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**FEASIBILITY STUDY FOR USING FROM SOLAR ENERGY IN
PUBLIC TRANSPORTATION ALONG WITH THE URBAN
SUSTAINABILITY**

(CASE STYDY: TEHRAN)



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Abstract

Today, about 90 % of the required energy for the industrial countries is supplied from the fossil fuels and it is predicted that if we do not change the amount of the energy consumption, all of the fossil fuels which 500 – 700 million years passed to generate them, at most will be finished at the end of this century.

In 2011 more than 81 % of total consumed energy of the world and more than 95% of the consumed energy in Iran was supplied by Fossil Fuels. Using from this type of fuels leads to generation of the toxic and air polluting gases, acid rains and consequently pollution of the water resources such as rivers as well as increasing the amount of the Carbonic Acid in the earth atmosphere.

Continuity of using from these fossil fuels in addition to increase the air, earth and water pollutions, leads to an increase in the temperature of the earth due to the increase of the Carbonic Acid in the Earth Atmosphere. This increase in the temperature of the earth which affects the precipitations, leads to intensify and higher frequencies of storms and floods, expansion of the sea and oceans waters and elevating the surface of their waters.

The transportation issue and its relation to the environment are from the most important issues and problems in the urban management in the today world.

The expansion of the cities and increase of the urban population is a big challenge especially in the developing countries, which the transportation for this extensive population in such an extensive range creates many big and complicated problems.

Regardless of the structural and operational dimensions of this process, the negative effects of the air pollution will make this problem harder and more challenging; in such a way that necessity of using from the renewable energies such as solar energy in the urban transportation will be more obvious. This energy is the greatest renewable source of energy on the earth, in such a way that even only one percent of the radiations in the desert regions were used in the thermal solar power plants, and then the total annual need of the world will be satisfied.

The solar energy has many advantages in comparison to the other sources and other energy sources available in the earth from the fossil fuels to the wind and hydraulic force; all are originate from the sun. Alongside with the attempts in order to use from the solar energy, the climate and the weather as a natural resource, is a good context for investigating the solar energy.

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I. Introduction

1. Preface

With the increasing growth of urbanism during last decades, cities, as the biggest residential complexes of the world, will contain more than two third of the world's populations by the year 2020. This trend will finally turn the earth into a metropolitan.

By rapid growth of industrialization, most countries, especially developing countries, will experience rapid growth of urbanism. In 1995, about 45% of the people around the world resided in the cities. It is expected the figure will increase to 60% to 65% by the year 2025. In 2003, 38% of the population in Asia (about 2\1 billions) lived in the cities and until 2020, the ratio of urban inhabitants will increase by 50% and urban population will reach to 2 billion.

Irregular energy consumption in most countries, world's attention to energy consumption improvement as well as environmental preservation have caused many countries to conduct research and studies for energy consumption improvement and replacement of oil products.

This issue is developing and on the other hand, transportation –especially in populous cities – is known as the most urban challenge subject in last decades. Transportations part is the most important consumer of energy around the world .The population growth, developing of cities, industrialized of societies, increasing of income and also increasing of vehicles cause that most of the energy is consumed in this part.

The effects of using from the fossil fuels, in addition to their destructive environmental effects, affect the economics and industries of the societies too.

Attempts in order to control these damages with different environmental, economic and social dimensions lead to providing the theories of the sustainable development within the report provided by the Environment and Development Committee (1987)¹, which is usually known as Bruntland² Committee such as: Developments which satisfy the requirements and need of the future generations without any risks for their current needs.

In this sense, the concept of the sustainability was defined by Mac Lauren and the way to distinguish it from the urban sustainable development is considering the sustainability conception as the descriptor of the desired condition or the sustainable conditions.

Although because of the different beliefs in the societies, there is no unique definition from the sustainability, and a set of the defined indexes and measures in order to evaluate the development in order to achieve to the general objectives of the sustainability in each society, cannot be suitable for the other societies, but there are some of the principle and main

¹ World Commission on Environment and Development

² The Brundtland Commission

characteristics for the sustainability measures which all of the societies are agree with them and they should be considered in the policies and programs. In the Mac Lauren's Opinion, some of the main features of the urban sustainability are the equality between the generations, equality in saving the natural resources (and living according to their capacities), using form the least amount of the non-renewable energies, economical surviving and its variety, self-dependent society, personal welfare and satisfying the main needs of the people of the society.

In the present conditions, one of the most important issues which is considered in the world, is minimum use from the non-renewable energies for the sustainability conception, because the effects of using from the non-renewable resources such as fossil fuels, is very extensive on other dimensions such as environment, economical surviving and self-dependency. There are different applications of the fossil fuels, which one of their most important one, especially in the view of urban planning, is using as the fuel for the transportation vehicles.

Within last 50 years, research on urban transportation has faced a lot of changes. In the initial decades, the focus of studies was on developing of capacity for meeting increasing demands of traveling with motor vehicles³.

Nowadays, all transportation experts are in agreement that they should find a sustainable transportation model in order to provide a city with safe, comfortable, fast and efficient public transportation. Sustainability in transportation means implementing a transportation development model that, in spite of developing cities, growing population and development of social and economic activities, which are among causes of traffic, cargo and passenger transportation moves smoothly without having problem on account of traffic⁴.

New strategies of urban transportation are based on sustainable transportation and qualitative and quantitative development of public transportation.

Energy consuming improvement measures in transportation aim at decreasing energy consumption ratio per passenger. Moreover, energy consumption value reduced per passengers is included in the same category by replacing cheaper fuels. The world moves with unbelievable speed toward producing environmental-friendly science and technology. Producing clean fuel instead of fossil fuel, using new energies and producing automobiles that burn clean fuels are the most important things that help to solve environmental problems.

Since green technologies have recently emerged and, therefore, their mass production has not started, they need financial and legislative support. In this way, the society gets used to consuming such strange and expensive technologies and producing clean and naturally cheaper technology will be possible. Since 40 years ago and after oil price shock, came as the result of oil price increase, the countries of the world decided to depend less on fossil fuels and find other

³ Jahanshahi 112:2005

⁴ Bahreini 29.1997

replacements. It was at this time that lots of investment went to conducting research on renewable energies such as biomass, wind, sun and geothermic.

Economically, by the increasing growth in clean energy consumption, and according to the reports of valid global scientific centers, renewable energies will have more consumption than fossil fuels within next 10 years. Apart from strategic importance attached to clean and renewable energies, this happens in the mid of all controversy over emptiness of gas and oil wells.

Raising fossil fuel price, environmental challenges led by using fossil fuels and strict rules and regulations for on the emission of greenhouse gases are some other factors for new approaches toward renewable energies. On the other hand, developing clean technologies lowers the price and renewable energies, especially solar energy, enter into competition. The economic, environmental, managerial, social and mental consequences of traffic in the last decades have changed the attitudes toward traffic management in the cities.

Considering advantages of public transportation system, including mass transfer of passengers in a short period of time, low fuel consumption, economic savings on national scale, decreasing air pollution and sound pollution, safety and more sustainability, many countries, within last decades, have chosen optimized passenger transfer management, developing and boosting public transportation and employing modern transportation models, together with demand management based approaches, as the main approaches in comprehensive transportation system of their cities.

Nowadays, special advantages of public transportation have encouraged developing countries to employ all types of public transportation above all urban transportation systems.

The fact is that, public transit is not rendered appropriately and it will turn into a crisis in the near future if no preventive or corrective measure is taken. That is why developed and developing countries have no option other than moving toward a sustainable public transportation management and consider the principles of sustainable public transit as the base of their future transportation plans, if they wish to solve various traffic issues.

All of these conditions will raise this basic question: Can use from solar energy as a renewable energy in the public transportation, lead to sustainable development of the cities?

The question which the present study has been formed in order to answer that and for this purpose Tehran City is selected as the case study. The complexities resulted from the being metropolis, high population, deficits in the public transportation system and excessive use from the personal cars and the location of Tehran which is in the center of Iran and having a significant amount of Solar Radiation as well as high air pollution, are some of the reasons why Tehran has been selected.

The present paper studies the importance of oil products and their role in transportation and then discusses the approach toward electrical transportation and using solar energy for lowering energy consumption. The strategy is more or less known in the world but, unfortunately, it has not been paid attention to in Iran because of low fuel price and governmental subsidy.

2. Necessity and Importance of this Study

And nowadays, by increasing the population of the world, the limitations of the energy sources their negative effects on the environment resulted from excessive use from fossil fuels, public attention to the use from renewable energies such as solar energy has been increased.

The Energy issues are a very extensive and comprehensive issues in all of the sciences, and from different points of view can be investigated. But from them, the nature of the human life pattern in today world, e.g. urbanization, has the most interactions with the energy and its related issues, and it can be said that the effects of all of the environmental, economic and social dimensions will result to different issues. Therefore, the Energy issue with an emphasis on the renewable energies is a very important issues in the sciences related to the city and especially to the science of urban planning. The issues is more important when we consider this fact that because of lack of attention and planning in this field, nowadays many destructive effects such as earth warming will place the lives of all people and creatures in the world in danger.

Although from the past, the human has used from the solar energy, consciously or unconsciously, but the history of optimum use from the solar energy and based on the planning of use from this type of energy is not very old. For example, the history of using from the solar energy in production of the warm water and warming of the buildings in the America, Russia, Australia and other modern countries started from 1940.

After the energy crisis in 1973, in which the importance of using from solar energy increased, many investments were implemented in most industrial countries in order to access to the optimum plans of use from solar energy. In the conditions in which the history of use from the solar energy in satisfying the needs of the construction and building sector (such as warming and supplying the hot water) is not for very long time ago, the studies and actions which are done in the transportation sector is more limited. In such conditions in which the non-renewable energies have a large portion in the transportation sector of many countries especially the developing countries, for example the highest rate consumption of two oil products such as gas and gas oil as the fossil fuels in Iran belongs to transportation sector.

In contrast, it is observed that excessive use from the fossil fuels along with the improper plans and programs, has led to some problems such as air pollution, and after that many environmental, economic and social damages and an increase in the death toll resulted from

the air pollution has been observed. According to the official reports, 3000 Tehran Citizens in 2012 died because of the air pollution. The macro dimension of these conditions has been considered from the urban sustainability point of view.

It means that excessive use from the non-renewable energies and its effects on the sustainable development and in the other words, satisfying the needs of the current generation without decreasing the capabilities of the future generations, development of the quality of the human life to the allowable limits of the supportive environmental organizations capacity, and maintaining the environmental, economic and social systems to which the society is related, has created many big challenges.

It should be mentioned that air and environmental pollutions currently in addition to the making dangers for the ecological conditions and life on the earth, have many negative effects on the human life, in such a way that according to the evaluates and estimates of the World Health Organization, the tiny particles in the air, annually lead to death of more than 500000 people in the world. Also in many of the countries, the economic costs of the air pollution are about 2 % of the net domestic production. On the other hands, the transportation as an indirect factor is affective in air pollution. With regard to the impermeability of surfaces of the roads and streets, the pollutants cannot penetrate into the earth, and due to the storms, these particles will enter into the surface waters. In addition to these pollutions, atmospheric pollutions and sound pollutions resulted from the transportation of the cars and vehicles should be taken into consideration.

3. Research questions

Therefore with having the above mentioned issues in minds, the importance and necessity of conducting this kind of study will be defined with emphasis on three subjects that the present study has been conducted in order to answer these three Questions:

1. To what extent, using from renewable energies with emphasis on the Solar Energy in the Urban Transportation Sector can lead to Urban Sustainability?
2. How and what are the potentials of Iran, with emphasis on the use from the Solar Energy for the Urban Applications?
3. Will use from the Solar Energy in the Urban Transportation, help to City of Tehran?

4. Research Aims

The present study tries to answer this question: If using from the Solar Energy as a Renewable Source of Energy in the urban transportation system, can lead to sustainability of the City? The planning method is based on the future-oriented planning method. Although the problems and issues related to the urban public transportation and energy crisis exists currently, but with continuity of these problems in the future, they will be really disastrous. For this purpose, the

prediction is very important in this field. The prediction is an intellectual model from the possible future with a not-specified or unknown prediction level.

The achieving to the urban sustainability, means using from the sustainable development theory from which the sustainable transportation will be resulted from that with regard to the subject. The transportation system, by providing access to the resources and consumer market, are in the economic development service. Also, through communicating with facilities and occupational, educational, health and welfare services, will affect the quality of the human lives. Therefore, transportation has a determinative role in the social and economic development of the society. However, the transportation has many side effects such as traffic jams, consumption from non-renewable energies and decreasing the safety level.

5. Research Methodology

The methodology used in the present study in Descriptive-Analytical. Therefore by using from the documentary studies, theoretical patterns and models, main conceptions and research variables were defined and recognized and by a review in the literature and theoretical discussions of the research, the main and general terms and hypotheses related to the problem were defined. Finally, by using from the general terms and hypotheses, the desired problem was investigated and the obtained deductions in order to answer the research questions were analyzed and finally the results were proposed.

6. Data Analysis Methodology

The Data Analysis methodology in the present study included two following methods;

a. The current Analysis Method: According to the theoretical framework, the documentary researches, descriptive observations, the current situation was studied and recognized with emphasis on the under study subject, and then the data according to the need to categorization and finally with descriptive methods, were analyzed. Therefore, the relation between using from the solar energy in urban transportation and the urban sustainability can be defined. This method was used in the present study in order to answer the research questions.

b. Prescription Method: in this method, the theoretical framework and the results obtained from the study were adapted on the under study field along with the study objective.

7. Research Background

Mike Jenkes and Colin Jones (2010) in their book, *The Dimensions of the Sustainable City*⁵, have investigated the city sustainability from different aspects. After describing the conceptions and dimensions, achieving to the different dimensions of the sustainable city was investigated with emphasis on the sustainability of the environment, transportation, Energy consumption, Social

⁵ Dimensions of the Sustainable City, Mike Jenkes and Colin Jones (2010)

acceptance and Economical Surviving. The third chapter of this book is devoted to traveling and transportation, and totally it is focused on the automobile possession and use from it as well as the Urban Compaction issues on the travelling behavior.

In the fourth chapter of this book, the negative effects resulted from the urbanization on the environment was described, some subjects such as changes in the habitat (for example removing the plant coverage) and changes and evolution in the ecosystem services (for example the climatic changes). The other significant and important discussion in this book in the subject of Energy Consumption which in that the balance between the use from the transportation services and energy supplying is mentioned as well as other energy-related issues.

Kate Williams, Elizabeth Burton and Mike Jenkes (2000), have gathered the studies conducted by themselves and other researchers in a book⁶ titled *Achieving to the Sustainable Form of the City*. The emphasis of the writers in this book is on the city form and its effect on the sustainability issue, but in that, there are many useful materials related to the sustainability conception and its features provided by them. Especially in the second Chapter of this book, the emphasis is on the Urban Transportation Issue and some methods are suggested for sustainability of the city.

The studies and researches conducted by Willer and Bitley⁷, in addition to the articles from the other researchers are gathered in a book titled *Notes on the Sustainable Urban Development*, and this study is related to this thesis too. Transportation Sector, Energy Consumption, Environmental Equality, Economic development with the case samples from the urban sustainability, are some of the discussions which have relations with the under study subject.

The articles gathered by Sedrik Pug (2000) titled *Sustainable cities in the developing countries*⁸ has some discussions related to the sustainable development, long term feed backs of sustainability, expansion of the welfare and poverty in the cities, economical activities and government-related evolutions, Housing and evolution in the important international organizations such as World Bank and Human Settlement Center of United Nations.

The project undertaken by *The Louis Berger Group Inc.* (2011) is one of the most important relevant studies. This study was requested by the American Association of State Highway and Transportation Officials (AASHTO), and conducted as part of National Cooperative Highway Research Program (NCHRP).

The objective of this research is to develop technical and case study data on the use of solar or wind power as an alternative power source for a wide variety of transportation infrastructure

⁶ *Achieving Sustainable Urban Form*, Kate Williams, Elizabeth Burton and Mike Jenkes (2000)

⁷ *The Sustainable Urban Development (READER)*, Willer and Bitley

⁸ *Sustainable cities in developing countries; Theory and practice at the millennium*, Cedric D.J. Pugh

settings and to present this data in a handbook for use by State Departments of Transportation (DOTs) that are considering the use of Renewable Energy Installations.

Renewable energy installations (REIs) have numerous applications and benefits; however, the success of their implementation is dependent on a detailed assessment of a variety of factors. An understanding of the physical, economic, and institutional feasibility factors for implementing various existing and emerging technologies is a core component of this research project. The objective is to provide a framework for identifying and developing innovative tools and techniques for transportation agencies to successfully select and implement appropriate REIs.

The focus of *Patrick and Roseland's* (2005) paper, developing sustainability indicators to improve community access to public transit in rural residential areas, is on the development of sustainable transportation indicators for rural residential areas. While sustainable transportation indicators exist for urban regions the transfer of those indicators to rural residential areas is problematic, in part owing to differences in settlement density and land-use intensity. The continued spread of ex-urban growth to the rural fringe of the Georgia Basin, British Columbia is commensurate with increased automobile dependency that threatens the sustainability of these non-urban areas.

With the extension of regional public transit service into many rural residential areas in BC it is now prudent to develop sustainability indicators to assist local governments intent on improving the sustainability of their communities through improved access to public transit.

A set of sustainable transportation indicators is developed based on three indicator types: land-use, community design and transit policy. Using these indicators a mail-out questionnaire was sent to eight municipal transit systems serving nonurban areas within the Georgia Basin of British Columbia. These sustainability indicators offer a first step toward reducing automobile dependency in rural residential areas through improved community access to public transit.

Saghafi and all in their study titled the Optimum gradient of Solar collectors⁹ and their comparison with the installation on the southern facets in Tehran, have suggested that one of the solution in order to counter and face the energy crisis and also the environmental crisis in the world, is using from the green and renewable energies, especially the Solar Energy. For this purpose in their study, they have focused on the solar collectors.

Solar Energy Collector are from the most used systems in the building in order to direct use from the Sun Radiation Energy and its heating, and also in the composite systems they are used in order to supply the hot water and warming applications in the buildings. Although this study has been focused on the calculation of the optimum gradient for the Solar Energy Collectors in

⁹ Optimum gradient of Solar collectors, Saghafi, 2010

Tehran, but it reveals much useful information about the Solar Energy especially in Tehran as a case study for the present research.

The study conducted by Sherbafian (2008) titled the Estimation of the technical and economic potential of the Solar Energy Heating in Iran¹⁰, Solution for sustainable development of the Solar Energy, has placed the Iran on the top of the Persian Gulf Countries in the field of Energy Variety and introducing the renewable Energies. In his opinion, not only Iran is enriched by the fossil fuels, but also it has great potentials in Renewable Energies.

In such a way that its potential for the renewable Energy is estimated much more than the fossil fuels. Also they have concluded that the Renewable technologies should be localized with regard to the conditions in the Country, and in this way the Solar Energy Projects can be placed in the supported governmental policies. Also in order to change the technical potential to the economic potential, it is necessary to provide Market-based solution in which the renewable Energies are developed in a sustainable way and by private and public Sectors.

Taajdar and Akbari (2008) have studied the international approaches for the public transportations in their research¹¹. According to the study conducted by Newman and Kenorthi (1999) they have suggested that the more allocated road infrastructures and spaces to the intra-urban transportation, the more use from the vehicles, fuels consumption and the more pollution. Therefore It is necessary to consider the sustainable transportation patterns in the cities in order to have a healthy and peaceful city with a fast and useful, safe and effective transportation system and finally a sustainable city.

Sustainability in the transportation sector, means that the transportation should be based on a pattern that despite the population growth and development of the economic, social and other activities which lead to an increase in the traffic volume, the cities have no problems in terms of traffic in such a way that they can satisfy the needs of transferring people and goods, and by development of these activities, the transportation system should not have any problem and remain sustainable.

The article written by Rahaei and Maqami (2008) titled Sustainability of Tehran and Public Transportation System¹², has pointed out the disastrous effects of the excessive and improper use from the non-renewable resources, especially in the developing countries such as Iran, and suggested that the main reason for the deficit in the current traffic systems, is improper maintenance from the roads and improper use from the vehicles and cars. This article, just at it is shown in its title, emphasizes on the planning in order to more use from the public transportation system and using from the persuasive policies in this field.

¹⁰ The Estimation of the technical and economic potential of the Solar Energy Heating in Iran, Sherbafian, 2008

¹¹ International approaches for the public transportation, Taajdar and Akbari, 2008

¹² Sustainability of Tehran and Public Transportation System, Rahaei and Maqami, 2008

The study and Planning Management of the Traffic and Transportation Affairs in Tehran (2011), in the 128th City Science Magazine, has studied and provided the policies for achieving to a sustainable transportation system in Tehran comprehensively.

In this study, at first the literature related to the sustainable transportation has been studied, then the obstacles for achieving to a sustainable transportation in Tehran have been investigated and the implemented methods and solutions by Tehran Municipality for this purpose have been introduced and finally by using from SWOT technique, some solutions are provided and prioritized in order to achieve to a sustainable transportation in the city of Tehran.

A review on the conducted studies reveals that the use from the solar energy in the Transportation system has been considered rarely, and it can be said that almost in Iran no study has been conducted in this field.

II. Research Literature

1. Urban Sustainable Development

Urban sustained development theory is resulted from the environment supporters in the field of environmental issues especially city environment which was proposed following the sustained develop to support environmental and natural resources. In this theory the topic of maintenance of resources for the present and future by optimum using of lands and minimum wastes to the renewable resources is presented. The theory is a strategic view which considers significantly to the role of government in these schedules and planning and believes that the governments should support environment in all cases and aspects.

The theory of city sustained shape studies the effective pattern of transportation in the field of fuel consumption and also evaluates the city in the field of urban area hierarchy. The main important of theoretical concept of urban sustainability includes the following: decrease of pollution, maintenance of natural resources, energy consumption decrease, social balanced structure of public transportation and decrease of traffic jams, so that, by substitution of resources and their reconstruction, correct and efficient applications policy of lands and their protection will be used and then sustained urban development regarding to the urban planning regional and space organization considerations of macro transportation planners of cities was first the users of traffic path networks and cost of travel time and safety.

In addition, its main focus was on technical aspects and then included the citizens participation in decision making process of transportation to the growth of the vehicle numbers, complicated travel models was the main limits to achieve sustained urban development.

The attitude of urban transportation planning is revolutionized in attitude of metropolis cities. Unity and comprehensive views regarding to the defined aspects of sustained urban development, meeting the essential needs of people in the field of transportation should be in a

way that the city would be habitable in terms of environment, sustainable in terms of economics and equivalent in terms of society.

Transportation networks are of the main factors influence urban development. Variations of conventional transportation systems and using new transportation networks, distributes the regional potentials to absorb development. The influence of these new networks of urban transportation networks on urban development is to create nodes around the stations so that the main stations can be considered as development places.

By establishment and definition of city transportation networks, the urban structure and potentials of regional development will change. Establishment of the new transportation networks will influence urban structure, however, this influence needs time and is applied along with other effective factors.

Beside the growing numbers of vehicles, the complex travel patterns are major limitation in achieving sustainability. To adopt the sustainability principles to transportation system the following items should be regarded:

- Duration and intensity of the traffic of the vehicles are increasing, while it should decrease considerably.
- Air pollution, has exceeded over the thresholds in many cities, according to the air quality standards and WHO standards. Air pollution influences the health and sight field of people and damages the buildings and environment ecology and in the other word, declines the life quality of the cities.
- The disturbance of noise and acoustic pollution derived from traffic influences the whole life of the city. The obtained estimations show that in one hand, about 105% of people live in developed countries exposed to a high level of acoustic pollution which is more derived from traffic.
- Global heating of the world is resulted from fossil fuels. Today, 25% of the emitted CO₂ in the atmosphere is resulted from transportation. The amount of which is increasing, transportation completely depends upon fossil fuels which is considered as un-renewable resources.

Increasingly growth of personal cars on one hand and insufficient facilities of public transportation in big cities especially in Tehran, on the other hand, have created many problems for citizens. Inefficiency of no massive transportation and its oldness has distributed traffic procedure in transportation networks of Tehran. What is more considered here is the need of training and codifying the traffic culture to the citizens to use public transportation efficiently and more than before instead of personal cars as a main strategy to solve traffic problem of Tehran which help urban planning .

Sustainable Transportation Theory

Sustainable transportation conception in summary tries to transport the human and goods with a sustainable environmental, economic and social feature. The Commission of European Societies¹³ defined the following features for a sustainable transportation system:

- Ability to provide an equal access for the people, groups and companies in a safe and social environmental-friendly form.
- Being efficient and having variety with an acceptable cost in order to provide a field for the regional competitive economics and equal development.
- With the minimum pollution, and used from the renewable energy sources as much as is possible with the minimum side effects.

Also the definition defined by the Transportation Association of Canada¹⁴ for the sustainable transportation has the following features:

- A system in which the generation and accumulation of the wastes in each region is related to the absorption capacity of that region, and it is strengthened by using from the renewable sources, recyclable materials and minimum use from earth.
- A system that provides an equal access for the people and their goods in order to achieve to desirable health and quality without any loss for the people lives.
- A system with the maximum level of efficiency and affordable economical costs.

Thomas and Fordham suggested that the sustainability in the transportation is equal to a decrease in the dependency to the vehicles and defined the following features and specifications for sustainability of the transportation system¹⁵:

- Decreasing the need of the people to travel (Decreasing the amount and distance of the travels)
- Changing the travelling methods and approaches (Decreasing the use from the non-public and private vehicles and using from non-motorized vehicles)
- Increasing the efficiency of the motorized vehicles (In terms of Energy Consumption and Pollution generation)

The Organization of the Economic Cooperation Development (OECD), describes two different approaches for the sustainable transportation¹⁶: First, the technique-oriented approach which is formed with regard to a conception known as Hyper Car (Electrical Energy Consumer). It is claimed that this generation of the cars and vehicles are about 15-20 times more efficient in

¹³ Commission of the European Communities-2006

¹⁴ Transportation Association of Canada (TAC)

¹⁵ Thomas and Fordham, 2003: 3

¹⁶ Organization for Economic Co-operation Development (OECD)-1996

comparison to the current generation, and also they have some advantages such as safety, lower prices, comfort, longer life, and beautiful appearance.

The second approach is based on the less activity and consequently less dependency to car. This approach tries to decrease the tendency to use from the cars in comparison to the other alternatives or decrease the necessity of using from the car. This objective can be obtained through an improvement in the infrastructures, development of the alternative travelling methods, improving the application patterns for the earth and emphasis on correcting the habits and life style of the citizens. These two approaches can be defined as the minimalist and comprehensive approaches, respectively.

However, paying attention to one of the above mentioned approaches is not enough. For example, even extensive use from the hyper-cars cannot solve the problem resulted from lack of access to the urban services, even this is possible that due to lower prices and costs of these hyper cars, the amount of the dependency on these cars increases. Therefore three Scenarios can be proposed for a sustainable transportation:

- Technology Scenario (Changing the transportation technology such as production of cars with better combustion)
- Human Scenario (Changing the behavioural patterns of the users)
- Combinational Scenario (Changing the technology and the behaviour at the same time)

It is very important to define which scenario the most effective one. But it is even more important to know that which scenario is more acceptable in the people's opinion. Especially when we want to change the citizen's behavior structurally. Implementation of these scenarios depends on evaluation of the people's expectations in terms of the life quality improvement. It is necessary that policy makers and decision makers be aware from the effectiveness range of the transportation schemes and models on the life quality of people in the society.

Talking from the sustainable transportation is acceptable when it does not lead to a decrease in the life quality of people. Also Bruntland Commission has emphasized on the importance of the life quality factor in the definition of the sustainable development: Satisfying the current needs without any limitations for the future generations in terms of their needs.

This definition has emphasized on the life quality and satisfying the need of the current and future generations need, simultaneously; and tries to improve the life quality for present and future. The sustainability ideal for transportation, should consider the values and needs of the today people. In addition to the effects resulted from the sustainable transportation planning on the life quality, there are other factors which are affecting the acceptability of the sustainable transportation policies:

- The sustainable transportation system will be accepted at high levels if the citizens be ware from the present and future problems and also the possible solutions for them.
- It is important that the car users be ware from the role and responsibility of themselves for the society. The self-amenability can prepare the conditions for making a public common decision.
- Social tendencies and norms are very important in accepting the transportation policies and plans. With the more positive though about the cars, the chance of success of cars in comparison to the other travelling alternatives will be more. This is related to the feeling of better life and higher quality of life when using cars.
- Providing the alternatives is very important. Limiting transportation plans and policies, when there is no proper alternative for the cars, will be resisted. The acceptability and suit of the other alternative not only means the access to them, but also it means the quality and service level of them in comparison to the other available alternatives.
- The sustainable transportation plans will be successful only if they can solve the urban problems. Most people believe that these plans cannot be successful due to the centrality of the cars. The citizens use from their cars because they have no other alternative and they should. Therefore, until there is no proper alternative for cars, the plans cannot be successful.

Assessment and Decision Making for Sustainable Transport¹⁷, defined the sustainable transportation as a system which is available, safe, environmental-friendly and affordable (ECMT¹⁸, 2014).

Also in different resources and literature, various objectives have been suggested related to the sustainable transportation, which can be summarized as follow:

- The variety in the transportation system: Choice between different methods, locations and prices for transportation, specially the safe, effective, affordable, healthy and not driver-dependent alternative.
- Incorporation and Integration of the system: Different factors of transportation system such as walking, cycling, and using from the public transportation, will enable the incorporation and integration of the transportation planning and earth application in order to achieve an integrated transportation system.
- Affordability: The transportation systems provide the affordable alternatives which the lower income families spend less than 20 % of their income and budget in order to access to the goods, services and their main activities.
- Efficiency of the Resources (Energy and Earth): Transportation planning will improve the efficiency of Energy and Earth. Using less from the ending resources and substituting

¹⁷ Assessment and Decision Making for Sustainable Transport- www.oecd.org

¹⁸ European Conference of Ministers of Transport (ECMT)

them with renewable resources, leads to more decrease of use from the fossil fuels and consequently the environmental pollutions resulted from the provided strategies in this field.

- Pricing along with the priorities of the Efficient Systems: Roads, Parking lots, Insurance, Fuel in order to improve the performance, will be priced and the better travelling facilities will be managed by the more efficient methods.
- Access to Earth Applications (Intelligent Application): The transportation policies support from the compact and incorporative development in order to improve the access to the transportation alternatives and applications.
- Efficiency in Implementation: Transportation agencies and service providers will be managed efficiently in order to minimize the costs and maximize the efficiency of the service quality.
- Integrated and Comprehensive Planning: Transportation planning should be comprehensive (with regard to the objectives, effects and main alternatives), integrated (incorporation between different sectors, power territories and various departments) and pervasive (All of the peoples affected by the plans can be involved in them).

About these issues one can mention to the Comprehensive Report View to the Sustainable Transportation in 2035, which has the following objectives in achieving to a sustainable transportation (CST¹⁹, 2005):

- Emphasis and Focus on the Access and Availability: In a society with a sustainable transportation, the daily access of people to the goods, services and social opportunities is high. Specially the people who have high social levels or the people who suffer from physical-motor disabilities.
- Non-motorized Transportation: Most of the accesses are depended to the extensive use from the non-motorized vehicles, in order to transport the people in different regions of the City. Walking, Bicycling, Roller Skating and other non-motorized methods are accepted and desired.
- Motorized Transportation by the common vehicles: Some of the accesses are done by many different and modern technologies in public scale, and these methods are used daily, including use from renewable resources as fuels such as hydrogen fuels or solar energy, intelligent transportation system and automatic highways, railroad services and other technologies.
- Good Transferring: Goods transferring are done by the proper methods according to their distances from the destination. Cargo ships and other carriers provide the proper field in order to achieve to the economic objectives.

¹⁹ Center for Sustainable Transportation (CST)

- Less need to transferring the people and goods: In average, the travels which are done in order to transfer the goods and people by the motorized vehicles will decrease. Because the cities are more compact and a proper and desirable combination of the applications has been created. More access will be achieved by connecting to far distances and less transportation of people.
- Less effects or removing the negative effects on the environment and human health: The results of the sustainable transportation in comparison to the regional and global scales, is less. For example, currently emission of the greenhouse gases such Carbon Dioxide resulted from the transportation result, is one fifth of similar amount of these gases in 1990.

2. Effective Factors in Developing Urban Transportation

Business and industry has developed besides increasing development of towns in developing countries and this has attracted the rural immigrants who seek employment and more income. According to available estimations, in developing countries, minimum 50% of GNP belongs to cities and in most cases, it reaches to 70%. It demonstrates that the cities have had effective efficiency and their resources are vital in maximizing urban participation in national income.

Public transit may claim having an effective role in urban efficiency when it transfers the passengers and cargo with the least investment and operating costs. Industry and business are depended, to the most extent, to easy access to different parts of a city. Economic development is based on continuing growth of specialization in factories, working places and offices and such progress requires more transfer of passenger and cargo. Residents of cities must be attached to working places and producers and service providers shall have access to the market. Moreover, an appropriate urban transportation system will enable the cities to be organized for political, social, cultural and economic developments.

On the contrary, inefficient and incapable transportation system decelerates economic development. Cities in the Third World suffer from crowded traffic in spite of their low motor vehicles numbers in comparison to their counterparts in industrialized countries. Most studies on transportation issues are conducted under national and political pressures rather than accurate economic and rational considerations. In most countries, instead of correcting available urban roads and streets and operating public transport bus services, great investments go to expensive and politically attractive projects such as monorails. Since construction costs for metro amounts to one hundred million dollars per kilometer, therefore, miles of good streets may be constructed in exchange of some meters of metro.

Transportation development model depends mostly on the location and situation of the city. However, there are some basic factors that are related to demand level. Population increase

due to natural high birthrate, immigration to cities from villages and town, geographical decentralization, increase of family revenue and developing industrial and business activities are among the said basic factors.

The Effect of Transportation Network on Urban Development

Generally speaking, public transport is viewed as one of the most important factors in urban development. New transportation networks are always considered as potential for development. Metro is a new public transport system for Tehran and, undoubtedly, it affects the population immigration and potential for development in the near future. It is very important to know how it affects urban development.

Accessibility is another important factor in development. Public transit provides the city with a new accessibility model that affects urban structure and developmental potential, unbalances available norms and forms new balances.

Sustainable Urban Transit

Studying the history of urban development and urbanism development together with conducting research on development of transportation technology makes it clear that urban development goes in line with transport technology development. Here, there exists a clear and specific relation between public transportation and urban development as well as emergence of super cities or mega-cities. Such relation is so interwoven that the most obvious and common specification of super cities is transportation and problems led by traffic and inefficient transportation. This has caused tons of other problems such as accidents, respiratory pollutions, audio pollutions, mental diseases, cardiovascular diseases and so on that have stood straight against urban management and wastes their energy and power.

Every citizen, in a given city, has 1.5 to 2 travels by motor vehicles, in addition to his on-foot travels, by bus, cab or private cabs. Although it is only 5% (2.1 hours per day) of the total time of a citizen for exchange between origin and destination; its cultural, mental, social, economic and even political consequences of such coefficient overshadows the remaining 95%. The consequences are so broad that threatens the physical, mental, cultural and economic health of the individual and society and its side effects are obvious in finding the roots of dilemmas.

Shortages are the first and the main causes of public transit that hits the minds of citizens. Lack of motor vehicle, pavement, cab, parking lot and so on are among the said shortages that, if solve, it is as if everything would be in place. If one goes deep through the problem, it becomes clear that incompliance with rules and regulations, weak public education, inappropriate use of available facilities, unfair allocation of resources, poor looking toward future, inefficient existing technology and lack of coordination between decision makers and executive authorities, are the roots of the said problems.

Qualitative and Quantitative Development of Inter-city Transport

Traditional management of public transportation has led to inappropriate use of available capacities. Low economic and technical efficiency, energy consumption, wasting almost one third of total energy during consumption and increasing environmental problems necessitates employing energy consumption management, promoting energy outcome and profitability. Such management becomes valid and effective when supported by legal rules and regulations.

Therefore, adopting energy efficiency management law, which assures general circulars and specifies the scope of duties, is an inevitable issue for different economic sections including public transportation, in order to reach the objectives of energy efficiency promotion. Transportation is prerequisite for economic development. Increasing demand for transportation changed the attitudes toward its systems and transfer of passenger and cargo was paid attention to.

The projects aimed at finding ways to have better use of special lines, specific lines and priority in intersections. The practical outcome of the project is the same chance for passengers of public transit and passengers of private vehicles. On the other hand, conducted research in Iran and other countries show that pollution of motor vehicles is not related merely to lifespan. Repair, maintenance and using appropriate spare parts are effective factors in correct fuel consumption.

Evolution of Transportation in Megacities

A glance on the results of urban transportation planning, performed within recent five years, clearly proves that attitudes toward public transit in megacities have greatly changed.

It was assumed that only users of urban public transit should be paid attention to. Then, the question changed toward those who were not using the urban public transit. Should these users be handled like those who take advantage of the system? Does urban public transit consider factors such as time, cost and safety of travels?

Are there any other factors such as regional air pollution, national economy and shortage of energy worldwide? It seemed that only highway engineers were able to plan for urban highways but after a while, some groups together with local planning team, mayor of the city and other decision makers plus State High Council of Planning helped the said engineers in planning and executing highway projects. This shows that transportation issue is in continuing change in view of megacity attitudes. Such transforming phenomena may not succeed without a broad attitude toward urban transportation²⁰.

²⁰ Shahidi, 1992:78

History of Studies on Transportation and Traffic in Tehran

Increasing urban development in developing countries has caused lots of problems in urban management. Cities with growing and rapid development face problems such as concentration, air pollution, unsuitable situation of residential complexes, and many other issues. Some short-term solutions worsen the situation because they are not based on principles and logics and that they are not in coordination with macro policies.

Undoubtedly, these problems can't be solved automatically and for finding solutions, we should investigate them deeply. After basic change and revolution that were done between 1906 to end of the first war (1920), in Iran, government attention to the urban different rules and principles are done like establishing city halls, developing passage ways divided country and correct the role of passage ways developing. after correcting of city halls rules , ratification of urban developing council and Iran architects and providing urban's complete and general designs (1966 onward) , field of this inventions consist all countries cities²¹.

After Islamic revolution, beside of urban general plans, special studies are done about transportation a traffic after years of Islamic revolution in some large cities of country last studies of Tehran traffic consist of different plans, like general plane studies from Japan (1970), engineer studies of technical cooperation agency from France so for to (1973), the studies of America Harvard from England (1977) and so on. Studies weren't enough for dynamic decisions for Tehran transportation and traffic.

Tehran city, needs studies to great planning about transportation few public transportation system of Tehran city: increasing of individual vehicles on facilities unsuitable transportation in big cities especially in Tehran, cause many problems for citizens. Clear example of these unsuitable development area, long, consuming time and investment using a lot and consuming the fuel, vehicles early depreciation and environments pollution. Difficulty of using individual carrying cars, in transportation system, cause many problem in the big cities of country, especially in Tehran organization this set and didn't attention to ways of replacement of passengers. Not only increase disorganized intra city transportation, also make many social problems. (Mohammad Zadeh)

Non Massive Public Transportation System of Tehran

Increasing growth of cars on the insufficient facilities of transportation in metropolises or cities especially in Tehran has brought many problems for the citizens. Longtime traffics, time and capital waste, high energy consumption, premature amortization of the vehicles and environmental pollutants are of the main examples and results of this unstable development.

²¹ mohammad zadeh,2004

The problem in using personal car taxis in transportation fleet of city travels in Tehran is the problem which has been emerged during the recent years, even in cities except Tehran.

Lack of regulations and organization for this field and insufficient attention to it which transmits lots of passengers in the cities, not only has increased disorder and irregularity within the city, but also has led to lots of social results.

3. Tehran Pollution and its Influences on Health

Tehran air pollution

Air pollution derived from fossil fuels of the automotive in Iran, especially in metropolises or big cities like Tehran is under critic and dangerous conditions. Air pollution in Tehran has reached to a high amount in many cases which resulted in a dangerous status reported by environment official and healthcare managers and they warn seriously for not going out from home.

Transportation section has had the highest demand for energy consumption which has led to many difficulties either for industrial or for developing countries in terms of economic and air pollution. Each year a great deal of the country budget which should be assigned to infrastructures (economic and industrial), is allocated to import petrol and pay the related subsidiaries.

Ratio of available cars in Tehran the advanced countries car number is low but it is higher than that of Iran. Therefore, the main problem of Tehran is not just the great number of the cars but is the low level standards of the cars and also low capacity of city facilities to adopt more cars.

In brief, the reasons of air pollution in Tehran can be discussed as follows:

- 1 – Climatic and geographic conditions of the city which is surrounded by mountains in the north and east and also mild winding most of the times during a year and low snowfall and rainfall in a year.
- 2 – Lack and shortage system of public transportation.
- 3 – Outdated technology of public transportation vehicles and long lifetime of city transit system.
- 4 – Low price of subsidiaries petrol.
- 5 – Low quality of fuels (diesel fuels with high level of sulphur).
- 6 – Overuse of personal cars making traffic and heavy traffic for lack of respect to the traffic rules and blockage of routes and roads or highways.
- 7 – Lack of efficient urban plans.
- 8 – Economic problems and social matters such as immigration, lack of public knowledge about environmental problems.

Regarding the city topology and wind direction, it is apparent that the possibility to discharge the pollution of Tehran especially in days with slower winds is very difficult and the air is stable, so this problem will be very difficult to overcome.

Harmful influences of air pollution on human health have been the main reason to the attempts to decrease air pollution. Increasing of pollutants resulted in a great number of cardio-respiratory diseases and patients and deaths. Here, dangerous pollutants for human health and their harmful influences are studied in brief. Of the dangerous matters which are known as pollutants, WHO has introduced 6 main pollutants which are as follow:

Nitrogen Dioxide (NO₂), Sulfur Dioxide (SO₂), Carbon Monoxide (CO), Lead (PB), Ozone (O₃) and pollutant particulates which are very harmful for human health. Carbon dioxide should also be added to the list of pollutants as the indicator of greenhouse gases and also volatile organic compound is the other matter of the list.

These 6 pollutants are originated from different resources and their effects are also different on human health. Three groups of humans are more subjected to the pollutants: children who are their circulation and respiratory systems are growing yet and are very vulnerable, elderly people and those with cardio respiratory disease history, like Asthma.

For instance, during the recent years, elementary and secondary schools were closed for a few days for many times and the whole city organizations were also forced closure in emergency cases. Urban pollutions extend to 100 km, influence it and increase accidents. By decreasing temperature the air pollution increases and in the summer it forms smog on the ground surface which is a type of pollution.

65% of air pollution of Tehran is resulted from the cars. Toxic gas ozone is produced from the hot weather, intense sun radiation and dryness and forms smog with NO₂ from the cars exhausts.

Smog formation is very dangerous. Studies show that these conditions occur in some hot days of the year in Tehran and causes difficulties of respiration and respiratory system failures in the citizens.

Two Important Indicators of Pollution

- Carbon Dioxides

Carbon Dioxide is one of the main pollutants. A colorless odorless gas which is most formed by carbon materials combustion. Average stop of this gas in the air is between one to five years. That's why its concentration is used to estimate dissipation of other pollutant gases. The main resource of this gas production is motor vehicles and also insufficient combustion of their fuels.

- Nitrogen Compounds

Nitrogen oxides are of the air pollutants which are evolved in different forms like NO_2 , NO and NO_3 . Nitrogen dioxide is the most important compound among them, an invisible gas which is known by a yellowish brown or reddish brown color.

Other nitrogen oxides like N_2O , N_2O_3 , N_2O_4 and N_2O_5 are generated in low amounts. Because of existence of nitrogen in fuel or high temperature in combustion chamber of the cars and accessibility to free O_2 , they are more produced. Nitrogen oxides which are generated during the combustion process are known as thermal NO_x .

The discussed pollutants are all considered as initial pollutants. Initial pollutants are affected by environmental factors like sun radiation, moisture, particles and etcetera, and converted into secondary pollutants which have a more destroying and harmful effect than the initial ones.

As a whole, it can be concluded that only through the traffic and motor vehicles, about 40 pollutants enter the air in Tehran. The major concern about nitrogen dioxide is originated from where the compound is converted into particulates of nitrate, through complicated processes; also, nitrogen dioxide is one of the main pollutants to form smog just like nitrogen oxide. About all the nitrogen oxide resources are originated from human, two of which are cars and fossil power plants.

Noise (Acoustic Pollution)

Population growth, increasing the number of motor vehicles, development of industries and as a whole extensive life with a growing technology and human communities produce noise by creating bad voices or screams, the influences of which are harmful and threat the health and welfare of beings especially humans.

Problem of population growth especially in big cities and developing cities is challenging and struggling with more difficulties every day. Because of over population growth and unplanned immigrations, different big and small problems are being encountered in big cities of which noise or acoustic pollution is a big problem. Most of developing countries try to fast industrial develop to improve economic and social conditions. However, this development will cause better quality and lifestyle for the citizens, but uncontrolled conditions will make environmental pollutions like noise.

Consistent increase of traffic noise in the highways will cause more problems indirectly or directly influence on routine life and also great number of the cars and their high speed has made many problems around the highway areas. By using information and basic data about the people exposed to noise, noise pollution conditions can be predicted and its influences can be assessed. The standards on which management and encounter to the noise and acoustic pollutions is determined, are variable in different countries. Unfortunately, our country has

acted very poorly in this field and in some cases; it has no standard technology in many fields such as urban and regional plans to overcome these problems.

According to standards of WHO, acoustic pollution is 55 and 45 db at day and night, respectively, but this value extends to 75 db and over in Tehran highways or urban areas which is 20 db more than its international standards. Also, unlike most of the countries, its night noise is not less than that of day, while in most countries; the difference of pollution reaches to 10 db for day and night. The noise intensity is also one of the most significant parameters to determine and measure the pollution. To exposure to a noise with 85 db which is heard in a heavy traffic can hurt the human ear seriously.

4. Necessity to Decrease Tehran Air Pollution by Alternating Fuels in a Part of its Public Transportation

Developed countries are faced with severe problems of pollution and spend lots of expenses to control it. Recent climatic observations have also shown a significant increase in carbon dioxide concentration and also other greenhouse gases with its threatening results for the earth climate.

Japan spends about two percent of its GNI (Gross National Income) to fight pollution. Developing countries which have no serious problem on pollutions, can utilize technologies to fight pollution from advanced countries. Therefore, along with a trend to have clean air and less dependence to oil resources and fossil fuels, interest to use alternative fuels for public transportation has increased during the recent years. The produced electricity from the sun energy or any fuel with non-oil resource or has inherent energy content for the equipment, is considered as an alternative fuel.

Environmental pollution of big cities is one of the challenges of the world today. Advance of technology and increasingly using the natural resources have doubled this problem.

Overgrowth of population in Tehran and following that growth of cars and vehicles number and also economic development along with industrial development around the cities have encountered this city to environmental problems. Everyday more than 100 tons of carbon monoxide enters to the air. In Tehran, as a known example of metropolises for which Traffic is a big challenge, every day, about 8 million individual hours are wasted and per year 100000 billion Rials is spent for traffic.

Electric Power as an alternative fuel

Using electricity in different fields of the life has absorbed scientists' attentions for many years so that this immense power has been substituted for common fuels such as coal, oil and gas which has led to decrease the fossil fuels, on one hand, and air pollution in the cities, on the other hand. Therefore, using electricity power instead of gasoline and diesel in automotive is

one of the rational approaches to decrease air pollution in cities and also to reach economic effects and saving fossil fuels.

This issue has been adopted in many countries like Japan and electric trains (tramways) have been used to transport passengers in many cities. Today, application of electric power in public transportation is growing throughout the world and consumption of the electricity power reached to 255 twh in 2006.

A main part of electrical power contributed to transportation is assigned to the electric trains in cities (subway). Lack of air pollution, lower space occupation, significant decrease in fuel consumption and ability to apply update technologies in the world have resulted in fast growth of electric trains for cities so that 150 million travels is carried out by this transportation system per day throughout the world.

On the other side, electric car can be a good alternative for the present motor vehicles. Electric cars make no pollution and have little noise and their easy movement and transport is of their other advantages and also they have a higher capacity for energy conversion. Development of newer types of storage batteries with a higher capacity and fuel cells which apply hydrogen or light hydrocarbon fuels might substitute them for the internal combustion engines.

5. Bus as a part of public transportation system of Tehran Metropolis

Prediction of Tehran population

The whole population of Tehran has been 7,775,000 people in 2006. The rate of population growth in Tehran has been reported as the half of the whole country population rate and the country population rate is 1.7. By applying the reported population growth rate, Tehran population will be 8,462,000 in 2016. The results of the prediction is provided in table.1

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Population (million persons)	7,775	7,821	7,908	7,975	8,043	8,111	8,180	8,250	8,320	8,390	8,462

Table 1: prediction of Tehran population until 2016(Source: Journal of Iran Energy, 13th Course, 2010)

Bus- oriented transportation systems

Since long ago, transportation of lots of passengers in a workday by bus has presented it as a public transportation vehicle. Although bus has a lower capacity for passenger transportation than the other vehicles such as tramway and subway, lower service and infrastructural costs has made it be used extensively.

One of the most important challenges of urban officials on transportation by bus in the cities has been its traffic integration with other cars and pedestrians. This challenge along with attempts to improve the bus transportation capacity has created many bus-oriented systems which can lead to higher efficiency and their more effective role in public transportation.

Diesel bus ccontaminants	gr/km
CO	3.1
NOX	12.4

Table 2: Two important indices of air pollution by gas oil buses (Source: 39.Strategies to optimize energy consumption, assistance of energy affairs, Jan. 2002)

Prediction of the travelled distance of city travels in Tehran per day in Kilometer

According to the studies conducted in 2006, total travel in Tehran is 5,913,000,000 per year. Also, according to these studies, average travelled distance in each travel is 5 Km per individual in Tehran. Regarding to the two parameters, total travelled distance for all travels will be 29,565,000,000 individual Km in Tehran.

According to the following relation:

$$\text{Travelled distance by each individual} = \text{total travelled distance} / \text{total population}$$

The travelled distance by each individual in all travels during a year will be 3801 km. By dividing the value by 365, total travelled distance will be obtained 10.4 km for each individual per day. In this study, the associated parameter has been assumed constant during the prediction period.

Portion of electric bus in transportation system

Regarding to the obtained data from Tehran and Suburb United Bus Company, the portion of electric bus out of the total travelled distance in Tehran has been the values provided in table.2

for 2004- 2006. As it can be seen in the table, the portion of electric bus in public transportation has decreased 28% in 2005 and has increased 17% in 2006.

Average growth rate during the three year period has been 5.5% and it's been descending. According to this rate value, the portion of electric bus in public transportation is measurable for 2008-2016. The measured data are presented in table.3. It should be noted that it has been measured by the ratio of total travelled distance by individuals using electric bus to the total travelled distance.

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Portion of electric bus(percentage)	1.83	1.43	1.71	1.62	1.53	1.44	1.36	1.29	1.22	1.15	1.09	1.03	0.97

Table 3: portion of electric bus out of public transportation system until 2016 (Source: Journal of Iran Energy, 13th Course, 2010)

Prediction of electric energy demand of the electric buses in public transportation system of Tehran

Energy crisis is one of the issues which have absorbed more attentions in today communities. Development of city electric trains (subway) is one of the main solutions discussed to overcome the car fuel growth demand in city travels. This solution has been also discussed in our country since thirty years ago and has increasingly advanced now.

Of the other public transportation vehicles is the electric bus fleet which was however desirable for the environmental effects (especially in Tehran) but couldn't develop for the lack of proper infrastructures to make its new lines. With these two public transportations, the required demand in this section should be measured and considered in national planning like other sections.

History of application of electric bus refers to 1901 in France. Although these buses could be desirable first for their significant decreasing effects of air pollution (compared to the fossil fuels), following that, they encountered many problems. In each city around the world, the need to develop transportation system and other facilities of electric bus has increased depending on the architecture of the cities.

The electric bus system was established in Iran in 1992 but its development process paused for the lack of proper infrastructures to create construct transmit installations and therefore its action was constrained (now about 30 million travels is carried out by this public transportation

system per year in Tehran). In addition, the electrical energy consumption has been 7000 Mwh in 2006 in Tehran.

Although the establishment of subway in Tehran refers to 1975, the first subway line started to work in 1998 with a capacity of 300 thousand travels per year and has developed during the past 15 years so that at the present time, about one billion travels is done by subway in Tehran per year. The electricity energy consumption of Tehran subway has been 236 Gwh in 2006.

According to the data presented in Iran energy balance sheet in 2006, electricity energy consumption in Iran transportation section has been 11 million crude oil barrels which is a slight value compared with 91 million barrels for the total electric consumption of the country.

However, regarding to the long term aims in energy section and the decided policies in the national twenty year- scope program, it has been approved that the annual electrical energy consumption of the transportation section should reach to one million crude oil barrels in 2025.

Since no comprehensive studies have been conducted in other cities than Tehran, on other transportation parameters has been accounted so using technical and engineering approaches is not feasible to measure the electrical energy consumption in the public transportation section and only the prediction of utilizing companies of electric bus and subway sections can be a good strategy.

Electric bus energy intensity

According to the obtained data from Tehran Bus Company, the electrical energy intensity of each bus is 66 kWh per 100 km. This value has been presented constantly from 2004 to 2006 and is assumed constant during 2006-2016.

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Energy intensity electric bus KWh/100 km	66	66	66	66	66	66	66	66	66	66	66

Table 4: electric energy intensity of electric bus fleet until 2016 (Source: Journal of Iran Energy, 13th Course, 2010)

The demand increase of transportation is unavoidable following the social welfare and economic developments. In addition, provision of cost effective transportation services will result in many advantages in increasingly development of the countries. Therefore, decrease of fuel consumption in transportation section is necessary for continuity in inexpensive transportation price and energy consumption optimization.

Electric bus load index

The load index of each vehicle is the number of the passengers travelled per day. According to the data reported by Tehran and Suburb Bus Company, the load index of each bus in 2004-2006 has been in accordance with the values in table.5.

According to these data and the time series in 2004- 2005, the load index of each electric bus has decreased 3.8% per years. It should be noted that the value differences every three year, also shows this value. Regarding to the growth rate of 3.8% per year in a descending order, the electric bus load index will be obtained according to table.4 in 2008- 2016.

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Load factor Of the vehicle	49,2	47,4	45,7	42,3	40,7	39,1	37,7	36,2	34,8	33,5	32,2	31

Table 5: electric bus load index until 2016 (Source: Journal of Iran Energy, 13th Course, 2010)

Measurement of total electric energy consumption of the electric buses available in Tehran public transportation section

By inputting other variables which were discussed in the previous sections and also some technical measurements to obtain interface parameters and finally extraction of the total electric energy required for the electric buses available in Tehran transportation section is obtained according to table. 6:

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
The total power consumption by electric bus (GWH)	7	7.9	7	7	7	7	7	7	6.1	7	6.1

Table 6: electrical energy required for electrical buses available in Tehran until 2016 (Source: Journal of Iran Energy, 13th Course, 2010)

Prediction of electronic energy required for transportation system in Tehran regarding to the obtained data is a good tool while electronic bus fleet has not developed properly for the lack of sufficient infrastructures and if other developments of electronic bus in Tehran will be conducted on time according to the 20-year development scope plan, the amount of consumed electricity energy will be more than that predicted in the scope plan until 2016, accordingly, the consumption electrical power of this section should be increased to coincide with the amount of the scope goals (Journal of Iran Energy, 2010)

6. Comprehensive System of Bus Rapid Transit (BRT)

BRT or Bus Rapid Transit is a rapid transportation flexible system with rubber wheels which includes safety stations, special lines, high capacity buses and intelligent transit systems which is provided in a whole and harmonic system in a united, complex and lines with ability to transmit lots of passengers safely and quickly.

In the other words, BRT is a bus system with rail systems as along with bus-orientation of the system, it transmits many passengers. As it is shown in figure 1, comparison between massive transportation systems based on number of transmitted passengers to the investment costs, shows that BRT transmits more passengers with lower costs.

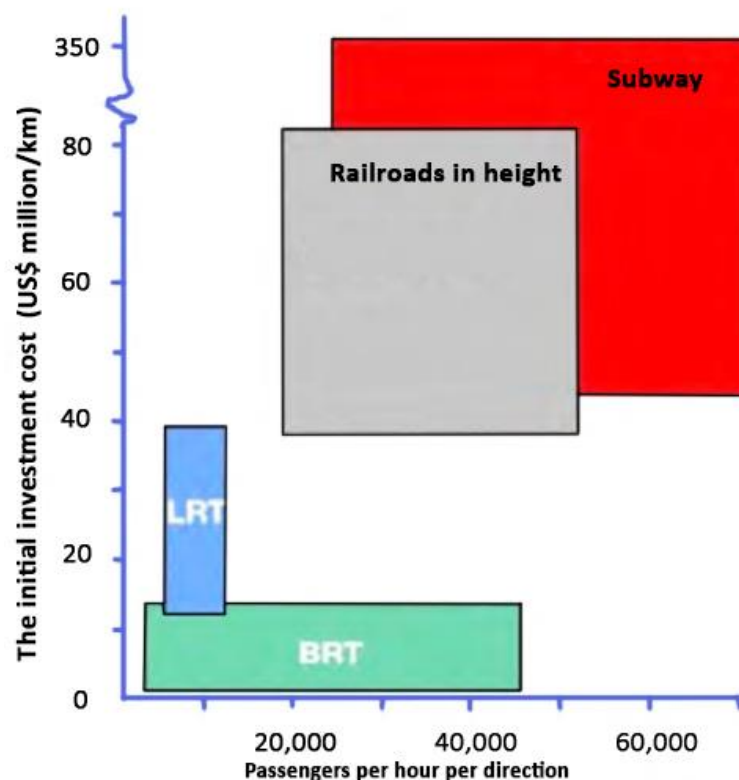


Figure 1: comparison between massive transportation systems based on number of transmitted passengers (Amirkabir6:2007)

Although this system has been introduced from 1990 formally, it is popular in more than 100 cities in the world because of its high efficiency and is being performed or utilized. BRT emerges as an important option, with low infrastructural costs and ability to be managed without need to macro financial supports and possibility to utilize it in short time (1 to 3 years after the start) is of the advantages of this system.

Flexible nature and scale ability of it shows that this system is in compliance with different cities conditions. Required infrastructures to perform comprehensive BRT system includes stations and intelligent control system in addition to one or more streets or highways which are assigned for the buses, these lines are sometimes used for emergency cars and ambulances.

The unique advantages of the system includes special lines of the bus which is completely separated, fast getting on and off of passengers, efficient method to pay movement tolls of passengers easy and comfortable stations, unity with different transportation methods, non-pollutant bus technology and excellent ability to compete.

Advantages of BRT Bus

A type of street transportation equipped with modern ITS technologies which includes precise and speed on Rail transit system and flexibility of Bus Transmit spontaneously.

BRT system has many benefits for citizens and urban management such as:

- Shorter time of waiting in the stations which increases satisfaction of the passengers.
- Receiving tickets before entering to this station an elimination of direct contact between the passengers and the driver.
- Safety and security of the passengers within the bus stations.
- Feasibility for disabled people.
- Proper schedules to use better from bus transportation system.
- Assignment of intelligent buses to the paths which decrease the crowded passengers in the stations and increase efficiency of buses.
- Lower costs of BRT preparation than Rail Road Systems.
- Presence of a control centre unit which increases the efficiency of the system.

Possibility to use structures and equipment available in the system is provided by the following factors:

- Special line,
- Priority pass for the traffic lights,
- Special design of the bus,
- Special design of the station and more required space,
- Intelligent ticket payment.

Architecture of a BRT System includes the Following Properties:

- Special and assistant lines.
- High capacity stations.
- SUV Buses.
- Pre-Ticketing System.
- Articulated or two articulating buses with 150 to 300 passengers.
- Stations with 500 to 1000 meter long distance.
- Having priority to pass in intersections.
- Information and control systems.

In Tehran, in spite of all attempts provided to overcome traffic problems regarding to current conditions and also equipment, policies and different applied methods, one of the ways to decrease the current problems, is to construct BRT system which includes many favors and benefits regarding to the high speed of the buses and also high capacity of passengers transmit.

BRT Lines in Tehran

Tehran with 8 million people resident and daily 15 million people is the most important metropolis in Iran. This city is the center of economic, politic and social activities of Iran and the city development and also modern policies of the government to free the fuel prices have made great number of city travels. One of the most significant weak points of transportation system of passengers by bus is the low speed traffic and lower efficiency of the system.

Factors like lack of easy accessibility, over population of passengers in stations and buses, lack of proper information about routing, disorder in time of buses movement, lack of a good and appropriate scheduled time to stop the buses in the stations, long time of waiting in stations, long time of travels because of low speed, unfavorable conditions of the buses and some other problems have made dissatisfaction of the passengers from the public transportation system and active bus lines.



Bus rapid transit system, is the beginning of changing of view and making big revolution in urban traffic and transportation management structure and it is a symbol of using technology for solving problems of metropolis like Tehran. Also, this project is great option, for coordinate management intra organization among Tehran city hall and organizations and active offices in urban management area.

Establishing bus rapid system is one of the factors of Tehran developing bus service company use this system for increasing passengers to system, decreasing air pollution and vocal pollution of traffic density from 2006. According to studies, 10 main corridors of city are chosen for making rapid bus system and 6 lines are established until now and can attract a lot of passengers establishing three 6 lines can the traffic capacity of corridors are decreased by suitable optimization of urban bus system and increasing intra city travels.

Decreasing of corridors traffic capacity, cause that pollutions of corridors decrease too and it is the main goals of bus rapid transit lines is developing of bus special lines and low price and effective solution for Tehran traffic situation. Now, there is 164 KM bus special line in Tehran. But for safe and easy plying of public vehicles in Tehran, we need to 200KM special line.

The putting into operation of these 6 lines of BRT by 1100 bus and omitted 1735 worn-out bus by 10 years life during 2008 to 6 first month of 2011 year and using 3547 gas burner bus are another step for decreasing of air pollution of Tehran.

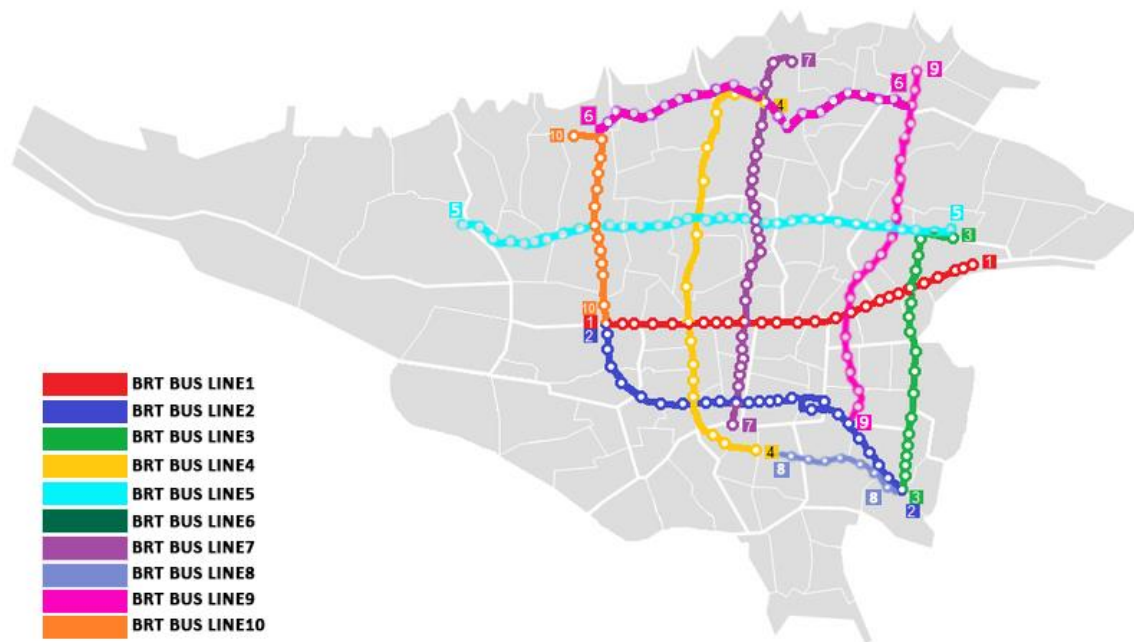


Figure 2: Plan of BRT bus lines in Tehran (Source: Author)

Line	STATUS	Start point	End point	Stations	Distance (KM)
1	ok	Azadi Terminal	Tehran-Pars	26	18.7
2	ok	Azadi Terminal	Khavaran Terminal	26	18.7
3	ok	Elm-O-Sanat Terminal	Khavaran Terminal	18	14.3
4	Under construction	Parkway	South Terminal	21	21.5
5	Under study	Elm-O-Sanat Terminal	Dehkadeh Olympic	16	22
6	Under construction	Babayee Highway	Ponak		19
7	Under construction	Railway station	Tajrish	27	17.5
8	Under study	Besat Highway	Basij		6.2
9	Under study	Besat Highway	Babayee Highway		17
10	Under construction	Ponak	Azadi Terminal		6

Table 7: Tehran BRT lines (Source: World Academy of Science, Engineering and Technology Vol:5 2011-11-22, P. Parvizi, S. Mohammadi)

7. Electronic-Solar Systems (Photovoltaic), a Clean Energy Resource

Today, by increasing growth of population of the world, limitation of energy resources and harmful environmental effects from overuse of fossil fuels, world attention has been absorbed to use renewable kinds of energy.

In this parts, in addition to introduce photovoltaic systems as a new energy system, different kinds of photovoltaic cells and its applications, advantages and disadvantages of this systems and optimum conditions to install these cells are studied.

According to the obtained results always a high power to attain this rich resource of energy has been encountered to different problems. All the technologies to produce solar electricity are of the developing technologies. Nonetheless, at the present time electricity production from this source has been considered more and more in many countries so that photovoltaic system capacities have increased in 2010 in more than 100 countries of the world and has brought the fastest growth in the world among energy production technologies for the photovoltaic systems.

Photovoltaic systems are of the best ways to generate energy from the sun. The material used in photovoltaic systems is silicon. When the silicon panels are exposed to the sun light, a direct DC current is generated in them. Photovoltaic panels react to the direct and dispersed radiations but the output electrical energy increases with the high radiation of sun light.

The new photovoltaic capacity installed during 2010 was about 17000 MW (in comparison to 7000 MW in 2009) which has reached the world capacity to 40000 MW. Therefore, increasingly attention to investment has also increased ascending procedure of solar technology developments and following that descending procedures of the costs.

Since electrical energy is one of the powerful bases of economic power and welfare indicator of the citizen, during the last decades, increase of electrical energy and its added value have been considered more. Also, new energies play their main and important role regarding the limitations and current problems in using fossil fuels and researcher's interests have been absorbed in utilizing clean resources and a world jump has started to use these resources.

Of the most important reasons to use new energies is easy access and low costs of electric energy generation, among which photovoltaic systems of new energies (PV) has the mentioned advantages because of no need to interface processes to convert energy obtained from solar radiations and their installation and start up.

Regarding to this fact that in most applications, photovoltaic modulus is used as a dispersed resource and other techniques are used to apply solar energy in massive generation, the importance of the study of this system will double electrical energy generation.

In addition, regarding the extensive area of Iran and power waste in national general network which are far away from international standards, most part of energy from power plants is wasted and gapped in distribution and transmit system and as a result, by using small power plants which are connected to the distribution system network, effective steps and initiations can be conducted in the field of network safety and decrease energy waste and also increase of electricity power, as well.

Electricity Generation in Solar Cells

Photovoltaic cells are considered as the direct producers of DC current by solar radiation. Once photons impact the solar cells, they will hit the free electrons in silicon crystals and drive them to the out orbit (battery and inverter) and on the other hand, they enter the cell to repeat the process.

Output voltage from a crystal is about 0.5 V which is proportional directly to the cell surface area and about 7 amperes per each cell with 6 inch² surface area which is composed of a new crystal (multi layers). For example, 30 – 36 cells are connected in series in each solar module which will generate 17 volt power in a maximum power (with a nominal output of 12 V). By connection of modules in series or parallels a solar array will be formed.

Solar cells work in all points and areas and better work in some point, solar radiation is a parameter to measure solar power on the ground surface and the maximum output is about 1000 w/m². With a typical efficiency about 14 to 20% for the solar cells, it can be expected that about 140 to 200 watt/m² of the cells will be generated in a complete sun light.

A base to measure accessible energy of the sun can be stated in hours if full sun radiation (for example, four hours a day for 1000 watt/m²). Some parts receive more light on the Earth. Therefore, the map of areas of sun radiation is a general idea of the transmitted energy in each area in maximum radiation times.

Different components are available to complete a solar energy system but four cases of solar modules, charger controllers, battery and inverter are of the main components. Solar modules are installed on physical structures and the produced DC electricity enters the charger controller before storing in the battery.

Two main duties of the charger controller are to prevent extra charge in the battery and also elimination of invert current from the battery to the module at night time. Batteries save the energy produced by cells during the day to be used for each situation. Batteries are manufactured in different sizes and grades. An inverter converts the stored DC energy in the batteries into AC 120 or 220 current.

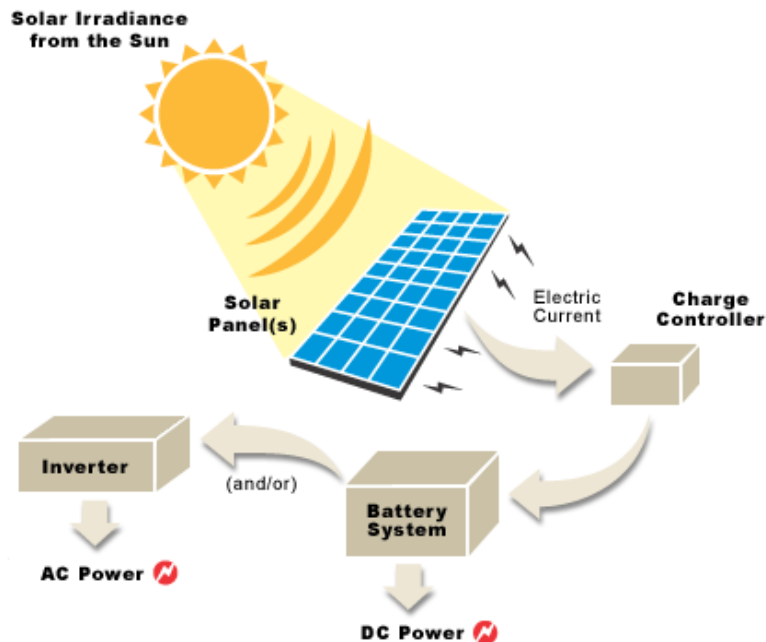


Figure 3: Electricity Generation in Solar Cells(Source: <http://www.earthlyissues.com/solar.htm>)

Solar Sites to Install Photovoltaic Panels

The sites should be in accordance with physical required standards, such as their direction which should be oriented to the south and they should be exposed to the light and have enough space to install photovoltaic panels.

Electricity generation by PV systems does not depend upon seasons, but they can produce electricity from early morning to sunset time. The production peak is at noon hours. Photovoltaic units can produce electric current even in cloudy weather, although their output decreases.

On a cloudy low light, a PV system may receive 5 to 10% of the sun light on normal days, and following that, its output will also decrease. Solar panels produce more electricity current in lower temperatures. These equipment work better when their cool like other electric instruments.

However, PV systems produce less energy in winter days than summer days, and the cause is not low temperature but is decrease of day hours and smaller angle of solar radiation. Solar panels are built so that they can resist against all environmental problems such as severe cold and polar cold, desert hot, equator moisture and winds more than 125 miles/hour.

Solar Energy in Iran

Iran with about 300 sunny days per year is of the best countries of the world to produce potential solar energy, which is more than 6 times of European countries. Also, annual solar

radiation in central areas of Iran is 77 h/day or 2800 h/year. Therefore, regarding this, the average solar radiation is about 5 kwh/days while the sequential cloudy days per year in our country are less than 5 days/year.

Regarding to the international standards, if the average solar radiation per day is more than 3.5 kWh per m² (3500 w/h), using solar energy inverters like solar collectors or PV systems are cost effect and economic. In most Iran areas are higher than the international average and even in some points more than 7 to 8 kwh/m² but the average solar energy on the ground is about 4.5 kwh/m² in Iran.

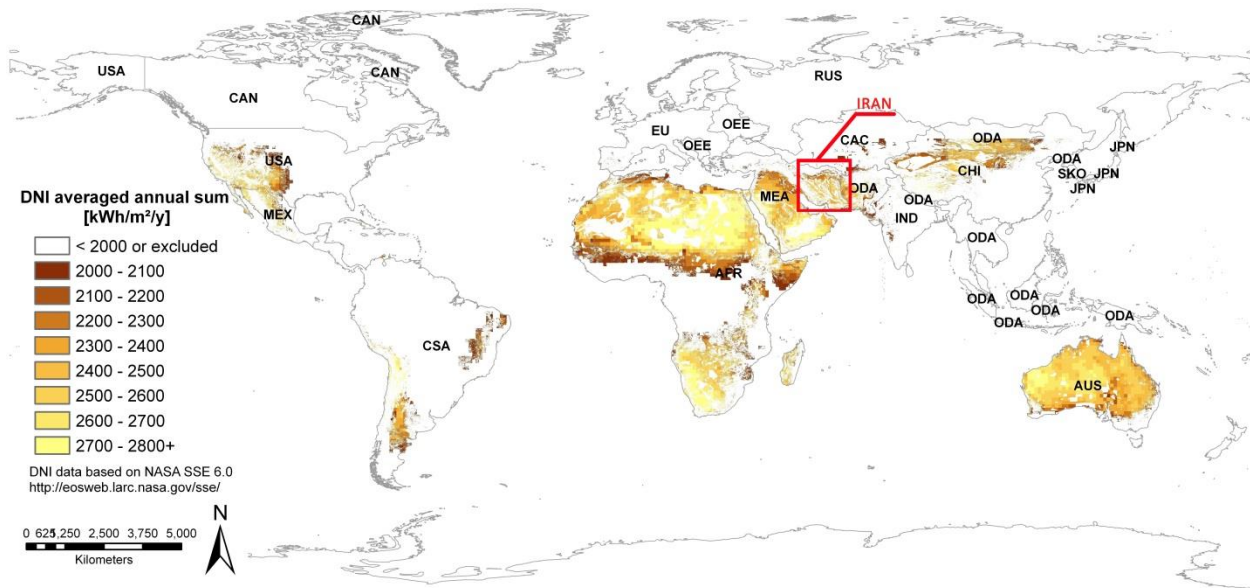


Figure 4: Resulting map of the annual sum of DNI (Direct Normal Irradiation) for potential global CSP (Concentrating Solar Power) sites. (Source: German Aerospace Center (DLR))

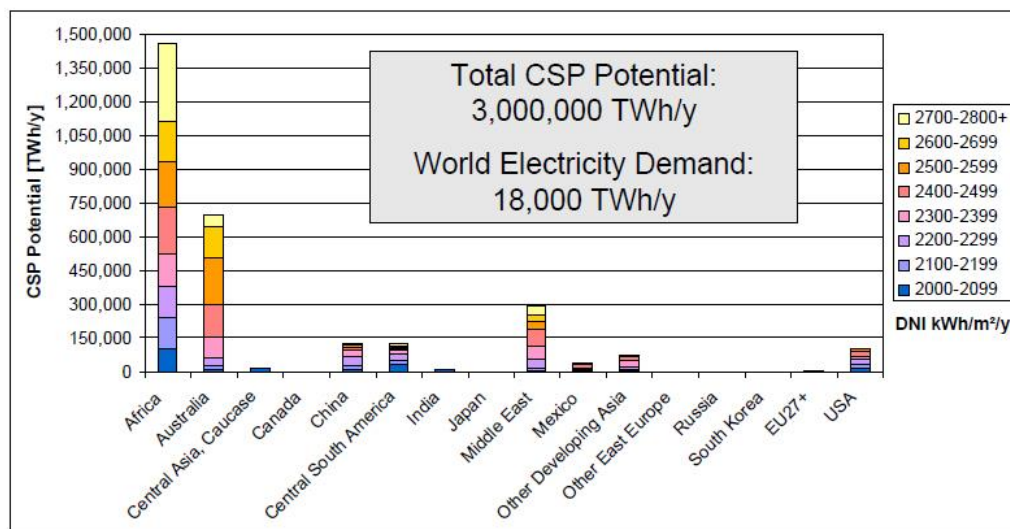


Figure 5: Global CSP Potentials by DNI Classes and Regions (Source: German Aerospace Center (DLR))

On the other hand, PV cells about 1 kw, occupy about 5 to 6 meters and will weigh about 7 to 10 kg/m² and their efficiency is about 20% which shows its power on direct sun light (1000 w/m²) is 200 w per m². Studies show that installation and using each one kW unit prevent about 1.8 tons of pollutants to the environment.

What should be noted in Iran is that it contains a huge potential to use free of charge solar energy with a wide area of desert and dry regions which are exposed to the direct and intense sun light and fossil fuel power plants should be substituted by solar power plants and even in long term by investing on this energy its advantages to the nuclear plants will be attained. Therefore, the human emits more than 30 billion tons of carbon (only from fossil fuel combustions) in to the atmosphere to meet his requirement to the energy.

It is predicted that if no action is conducted to decrease carbon dioxide emission from energy production, emission of this pollutant in 2050 will be two times more than today. It is apparent that using solar energy as a clean energy can avoid more environments destroys and increasingly emission of greenhouse gases and on the other hand can be a good and proper response for human beings worry for termination of fossil energy resources.

The current portion of solar energy in production and consumption energy of the country is about zero. The electric industry of the country produced 250 TWH electricity in 2012 of which 96% was produced in thermal power plants and the left was produced by water-electric power plants. Portion of small windy solar and water electric power plants and other renewable energies have been little and only 200 million kWh of the total generated electricity was from the renewable resources (less than 1/1000).

Estimations show that limited solar generators have been installed in the country while in Germany which its sun light radiation is half of that in Iran and its peak is in winter and the solar generators don't help the decrease of the load peak, more than 32000 MW of solar generators are installed.

8. Economic Explainable of Electric Energy Produce Using Solar Energy Compared with Fossil Fuels

Variable changes of prices in fuel market and increasing growth of fossil fuel prices in the recent years, CO₂ emission for the use of fossil fuels, environmental pollution for using fossil and nuclear fuels and the world pressure to absorb government attentions to the environment problems, have made the governments invest more on modern and new energies specially solar energy.

Advantages to Use this System

- Solar plants are modular and their capacities can be increased gradually by increasing the load.

- Time of construction of the solar plants in comparison to other technologies is short and this will decline investment risk.

Their fuels are free of charge and create no pollution. The following figure 2 shows the growth trend of different plant capacities in 1993 – 2003 in USA. Solar energy is in the second rank.

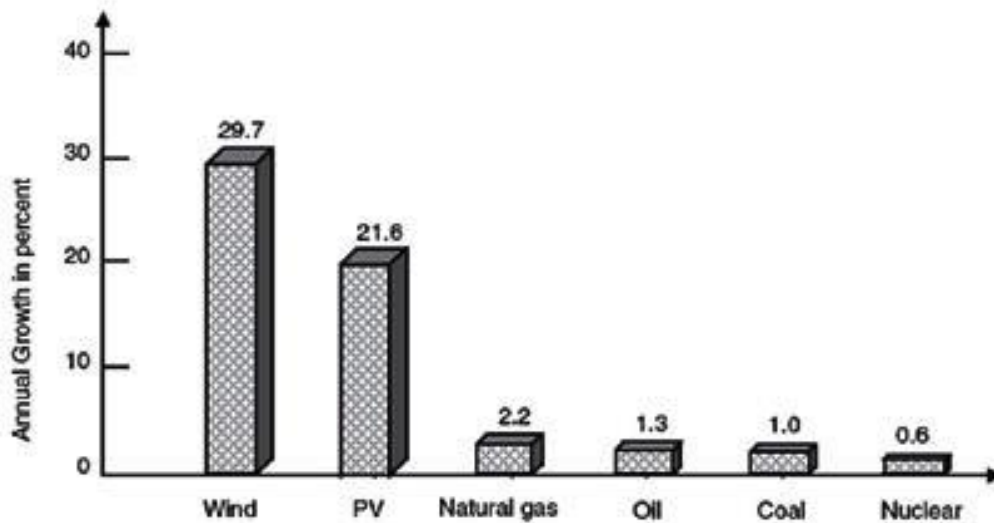


Figure 6: The growth trend of different plant capacities in 1993 – 2003 in USA (Source: Portal of Energy of Iran)

Investment increase to use solar energy and technology advances about solar cell construction has decrease solar modular prices according to the following figure 3.

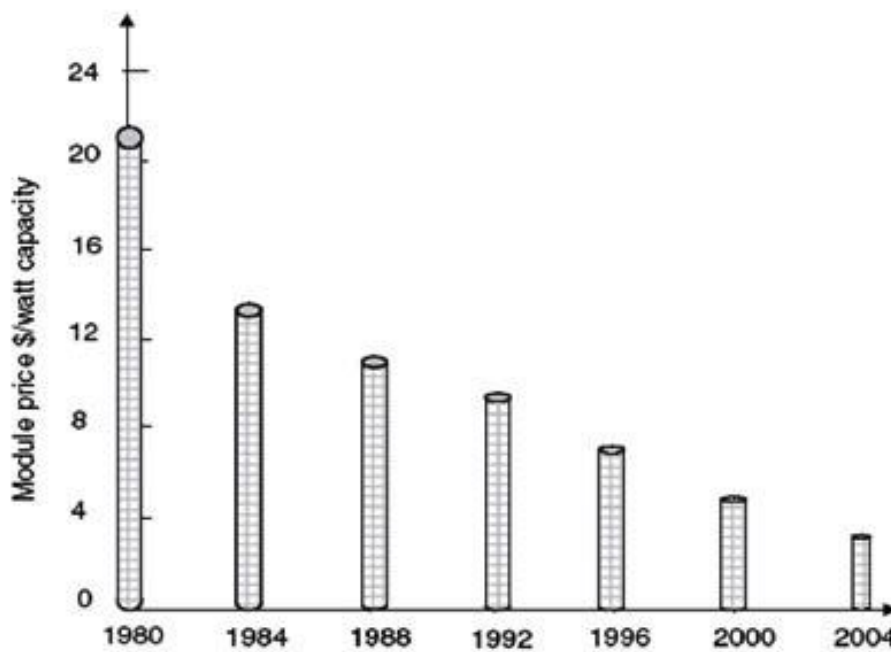


Figure 7: Increase of Investment to use solar energy and technology advances about Construction of solar cells (Source: Portal of Energy of Iran)

Regarding to this issue, the electricity cost produced by solar panels has decreased.

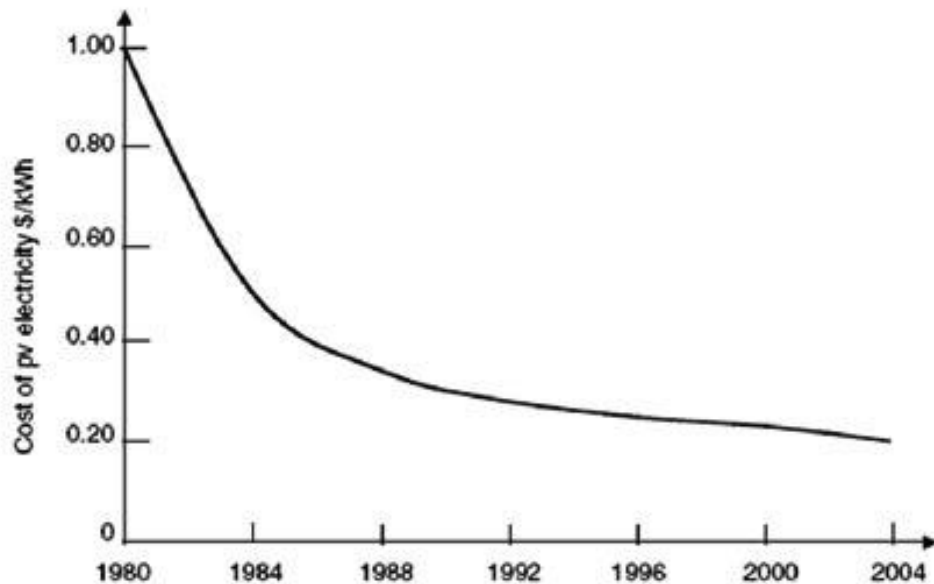


Figure 8: Cost of Produced Electricity by the Solar Panels (Source: Portal of Energy of Iran)

Therefore, solar energy can be used to produce electrical energy and thermal energy. At present time, 70% of the consumed energy is electrical energy and of the problems to produce electrical energy using solar energy is its production only in time of solar radiation, in addition to its high costs.

Because of the variable nature of solar radiation in different hours of a day, or seasons and different points of the world and also climatic variations and temperature influence on solar cell efficiency, there's need to store electrical energy to meet the requirements and demands of electrical energy. Technology and cost limit the storage amount of electrical energy so at the present time to supply the electrical energy of the systems independent of grid or networks hybrid systems. Systems are used basically, so solar arrangements are only a part of electrical energy system.

In general, it can be noted that in spite of the fact that solar energy is usable for all human being requirements, but now required technology to do this is not possible comprehensively and solar energy cannot supply all the requirements alone.

Solar energy just like other energies directly or indirectly can convert into other forms of energy, like thermal and electrical energy, but problems like efficiency weakpoint to convert into other energies because of lack of information and field experience, variation and alternate nature of energy amount because of climatic changes and seasons and radiation angle and limitation in distribution, have emerged in different countries of the world.

Two important issues in this field are its permanent resource and accessibility in about all parts of the world which is variable for its distance of the equator and its angle. Also, importance of pollution decrease which is today a big problem in industrial countries, solar energy prevalence with minimum negative effects can almost meet a good future for the environment.

Scientists studies in the past centuries showed that solar radiation on a semi-conductor surface from a special metrical and passing through it can create ability of electricity current, so that the more the surface area exposed to the sun light, the more electric energy produced.

The principle of solar cell performance is like that. Today it is observed that large industrial centers around the world redesign the solar cells in addition to produce it, to achieve more efficiency.

Economic Estimation and Explainable of Solar Energy in Iran

Solar generator installation in the place of consumption, unlike the public beliefs, is cheaper than concentrated power plant construction.

Studies show that according to the practical power of the concentrated plants in comparison to their nominal power, network gaps and readiness index of the plants in the peak season to respond 1000 MW load in the place of consumption, at least 1600 MW thermal concentrated plants along with distribution and transmit of its generate electricity should be constructed, while by installing 1000 MW solar generators (1 million of 1 kw generators) in the place of consumption, this requirement is met.

Comparison of respond costs to 1000 MW loads of day peak with two options of installation of solar generator and thermal power plant is summarized in the following table. As it can be seen in the table, cost and life time of 1000 MW of solar generator is 60000 Billion Rials.

But, the cost of installation, storage and maintenance of the required fuel to supply the produced electricity of 1000 MW is more than 68300 Billion Rials. In the other word, in the first year, the solar generator is more cost effective than the thermal power plant which is centralized and this belief should be avoided which the solar generator is very expensive.

		First year	Second year	Fourth year	Fifth year	Sixth year
Solar generators	Installation costs	6000	-	-	-	-
	Operating costs, maintenance and repairs	-	-	-	-	-
	Fuel Costs	-	-	-	-	-
	The total cost of the productive lifetime of solar generator	6000				
Combined cycle power plant and network	Installation costs (Power plant and network)	5600	-	-	-	-
	Operating costs, maintenance and repairs	380	380	380	380	380
	Gas, oil fuel costs (with an efficiency of 45% and transmission and distribution losses of 15%)	850	850	850	850	850
	Total costs of thermal power plant lifetime	6830	8060	9290	10520	11750

Table 8: Comparison of respond cost to 1000 MW day peak load in the place of consumption (Source: Portal of Energy of Iran)

One of the main important barriers to develop renewable energy resources is the subsidies of fossil fuels which removes the economic justification of these energies.

During the last decades gradual removing of subsidies and increase of fuel price and some of the government policies to encourage development of new energies more feasible and explainable. Entire implicit subsidies in transportation section have increased from 3.6 billion dollars in 1996 to 12.4 billion dollars in 2005.

Under the current conditions on which the international price of fuels has increased significantly, these subsidies reach to 100 billion dollars the main part from which is assigned to

the transportation system. More than 30% of the consumed energy in the country is assigned to the transportation section, so modulation of this amount of consumption is very important.

So, electrification of public transportation vehicles plays an important role in energy policies of the country and movement toward renewable energy consumption.

Regarding to the cost of electric energy accost in solar power plants of Iran of 19.4 cent/KM and the price fluctuation and also analysis of energy market in Iran during the recent years, economic explain ability and utilization of solar power plants have increased.

Incentive Policies of Government

Renewable energy history in Iran refers to 1975 with the initiation of ministry of power on project heat-ground. To do so, organization of renewable energies (SANA) was established under the supervision of ministry of power which is a stable organization.

This company has purchased 50 private companies to work in the field of renewable energies. According to the fourth 5 year economic development plan, portion of renewable energies of the total installed electric installations should reach to 1% until 2009. If the total capacity of the installed electric equipment reaches to about 50000 MW, the portion of renewable energies should reach to 50 MW as well.

Also, according to Article 19 of Budget Rule 2003, about 2-year saving of liquid fuel is paid for the solar generator installment. By consistency of this article in the following years and increase of payments for renewable energies to 3 years of saving of liquid fuels, 60% supply resources required for incentive payments of solar generators can be provided.

On the other hand, according to Art.69 of Budget Rule 2013, in this year, 30-Rial tax has been assigned and approved to each KWH of the consumed electric energy to develop renewable resources energy and the network. Consistency of these conditions and gradual increase of the tax to 100 Rials can provide the left 40% of the financial resources to pay the incentive payment to install solar generators.

The present project has created some necessities to the use of this golden situation in addition to explain the capacities of articles 19 and 69 of the budget law for renewable energy generators.

Although during the last decades, government approaches for application of renewable energies, in order to improve and develop these projects quickly, a market-oriented approach is required on which the fuel subsidy is stopped completely and its price increases. Meanwhile, according to the market-oriented approach, loans and financial aids are assigned to the projects of renewable energies with a preferential rate.

III. Estimation of Technical Potential to Use Solar Panels in Tehran Public Transportation System

Pointing out the experiences of other countries to apply solar power plants, BRT line of Tehran which is more than 60 KM can be covered by solar panels to generate electricity in the first step to decrease the pollutants from city buses fuels and decrease their noise and acoustic pollutions and a sustained environment and also to help public transportation system of Tehran.

One of the experiences of the case is the green train of Amsterdam-Paris which has recently started to work. On this path, the 3.6 KM tunnel which passes from Antrope in the north of Belgium, has been covered with 16000 solar panels which is 50000 Sq. M area (about 5 football grounds).

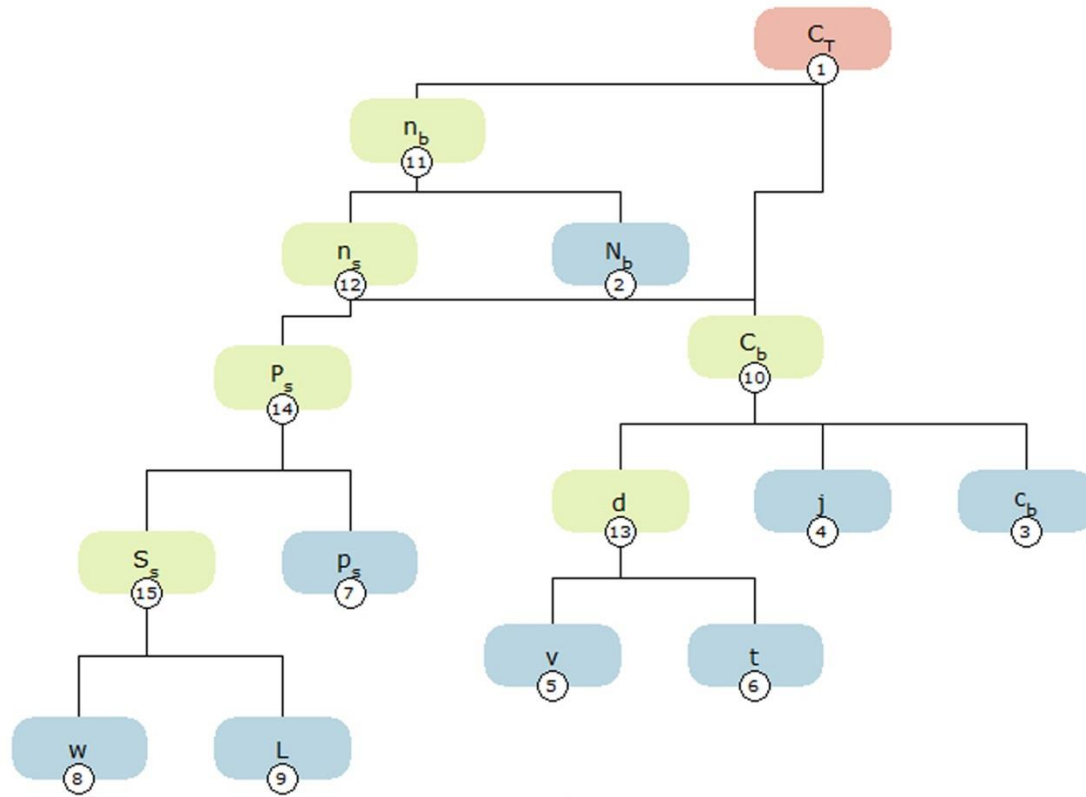
The panel produces 3300 MW/h electricity which is the power consumption of about 1000 house every year. The produced electric energy is supplied to the railway infrastructure and used for illumination, message announcement and inter-train power.

1. Comprehensive Data for Estimation :

Regarding to all information's and mentions not in this paper we can use follow supposes:

- The total length of BRT line bus in Tehran : 164 km
- Normal width of BRT line bus : 8 m
- The output power in the year for 1 m² solar panel : 140 kwh /year
- The rate of electricity consumption for an electric bus : 66 kwh /100 km
- Total number of diesel buses in Tehran : 3547
- Total number of BRT buses in Tehran : 1100
- BRT bus speed : between 20 ~ 50 km/h
- The average of bus speed : 35 km/h
- The time of moving buses per day : 15 h (6 am ~ 9pm)
- Average moving distance per day for each bus : 500 km
- Fuel consumption of buses: 0.3 Liter/ km

The mentioned assumptions could be analyzed according to following algorithm. The Toster system Program could be run in Matlab software to calculate the data. Different scenarios will occur as the length of BRT line covered by solar panel or velocity change:



1	C_T : Consumption of the transportation system (kwh/y) $C_T = n_b \cdot C_b$	9	L: Total length of BRT line bus(m) $0 \leq L \leq 200000$
2	N_b : Number of using diesel $900 \leq N_b \leq 2000$	10	C_b : Total consumption of 1 bus(kwh/year) $C_b = d \cdot c_b$
3	c_b : The rate of electricity consumption for a solar bus(kwh/km) $0.5 \leq c_b \leq 0.66$	11	n_b : Number of buses $n_b = Nb - n_s$
4	j: Number of day $300 \leq j \leq 365$	12	n_s : Number of buses using solar energy $n_s = P_s / C_s$
5	v: Speed of one bus(km/h) $20 \leq v \leq 50$	13	d: Distance $d = v \cdot t$
6	t: The time of moving buses per day(h) $t = 15$	14	P_s : Total power of BRT line per year $P_s = S_s \cdot p_s$
7	p_s : The output power of solar panel (kwh/m ² /year) $140 \leq p_s \leq 200$	15	S_s : Total area of BRT line (m ²) $S_s = w \cdot L$
8	w: Normal of BRT line bus (m) $0 \leq w \leq 10$		

Figure 9: Estimation of the transportation system (kwh/y), (source: Author)

2. Hypotheses

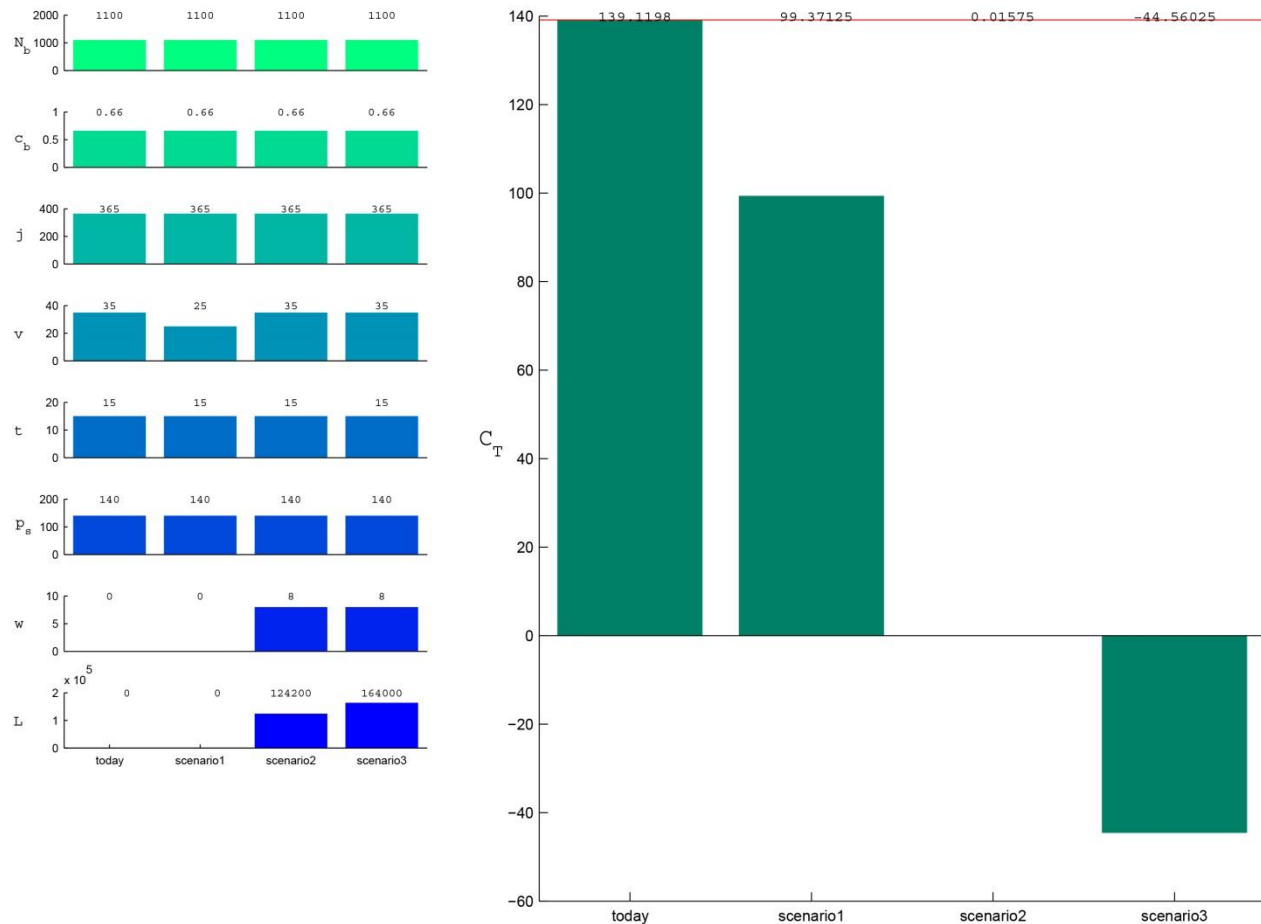


Figure 10: Hypotheses (Sours: Author)

- Today:

If all the BRT Buses are electrified, the energy consumption will be 1391198KW per year which is quite high.

- Hypotheses 1

As velocity rises while all other variants are kept constant, the energy consumption decreases but the transporting activities slow down which causes further problems in transforming passengers.

- Hypotheses 2

If 124KM of BRT line is covered by solar panels all amount of electric energy needed by Buses will be supplied.

- Hypotheses 3

According to the diagram If total length of BRT line(164km) is covered with solar panels, all amount of electric energy needed by Buses will be supplied and considerable amount of generated electric power remains.

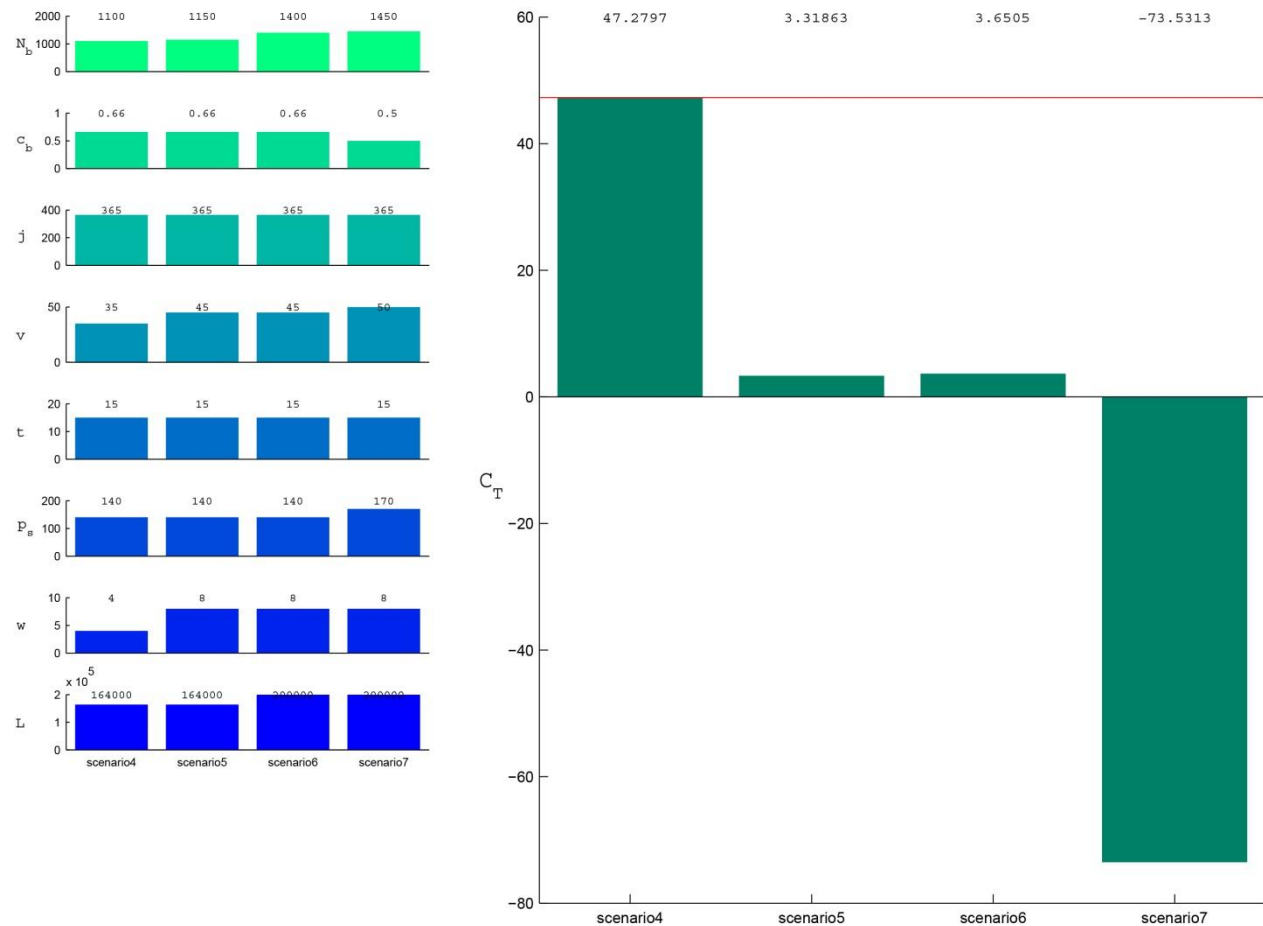


Figure 11: Hypotheses (Sours: Author)

- Hypotheses 4

If half width of BRT line (4m) is covered by solar panels, a considerable amount of electric energy needed by Buses will be supplied.

- Hypotheses 5

If total length of BRT line (164km) is covered by solar panels, it is possible to add 50 buses to current number of buses (1150buses) and raise the velocity up to 45 Km/hr.

- Hypotheses 6

As the total bus line's length accomplished to 200km, if the total length is covered by solar panels, 1400 buses can be run with velocity of 45km/hr.

- Hypotheses 7

If the buses and solar panel will be optimized efficiently in the future it can be possible to have 1450 buses with velocity of 50km/hr and remained significant extra generated electric power.

3. Estimation of Reduction of Air Pollution by using Solar Panel in Public Transportation in Tehran

Title	Unit	Definition
$R = 1 - (P_{\text{solar}} / P_{\text{diesel}})$	[%]	Reduction of chemical pollution in public transportation
$P_{\text{diesel}} = V_{\text{diesel}} \cdot D$	gr	diesel pollution variable
V_{diesel}	Gr/km	Substances Pollution Emissions
D	km	Distance
$P_{\text{solar}} = P_{\text{diesel}} (T - \Delta T) / P_{\text{diesel}}$	gr	Pollution variable after adding solar panel
T	-	Total number of diesel Buses
ΔT	-	Number of Electric Buses
NO_x	gr	$NO_x = (NO + NO_2 + NO_3)$ Nitrogen oxides
CO	gr	Carbon monoxide

Table 9: Databases for Reduction of air pollution (Source: Author)

- **Emissions for Diesel bus:**

$$\text{Co}=3.1 \text{ gr} \quad \rightarrow V_{\text{Co diesel}}=3.1 \text{ gr/km}$$

$$\text{Nox}=12.4 \text{ gr} \quad \rightarrow V_{\text{Nox diesel}}=12.4 \text{ gr/km}$$

$$\left. \begin{array}{l} P = V \cdot D \\ D = 1 \text{ km} \end{array} \right\} P_{\text{Co diesel}} = 3.1 \text{ gr/km}, P_{\text{Nox diesel}} = 12.4 \text{ gr/km}$$

- The Emission of Carbon Monoxide for each Bus: $500 * 3.1 = 1550 \text{ gr/day}$
- The Emission of Nitrogen Oxides for each Bus: $500 * 12.4 = 6200 \text{ gr/day}$

As a bus travel 500 kilometer, 1.7 ton Co and 6.8 ton Nox emitted to the air.

- **Reduction of Diesel bus:**

$$R_{\text{Co}} = 1 - (P_{\text{Co solar}} / P_{\text{Co diesel}}) * 100 \rightarrow R_{\text{Co}} = 1 - (2447 * 3.1 / 3547 * 3.1) * 100 \rightarrow R_{\text{Co}} = \%31$$

$$R_{\text{Nox}} = 1 - (P_{\text{Nox solar}} / P_{\text{Nox diesel}}) * 100 \rightarrow R_{\text{Nox}} = 1 - (2447 * 12.4 / 3547 * 12.4) * 100 \rightarrow R_{\text{Nox}} = \%31$$

Conclusion

All mentioned above leads us to the conclusion that using solar panels in BRT lines reduces the annual fuel consumption of 60 million liters. As a result the two air pollutant indexes of CO and NO_x will be decreased as 2000ton and 8000 ton respectively. It is a significant step for changing consumption pattern and using recycled energy instead of fossil fuel.

Besides, the noise pollution also is reduced. Although this is not much, it would bring great advantage to public health. Financially speaking, around 300 milliard Rials would be saved through using the solar panels which can be invested on improvement of transportation system. Also the extra generated electric power can be spent the same way.

According to what is said, in order to define the sustainable transportation measures, many attempts have been done, which one can categorize them into three categories. For example, the important sustainability measures for the environment are energy consumption, Air pollution, sound pollution, and destruction of the natural resources.

Totally, it can be said that sustainability factor for the transportation, includes the reduction of energy consumption, reduction of the environment destruction, increase in the social sustainability for access to the transportation system as well as improvement in the efficiency and performance along with the economic development.

Also it should be mentioned that the Urban Sustainability with emphasis on the urban transportation, should be focused on two simultaneous approaches in changing the behaviors and also improvement the technical situation of the transportation system, for example reducing the energy consumption and using from the renewable energies.

In the other words, with regard to the proposed scenarios including technical scenario, human scenario and combinational scenario, the latter approach is the dominant and the best approach in the present study.

Also with regard to the three defined levels about the sustainable transportation, namely environmental, social and economic levels, the present study emphasizes on the environmental dimension in order to reduce the pollutions resulted from the transportation sector by using from the renewable energies especially the solar energy.

The environmental dimension of the sustainable transportation includes the different approaches and methods of transportation which are focused on reducing the energy consumption and emission of the polluters and other negative ecologic effects.

With regard to the importance of the air pollution in the metropolises, do the environmental dimension of the transportation is very important in sustainability of the cities.

With regard to the special situation of Iran and specially Tehran City in terms of its complexities, the challenges faced by the urban management and transportation sector and also proper use from the radiation of the Sun in this region, the emphasis of the present study is placed on the use from the Solar Energy as a proper pattern of the Renewable Energies in the Sustainable Urban Transportation.

All these can make the dream of having clean air come true and provide people with sustainable metropolises.

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