Application of System Thinking in Developing of the Public Transportation Network in Norway

Ebrahim Qaredaghi

Department of Science and Industry Systems
University of South-Eastern Norway
Kongsberg, Norway
Email: qaredaghi@gmail.com

Mo Mansouri

Professor at Department of Science and Industry Systems
University of South-Eastern Norway
Kongsberg, Norway
Email: mo.mansouri@usn.no

Abstract—**Public transportation systems have always provided important services to people. People or customers, as the main stakeholders, need available, fast and reasonably priced transportation systems. However, developing the public transportation system, on one hand, needs educated people to run and update the system based on the new technologies, and, on the other hand, needs to cover environmental agencies' requirements. Global warming as the main concern of environmental agencies has forced the public transportation system to control the greenhouse gas emission and find environmentally friendly solutions for public transportation networks. It is, therefore, important to not just think about the development of the public transportation network, but also consider other stakeholders' requirements as well. In this paper, the authors apply the "system thinking" approach to understand the stakeholders' requirements and how to have a public transportation system that respects all stakeholders' requirements. By using the systemigram method, we model the public transportation network in Norway, and analyze where we could affect the problems of its development.**

Keywords-system thinking; public transportation system; systemigram; system context diagram.

I.   INTRODUCTION

Developing public transportation networks starts when people need to have an available system near their homes to cover daily basis requirements. It could be access to their workplace, shopping malls, their children's school and so on. The network development could be based on the other stakeholders request as well. However, developing the public transportation system is not just to build roads or rail tracks or physical development, it could be an update based on the new technologies, and it has its complexity both technically and environmentally.

In this paper, the authors applied a system thinking approach to analyze the existing public transportation system and how the stakeholders' requirements affect the development of it. The authors tried to study the current system to investigate different stakeholders, their roles, and requirements as well. Moreover, the authors tried to explore all the stakeholders, their interests, and look at the external influences that have evolved the problem to its existing state. Next, the systemigram method was implemented to obtain an understanding of what influences the issues and development of the system, and finally, the concept of openness [1] is applied to the systemigram in order to understand what part of the problem of the network development can be addressed.

The case. In this paper, the development of the public transportation network is followed. The public transportation system organization starts network development as a direct response to the stakeholders' requirement or their need for a new facility. This requirement is given to the organization in order to develop the existing network or build a new network. The organization should consider several solutions, and choose the feasible one in terms of cost, being environmentally friendly, and being compatible with the new technologies.

System (organization) of research. The system being targeted for this research is an organization that works under the supervision of the Public Transport and Communication Ministry. In other words, the organization works in the private sector and the government is one of the main stakeholders to ask directly or indirectly the organization for network development. The authors have conducted the research within a Norwegian transportation system.

II.   BACKGROUND

There are several definitions of system thinking in the literatures. According to INCOSE (International Council on Systems Engineering), *"system thinking is a way of thinking use to address the complex and uncertain real-world situations with emphasis on interconnected technical and social entities which are hierarchically organized producing emergent behavior"*. In addition, system thinking can be defined as a method to a problem or issue that considers how elements within the whole system interact and operate over its lifecycle, and how to optimize the design, implementation, and evaluation [2]. Haraldsen [3] defined system thinking as the "*science that deals with the organization of logic and integration of disciplines for understanding patterns and relations of complex problems. System thinking is also known as principles of organization or theory of self-organization and the way of using it involves "systemic" or "holistic thinking". It is a science based on understanding connections and relations between seemingly isolated things"*. He stated that, in general terms,

system thinking is both the science of structuring the logic, the mental modelling, asking relevant questions, and practical applications through System Analysis and System Dynamics. As can be seen in Figure 1, system thinking embeds two concepts, System Analysis (SA) and System Dynamic (SD). System analysis involves group modeling, where the initial questions of the problem can be asked, and a mental model structure can be created by using Causal Loop Diagrams, to reflect that problem. However, the system dynamics is a mathematical recreation of our mental models to deals with and numerical analysis and understanding uncertainty of the practical representation in the developed mathematical model.

For defining the system openness, we define three boundaries for the system. Control, Influence or transactional environment and appreciate. Control is for the item of the system we could control to some extent. Influence is for items, we only influence and cannot control, and appreciate is for the environment the system operates in [4].

Systemigram is a system thinking tool whose evaluation may be recognized in three phases. First, its development as a structure of visual language. In this phase, the development of the technique focuses on the graphical portrayal of a structured pose. Second, its development as a procedure for business architecture. It is vital to emphasize that systemigram is not an architecture itself, but rather it can provide an inactive and simple environment for comparing and aligning business architectures. The last phase is its modification as a grateful learning system. The systemigram's writer creates a storyboard using carefully selected scenes which are subnets of the systemigram [5].

III. THE PROBLEM CONTEXT

In order to define the context for the problem, first we need to study and define the System Of Interest (SOI). In the following, we present the system of interest definition.

A. The System Of Interest For Development

The public transportation in Norway is the SOI in this paper. The main purpose of the public transportation is to provide transportation vehicles and networks for people who want to use them daily. Several parameters are necessary for customers or people as the main stakeholder, such as price, access to transportation vehicles, roads, and its network, being environmentally friendly etc. In order to cover these requirements, there are many other systems, and infrastructures which should cooperate with the SOI. The public transportation system in Norway consists of rail transportation, road transportation, water transportations, and aviation transportation. Trains, trams, subway count as rail public transportation system. Taxis, busses and minibuses are road public transportation systems, and ferry is the water public transportation system. The authors of this article do not count aviation transportation since they are not used as daily purposes. However, trains are public transportation because many people take them every day from their hometown to workplace. Basically, all the mentioned transportation services can be found in the big cities like Oslo. However, for small cities, we have some of them.
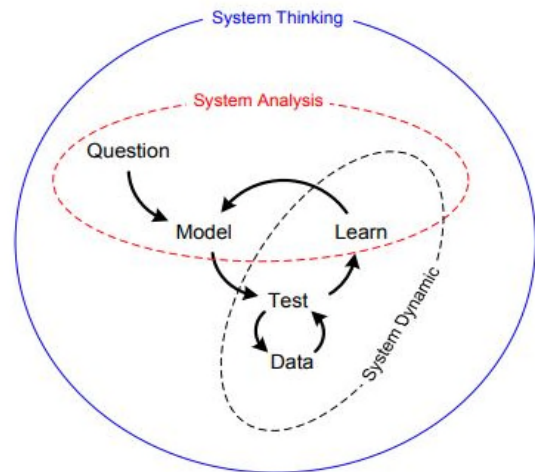

Figure 1. System thinking definition diagram [3]

The two popular public transportation vehicles among people are electrical scooters and electrical bicycles these days. Normally, people are using them inside the cities for short-distance travel. To use them, it is necessary to install an Application (App) on the phone and scan a barcode that is on the vehicles. The payment is based on the time and is very reasonable. The municipalities of the cities have also provided enough parking slots for electrical bicycles. There are several operators that provide electrical scooters, and services as well. However, safety, lower speeds, a campaign to get users to be more considerate, and better parking facilities, are among measures discussed these days to address this new business's issue in municipalities. Since it is necessary to implement the new rules for using them in cities, the writers of this article considered these two new public transportations systems as the new technology and did not consider them as the main and common public transportation system in Norway.

B. The System Boundaries-Developing Context

Figure 2 presents the system boundaries for development context. The public transportation organization is in the inner circle. We can control it, and the team and organization that is responsible for network development is in this circle. Environment, particularly CO_2 emission, sub-contractors included maintenance contractor, education system (schools, universities), and business such as, shopping malls, restaurants, companies can be developed, and are influenced by the public transport network development system. Other items that are in the boundary include people, political decisions, new technologies, and government. These are items which we cannot influence and we should appreciate.

C. Stakeholders Context Diagram

After the SOI explanation and system boundaries, we can define the stakeholders and their main interests. Figure 3 illustrates the high-level stockholders. The main stakeholder is represented by the people or customers who are using the public transportation system. Since in Norway, people pay a
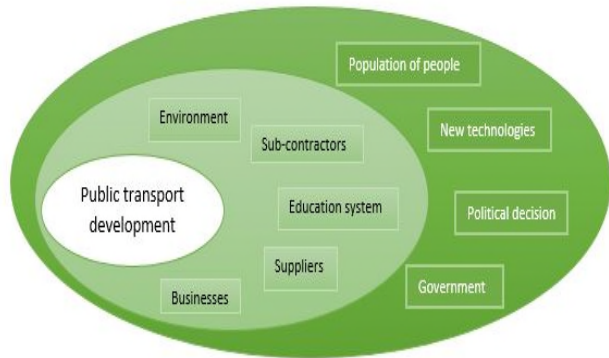
Figure 2. System boundaries in development context

high amount of tax from their salaries, they expect high-quality services in terms of new and comfortable facilities in public transportation vehicles, roads, and infrastructures. In addition, Norway is a relatively expensive country compared to the other European countries, and price is the main concern of the people for receiving services from public transportation system. Developing new methods of transportation could be an option to tackle the expensive transportation system.

On the left side of the interest map, we have people who have an interest in the public transportation system with yellow color in Figure 3. People or customers, tourists, politicians, private owners of lands, people who are working as staff or clerks for public transportation organization are in this category. Customers, tourists and clerks are willing to have a developed transportation system, while owners of land who should sell their land to government do not want it. In order to solve lands' owner issue, either the government should pay good money for it or change the network root. For both solutions, the organization should spend money to tackle these issues.

On the right side of the interest map, there are organizations that have an interest in the SOI with green color in Figure 3. Government, environmental agencies, banks, and legal regulation organizations are these organizations. By developing the public transportation, all these organizations or institutes receive a benefit. The government could get people satisfactions by developing the public transportation system. Environmental agencies should set some rules for transportation system organization to control the greenhouses gas emissions and pollutants based on their criteria and limitations. Banks could provide the loan for SOI, and could also receive interest. The legal organization authorities could set some urban rules for public transportation organization such as, parking places, speed limit etc.

At the bottom of the interest map, we can see the rest of the stakeholders with orange color in Figure 3. These stakeholders are IT and ICT companies, neighbor countries, suppliers or manufacturers, maintenance companies, and the new businesses or markets.

All these stakeholders have connection with the public transportation system directly or indirectly. IT companies

need to provide the App(s) and Internet infrastructures to keep updating the business based on the new technologies and communication services. Neighbor countries could develop their transportation network to Norwegian transportation network easily. Manufacturer or suppliers and maintenance companies or subcontractors could earn money from the public transportation development. They could hire more people and expand their businesses. In addition, new markets or business such as, electrical scooters and electrical bicycles, could be developed as well as existing public transportation to expand the network.

IV. THE PARIS AGREEMENT

In 2016, there was an international agreement called the Paris agreement to control global warming. This agreement is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) to prevent dangerous anthropogenic interference with the climate change. This agreement gives the long-term temperature aim
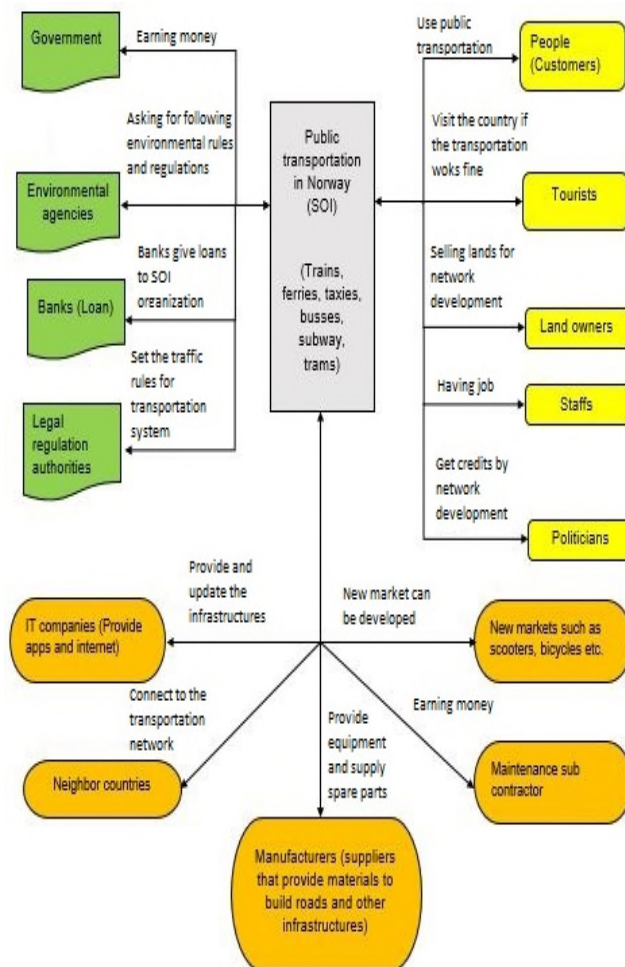

Figure 3. Stakeholders' interest map

holding the increase in the global average temperature to below 2 °C above pre-industrial levels and to follow efforts to restrict the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would reduce the risks and effects of climate change pointedly [6]. The countries involved in this agreement have tried to find solutions to control and mitigate global warming. Norway, as one of the European countries involved this agreement, has tried to play a role by developing green industries and applying a green energy mindset in all aspects of industries, as well as transportation. Therefore, using renewable fuels instead of fossil fuels was part of the Norwegian public transportation development plans. In order to follow this plan, the suppliers need to develop new technologies and update the current fuel consumption system in the public transportation systems which cost them as well. As mentioned before, the electrical scooters and electrical bicycles are new technologies to mitigate the greenhouse gas emissions as well.

V.   THE SYSTEMIGRAM

Following the stakeholders' interest maps, we developed the systemigram to visually represent the problem. Figure 4 illustrates the systemigram for the whole system of interest.

A.   The Mainstay – The Purpose of the System Development

Figure 5 shows the mainstay of the system. We can read the story as "*Public transportation organization shall develop the new transportation network and system to cover environmental criteria to provide accessible transportation services to tackle customer requirements.*" The mainstay is the path for how the public transportation systems develop from where they are today to where they should be in the future.

B.   The Other Parameters

Figure 6 presents the agencies that set sorts of rules and

centers communicate directly, and control the developing system. The environment quality center sets environmental regulations to ensure that greenhouse gas emissions is under the criteria, and the public transportation system is working properly. This center will communicate with the organization to ask them to make a change in their system and modify it to cover the environmental criteria in case of any deviation from the regulations.

The traffic control center is responsible to monitor the public transportation traffic. This center is also communicating with the organization if there are issues that could be solved by public transportation cooperation. Basically, this center either receives a report from public transportations, or checks the transportation system itself and if there is an issue that could be managed by the organization, they will contact the organization. Normally, the issues discussed with the public transportation organization first, and if they could manage it, they will cooperate. The issues that could be tackled, such as traffic jams, the design of the public transportation system network, and improvement of the transportation network can be discussed with the traffic control system.

The legal regulation authority is responsible to set the driving rules such as, speeding control, parking zones, road pricing, road taxes etc. This center will impose rules to the new public transportation network, and the existing network. In addition, this legal regulation authority regularly controls the transportation system to find out if there is any need for improvement of the network. Basically, government asks this organization to set these rules and impose to the transportation system.
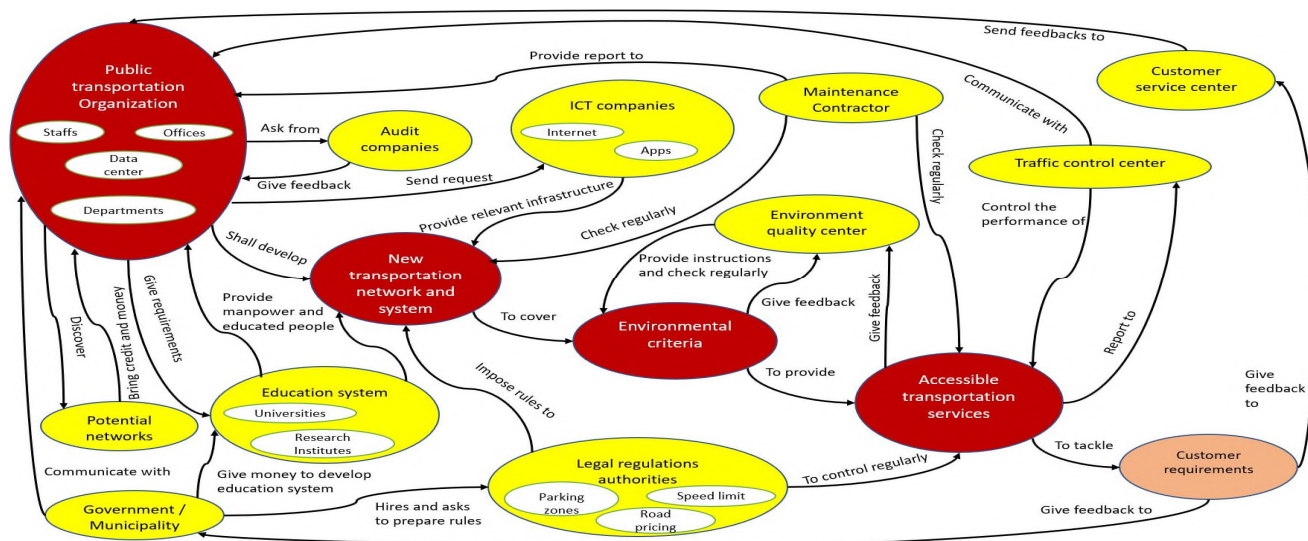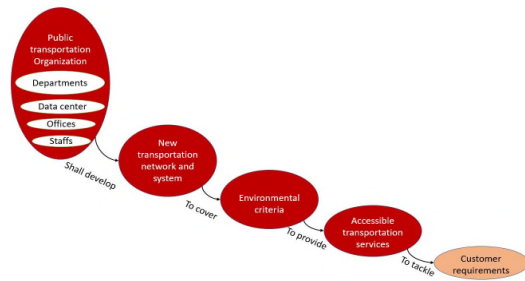

Figure 4. Systemigram

Figure 5. The mainstay

Figure 7 shows the subsystems and sub-contractors. The education system, the potential market, ICT (Information and Communications Technology) companies, audit (third party) company, and maintenance contractor are listed in this group. These subsystems and sub-contractors either support the system or the system gets influenced by them.

Education systems play a significant role in the public transportation development. On one hand, the education system receive money from the government to increase the education quality, and, on the other hand, they have a close relationship with the transportation organization to keep the education system updated, and if necessary, start to research and find a solution about the possibilities to increase the efficiency of public transportation system. As an output of
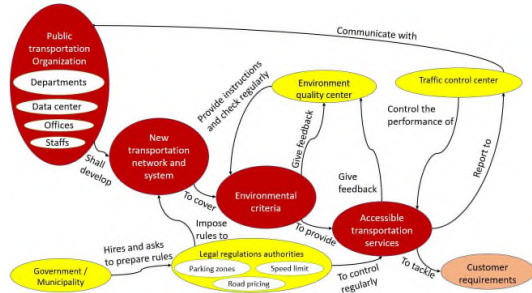

Figure 6. The regulation agencies

the education system, either they perform the research based on the public transportation system order or they provide educated people to help the transportation organization with their knowledge. The education system keeps itself updated and supply the manpower for the public transportation organization by providing and updating the education courses. The main goal of the education system is to support the public transportation system and increase its efficiency.

The potential market is referred to new markets and technologies that could improve the public transportation network services. Since the potential market and new technologies are underdeveloped, they try to find how to impact the SOI.

As mentioned earlier, the electrical scooters and electrical bicycles are the new technologies that could help the current public transportation system. In addition, the SOI has several

departments and they can study the new markets and possibilities. The studies could be about the new roots and finding new networks.

The main responsibility of the ICT companies is to keep the SOI updated in terms of online services such as, Apps and available internet networks. Nowadays, customers buy online tickets, and it is important for them to know the schedule of the public transportations as well. In this regard, Norway is one of the countries that online information and tickets are available for customers, and customers need to receive accurate information in time. It is therefore important for customers to have accessible information in time to plan based on them. The SOI, basically, order to ICT companies what they need, and the ICT companies are responsible to develop the online infrastructures.

Another subsystem that supports public transportation organization is the audit companies. The audit companies perform audits based on the standards to issue certificates. Besides, they perform audits to show the transportation system organization's possible improvement areas. Since the audit companies are external companies, they do not hide the system management negative points and organizations can trust their advice in order to improve the system.
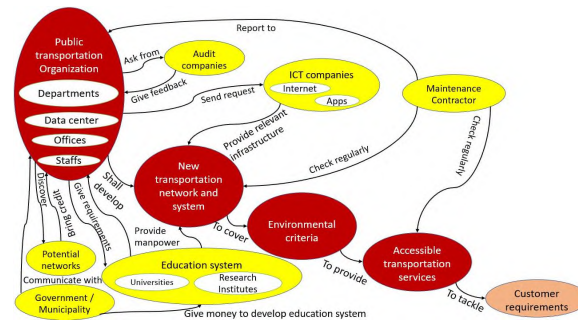

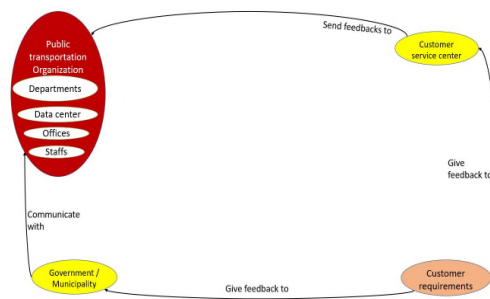Figure 7. The subsystems and sub-contractors

Figure 8. The customer service

The main responsibility of the maintenance contractors is to fix any damage or possible damage. Unlike ICT companies that are trying to support online services, the maintenance companies provide physical services and they are much bigger than ICT companies in terms of the staff and hardware facilities. The maintenance companies have plans and schedules to give SOI services. So, it is very vital for customers and SOI to receive high-quality services from the maintenance subcontractors based on educated and experienced staff.

Figure 8 illustrates the customer service of the SOI. As can be seen from this figure, there are two options for customers to give feedback to the SOI. One possibility is to contact the customer service centers and provide their feedback to them. This could be by calling or even by sending emails. Even some centers have their online questionnaire forms to receive feedback from customers. Another method or way is to contact to government. The customers can provide their feedback to the government through political parties. This method takes more time compared to another way and customers normally use this method if they are not satisfied with the SOI at all, and the consequence of this method could change the whole system.

VI.   How To Tackle The Problem

We used the systemigram to analyze the system of interest and to have a good visual representation of all the factors and forces that can play a role in our system. In order to analyze the system better, we will use the openness principle of the systemigram to analyze where the system interest can influence other forces and where the system of interest can be influenced by the other forces.

Figure 9 presents the openness principle to the systemigram and we categorized the systemigram the nodes into control with green color, influence with purple color and appreciate with red color. Following is the brief explanation of each of them.

A.   Control

As Figure 9 shows, the important nodes that can be controlled to develop public transportation systems are technical factors. In other words, ICT companies and

Figure 9. The openness principle

maintenance sub-contractors are the most important subsystems for controlling the SOI. Basically, ICT companies and maintenance companies receive orders from the public transportation organization to develop the public transportation system.

B.   Influence

The most important nodes that can be influenced in the influence category are customer requests and the SOI itself. These two nodes are important since the aim of the development of the public transportation system is to cover the customer requirements. On the other hand, by developing the public transportation system the organization can be influenced as well.

C.   Appreciate

Many nodes in Figure 9 are categorized as appreciate nodes. These nodes cannot be controlled or influenced and as we can see clearly the legislation organizations such as, environmental quality control center and traffic control center are in this group. The main nodes as can be seen are the government, environment quality control center, legal regulation authority, and the traffic control center. One of the main concerns during the developing public transportation system is to cover the environment quality control criteria based on the Paris agreement. The environmental quality center is the most important center among other nodes in the appreciate group.

Based on the openness principle of the systemigram and analyzing of the systemigram, we could say that the main factor to have a successful development of the public transportation is first to analyze and understand the customer requirements. The customer requirements for having a public transportation network consist of ticket price, accessible public transportation system, comfortable, and environmentally friendly services. The next step is to start a technical study of the possible networks and select the feasible one among other options in the public transportation system development organization. The next step is to influence the items that development the organization can do. The next step is to cover the rules and standards which are sets by the legislation agencies and authorities such as, traffic control agencies, legal regulation authorities in the design and in the construction phase of the development, and the final step is to control the items that can be controlled by the development system. Basically, the factors and aspects that could be controlled are technical factors.

VII.   Conclusion And Further Work

Public transportation plays a significant role in the daily life of the people. It is, therefore, important to cover, and plan based on the stakeholder's requirements. Normally, the customers require for public transportation development. They are expecting a high quality of the services. In order to analyze the stakeholders' requirements, in this paper, we used the application of the system thinking. Specifically, we used the systemigram method and principle of the openness to analyzing the necessary factors to develop the public transportation system.
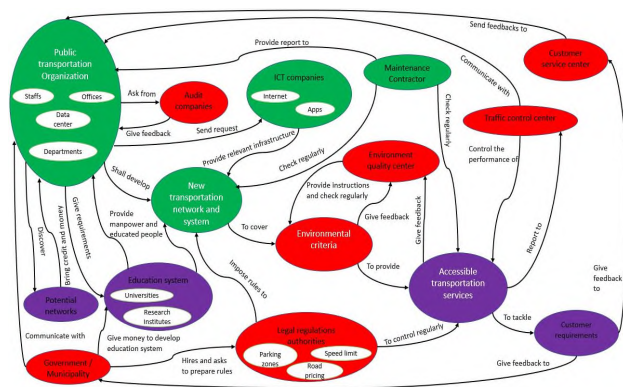
Systemigram is a useful method in order to analyze the system. This method also gives the visual presentation of the system and the connection between the factors. By applying the openness principle, we could analyze and tackle the problem and provide the solution for the issue step by step. There are several stakeholders that are involved in the public transportation development. The government, people, and education system play a significant role among stakeholders. The environmental quality center sets the rules and regulations in order to control the greenhouse gas emission and find the environmentally friendly solutions for public transportation system development.

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