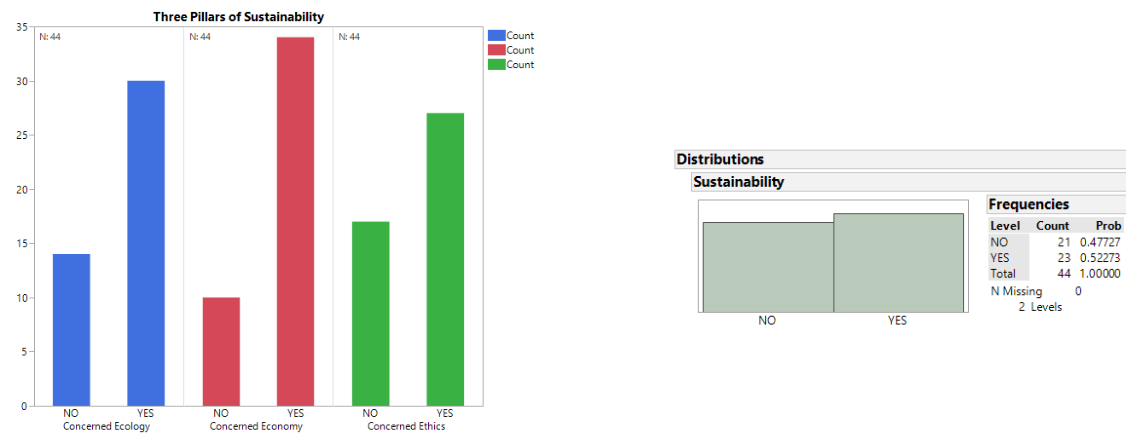

Fig.32. Distribution of Sustainability practice and their main three pillars according to all companies

Next figure illustrates that, Among the 9 parameters for ecological aspects of GSLA, the most ignored 03 parameters are, - *Obsolescence Indication, Radio Wave Information* and *Toxic Material Information*. Most of the ICT based companies are ignoring these 3 parameters of GSLA model, whereas they are pretending to concerned about ecology for sustainability practice in their product or service development.

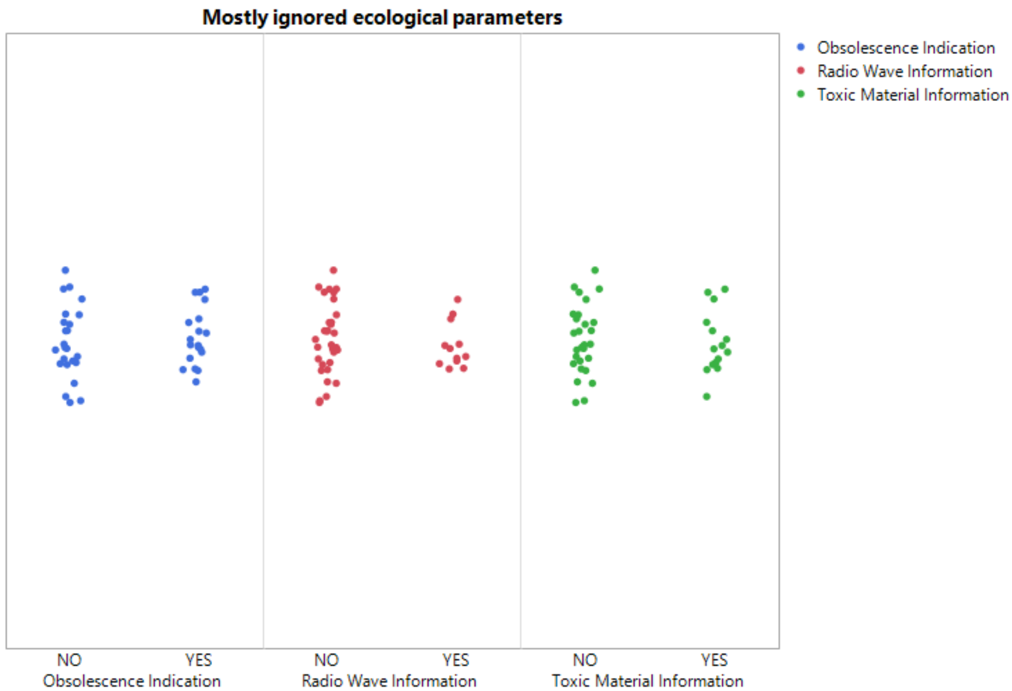

Fig.33. The mostly ignored ecological parameters from the companies

The following figure shows the average concerned three pillars of sustainability for all companies' feedback. The concerned ecology is almost 68%, economy is 72% and ethical concern is 61% for achieving sustainable GSLA model in their current product or service deployment.

Fig.34. Average concerned ecology, economy and ethics vs. Sustainability

In the economic aspects of sustainability, the most interesting point is that, very few companies are currently concerned about *carbon taxation*. Though most of the companies showed that, they are very much concerned about economical parameters of sustainability but they did not focus on carbon tax. This is due to lack of proper authority/law or governess according to their country's perspective.

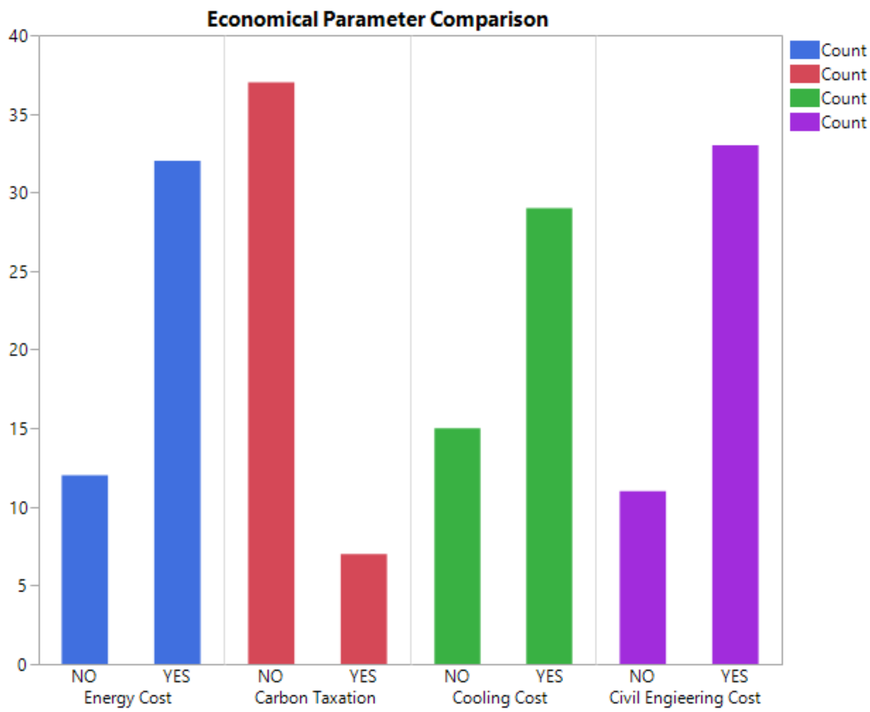

Fig.35. Compare between economical parameters of sustainable GSLA

ICT product life cycle is another main aspect in the proposed designed GSLA informational model. The feedback regarding ICT Product life cycle and sustainability in the next figure demonstrates its importance and validate the model to some extent (Fig.36a). According to different companies' feedback, most of the companies consider their *product/service reliability and security* as the product/service performance (Fig.36b). While considering the product performance, these industries misunderstood ICT product life cycle in their scope too. Only 34% of the ICT based industries considering *Product Life Cycle*, while practicing sustainability in their service/product deployment.

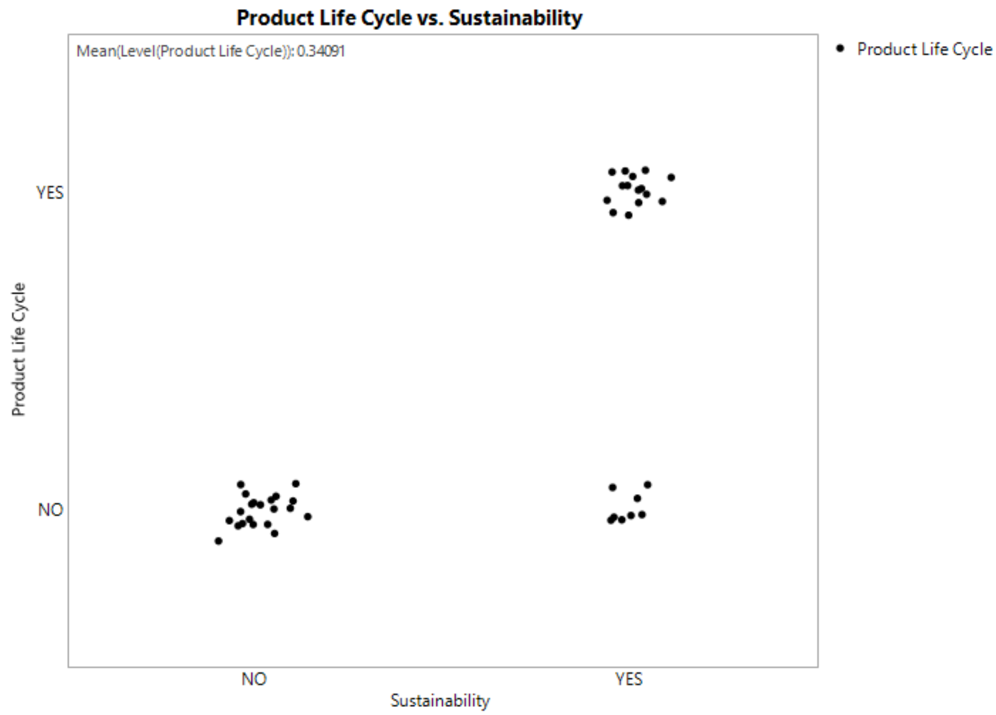

Fig.36a. Product Life cycle vs. sustainability

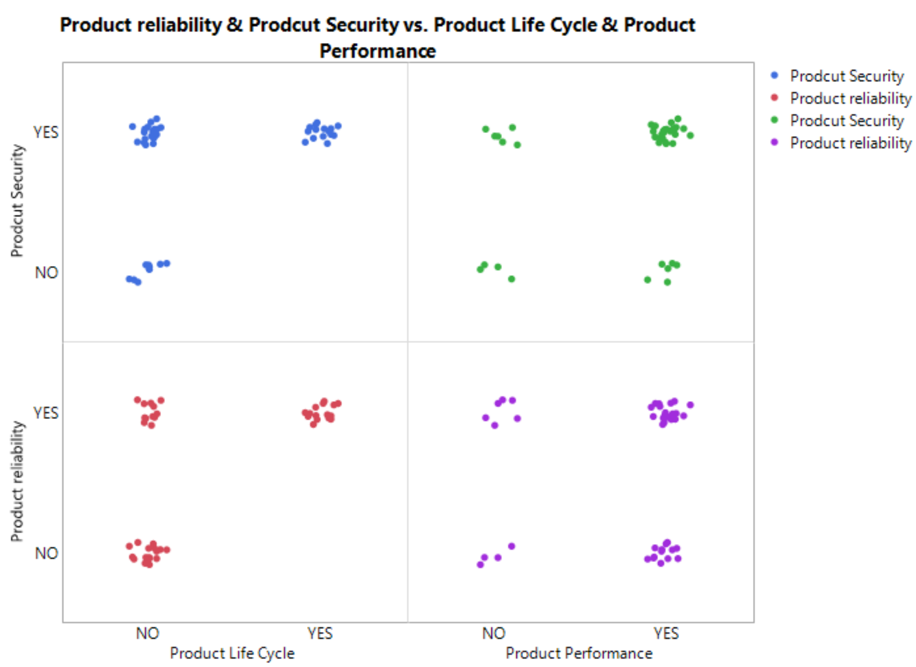

Fig.36b. Comparison between Product life cycle vs their performance in accordance with product reliability and security

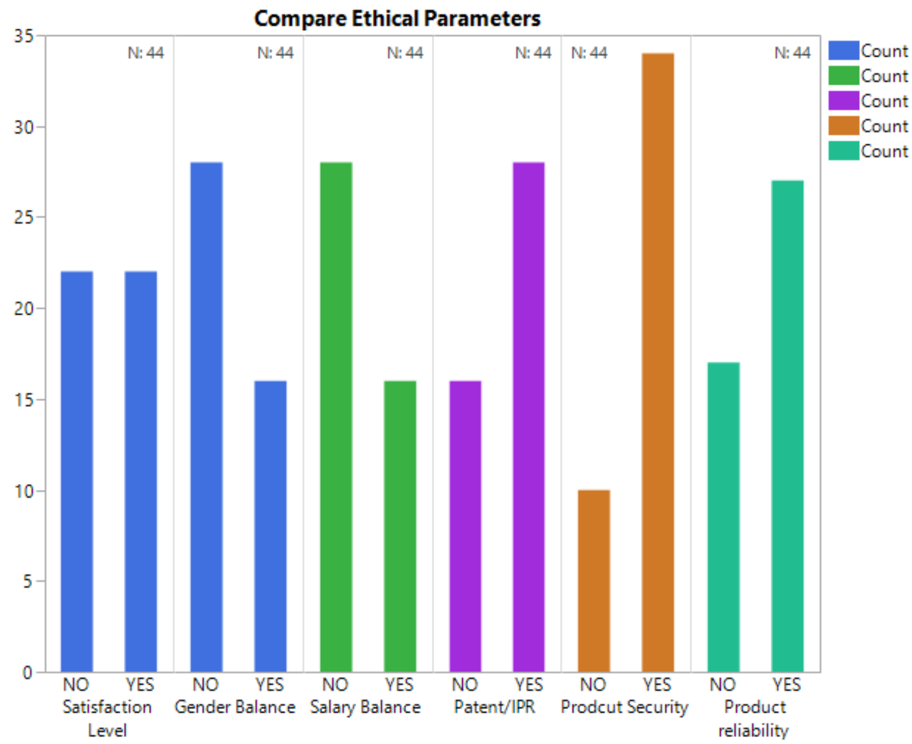

Fig.37. Compare between ethical parameters of sustainable GSLA

Fig. 37 compared the most significant ethical pillars of sustainable GSLA model. The *user satisfaction, gender and salary balance information* are mostly ignored and companies did not respect these parameters whereas they are mostly concern about *IPR/Patent, product reliability and security information*. The most interesting facts shows from the distribution that, almost 27 companies argue that they are concerned about ethics but not considering all important ethical parameters of proposed GSLA model. The following distribution shows the fact here.

Bayesian Network Model (BNM) result analysis:

BNM finally helps to evaluate the general global informational sustainable GSLA model by analyzing all feedback from different ICT based companies. This model helps to visualize the proposed GSLA model with higher confidence. Moreover, the validation of the model is done by leave 1 data set out approach, therefore, in total 44 test data sample sets are created. All these test samples helped to visualize the posterior probability as the number of evidence/sample increases in future. The average accuracy of proposed BNM for sustainable GSLA model is almost 68% while considering all 44 test data sets. When the average log-likelihood is <0.5 the accuracy is almost 100% for 28 test samples. However, when the likelihood is >1.5, the estimation accuracy is very low for only 03 test samples. The Fig. 38 illustrates the average accuracy of proposed BNM with average log-likelihood.

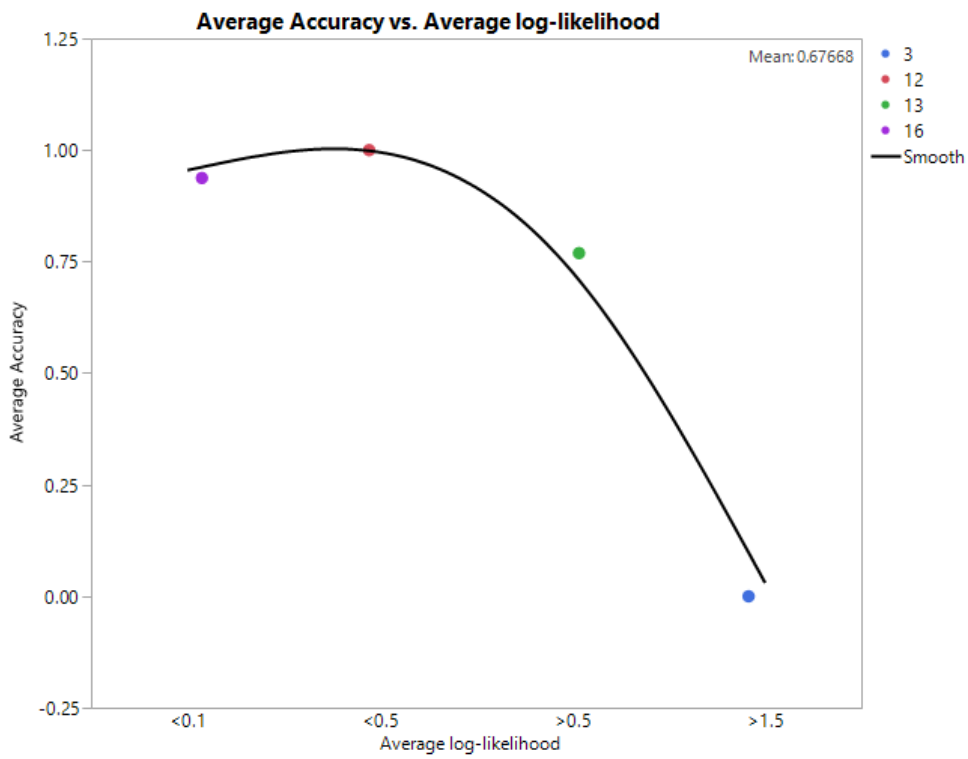

Fig.38. The proposed BNM average accuracy for evaluating sustainable GSLA model

In addition, the research discovered that, the test sample data might not be enough to satisfy the proposed Bayesian model. Therefore, the entropy of proposed BNM model's outputs was calculated to achieve reliable discrimination and use it for discrimination-suspension rule [78,79]. Entropy indicates or interprets as the risk of incorrect discrimination and if entropy exceeds some predefined discrimination threshold, then the discrimination could be suspended. The following equation used to calculate the entropy between two states of sustainability achievement in the designed model.

$$entropy = -\sum_{i}^{n} P_i log P_i \quad (1)$$

Where, P_i = results of posterior probability for the Sustainability achievement (yes/1) or not (no/0). The higher entropy means the designed network model is ambiguous and less entropy derive the more confident model. According to Fig. 39, while the model has higher confidence (less entropy value <0.18), it is 100% accurate for 15 company's data sets. Additionally, when the entropy value is <0.23, the accuracy of the model is lies within 75-80% for 16 other company's data sets. Therefore, the overall validation of our proposed sustainable GSLA model could be achieved almost 100% accurately according to discrimination-suspension rule for proposed BNM.

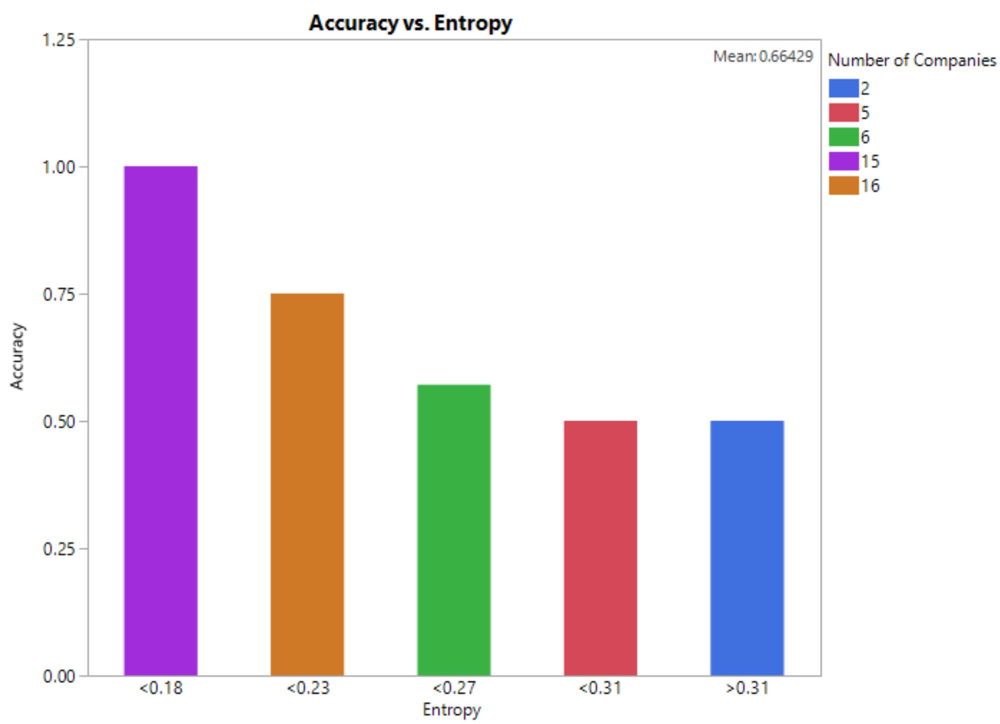

Fig.39. The accuracy of proposed BNM with higher confidence

4. 6 Concluding Remarks

Results and contributions section discovers the missing performance indicators and their measurable units through survey on exiting green SLA and organize them in a tabular form under all three pillars of sustainability. In addition, the main objective of defining proposed GSLA using informational model is to demonstrate the relationships among all three sustainability pillars (ecology, economy and ethics) through identifying some new services in future. All these relationships and dependencies make proposed GSLA more complex for ICT engineers in recent day industry. Therefore, this research also contributes to the ICT engineers by defining all these relationships and their effects among the performance indicators of all identified new services for future GSLA. The implementation and validation section helps to automate future GSLA for the industry to some extent. Moreover, the monitoring and evaluating sections also helps the way out for incorporating basic performance based SLA parameters with green parameters, which might be helpful in future for the automation of GSLA. The overall framework is validated by using the Bayesian network model (BNM) among the data collected from various IT and ICT based industries in different countries. The validation of using BNM is done with the feedback of 44 different IT and ICT based companies from Japan, India and Bangladesh. The average accuracy of using BNM for validating sustainable GSLA model is 68% while considering all sample data sets. Moreover, while the proposed BNM have higher confidence with entropy calculation, then the accuracy is almost 100% for most of the companies' feedback. The proposed idea of using BNM for evaluating and validating sustainable GSLA model would definitely help the ICT engineer to design and develop future green services in their industries. Still there are some important open issues arising to respect future GSLA under sustainability practice in IT industry. There might be necessary to appoint new CEO in the industry, who has already enough understanding and knowledge about upcoming sustainability issues for the society. The companies also need to setup some guideline and IT ethics program in their scope towards their customer, employee and community. The educational program regarding sustainability and green computing need to boost up recently and therefore, it creates new job field in the IT industry. The proposed GSLA model could support ICT engineer, contractors and QoS specialist to respect future green SLA parameter for achieving sustainability. The informational model would help them to understand the different level of interaction, interdependencies and management complexity between green parameters for various new services from both users and company side as well. In future, the model could be automated with a common standard platform and thereby, the proposed model might be standardized within a common harmonized region such as (European Union) EU.

CHAPTER FIVE

5 CONCLUSION

This GSLA research did survey and review on different basic SLA parameters for network, computing, storage and multimedia services in IT and ICT business arena. Research review section demonstrates most of the basic SLA performance indicators and their measurable unit for all mentioned services (Table 5 to Table 8). On the other hand, existing GSLA survey covers most of the recent days green metrics and their measurable unit which are presented using Table 9 from different computing industry. In addition, Table 9 also discovers today's concerns are mainly on energy issues and productivity through the greening lens. Missing performance indicators and their influences on GSLA with respect to 3Es are discussed and identified next. Table 10 to Table 12 lists all new proposed performance indicators and their measurable units. Thus incorporating all new and existing indicators for future GSLA might be difficult and cumbersome work for the ICT engineers.

The management complexity of all identified indicators in future GSLA would be the most challenging task. Therefore, the definition of GSLA section thus proposes an informational model to help ICT engineers to understand the interactions and important effects of various performance indicators in future GSLA (Table 13). The informational model also helps to design a new sustainable GSLA and to derive new services under sustainability lens. The model could be regarded as future framework to develop sustainable GSLA in the industries. Monitoring the green indicators is an important part for proper implementation of future GSLA. Relationships among classical SLA indicators and three GSLA indicators are established based on some existing works in order to simplify the monitoring process of the green performance metrics.

Finally, the overall framework (informational model) is validated by using the Bayesian network model (BNM) among the data collected from various IT and ICT based industries in different countries. The validation of using BNM is done with the feedback of 44 different IT and ICT based companies from Japan, India and Bangladesh. The average accuracy of using BNM for validating sustainable GSLA model is 68% while considering all sample data sets. Moreover, while the proposed BNM have higher confidence with entropy calculation, then the accuracy is almost 100% for most of the companies' feedback. The proposed idea of using BNM for evaluating and validating sustainable GSLA model would definitely help the ICT engineer to design and develop future green services, GSLA in their industries.

Still some challenges exist for designing sustainable GSLA research such as, some performance indicators need to be defined accurately which has association with other indicators; most of the subjective, qualitative indicators related with ethics issue need standardization or governed and authorized by proper laws and directives. Moreover, it is very important to mention here that the definition of GSLA is crucial in development of Green ICT solutions and requires long time to be standardized. The standardization of green indicators is one of the main issues as mentioned by ITU-T report (2012). There are many international initiatives that define green indicators, which results in disharmony such as European Telecommunications Network Operators Association (ETNO), European Telecommunication Standards Institute (ETSI), The Green Grid (TGG), GSM Association, International Electro technical Commission (IEC), and International Telecommunication Union – Study Group 5 (ITU-T SG5). Also, further research is necessary on monitoring the metrics which depend on human interactions.

Moreover, sometimes it is difficult to respect the performance indicators mention in basic SLA and the ones in proposed green SLA. The GSLA research contributes to the ICT industry by defining an informational model with all missing performance indicators for future green SLA. In this regard, the general informational model (Fig. 14) and its decomposition (Fig. 16 to Fig. 22) help to identify the new services under green computing and sustainability domain. This model definitely helps to ensure the green SLA to be realistic for consumers and also for service providers in future. Finally, this research work would also provide a new dimension and strategy for well known service providers to achieve win-win situation with their consumers for achieving sustainability in near future.

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