

A Critical infrastructure from a sustainable public transportation perspective: Jordan as A Case Study

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Abstract: Infrastructure is the fundamental facilities that plays an important part in socio-economic development for modern societies, if such sector is well planned, managed by decision makers in a way that is compatible with the population growth, safety, and national security needs; it will enrich progress, prosperity, awareness, social and economic welfare for any country. Infrastructure is the most important socioeconomic aspect of life, because it can provide materials, products and services that will improve and facilitate living conditions and maintain sustainability at the same time, and in order to study critical infrastructure in general we must think sustainability, otherwise there will be a significant gap.

Recently researchers all over the world are paying more and more attention to the critical infrastructure systems the urban infrastructure is considered one of the most important sectors of the economy, which affect all sectors in the communities of both developing and developed countries because it is linked to the civilizational and urban development, meanwhile, choosing the appropriate transportation mode that will provide a good level of service and increase the satisfaction of the potential users is a difficult task.

This research paper tries to assess where is Jordan located vs. each Transportation Sustainability dimensions in aspects related to social, economic and environmental dimensions based on (Zietsman et al. 2006) adopted model for Sustainability Transportation infrastructure. Performance measures for each dimensional goal were traced and supported with needed data and statistical findings. The study uses Analytical descriptive style and methodology based on different references and previous studies from secondary data sources to support the case and conclude with recommended actions and future directions to reform the investigated case. Although this is the case for Jordan, it also can be applied to most developed countries, since most of them suffering from significant problems related to infrastructure and public transportation services.

Keywords: Infrastructure Transportation Sustainability, Economic, Social, Environmental.

1. Introduction

Critical infrastructure can be defined as industries, institutions, distribution networks that provide a continual flow of goods and services essential to country's defense, economic, security and to the health, welfare, and safety of its citizens. Five major sectors can in general be considered: Critical human services, information and telecommunication, energy, banking and finance, and physical distribution. They play a crucial role in the life and they are much more dependent on each other, once any of them are damaged, there will be a direct threat to the stability of economic, to public health, to safety and security aspects and the damage may even lead to disasters and collapse of the entire socioeconomic system. With the development of society and the application of information technology, critical infrastructure systems are much more efficient.

The scope definition of infrastructure differs according to country, for example in UK "The [Critical National Infrastructure] comprises those assets, services and systems that support the economic, political and social life of the UK whose importance is such that loss could: 1) cause large scale loss of life; 2) have a serious impact on the national economy; 3) have other grave social consequences for the community; or 3) be of immediate concern to the national government." [1].

While in United States the general definition of critical infrastructure in the overall US critical infrastructure plan is: "systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters." For investment policy purposes, this definition is narrower". [2]

Sustainability implies the provision of more efficient services that maintain public health and welfare, are cost-effective, and reduce negative environmental impacts, today and into the future. A definition of sustainable development from an ASCE/UNESCO working group on developing sustainability.

Sustainable development is truly about achieving a balance between several objectives (environmental, economic, and social) over dynamic time and spatial horizons. Accordingly, Research in the area of sustainable urban infrastructure reflects the need to design and manage engineering systems in light of both environmental and socioeconomic considerations. A principal challenge for the engineer is the development of practical tools for measuring and enhancing the sustainability of urban infrastructure over its life cycle [3][4].

Infrastructure as well as the transportation sector in Jordan like any other developing countries suffers from short sighted planning and lack comprehensive and integrated vision, which have left Jordan now days with serious problems related to high congestions in general especially at a certain time (rush hours), low safety procedures, high incremental traffic accidents figures combined with high fatal rates and low quality requirement for transporting goods and passengers.

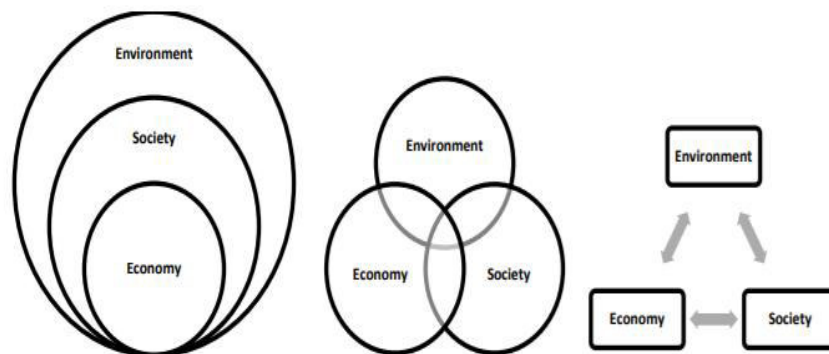
This paper will consist of the following sections; first section is literature review regarding sustainability definition in general and transportation sustainability in specific, second section analysis of Jordan infrastructure from public transport perspective, third Section explains the methodology of research, last section provides Results of analysis, conclusions and main recommendations.

2 Literature review

2.1 Sustainability, transportation sustainability

According to the World Business Council on Sustainable Development (WBCSD), sustainability involves “the simultaneous pursuit of economic prosperity, environmental quality and social equity. Companies aiming for sustainability need to perform not against a single, financial bottom line but against the triple bottom line” (WBCSD 2000) [5]. The term “Sustainable Development” (SD) was popularized in the 1987 within UN report “Our Common Future”, also known as the “Brundtland Report”, of the UN World Commission on Environment and Development. This term provided what later became one of the most cited definition of sustainable development in literature:

The “three-dimensional model” of sustainable development was introduced in the Rio Summit’s declaration as one of two main pillars (UN 1992). The concept rests on: (1) equity between and within generations, and (2) the equal status of social, economic, and environmental goals (IFRAS 2004) [6]. The combination of these two pillars is illustrated in Figure 1 below.



Source: (Mann, 2009) [7]

However, sustainable transportation in specific balances “the need to travel with the need to improve quality of life [7]. In the US context, the Committee for the Conference on Introducing Sustainability into Surface Transportation Planning [8] defined a sustainable transportation system as “one in which (a) current social and economic transportation needs are met in an environmentally conscious manner and (b) the ability of future generations to meet their own needs is not compromised”. The American Association of State Highway and Transportation Officials (AASHTO) listed a set of 17 goals for sustainable transportation, which include improved accessibility, mobility, and safety, reduced pollution, ecosystem impacts, et [9]. The substantial impacts of transportation on environment, society and economy strongly urge the integration and incorporation of sustainability into transportation. A comprehensive definition of sustainable transportation that includes most of the social, economic and environmental concerns is provided by the European Council of Ministers of Transport (ECMT 2001, pp.16.) [10] defines a sustainable transportation system as one that 1) allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations, 2) is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy, 3) limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

There is no universally accepted framework for assessing sustainability, whereas research has been conducted mostly after 2000 by universities and institutes on sustainability performance measures that have the potential to move a transportation system towards sustainability. The Center for Sustainable Transportation (CTS 2002) developed and used indicators to study whether the transportation sector improves in respect to its adverse impacts on environment and health.

Jeon and Amekudzi (2008) [11] have studied the sustainability initiatives in North America, Europe and Oceania and reported that a standard definition of transportation system sustainability which is followed by a standard set of indicators for the assessment of transportation systems is not available suggested 28 indicators representing 13 goals and four sustainability categories for evaluating transportation system sustainability.

Renne (2009) [12] evaluated Transit Oriented Development (TOD) sustainability by deploying a survey in five transit stations and by using indicators based on six categories. The six categories with the number of proposed indicators for each one shown in the parentheses are: 1. Travel behavior (11) 2. Local economy (11) 3. Natural environment (4) 4. Built environment (21) 5. Social Environment (12) 6. Policy context (3).

Jeon et al. (2008), [11], eleven indicators that were quantified to determine environmental, social and economic impacts as well as the sustainability

performance of the transportation system for different scenarios in the Metropolitan Atlanta. The eleven quantified indicators were aggregated into four dimensions of sustainability indices. Scenarios were evaluated based on a composite sustainability index that was embracing the indices for the four sustainability category (environmental, social, economic impacts and transportation performance.) (Jeon et al. 2010) [13].

Sustainability dimension	Goals and objectives	Performance measures
Transportation System Effectiveness	A1. Improve Mobility	A11. Freeway/arterial congestion A12. Travel rate (minute/mile)
	A2. Improve System Performance	A21. Total vehicle-miles traveled A22. Freight ton-miles A23. Transit passenger miles traveled A24. Public transit share
		B11. CO ₂ emissions B12. Ozone emissions
		B21. VOC emissions B22. CO emissions B23. NO _x emissions
Environmental Sustainability	B1. Minimize Greenhouse Effect	B31. Traffic noise level
	B2. Minimize Air Pollution	B41. Fuel consumption
Economic Sustainability	B3. Minimize Noise Pollution	C11. User welfare changes C12. Total time spent in traffic C21. Point-to-point travel cost
	B4. Minimize Energy Use	C31. Improved accessibility
	C1. Maximize Economic efficiency	D11. Equity of welfare changes D12. Equity of exposure to emissions D13. Equity of exposure to noise
	C2. Maximize Affordability	D21. Exposure to emissions D22. Exposure to noise
Social Sustainability	C3. Promote Economic development	D31. Accidents per VMT D32. Crash disabilities D33. Crash fatalities
	D1. Maximize Equity	D41. Access to activity centers D42. Access to major services D43. Access to open space
	D2. Improve Public Health	
	D3. Increase Safety and Security	
	D4. Increase Accessibility	

(Jeon et al. 2010.) [13]) developed a tool as an add-on module in an integrated and transportation land use model for assessing urban sustainability. Indicator were based on large scale simulation models such as the SPARTACUS, PROPOLIS and PROSPECTS to reflect aspects of environment, society and economy. The indicators, which represent five distinct criteria, were grouped into three sustainability categories. The weights for the individual criteria were developed through a Delphi process using four experts in the field of transportation planning. The weights of the indicators were based on the relative costs to society for those indicators, [14] It provides information on identifying appropriate performance measures for sustainable transportation as follows:

Sustainability Dimension	Goals	Performance measures
Social	Maximize mobility	Travel rate
	Maximize safety	Accidents per VMT
Economic	Maximize affordability	Point-to-point travel cost
Environmental	Minimize air pollution	VOC, Car on CO and NO _x emissions.
	Minimize energy use	Fuel consumption

Based on: Zietsman et al. (2006) [15].

2.2 Sustainable transportation – jordan

Infrastructure projects in Jordan suffer from significant problems that has its impact on Sustainability dimensions for transportation, as this the case in most underdeveloped countries which hinder the economic growth and social development and welfare for any country.

In this paper we will evaluate to which extent Jordan Critical Transportation's structure meet the performance indicators for each dimension in order to see how far effective we are in applying sustainable transportation dimensions.

In Jordan (existing of narrow roads, expensive costs of opening new roads, pavements, lack of modern developed wide roads, building bridges, tunnels, culverts and circles as well as traffic light systems, etc.) all of these unable to meet the fast and quick growth.

The main reasons for major infrastructure projects problems are mostly due to lack of service oriented perspective in actual implementation due to poor comprehensive planning, lack of funding and Inflation in project costs.

To add to above points, there is lack of safety and secure studies, lack of professionally and risk management studies, in fact there are some times under estimated or poor estimated of the importance of risk management capabilities.

All of the above and more can be controlled if across the entire life cycle of the project and in each stage risks are managed, well planned, well designed and well implementation and revisable are applied when needed.

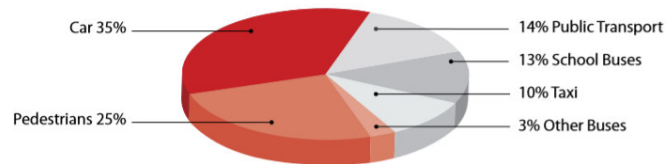
2.3 Sustainability dimension

Although the three Sustainability Dimension are the basics that need to be considered in explaining and solving any problems the following also should not be negligible in studding the Public Transportation and Infrastructure.

2.3.1 Mobility performance measure: Travel rates

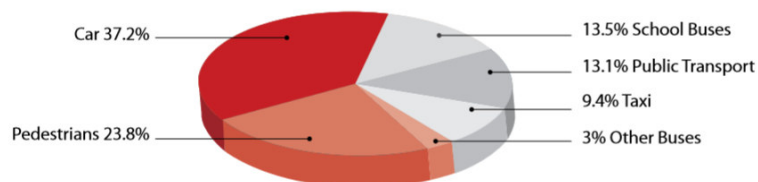
Urban development is an issue that many cities are facing, due to the demography growth which results from the economic attractiveness of the urban centers. Based on common standards, it is necessary to structure the transportation system according to sustainability requirements [16].

Jordan actual figures in term of mobility shows that based on 2010 the percentage of public transport users is very humble 14%, this shows that in the base year the most important mode with highest share of trips is the private car, whereas Public Transportation(PT) has a rather low share. as shown below: [22].

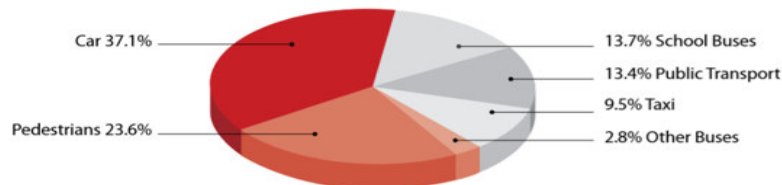


The following chart scenarios present the models split that has been calculated to forecast mobility in the future, comparing with base year an increase of car trips can be observed, whereas the share of Public Transportation(PT) decreases as shown below: [22].

Modal Split 2030 (Baseline Scenario)



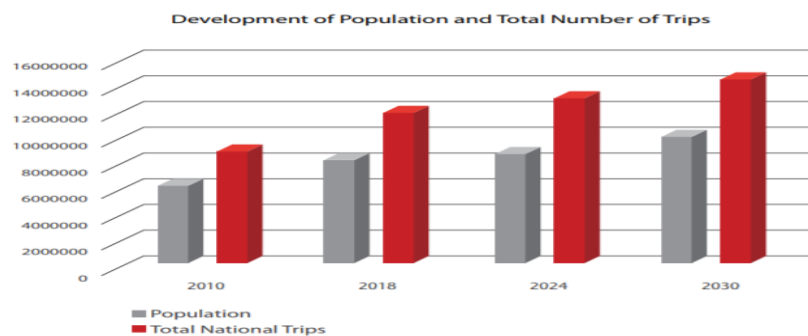
Modal Split 2030 (Strategy Scenario)



However, based on long run Jordan Transportation and transport model simulations, Passenger transport requires a strong commitment towards the promotion of alternatives to pure private, road transport. At this regard, the Strategy proposes a set of integrated and complementary measures to increase the quality attractiveness of public transport: the full implementation of new bus network and services, setting and enforcing minimum standards for vehicles in order to improve safety and quality, restructuring the sector and the way Public Transportation (PT) services are operated and awarded to operators, upgrading the facilities (terminal, bus stops, border crossing) while fostering inter modality. Developing and specializing Jordan airports (Amman Queen Alia, Amman Marka, Aqaba King Hussein) is also a key strategy in order to improve the passenger (and

freight) connections of Jordan to the Region and beyond. As a result, while in the baseline scenario the share of the demand using public transport is declining through time, in the strategy it shows a moderate increase reaching 13.7% of the total demand compared to 13.1 % in the baseline scenario. A number of cross cutting issues are addressed by the Strategy as well.

It is expected by planners that in the long term (2030) the new railways will attract 21.2 million tons of freight per year amounting to 5,100 million ton kilometers on Jordan rail tracks. This will ease road traffic flows by 4,200 ton kilometers. If accompanied by proper “push and pull” policy measures to modernize and consolidate the trucking industry (such as for instance incentives to renewing the fleets, enforcement of regulations and licenses, tolling of highways), [22].



The significance of transport infrastructure as a factor for destination development is another factor to consider within mobility and considered within many research papers showing it to be part of the classical demand for international tourism functions.

One paper has investigated the significance of transport infrastructure as a factor in destination development [17], showing it to be part of the classical demand for international tourism functions.

An application involving the island of Mauritius is presented, whereby total tourist arrivals are modeled. The findings show that tourists from Europe/America and Asia are particularly sensitive to the island’s transport infrastructure.

Gearing (1974) [18] study the case of Turkey as a destination and find that infrastructure (comprising roads, water, electricity, safety services, health services, communications, and public transportation) is a key determinant explaining arrivals. More recently [19] for the case of Sun Lost City, South Africa, and for the case of 51 islands highlight the importance of infrastructure, particularly government-financed, in the success of a destination [20].

2.3.2 Safety

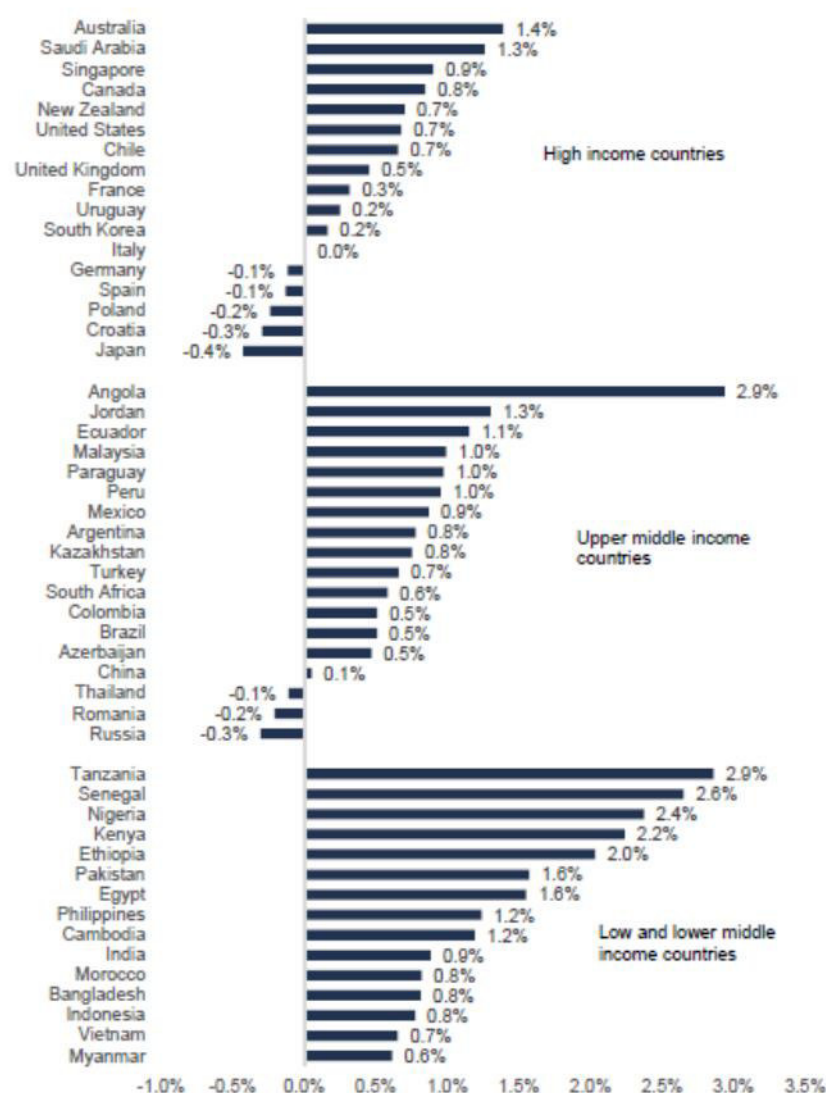
Performance measure: Accidents per VMT (accidents per vehicle-miles traveled),

Jordan is considered one of the top countries worldwide in terms of having higher number of traffic accidents involving fatalities and injuries. Where there is an annual increase of population and vehicles in Jordan, in addition to the arrival of many foreign visitors and vehicles to the country, Statistics show that at the end of 2016, the population of Jordan reached 9.798 million, compared to 6.4 million in 2010.

Jordan with limited infrastructure and resources has faced several immigrations waves from neighboring countries (Iraq, Syria, Yemen and other countries) due to geopolitical reasons which has created a sudden population increase and added extra pressure on the roads and traffic. The total length of roads has been estimated at 18500 km in the year 2016.

Statistics show that during 2016 the number of people who They entered the kingdom was 926658 persons, in 2016 a total of 144521 traffic accident occurred in the Kingdom, with 10835 casualty's accident resulted in 750 deaths, 1841 seriously injured and 15594 Simple injuries at an estimated total cost of \$455 million US\$, graphs below show the average annual population growth,2016-2040, and the location of Jordan,

Fig. 95 Average annual population growth, 2016-2040



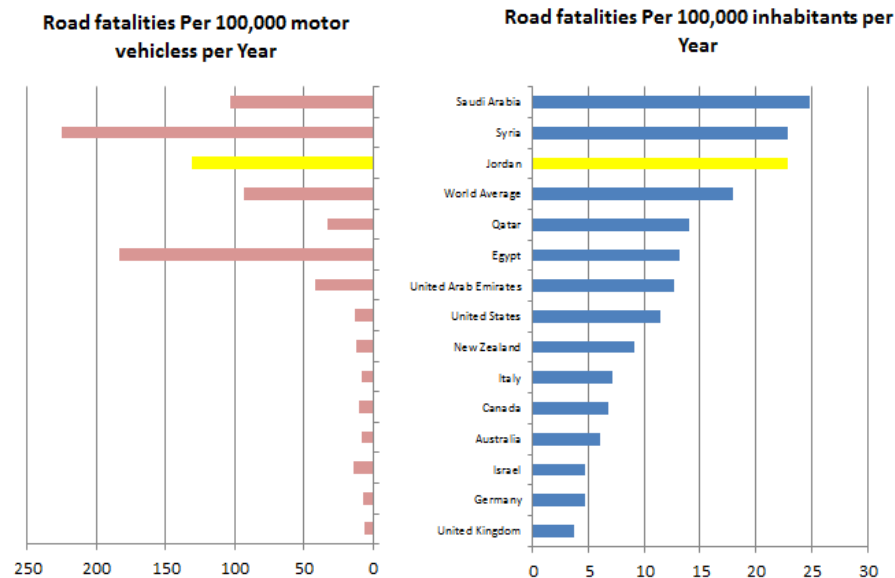
Source: UN, Haver, Eurostat, Oxford Economics and National Sources

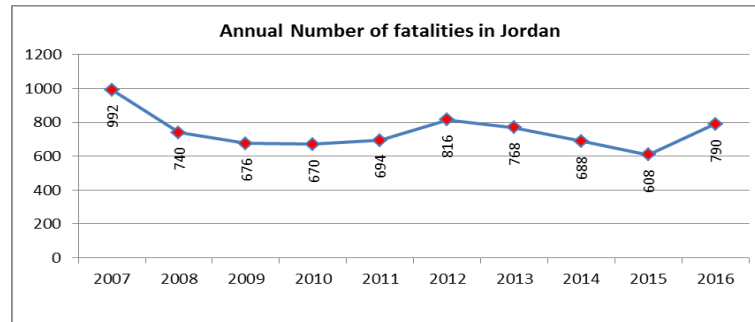
The fatality rate per 100,000 populations in 2015 was 6.38, which means;

- high congestions in general especially at a certain time (rush hours),
- low pedestrian's safety procedures,
- high incremental traffic accidents with high fatal rates,

It is shown below how serious is the situation compared to the rest of world [23] [24].

Country Region	Road fatalities Per 100,000 inhabitants per Year	Road fatalities Per 100,000 motor vehicleless per Year
United Kingdom	3.7	6.5
Germany	4.7	7.6
Israel	4.7	14.3
Australia	6.1	8.5
Canada	6.8	10.7
Italy	7.2	8.3
New Zealand	9.1	12.3
United States	11.4	13.7
United Arab Emirates	12.7	42.3
Egypt	13.2	183.3
Qatar	14	32.7
World Average	18	93.3
Jordan	22.9	131.5
Syria	22.9	225.5
Saudi Arabia	24.8	103





Risk is inherent in large construction projects and refers to the potential complications in achieving the project goals and impact safety aspects [21], it is greatly plagued the construction industries which necessitate the risk assessment for the large scale construction projects. especially, risk assessment is critical for new construction or renewal of ‘Critical Infrastructure (CI)’, such as bridges as they are the vital links for a transport network. Gradually increasing complexity in road construction and constant exposure to environmental conditions increase the vulnerability of large Critical Infrastructure construction projects to the unexpected hazardous events.

Based on Jordan Long Term National Transport Strategy; Transport safety is a critical issue in Jordan. Although the Jordan National Transport Strategy encompasses all transport modes, it can be easily asserted that significant improvements in Jordan’s transport-related safety challenges are to be achieved mainly in the road sector. Several priority areas have been identified as posing particular concern and deserving special attention in the design of the measures: young drivers, impaired driving, speeding, vulnerable road users, motorcyclists and road infrastructures. The proposed relevant measures considered cover three fields of action: road users’ behavior, vehicles characteristics and infrastructure characteristics

A National Transport Safety Program is a fundamental part of it, being aware that significant improvements in Jordan’s transport-related safety challenges can be achieved mainly in the road sector. Relevant measures therefore cover three fields of action: road user’s behavior, vehicles characteristics and infrastructure characteristics.

Jordan long term transportation strategy is keen to improve traffic and Transport safety. Although the Jordan National Transport Strategy encompasses all transport modes, it can be easily asserted that significant improvements in Jordan’s transport-related safety challenges can be achieved mainly in the road sector. A number of policies and actions, as well as legislation acts, are in place in Jordan, although a transport safety national strategy is still missing. A separate National Transport Safety Programme, which complement this Strategy document, aims at filling in this gap, suggesting a number of integrated measures to face the major risk factors affecting road safety. Several priority areas have been identified as

posing particular concern and deserving special attention in the design of the measures: young drivers, impaired driving, speeding, vulnerable road users, motorcyclists and road infrastructures.

Renewing the fleet of public transport buses (to be coordinated with the progressive implementation of hierarchical network levels) is fundamental to improve quality (comfort and attractiveness), safety while reducing environmental impacts and fuel consumption. Two are the policies to be considered in this respect: 1-To deploy financial contributions for the purchase of new vehicles, or taxes/duties reductions 2-To set (and enforce) minimum standards for vehicles: definition of quality standards, technical specifications, maximum age for busses transport Policies/Regulations REF 2018 2024 2030 ,1. Renewing the fleet of public transport buses (to be coordinated with the progressive implementation of hierarchical network levels) ✓✓ 2. Minimum standards for vehicles. Definition of quality standards, technical specifications, maximum age for busses, enforcement ✓ 3. Restructuring of the sector/ industry: consolidating small operators into bigger organizations, 4. competition and efficiency ✓5. Fares and contracts 5.1 New contracts replacing old licenses (never expiring) ✓ 5.2 Revision of fare system (incl. technologies, ETMs electronic ticket machines) ✓ 5.3 Separate services for which fares can be liberalized from regulated services and assess the need to introduce subsidies (to be coordinated with the progressive implementation of hierarchical [22] [23].

2.3.3 Economic, affordability:

Performance measure: Point to point Travel Cost:

We Need data regarding transportation affordability (expenses – cost – charges)

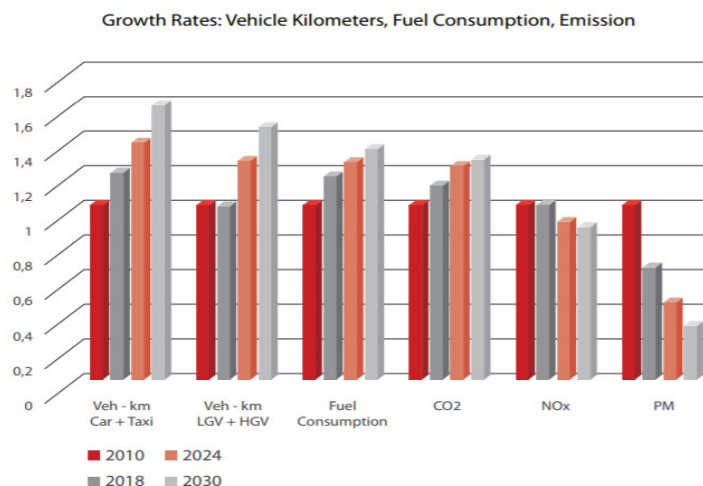
2.3.4 Environmental

Air pollution:

Performance measure: VOC, Car on CO and NO, emissions

Energy use:

Performance measure: Fuel consumption



Jordan Long Term National Transport Strategy and Action Plan | Drafting of the Strategy: main steps 68 Finally, the reduction of impacts of the transport sector related to the environment (pollutant emissions, greenhouse gasses, fuel consumption) is pursued by the Strategy, besides improving the competitiveness of alternatives to pure road, private transport, both for passengers and freight: incentives to renovate public and private fleets, through financial, regulatory and enforcement incentives and disincentives, and improving efficiency of the logistic and passengers transport chains (multimodal centers, facilities). As a consequence, while the vehicle kilometers in private transport increase by 56% (road freight transport by 44%) in the long term (2030), the fuel consumption only grows by approximately 30%, CO2 emissions show an increase by 26%, and NOx emission even decreases by 14% according to the transport model simulations [22].

3. Methodology of research:

The study used initially information from authorized Institutions, organizations, companies either from governmental side or private sector, the analytical descriptive style and methodology based on different references and previous academic studies that contrive from the following: -

- from published research.
- study via field questionnaire surveys, interviews, accurate observations.
- Secondary sources, periodicals, brochures, articles, regional, local and international similar studies

Conclusion, Remarks and recommendations

- -the behaviors, attitudes from the involved parties are randomly and unorganized.
- -individual traditions and habits which may contradict with legislations implementation.
- -several and random public transport stops,
- high density of passengers in the morning and evening,
- no public transit separated lanes.
- unplanned timing schedule for public transportation's vehicles
- -the slow movement of these vehicles due to lack of efficiency.
- all of these consider the main problems, while suggested solutions and recommendations can be summarized as mentioned bellow: -
- the future looking for serious and sustainable solutions that can be implemented easily
- -improving the infrastructure of public transportation to increase the effectiveness and the efficiency.
- -conducting new procedures and restricted legislations and rules for individuals and train the staff of the public transportation vehicles.
- -using modern intelligent techniques.
- -encourage and facilitate investments in all the different modes of transportations
- -serious and sustainable studies for the population growth and related topics.
- -making statistical periodicals survey to predict the future needs (establish data bank, short term and long term strategies with environmental support).
- -develop complain, suggestions and inquiries system and conduct regional workshops to discuss transport issues.
- -increasing the efficiency of infrastructure and public transportation will not happen unless we choose the best analyzing methods to reach the most appropriate, social, economic methodology with minimum risk.
- -establish and built modern, intelligent and smart systems to serve the infrastructure and the public transportation sector.

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