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Sustainable development of Vehicular Fog Computing Using Karlskrona Manifesto

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Abstract

The emerging concept of smart cities, smart vehicles and smart traffic systems using Vehicular Fog Computing (VFC) technology is based on the concept of cloud and edge computing which assist in the automation and implementation of such smart concepts. But implementing and utilizing Vehicular Fog Computing (VFC) will need an excessive amount of power for the communication and decision-making system and will also lead to cause a huge amount of electromagnetic radiation. The sustainable and environment friendly development and implementation of such systems and infrastructure is still a key challenge for the industry. This research article undergoes a thorough sustainability analysis of the proposed system using the Karlskrona manifesto, which helped us to identify the current and future viable goals and aim of the system and their order of impact on the individuals. The development of the Sustainability and Analysis diagram (SusAD) explored the immediate, intermediate, and structural impact of technical, individual, social, environmental and economic dimensions of the system, this research article also proposes alternative ways to achieve sustainability and prevent the adverse effects of the system implementation.

Keywords: Vehicular Fog Computing (VFC), Edge Computing, Sustainability Development, Karlskrona Manifesto, SusAD.

1. Introduction

Fog computing, which is also called Edge computing, is an arising framework that focuses on augmenting cloud computing abilities to make productive use of network potential, where orthodox and modern tools i.e wearable devices and smart communication utensils edges are considered. It engages the application and research of practical technologies which surely allows network edge's computation so that computation occurs nearest to the data sources [1]. A useful fog computing application is the creation of Internet of Vehicle (IOV) or VFC by the combination of vehicle ad hoc network and fog computing [2]. In recent architecture, vehicles that are equipped with sensors, and carries communication/computational capabilities to collect important information of traffic conditions are considered as an intelligent vehicle. It collects information from both the external condition of vehicles as well as from vehicle's sensors [3, 2]. Cloud-Fog architecture proved its efficiencies and reliability, consumption of energy, and delivery of services [4, 5]. But still this fog architecture needs some efficient ways to be sustainable. Sustainability is the development of a system in such way that fulfill the current viable requirements and goals of individuals and group but also be able to maintain the needs fulfillment of the coming generations. Maintainable system must be able to use for long period of time for a specific purpose. Sustainable system focusses on long term benefits without compromising the benefits of short time [6]. The same way sustainability can be achieved in software system design and development by considering sustainability factor in requirement elicitation by taking only sustainable requirements to the development cycle and by implementing requirements in such a way that are easy to maintain in the future with less redundancy, in other words, considering sustainability in each phase of Software Development Life Cycle (SDLC) [7].

Sustainability can be analyzed through Karlskrona manifesto and Sustainability analysis diagram (SusAD). The Karlskrona manifesto consists of nine principles [table 1] for designing sustainability in a system. These principles use cross refences for software engineers to achieve sustainability in a software system [8]. These principles act as a guide for the software development community.

This article analyses sustainability in the VFC system. The system is first cross referenced with Karlskrona manifesto's nine principles to see which principle can be applied to our case study to achieve sustainability in VFC. Identified its current and future goals and also set indicators to check its sustainability. The SusAD is used to see the order of impacts of technology, social, individual, environment and economics of individuals and groups on a system. We have discussed the related Work in section II, section III details the KARLSKRONA MANIFESTO principles and their use. Section IV discusses the SDLC phases in regard with dimension and order impact. Section V concludes this work and discusses the future work.

2. Literature Review

A lot of work has been done on achieving sustainability in different systems, some of the worthy and most related literature to our case study is described below as a guideline for our work. Calero, C. and Piattini, M [9] discussed the importance and implementation of green software in other words which is called sustainable software in various sectors and organizations of the globe. Fernandes P et al. [10] tells that the sustainability indicators are the best way to quantify the traffic externalities to control various traffic impacts by testing on multiple routes according to their types but there is a future work needed by using 5G technology to integrate the traffic information through model analysis. Oyedeji S et al. [11] present a series of guidelines in the form of sustainability design catalog (SSDC) to help the developers and stakeholders to elicit the sustainable requirements for designing of sustainable system. Luca et al [12] trying to modify the traffic system to a sustainable traffic system in term of pollution and power consumption through a variable traffic light signal. Hinai et al [13] worked on the elicitation of requirements in a such a way that leads to the development of social sustainable development of software system which intend to provide social security to the user of the system. Guldner et al.[14] analyzed the induction of software and their functionalities in the hardware system to check the CO2 emission and other pollution due to the power consumption. Mancebo et al [15] presents a framework for energy efficiency testing to improve environmental goals of **s**oftware (FEETINGS), which act as a guideline for the stakeholders to test the amount of energy that can be used for software operation. Rashid et al [16] focusing on the green software development through agile method.

Table 1: KARLSKRONA MANIFESTO PRINCIPLES

Principle Number	Principle	Description
P1	Sustainability is systemic	Sustainability is never an isolated property. It requires transdisciplinary common ground of sustainability as well as a global picture of sustainability within other properties.
P2	Sustainability has multiple dimensions.	We have to include those dimensions into our analysis if we are to understand the nature of sustainability in any given situation.
P3	Sustainability transcends multiple disciplines.	Working in sustainability means working with people from across many disciplines, addressing the challenges from multiple perspectives.
P4	Sustainability is a concern independent of the purpose of the system.	Sustainability has to be considered even if the primary focus of the system under design is not sustainability.
P5	Sustainability applies to both a system and its wider contexts.	There are at least two spheres to consider in system design: the sustainability of the system itself and how it affects the sustainability of the wider system of which it will be part.
P6	System visibility is a necessary precondition and enabler for sustainability design.	Strive to make the status of the system and its context visible at different levels of abstraction and perspectives to enable participation and informed responsible choice.
P7	Sustainability requires action on multiple levels.	Seek interventions that have the most leverage on a system and consider the opportunity costs: whenever you are taking action towards sustainability, consider whether this is the most effective way of intervening in comparison to alternative actions (leverage points).
P8	Sustainability requires meeting the needs of future generations without compromising the prosperity of the current generation	Innovation in sustainability can play out as decoupling present and future needs. By moving away from the language of conflict and the trade-off mindset, we can identify and enact choices that benefit both present and future.
P9	Sustainability requires long-term thinking.	Multiple timescales, including longer-term indicators in assessment and decisions, should be considered.

They identified 36 practices that should be used in agile method to develop a quick sustainable software system. S.S. Alotaibi et al. [18] proposed a novel approach for the band width optimization and improvement of traffic light performance through the integration of smart homes and smart traffic fog nodes through model driven approach R. Amri and N. B. Ben Saoud in [19] proposing a Generic Sustainable Software Star Model (GS3M) in which they assign different software sustainability values against each sustainability dimensions like social, individuals, economics, technical and environmental, that act as a sustainable metric for software development.

The VFC is considered to be the best solution in smart cities for smart traffic control because it minimizes the energy consumption by transferring the data in a very low bandwidth to nearly installed fog nod in the city for a decision making, but there are still numerous ways that can be applied to achieve sustainability with the least pollution production, these different methods can be efficiently applied through Karlskrona manifesto for the cross checking to sustainability analysis in the system development.

3. KARLSKRONA MANIFESTO

The Karlskrona Manifesto for Sustainability Design (KMSD) has its foundations in the Third International Workshop on Requirements Engineering for Sustainable Systems (RE4SuSy) [16], held at RE'14 in Karlskrona, Sweden. Christoph Becker's paper [17] about the connection between the worries of maintainability and life span gave one of the thorough processes to the production of the proclamation. The key objective was to mix the assorted parts of maintainability to explain its degree, goals, and difficulties of the impression of maintainability prompting an interdisciplinary stage for exploring maintainability [17]. The declaration unites contribution from analysts of different trends in the field of programming with supportability research interests as the makers of the plan proclamation. The Karlskrona Manifesto for Sustainability Design incorporates nine standards of maintainability plan described in table 1. Those standards give the premise to making a reference point that can be applied during programming plan by various partners. The proclamation is open by means of the web where those keen on supporting the declaration can sign it. To analyze the sustainability of the proposed case study of VFC, which is discussed in the very first section of this paper (Background/Case study), we evaluate the sustainability of our case study with the nine principles of Karlskrona manifesto in Table 2. Among the nine (9) principle there are four (4) principles (P2, P3, P4, P9) that can be applied to our case study. This is because these principles are considered to closer to this study. There are five perspectives to be analyzed with respect to each of the Karlskrona principles which are given below.

- The Karlskrona principles and goals mean what are the goals that we want to achieve in sustainability.
- Current and future goals tell us that what are the current purpose of the system and what are the future goals.
- We want to achieve during sustainability development respectively.
- Questions ask that how we can achieve the required sustainable goals.
- Stakeholders are the people that are directly responsible or beneficiary of the goals.

Table 2: SUSTAINABILITY ANALYSIS THROUGH KARLSKRONA MANIFESTO

Karlskrona Principles and Goals	**Current and Future Principles Usages**	**Stakeholders**	**Questions**	**Indicator**
(P2) Integration with other devices.	**Current:** the vehicular fog node receives data from only the vehicles within the fixed area.	Developer and business analyst	Can both the devices be able to share data	Sharing of data of the integrated devices

	Future: Vehicular fig node must be integrated with smart home devices like home controller to increase the availability and efficiency of the data. This can simply be achieved by developing the interface of both the system to share and accept the mutual data		while integrated?	
(P3)(p4) Reduction of electromagnetic radiation/ Reduction of network bandwidth	**Current:** The vehicular fog node sends all datato the clouds for decision making **Future:** the vehicular fog nod should be able to take short term/real time traffic decision locally and send the data to clouds only for long term traffic information. This can be achieved by applying the required algorithm in the locally installed vehicular fog node also.	BusinessAnalyst	Does network bandwidth and electromagnetic radiation can be reduced?	Network bandwidth and electromagnetic radiation
(P4) Warn the Driver behavior	**Current:** the fog nod calculates and summarize all the information of each and every car for decision making and smart traffic signals scheduling **Future:** the data the vehicular fog nod received should also be used to educate the driver about the driving and safety principles like warning the driver of over speeding behavior, The data should also be used to calculate energy consumption and pollution creation by each car, that may	Software developer andbusiness analyst	Do the driver know the driving and safety principles and are they aware of the pollution by the vehicles?	Analyze the behavior of the driver after some time fromthe data

	help the driver to use the car in the time needed only for pollution prevention.			
(p9) Improve driving experience	**Current:** due to traffic congestion the time wastes and noise pollution increases due to horn usage, which make the driving so tedious. **Future:** vehicular fog computing will make the traffic signals fully autonomous so that can completely get rid of the congestion and horn pollution and it will also same the time for the driver that makes driving comfortable.	BusinessAnalyst	Do the driver feel comfortable while driving?	Review andrating

P2 sustainability has multiple dimensions: the goal of this principle considers all the dimensions like (economic, social, environmental, technical and individual) whiledeveloping the system to consumes less energy, produce minimum waste, andefficiently utilize the resources etc. the system should be developed so that the traffic fog node also be able to receive data from the smart home devices so that thedata communication and utilization increases, and to reduce resource waste.

P3 Sustainability transcends many dimensions: this developing system like addressing from Vehicular fog computing is to solve the problem of tedious traffic and autonomous cars, but I addition with these goals the problem of pollution production should be addressed too.

P4 Sustainability is a concern independentof the purpose of the system: the goal of thisprinciple tells us that sustainability should also be analyze while developing the system like as I discussed in P3 above that along with the main purpose of the system development, sustainabilityshould also be analyzed like pollution control. Along with pollution control the VFC should be able to educate the users (drivers) about the traffic principles, energy consumption and pollution generation from the vehicles.

P9 Sustainability required a long-term thinking: the main goal of this principle is that the sustainable system should focus for the long-term goals instead of only achievingthe current requirements, the VFC be able to increase the comfort level of driving by proving some entertainment to the drivers while driving, like recommend him/her his/her favorite music and completely get rid of the traffic congestion that can help us to save time.

Table 3: DIMENSION AND ORDER OF IMPACTS

Dimension/ Order of impacts	**1st Order**	**2nd Order**	**3rd Order**
Environmental	Increases of Electromagnetic radiation. Reduction in fuel consumption by reducing the travel time.	Increasing the smart devices and smart cars. Reduce human resources (traffic constables).	Increase the using of pollutant materials for the industrial based production of the Devices and different hardware.
Economical	Creating business opportunities for companies and labors	Along with fog a huge data center to build for managing cloud data.	Increasing demand in the production of IoT's devices and smart cars and smart home devices
Technical	Driving comfortability, entertainment	Possible exposure to DoS attack of the fog node, which can either disturb the traffic flow or steal the data	This will lead to the car industry to build less pollutant and energy efficient smart cars to compete in the market
Social	Promote new ways of transport and mobility	Build a behavior to share public transport	Minimizing the injuries and death causes by the road accident.
Individual	user will somehow depend on vehicular fog nod for scheduling their drive	Travel time will be lesser by avoiding the traffic congestion	This may build lifetime sustainable behavior in their daily routine

Apart from analyzing the sustainability of the given case study through Karlskrona manifesto principles, the indicator also analyzed with order of impacts for the dimensions like technical, social, individual, environmental and economics. These order of impacts address both the negative and positive impact over these dimensions. These orders of impacts are first order impact(immediate), second order impact (enabling) and third order impact (structural). Th first order impacts are those impacts that can be directly affected by using and development of the system. The enabling impacts are those affects which are indirectly affect after using the specific system in that specific domain. The structural impacts are those impacts that arises from using the system and the collective effects of immediate and enabling impacts. The dimensions for which we analyze the order of impacts are:

- The social dimensions are dimension which shows the relationship between the individual and the groups and address the conflict arising by using the system.
- The Individual dimension is abutting the freedom of usage of the system in the environmental, individual dignity, and free movement.

- The Technical dimension cover the system aspects like maintain and evolve the system over time.
- In the environmental dimensions we address the pollution generation and energy consumption and resource utilization by developing and using the system.
- The economical dimension is about the financial matter, the income and increasing revenue from applying system in the environment.

4. DISCUSSION

The dimensions and their order of impacts are shown in the table 3. For the explicit representation of the dimension of sustainability and their order of impacts are visualized in Figure 1. Following the above table 3. Show the dimensions and its impact can help the software designer and developer to develop a sustainable system. From the pilot framework proposed in Figure 2, acts as a guidance to assess developers and other stakeholders during SDLC to incorporate these the content of pilot framework in system development. Incorporate these contents of pilot framework in each phase to develop a sustainable system. The following information give a complete detail that how a sustainable system can be designed for the above use of VFG.

- *Phase 1 (project definition) with principles P1, P2, P3*: The stakeholder must plan the sustainable factor while plan the design and business opportunities of the system. Like VFC should be able to educate the user about energy consumption by the car and nodes, pollution generation like electromagnetic radiation from the cars and nodes, should also be able to educate the driver about traffic rules.
- *Phase 2 (User Requirement Definition) with Principles P2:* Once the sustainable development was discussed in phase 1, the developer now be able to include the requirement of sustainable development also, like the amount of electromagnetic radiation could be produced by driving car for a specific time, how much energy can be consumed etc.
- *Phase 3 (System Requirement Definition) with Principles P4 and P5:* In this phase the system's overall efficiency and sustainability will be checked, and the conflict of the main business requirements with the sustainable requirements will also be cross checked. The main goals to be broken into smaller goals like the reduction of electromagnetic radiation, network bandwidth reduction etc.
- *Phase 4 (Analysis and Design) with principles P2,P4,P6 and P8:* The main purpose of this phase is to design a software system which is easy to use, energy efficient and have awareness of sustainability. Like the sustainability of VFC shown in the SusAD in figure 3 with all the dimensions and their order of impacts.
- *Phase 5 (Development) with Principles P2 and P4:* In this phase implementation of VFC will be done with the awareness of sustainability, that what function to be add in the system that can help to educate the user about sustainability like energy consumption, pollution generation from network usage and fuel consumption per hour. And share that data to the other user of the system, also design the VFG that should be able to receive data from smart home devices to increase the communication and reduce the availability time.

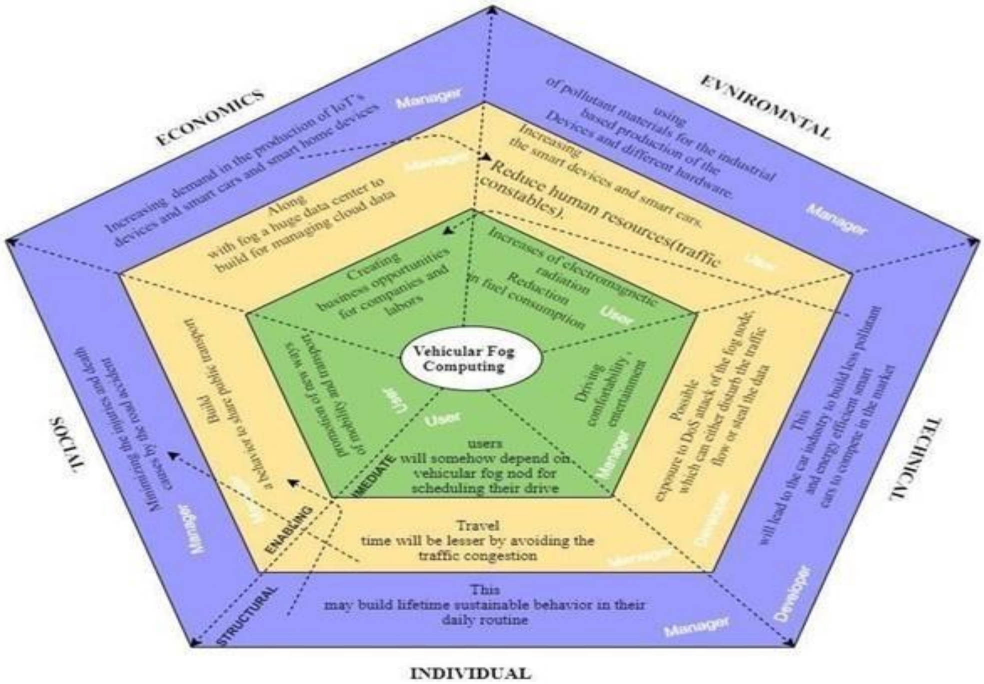

Figure 1: Dimensions and order of impacts

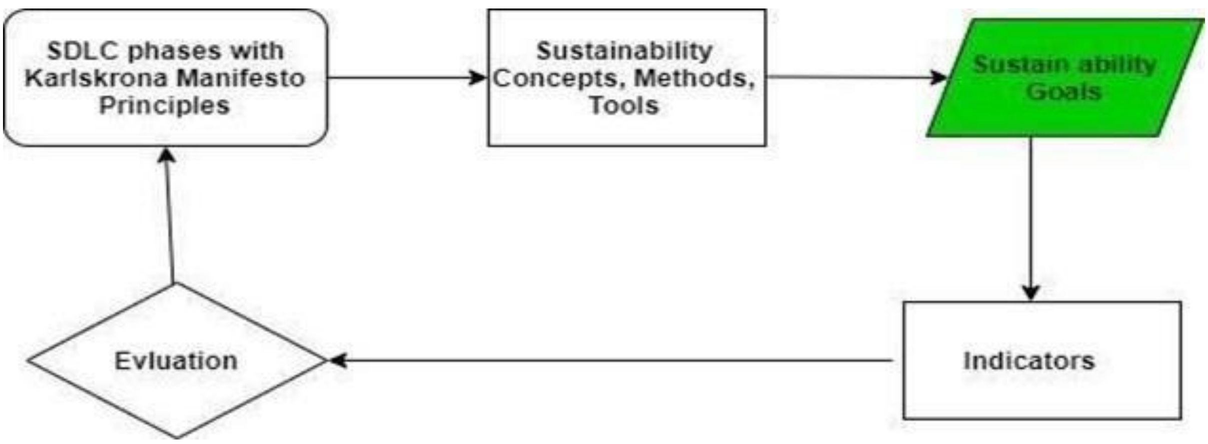

Figure 2: Pilot framework

- *Phase 6 (Integration and Testing) with Principles P2 and P4:* It must be focused on this stage that while integrating and testing the system the sustainability factors mentioned in the above phases should be consider according to Figure 4.

- *Phase 7 (Implementation) with Principles P5 and P7:* This phase should also focus on easy to use and sustainability awareness functionality. While implementing these functionalities the behavior of the developer towards sustainability be observed.

- *Phase 8 (Maintenance) with Principles P9:* This phase focus on the long-term objective of the system like what is the behavior of the user towards sustainability. The best method is to generate the user data of hours of driving and the energy consumptions and pollution generation by the car and nodes and observe the behavior of the users.

5. Conclusion and Future Work

We analyzed the sustainability of the Vehicular fog Computing case study to check how sustainable the VFC should be wand what would be its impacts on the individuals, society, and economy. To analyze the sustainability in the said case study we define the Karlskrona Manifesto Principles which are the guidelines and benchmark to analyze and achieve sustainability in a system, Then we apply the principles of Karlskrona Manifesto to our case study to observe that how sustainability can be achieved in the proposed case study, among nine (9) principles only four (4) principles P2,P3,P4 and P9 which were the most suitable and relevant to the nature and requirements of the VFC, applied to our case study. After applying the Karlskrona principles to our case study. These four principles selected on the basis of the nature of the system, the requirements of the system. Then we identified the first, second and third order impacts of five dimensions of sustainable software like Social, individual, technical, economical, and environmental dimensions through SSDC which shows the immediate, enabling, and direct impacts of applying these Karlskrona principles on the individuals, society, economy, environment etc. Then based on these orders of impacts we match the order of impacts with the Karlskrona Manifesto Principle to every phase of the SDLC that can help the stakeholder to develop a sustainable system.

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