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Elevated Highways in Residential Layouts: The Imposed Negative Impacts
(Case Study: Sadr Elevated Highway)

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ABSTRACT: Fast growing population, excessive expansion of cities, and dominance of automobile in urban life have troubled cities with complicated traffic problems. In many parts of the world, transport network development has always been considered as a solution for this problem. Apparently, one-dimensional 'traffic solutions' would never thoroughly bring best results as the city and its problems are complicated and interconnected. However, adding one floor to the existing networks would not necessarily solve traffic congestion. Therefore the aim of this paper is to identify the challenges elevated highways especially Sadr highway imposed on adjacent residential neighborhoods, and to provide recommendations mitigating the negative impacts of these challenges in favor of neighbor residents. Among the different challenges, this paper focuses on those which have instant effects on the potential neighborhoods including environmental, safety, and social challenges which affect nearby residents the most. Accordingly, this study provides policies to reduce noise, air and visual pollution, safety and security issues.
Keywords: *Sadr elevated highway, Residential layouts, Environmental challenges, Safety challenges, Social challenges*

INTRODUCTION

Taking a brief look at history of cities indicates that living in a city has always brought its own challenges. In recent decades and with the increased use of cars, problems such as traffic congestion, pollution, and environmental issues have been inevitable causes of urban planners and designers' decisions with relying on car-oriented modes of transport (Zabihi et al., 2013) in the existing out-of-scale expanded urban context and home of a huge number of people.

Nowadays, many people living in cities suffer from chronic traffic problems which impose explicit, and hidden costs on cities and citizens. Although developing transport networks does not necessarily mean less traffic congestion, building new highways or even adding one floor to existing ones has always been considered as a solution to ameliorate traffic problems in car-oriented transport approach. Also, lots of cities have witnessed the inefficiency of elevated highways, e.g. San Francisco, Seattle, Dallas, and Seoul. However, many of these infrastructures have recently been constructed or are currently under construction in other parts of the world like Tehran, Dhaka, and Jakarta.

Problems arising from these kinds of developments are heightened especially with incorrect routing through residential layouts, where different groups of people live during 24 hours; so with the aim of providing accessible routes for cars, cities and citizens are imposed to irreparable damages. Sadr elevated highway is an example of this scenario, which has caused extra challenges for adjacent residential neighborhoods. Noise disturbances, air pollution, undesirable views, and reduction in resident's safety and security are some of the instant, and socio-economic challenges are some of the long-term negative impacts of elevated highways. However, since Sadr elevated highway has been constructed just two years ago, long-term challenges have not been included in this paper. Further, these negative impacts need to be mitigated through appropriate policies in order to enhance the quality of living for citizens who live near elevated highways.

MATERIALS AND METHODS

The prospect of owning a car is now seen by most people as an access, mobility and comfort status as well as a measure of safety from fatal traffic accidents and freedom from the drudgery of inadequate public transportation (Ajibade et al., 2015). However, uncontrollable level of motorization and new

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infrastructure development can generate new traffic and thus turn the whole situation into a more complicated one.

Apparently, a new development like an elevated highway would generate different types of trips even in the existing highway. Therefore, it is the matter of increased numbers of automobile exceeding the finite capacity of the proposed development, which will cause new challenges and severe issues.

In such circumstances, it is little wonder that building new highways is often contentious. Yet, highways play a fundamental role in terms of mobility and convenience on substantial sections of population, and thus there is a paradox between these infrastructures and social convenience (Egan et al., 2003).

In this paper, before presenting some specific policies for mitigating the impacts of elevated highways for adjacent neighbors, the most important challenges of such developments are briefly reviewed and analyzed. It is noteworthy that the main focus is on qualitative assessment through using quantitative data to get a fair clear perspective about the issue being discussed.

Environmental Changes

In case of new transport developments and environmental challenges, noise, local air quality, greenhouse gases, landscape, townscape, biodiversity, heritage or historic resources, and water environment are criteria that need careful consideration. This paper's focus is on improving the deteriorated quality of living for neighbor residents of elevated highways, and therefore among mentioned criteria, three of them which have been reported as the most irritating impacts by the potentially affected receptors, such as "noise pollution", "air pollution", and "visual intrusion" are discussed below.

Noise Pollution

Noise is a major and growing form of pollution. It can interfere with communication, increase stress and annoyance, cause anger at the intrusion of privacy, and disturb sleep, leading to lack of concentration, irritability and reduced efficiency. It can contribute to stress-related health problems such as high blood pressure. Noise can also affect property values and community atmosphere (Therivel, 2010). A recent MORI poll found that 63 per cent of respondents were bothered by one or more source of noise, with noise from cars and motorbikes being most commonly cited; and 10 per cent of respondents suffered "a great deal or a fair amount" (MORI, 2008). In Europe, 57 million people are annoyed by road traffic noise, 42 per cent of them seriously; the social costs of traffic noise in Europe amount to at least €40 billion per year (CE Delft, 2007).

Noise, defined as "unwanted sound", is perceived as an environmental stressor and nuisance. Effects of noise can be defined as all those effects on health and well-being caused by exposure to noise (Stansfeld & Matheson, 2003).

Generally speaking, noise consists of pressure variations detectable by the human ear. These pressure variations have two characteristics: frequency and amplitude. Sound frequency refers to how quickly the air vibrates, or how close the sound waves are to each other (in cycles per second, or Hertz (Hz)). Frequency is subjectively felt as the pitch of the sound. Sound amplitude refers to the amount of pressure exerted by the air, which is often pictured as the height of the sound waves, which is described in units of pressure per unit area, MicroPascals (μPa). The amplitude is sometimes converted to sound intensity which is subjectively felt as the loudness of sound. However, none of these measures is easy to use because of the vast range they cover. As a result, a logarithmic scale of decibels (dB) is used. Since most sound analyses, including those in EIA, are concerned with the loudness experienced by people rather than the actual physical magnitude of the sound, an A-weighting curve is used to give a single index which takes account of the varying sensitivity of the human ear (Therivel, 2010). The range of audible sound is generally from 0dB (threshold of hearing) to 140dB (threshold of pain) as it is shown in Table 1.

Table 1: Sound Levels between threshold of hearing and pain (Therivel, 2010)

Sound level (dB)	Example
140	Threshold of pain
130	Riveting on steel plate
120	Pneumatic drill
110	Loud car horn at 1m
100	Alarm clock at 1m
90	Inside underground train
80	Inside bus
70	Street-corner traffic
60	Conversational speech
50	Business office
40	Living room
30	Bedroom at night
20	Broadcasting studio
10	Normal breathing
0	Threshold of hearing

Environmental Factors Influencing Noise Impacts

The principal physical factors, which influence how much effect a sound will have upon a potentially affected receptor, are the level of the sound being assessed and the level of other sounds which also affect the receptor. The level of sound being assessed is determined by several factors. Firstly, as one gets further away from a source of sound in the environment, the level of noise from the source decreases. The principal factor to this is probably geometric dispersion of energy. The rate at

which this happens is between 3dB per doubling of distance for very big sources such as major roads (Therivel, 2010).
The next most important factor in governing noise levels at a distance from a source is whether the propagation path from noise source to the receiver is obstructed. If there is a large building, a substantial wall or fence, or a topographic feature, which obscures the line of sight, this can reduce noise levels by, typically, a further 5-15dB(A). Thick areas (≥30m) of dense trees and underbrush may reduce noise by up to 3-4dB at low frequencies and 10-12dB at high frequencies; although thinner tree belts have little actual effects on noise, the visual barrier they form can make people think that noise levels have been reduced. Other physical effects like reflection and meteorological effects may have to be considered, if detailed noise calculations are to be carried out. A gentle positive wind (the wind blowing from the noise source to the receptor) slightly increases noise levels compared with calm conditions, but a negative wind has a larger effect (Therivel, 2010).

Road-Traffic Noise

Road-traffic noise is the combination of all sources of noise from a vehicle including propulsion, tire/road, mechanical, and aerodynamic noise sources. The engine, exhaust, intake, and other power-train components generate propulsion noise. The tire/road noise or road surface noise is generated as the tire rolls along the pavement. Aerodynamic noise is caused by turbulence around a vehicle as it passes through the air. Propulsion noise will dominate the total road noise at low speeds. As speed increases, a crossover speed is reached at which the tire/road noise becomes an equal source of noise. Then, at higher speeds, it becomes the dominant source. Only at high speeds will aerodynamic sources begin to dominate (NZ Transport Agency, 2014).
In addition, traffic congestion plays an important role in the ambient noise level. The more traffic congestion with a greater share of heavy vehicles concludes more ambient noise level (Bahram Soltani, 1995).

Road-Traffic Noise Impact on People

Road-traffic noise rarely causes hearing damages, but there are a number of physiological and psychological consequences which are heightened when the difference between background and maximum noise level is considerable especially during sleeping or relaxing times. It can cause frequently disrupted sleeping and shortened deep sleep duration, which affects human body directly in terms of fatigue, nervousness, and aggression. Moreover, some indirect consequences may be caused like allergy, digestive system disease, and chronic headaches. (Bahram Soltani, 1995).
Where there are many receivers, for instance along with a proposed road or rail line, representative receivers will need to be identified. A systematic approach is required, splitting potentially affected receivers into a) residential, b) non-residential and noise sensitive, and c) non-residential and not noise sensitive. Clearly, the latter (e.g. factories and other industrial premises) can be scoped out. The second group may need a further degree of sub-classification (a major broadcast studio may be potentially more sensitive than a shopping center for instance). It is advisable, however, to treat residential receivers uniformly despite the fact that individual sensitivities to noise vary enormously (Therivel, 2010). Table 2 shows permissible noise thresholds for a) residential, and b) non-residential and noise sensitive during daytime and nighttime.

Table 2: Permissible noise thresholds for big cities (Bahram Soltani, 1995)

Land use	Permissible noise threshold	
	Daytime dB (A)	Nighttime dB(A)
Residential	55	45
Non-residential and noise sensitive	65	55

Mitigation

Mitigation will be necessary if the noise from the proposed development is likely to exceed the levels recommended in the relevant standards. However, it may be useful to implement noise mitigation measures even if standards are met, to prevent annoyance and complaints and as part of best practice procedures. For a new potentially noisy project, mitigation of noise is best carried out at the source, before the noise has escaped (Therivel, 2010). This is accessible through specific considerations for vehicles, and road surface, e.g. its texture and porosity (NZ Transport Agency, 2014). Failing this, barriers and the siting of buildings can be used to separate noise sources from potentially affected noise-sensitive locations. As a last resort, noise can be controlled at the receivers' end through the provision of, say, secondary glazing or other noise insulation measures (Therivel, 2010).
In conclusion, noise mitigation solutions are briefly possible as below:

- at the source
- between the source and receivers
- at receivers' end

Air Pollution

A proposed development that will change the concentration of pollutants in the atmosphere, or alter the weather and climate, may result in effects on people, plants, animals, materials and buildings (Canter, 1996; Colls, 1997; Elsom, 1992; Ortolano, 1997; Turco, 2002). These effects can occur at the local, regional or even global scale. Major developments such as roads and elevated highways pose obvious potential pollution problems because they will directly result in vehicle

emissions. The principal factors upon which the generation of traffic air pollution depends are:
• Traffic volume
• Average traffic speed (usually represented by the posted speed limit)
• Traffic composition (the percentage of heavy vehicles)
• Road gradient (the longitudinal slope of the road)
• Driving conditions (free-flowing, congested)
• Individual vehicle emissions (a combination of emissions produced by the engine, the fuel system, the braking system, and materials from the road surface distributed by the wheels and by air movement around the vehicle)
• Driver behavior and vehicle operating conditions (including air conditioner use, braking and acceleration patterns, gear operations, emission reduction technology, maintenance, aging, fuel quality, and ambient temperature) (Queensland Government, Department of Transport and Main Roads, 2014).

Movement and Dispersion of Air Pollutants

The movement and dispersion of air pollutants are influenced by a number of factors including (Queensland Government, Department of Transport and Main Roads, 2014):
• Road configuration (whether the road layout is at grade, depressed or elevated)
• Distance between the source and reception point
• Meteorological conditions (primarily wind speed, wind direction, and atmospheric stability)
• Type of intervening ground cover between source and reception point (surface roughness affects the wind speed profile and the potential for entrainment of particles)
• The existence of natural or artificial obstructions.

Significant Air Pollutants

The main parameters that have been traditionally used for the assessment of the air quality impact of traffic are as follows:
• Concentration of air pollutants in µg/m3 (or ppm or ppb for gases): the substances of greatest relevance with their anthropogenic sources can be observed in Table 3.
• Particulate deposition rates: the fallout rate of insoluble dust measured in g/m2/month or mg/m2/day. Fine particulates' (PM2.5) deposition rate is far slower than other particulates, and wind or other mechanical turbulence would lead to further dispersion. Therefore, they are believed to be responsible for most of the health effects of traffic air pollution (Queensland Government, Department of Transport and Main Roads, 2014).

Road-Traffic Air Pollution Impact on People

Children, the elderly, and patients are the most vulnerable groups to air pollution. Also, air pollution and exercise can be an unhealthy combination; this is especially true if you have asthma, diabetes, heart or lung conditions, or lower respiratory disease. Even when you are not exercising, exposure to air pollution can cause health problems. However, with the combination of air pollution and exercise, the potential health problems are increased. One reason for this increased risk may be that during aerobic activity, you usually inhale more air and breathe it more deeply into your lungs. The reason is that you are likely to breathe mostly through your mouth during exercise, and the air you breathe in generally bypasses your nasal passages, which normally filter airborne pollution particles (Laskowski, 2014).

Air pollutant impact on peoples' health issues is influenced by both the concentration of the substances and the duration of the exposure. Some substances have a rapid impact at high concentrations (for example, nitrogen dioxide can cause eye irritation and coughing) while others have a more chronic impact, which may occur at quite low concentrations (for example, benzene may cause cancer). However, some substances can cause both short-term and long-term impacts by different mechanisms (Queensland Government, Department of Transport and Main Roads, 2014). Therefore, certain land-uses (residential, educational, health-care centers and hospitals, public realms, and parks) need careful considerations in case of appraising the most sensitive users to air pollution along with a proposed road.

Table 3: Key air traffic-generated pollutants and their anthropogenic sources (Walker & Dalton, 2010)

Pollutant	Anthropogenic Sources
Carbon monoxide (CO)	Motor vehicles, fuel combustion
Carbon dioxide (CO_2)	Fuel combustion
Nitrogen oxides (NO_X)	Motor vehicles
Sulphur dioxide (SO_2)	Diesel vehicles
Volatile organic compounds (VOCs), *e.g.* benzene	Petrol-engine vehicle exhausts
Ozone (O_3)	Secondary pollutant formed from VOCs and nitrogen oxides
Particulates -dust, smoke, PM_{10}, $PM_{2.5}$	Diesel vehicles

Mitigation

Improved fuel combustion designs can reduce pollutant emissions, such as by using low nitrogen oxides burners in furnaces. In many cases, the type and amount of pollutants emitted are a function of the fuel being burned, so alternative fuels can be proposed, such as fuel oil with a very low Sulphur content or natural gas. Traffic-generated pollutants decrease rapidly away from roads, and this process can be enhanced by roadway trenching, embankments, walls and trees, to reduce the pollution concentrations in nearby residential areas (Walker & Dalton, 2010). At the receiver's end, some of the air pollutants can be kept away from new and existing buildings and their most sensitive areas through a number of architectural considerations. In conclusion, air pollution mitigation solutions are briefly possible as below:

- at the source
- between the source and receivers
- at receivers' end

Visual Intrusion

Any kind of new development would change the urban landscape to some extent. In order to assess the visual impacts of a proposed development especially an elevated highway, it is essential to define the scope and importance of the mentioned changes and appraise the receivers' response to them.

An urban landscape consists of all the information relating to that space including form, function, and meaning which are perceived by human beings differently; it briefly is a combination of two elements: physical and human. Physical elements (natural and human-made) are the container of human elements, which together provide the basis for our mental image of the city (Pakzad, 2007). Therefore, in case of visual impact assessment of a new development, we need to consider:

- The existing environment and the proposed changes
- Receivers' response to these changes

Viewers Groups

Visual impacts of transport projects are considered both in the view from the road and the view of the road. As long as in this paper the main focus is on neighbors of the elevated highway therefore, the main focus is on the view of the road. In fact, in urban areas, there may be many "eyes per mile" along the right-of-way of a proposed project. Physical location, and duration of the view along with the type, and number of viewers, and their distance to the proposed development are critical in case of visual impact assessment. However, there are two other principal factors affecting the degree to which viewers are likely to be receptive to the visual details, character, and quality of the surrounding landscape which are viewers' activity and awareness (Federal Highway Administration, 1986).

Visual Impacts of Elevated Highways (neighbors' point of view)

On the one hand, elevated highways in terms of form, color, and material are in low adaptation with the surrounding environment especially when they are located in residential layouts. On the other hand, their function is visually incompatible with the adjacent residential fabric. In addition, these elevated structures with their impressive scale are unconditionally dominant in the adjacent environment. Moreover, elevated highways appear as a barrier between neighborhoods; the closer to them, the more visual intrusion will be faced by neighbors. Also, visual impacts of locating signs and lighting equipment need to be carefully taken care of.

Visual Characteristics of Highways

The visual characteristics of highways noted earlier do have great importance in terms of distinguishing their visual impacts, and then mitigating them.

- Roadway, Roadside, and Right-of-way

Road surface including the number of travel lanes, their width, and pavement material and color, the coordination of horizontal and vertical curves, and even the shoulders are visually significant. The roadside includes all lands within the right-of-way that are not part of the roadway, but the visual characteristics of the roadside which are determined by the land cover and landform modifications employed to fit the roadway into the right-of-way. In other words, the appearance of the roadside helps to determine the visual scale and dominance of the highway.

- Structures, and Appurtenances

Structures divide in three parts: a) for the roadway itself (bridges, viaducts, tunnels, and their portals) b) grade separation structures (interchanges, overpasses, and underpasses), and c) slope retention and drainage structures (retaining walls, bin walls or gabions). Lights, signs, traffic control devices, and noise barriers are among the highway appurtenances that can have significant visual effects (Federal Highway Administration, 1986).

Mitigation

Appropriate design, form, material, lighting, and signs are some of the common mitigation measures, which can be considered for the elevated highway structure. Moreover, noise barriers design, and planting may serve to reduce the negative visual impacts of elevated highways between the structure itself and the viewers. Finally, architectural measures would help to remedy the mentioned impacts at the viewers' location. In conclusion, visual impacts mitigation solutions are briefly possible as below:

- at the structure
- between the structure and viewers
- at viewers' location

Safty Challenges

Nowadays, the human and financial costs of highway accidents have become a major threat to citizens and communities. As it has been mentioned several times, this paper's focus is on improving the conditions for the neighbors of the elevated highways. However, since the neighbors' safety depends on drivers' safety; therefore, travelers need to be considered in this section because it is necessary to investigate the vehicles diversion reasons from the highway path especially for elevated highways which dominate the adjacent environment,

and sometimes are very close to nearby buildings.
Diversion from the route is due to three factors: a) human b) route c) motor-vehicles. Except for the factors relating to vehicle technical deficiencies, the other factors can be sub-categorized as (Iran Ministry of Transportation, 2005):

- Sharp turns
- Road surface condition
- Speed limitation
- Roadside space
- Weather conditions
- Driver behavior

Mitigation

Like the other challenges, mitigation measures do have the best results at the source location. Therefore, providing a smooth surface with sufficient roughness, and suitable surface water discharge would help avoiding the probable accidents. In addition, appropriate sign location, lighting, and guard rails (especially in accident-prone areas) would increase road safety for drivers and prevent vehicle diversion from the route. Above all, the more the distance between the elevated highway and neighbors, the less we need to be worried about safety issues. Also, we may face noise barriers in the area between the elevated highway and neighbors, which need to be designed considering safety parameters. At neighbors' location, especially when they are very close to the elevated highway, all we can do is to protect the open spaces and openings with some architectural measures. In conclusion, safety impacts mitigation solutions are briefly possible as below:

- ■ at the highway
- ■ between the highway and neighbors
- ■ at neighbors' location

Social Challenges

New transport developments can cause community severance. Normally, all lost connections would be limited to a few pedestrian bridges, which are not practically efficient. However, elevated highways can exacerbate the situation because building another floor above an existing highway would affect negatively, or totally eliminate the visual connection between existing neighborhoods.
On the other hand, community severance would diminish the social relations within that community, and all the problems arising from adding a second floor to an existing highway, which partially has been discussed before, would gradually lead to gentrification, which brings about its own challenges for the community and society. In this case, sensitive social groups are prone to the highest social damages.
Last but not least, security problems need to be considered. Building elevated highways in residential fabrics where there are no active frontages nor enough surveillance over the route, would cause severe security issues especially on the edges which are not visible but hence, suitable for hiding and committing a number of crimes.
Considering many elevated highways that have been demolished and replaced recently, e.g., Cheonggycheon Elevated Highway in Seoul or Gardiner Expressway in Toronto, it is crystal clear that some of the social impacts of these infrastructures are irreversible and representing solutions to mitigate them would be so hard because of their complex nature. Therefore, this paper's concentration is on crime prevention through environmental design (CPTED) in order to improve the quality of living for the neighbors of elevated highways. The four CPTED principles are (Singapore National Crime Prevention Council, 2003):

- Natural surveillance
- Natural access control
- Territorial reinforcement
- Maintenance and management

Basic Design and Management Strategies
The four CPTED principles can be translated into various planning and design strategies that would enhance security. These strategies can be categorized as follows (Singapore National Crime Prevention Council, 2003):

- Allowing for clear line of sight
- Providing adequate lighting
- Minimizing concealed and isolated routes
- Avoiding entrapment
- Reducing isolation
- Promoting land use mix
- Using of activity generators
- Creating a sense of ownership through maintenance and management
- Providing signs and information and
- Improving overall design of the built environment

In case of elevated highways noted earlier we can apply these strategies mostly to:

- ■ the highway route
- ■ its surrounding
- ■ the neighbors' location

Case Study Introduction

Nearly three decades ago, Sadr highway was constructed to ease mobility in a west to east axis in north and north-east of Tehran. (Fig. 1) Even at that time the construction had some major difficulties including passing through residential neighborhoods, and topographical limitations. Anyway, this ease of mobility to east of Tehran resulted in developing many satellite towns over there, e.g., Pardis, Jajrood, Damavand, Roodehen, and Boomehen. However, these developments adversely affected the travelling demand in Sadr highway and made it fully congested.

Figure 1: Sadr highway (Esmaeili, 2013)

Based on evaluations and traffic-related studies, 40 percent of Sadr traffic congestion associated with trans-regional travels. Although four years ago (2011), traffic experts believed that directing these trans-regional travelers to a second floor and separating them from local travelers would best solve the traffic congestion in the existing ground-floor highway, my and many people's everyday experience has proved to be opposite. Generally speaking, this paper is not going to justify the reasons for or against building elevated highways or analyzing Tehran's traffic congestion issues. Therefore, considering the paper's aim, which is to mitigate the negative impacts of elevated highways for their neighbors, what follows is to assess the case study based on the literature review materials and results. As it was discussed, mitigation measures are applicable to a) the elevated highway and its appurtenances, b) between the elevated highway and neighbors, and c) nearby buildings. However, before examining these three, some of Tehran's meteorological conditions affecting air pollution will be discussed.

Wind (direction and speed)

Tehran's prevailing wind blows from the west with an average speed of 5.5 m/s. Although Sadr highway is located in its direction, many factors like scattered high-rise developments would change its direction and speed, and its effectiveness, which results in stagnant and persistent air pollution especially below the second floor of the elevated highway. In addition, there are anabatic breeze during daytime, and katabatic breeze during nighttime in the north-south direction, which disperse the air pollutants. Therefore, to some extent, northern and southern edges of the elevated highway are exposed to the movement of air pollutants during day and night.

Convection Currents

Convection currents can cause vertical movement of pollutants, which can be troublesome for nearby neighbors and even adjacent neighborhoods like Qolhak region. Unquestionably, one of the most important reasons of its current polluted condition is Sadr highway construction in the first place, and it will be even more polluted in the near future because of the Sadr elevated highway.

Inversion

Temperature inversion is a common meteorological phenomenon in Tehran cold seasons, which make the air pollution conditions worse. An elevated highway would increase the traffic volume, which indirectly exacerbates the negative impacts of the inversion.

Sadr Elevated Highway and its Appurtenances Analysis

Constructed in 2013, Sadr elevated highway, which is located approximately between Imam Ali and Modarres highways (Fig. 2), extends 6 kilometers in length. It provides easy access from the east to the west and vice versa for motor-vehicles (except for heavy vehicles, e.g., trucks, and buses) at a maximum 70 km/h speed. Qeytarieh and Kaveh interchanges link Sadr elevated highway with its surrounding urban fabric.

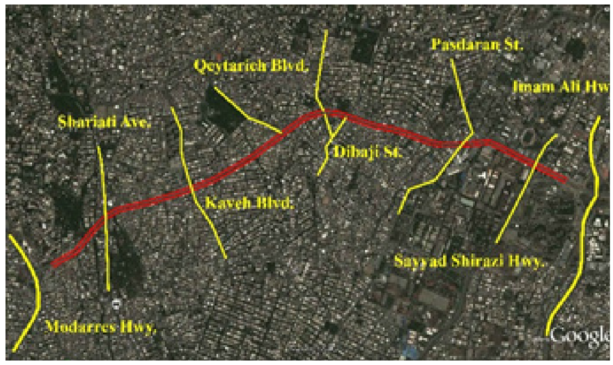

Figure 2: Sadr elevated highway location in red (Authors, Background map: Google earth, 2012)

Although, lack of appropriate hierarchy between them, has caused many traffic issues for the nearby neighborhoods.

What is more, its finished surface is 9.5 meters above the existing at-grade highway, which is even higher where it connects to the existing transport network (Qeytariyeh and Kaveh boulevards). (Fig. 3)

As it is obvious in Fig. 3, the giant scale of the elevated highway is not compatible with its surrounding layout; therefore, it causes visual intrusion for the adjacent neighbors. Also, distorted sight lines gradually form places, which cannot be surveilled; hence, it would result in the rise of criminal activities there; significant examples of this are pedestrian bridges, which have been located below the elevated highway deck, and need more thoughtful security considerations. In addition, these kinds of interchanges (Fig. 3) are prone to accidents, and can threaten neighbors' safety.

Noise barriers are the other important elements. What follows is to analyze Sadr elevated highway noise barriers:

Location: In principle, noise barriers must be located as close to the source of sound as possible (New South Wales

Government, 2006) which has been considered for Sadr elevated highway as it is obvious in Fig. 3, but just for some edges especially in interchange locations.

Regarding that the sound will reach a listener either directly (in a straight line) or indirectly by reflection or diffraction (New South Wales Government, 2006), these noise barriers at one side of the elevated highway cannot be efficient for the listeners on the opposite side.

Figure 3: Giant scale of the elevated highway structure, Qeytariyeh neighborhood (Tasnim, 2013)

Height: As a general rule, a barrier should at least be high enough to dissect the line between a point anywhere 1m above the road surface (on both carriageways) and a point 1.5m above the floor of an adjacent residence. Above all, on multi-lane roads, the noise from the furthest traffic lanes will not be reduced as much as that from the near lanes of the different path angles (New South Wales Government, 2006). It seems Sadr elevated highway noise barriers are not efficient enough in this criteria either.

Continuity: To be most effective, noise barriers must be continuous with no gaps in the vertical or horizontal plane (New South Wales Government, 2006). There are lots of gaps in Sadr elevated highway noise barriers (Fig. 4).

Material: When a low to moderate performance is required from a noise barrier, i.e. less than 10 dB reduction, the material from which the barrier is to be constructed is not critical from an acoustics perspective, but for noise reduction greater than 10 dB, material selection becomes more important; materials that have a surface mass of at least 10 kg/m² including concrete, fiber cement board, steel and timber are best for this purpose (NZ Transport Agency, 2010). According to Sadr noise barrier light materials, it is obvious that a low to moderate performance has been taken into account (Fig. 5).

Noise barriers and air pollution: Noise barriers located beside roads have the potential to affect pollutant concentrations around the structure by blocking initial dispersion, and increasing turbulence and initial mixing close to vehicles on the road. This can inhibit lateral air movements off the road, leading to elevated on-road and near-road pollutant concentrations which may also increase the exposure of commuters (such as pedestrians and cyclists) or sensitive members of the public (such as the young, sick, and elderly) to road-traffic pollutants (NZ Transport Agency, 2010). It seems that in Sadr elevated highway this negative impact would inevitably happen. However, it needs detailed quantitative assessments.

Noise barriers and visual intrusion: Regarding Fig. 3, totally transparent panels have been used at interchanges where a reduction in visual bulk has been required; while for the rest of the noise barriers, only the upper half of panel is transparent (Fig. 5) which indicates that visual issues have been one of the designers' concerns.

Figure 4: Discontinuity of Sadr elevated highway noise barriers (Ghorbani, 2013)

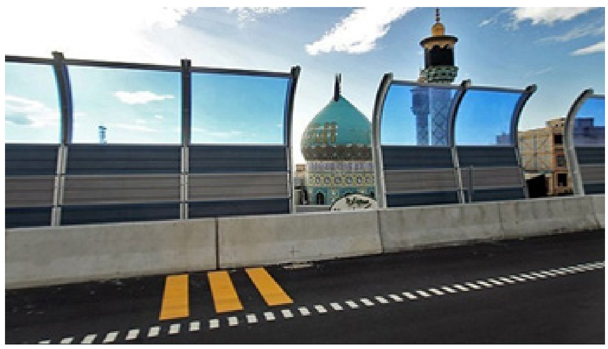

Figure 5: Sadr elevated noise barrier materials (Haghdoust, 2013)

Noise barriers and safety issues: Protection can be in the form of rigid (e.g. concrete), semi-rigid (e.g. guard rail) or flexible (e.g. wire rope) barriers. Where circumstances permit, modified concrete safety barriers can address both road safety and noise issues as a single cost-effective solution. Light reflection/glare to motorists can be a potential safety concern arising from noise barriers constructed from certain light reflective materials, e.g., metals, glass, acrylic, and polycarbonate (NZ Transport Agency, 2010). In Sadr elevated highway, noise barriers have been combined with concrete safety barriers, which sounds an appropriate choice.

Noise barriers and security issues: In case of noise barriers, the indirect risk of crime would be creating an unsafe environment for the public which somehow has been considered in the Sadr noise barriers by designing the upper half transparent providing surveillance to some extent.

Analyzing the Elements between the Elevated Highway and Neighbors

As long as Sadr elevated highway is too close to the surrounding urban fabric, there is not much between the elevated highway and the neighbors. Apparently, there are narrow rows of trees only in some specific locations at the northern edge of the elevated highway which is not even mentally efficient in terms of environmental mitigation measures most of the time.

Nearby Buildings

Around 90 percent of affected receivers at the northern and southern edges of Sadr elevated highway are residential and sensitive to noise and air pollution; the other 10 percent are concentrated at the east end of Sadr elevated highway.

According to Google earth map (Fig. 2), Sadr highway is not a straight east to west route. Therefore, there is not a dominant mass/space pattern on the north and south edges. However, on the south edge, there are masses (buildings) facing the elevated highway mostly, appearing as barriers between the elevated highway and their open spaces. While in some parts of the north edge the pattern is the same; in some other parts, first there are open spaces and then the buildings. Although in this pattern, the open space increases the distance between elevated highway and buildings, it is not protected against elevated highways' negative impacts.

It should also be noted that most of the existing buildings are at a distance of 5-25 meters from the edges of the elevated highway, which makes the situation even worse. Considering the elevated highway height from the at-grade existing highway, which is nearly as high as a three-story building, it is necessary to analyze the adjacent buildings height in comparison to the elevated highway and its interchanges. This can be categorized in three different situations. What follows explains the colors on the map of Fig. 6.

- Demonstrates low-rise buildings (up to 5 floors) which have been dominated by the elevated highway structure totally or to a large degree
- Demonstrates mid-rise buildings or low-rise on hills which are under the influence of the elevated highway structure, but are not dominated by its scale
- Demonstrates high-rise buildings at-grade or on an elevated position in comparison to the elevated highway structure which are not at all dominated by the elevated highway structure

According to Fig. 6, most of the neighbor buildings are dominated by the elevated highway structure, therefore, visual intrusion is inevitable. In this case, neighbors' safety is of great importance, too. Also, this positioning puts the buildings in an acoustic shadow of noise barriers and protects them against elevated highway-traffic noise.

Last but not least are building openings and walls. Observation has shown that nearly all the buildings on the edges of Sadr highway have some openings facing the elevated highway, which needs to be protected against all the negative impacts of elevated highways, which have been discussed in this paper. Finally, most of the materials, which have been used in buildings facades facing the elevated highway, do have a smooth surface. This avoids the building facades looking dirty all the time.

RESULTS AND DISCUSSION

Based on what has been discussed, it is time to set the objectives

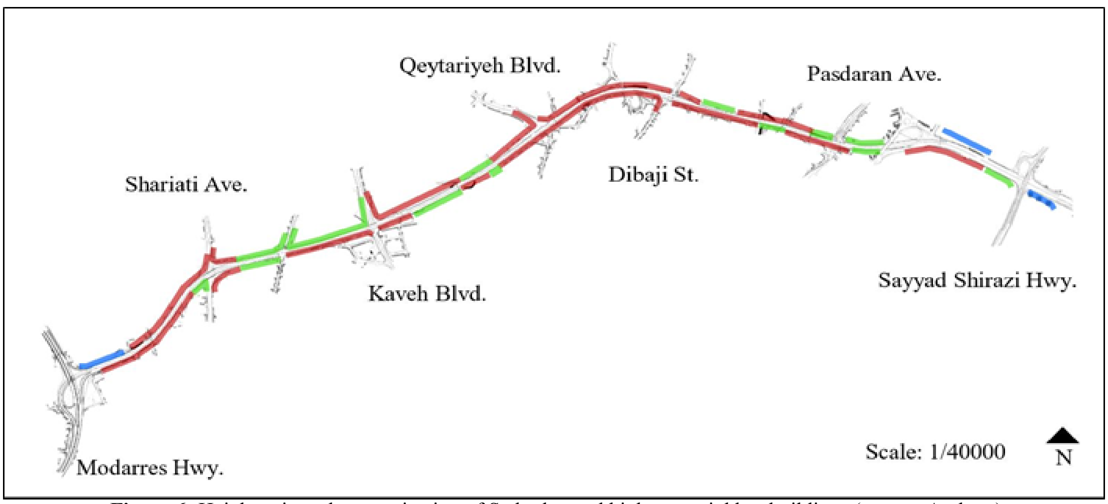

Figure 6: Height-oriented categorization of Sadr elevated highway neighbor buildings (source: Authors)

based on the main goal of this paper, and makes policies in terms of substantive and procedural in the operational stage.

Substantive objectives (operational stage)

■ Reducing environmental pollutions (noise and air pollution, and visual intrusion)

■ Improving safety issues

■ Improving security issues

Procedural objectives (operational stage)

■ Maintenance management

■ Public awareness

What follows is dedicated to developing policies based on these objectives: (Table 4 to 9)

CONCLUSION

Any kind of development especially transportation, brings about its own positive, and negative impacts. Despite the fact that new transport projects are seen as prospective new development success, in this paper it was tried to demonstrate how they can adversely affect their adjacent neighbors. This research has identified the challenges based on observation and field investigation. According to what has been discussed, elevated highways can cause many instant (e.g., noise pollution) and long-term (e.g., socio-economic) negative impacts for the neighbor residents. This paper tried to find out solutions and remedies for those instant negative impacts in order to improve the deteriorated quality of life for the residents.

Based on this study's findings, a) environmental challenges in terms of noise and air pollution, and visual intrusion, b) safety

Table 4: Noise pollution reduction policies (sorce: Authors)

Item (criteria)	Policy
Noise reduction at the source (elevated highway)	
Flooring	- use porous material with negative texture -avoid creating bumps and dents -apply suitable drainage
(Body structure (deck and piers	-avoid multiple noise reflection between the existing and elevated highway
Guard rail	-avoid aerodynamic noise
Noise reduction between the source and nearby buildings	
Noise barrier	-choose appropriate location -determine the suitable height, length, and materials -consider noise reflection reduction between noise barriers -apply careful detailing
Noise reduction at receivers' end (buildings)	
Land use	-consider accurate locating of residential & sensitive receivers
Mass & space	-avoid noise reflection between buildings & noise propagation in open spaces
Spatial relations inside building	-consider accurate locating of spaces based on appropriate noise thresholds
Window	-consider suitable location of windows and their openings -use laminated glass, double glazed windows or install a second window -apply proper sealing
Balcony	-consider accurate locating -use suitable materials for balcony handrail and ceiling -consider the possibility of balcony enclosure
Wall	-avoid using light materials -control noise reflection between high-rise buildings
Door	-use sturdy and thick materials -apply proper sealing
Ventilation	-use artificial ventilation systems

Table 5: Air pollution reduction policies (Authors)

Item (criteria)	Policy
Trapping air pollutants & avoiding their dispersion	
Noise barrier	-choose appropriate location -combine noise barrier design with vegetation -use of filter & catalyst
Vegetation	-plant vegetation & trees near the elevated highway
Mass & space (building)	-make a valley-shaped corridor by appropriate locating the mass of buildings
Air pollution remedies at receivers' end	
Land use	-consider accurate locating of residential & sensitive receivers
Mass & space	-locate buildings' mass near the elevated highway corridor & protect the open spaces
Window	-apply proper sealing -use anti-static window frames
Wall	-avoid materials with coarse texture & large pores
Door	-apply proper sealing
Ventilation	-use artificial ventilation systems -use filters

Table 6: Visual intrusion reduction policies (Authors)

Item (criteria)	Policy
Avoiding visual disturbances	
Lighting	-control glare and annoying lighting for the neighbors
Sign	-choose suitable location of signs
Noise barrier	-choose proper height, material & color regarding the environment nearby -avoid sudden changes in height and angles -choose suitable materials in places prone to graffiti -use vegetation in case of maintenance availability -integrate design of barriers with other appurtenances -avoid distorting favorable views
Visual quality improvement	
Body structure (deck and piers)	-use artistic designs for the elevated highway structure
Lighting	-use decorative lighting
Noise barrier	-use polished materials and suitable colors hiding dirt -combine noise barriers with vegetation
Vegetation	-plant trees and vegetation between elevated highway and nearby buildings
Building wall	-use polished materials to hide dirt -use polished materials and suitable colors hiding dirt

Table 7: Safety improvement policies (Authors)

Item (criteria)	Policy
	Avoiding Vehicles' diversion from the route
Flooring	-apply suitable drainage -use rumble strips just outside the travel lanes
Lighting	-apply appropriate lighting for the whole highway
Sign	-inform the travelers of places prone to accident -apply appropriate lighting
Guard rail	-apply guardrail reinforcement in places prone to accident
Noise barrier	-integrate safety guard rails design with noise barriers
	Securing adjacent neighbors
Window	-install safety guards
Mass & space	-consider the appropriate distance & locate buildings as far as possible

Table 8: Security improvement policies (Authors)

Item (criteria)	Policy
	Crime prevention through environmental design
Pedestrian bridge	-provide visibility -improve lighting -use warning signs -forecast emergency alarms & remote monitoring devices
Noise barrier	-consider suitable lighting -consider the appropriate line of sight in places where there is public access

Table 9: Procedural policies for maintenance management and public awareness (Authors)

Item (criteria)	Policy
	Regular visits with correcting defects
Flooring/ Highway appurtenances/ Lighting/ Guardrail/ Sign/ Pedestrian bridge	-maintain these in perfect condition
Noise barrier	-assess acoustic function -replace noise panels if necessary -keep the noise barriers clean
	Brochures
Pedestrian bridge	-raise awareness about the security conditions
Vegetation	-preserve the existing tress -encourage nearby residents to plant trees and vegetation
Building	-encourage nearby residents to use noise & air pollution reduction measures for windows & balconies -raise awareness about air conditioning advantages in polluted areas

issues, and c) security issues are amongst the most significant adverse effects elevated highways are predicted to produce for their neighbors, which affect residents' wellbeing physically and mentally, decreasing the quality of life in the vicinity of elevated highways. Analyzing Sadr elevated highway and its neighbors, we identified mitigation measures in terms of avoidance, reduction, and remedies in three main categories: a) the elevated highway itself, b) between the elevated highway and neighbors, and c) the neighbors' location. Finally, appropriate substantive and procedural policies have been represented to mitigate the mentioned adverse effects of elevated highways in favor of their adjacent neighborhoods.

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