BAU Journal - Creative Sustainable Development

Volume 3 | Issue 2
ISSN: 2664-9446

Article 9

May 2022

PARTIAL SYSTEMS' ANALYSIS OF TRAFFIC NOISE REDUCTION IN TARIK AL JADIDAH, BEIRUT

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Recommended Citation

El-Bastawissi, Ibtihal Y.; El Baba, Nour; Khalil, Shireen; El Hage, Nour; Joumblat, Rouba; and Gatzweiler, Franz (2022) "PARTIAL SYSTEMS' ANALYSIS OF TRAFFIC NOISE REDUCTION IN TARIK AL JADIDAH, BEIRUT," *BAU Journal - Creative Sustainable Development*: Vol. 3: Iss. 2, Article 9.
DOI: https://www.doi.org/10.54729/URLW9540
Available at: https://digitalcommons.bau.edu.lb/csdjournal/vol3/iss2/9

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PARTIAL SYSTEMS' ANALYSIS OF TRAFFIC NOISE REDUCTION IN TARIK AL JADIDAH, BEIRUT

Abstract

Traffic noise is considered one of the main pollutants in an urban space and has multiple side effects regarding the physical and mental health of the human being. Tarik Al Jadidah, one of the most densely populated neighborhoods in Beirut City- Lebanon, is selected as urban area for a project-based initiative and the focal point of different studies in BAU Urban Lab. The area suffers from various urban problems, but prominently traffic noise that highly damages the urban residents' quality of life due to its high levels of traffic noise that surpasses the World Health Organization (WHO) guidelines.

BAU Urban Lab, an interdisciplinary platform for innovation and knowledge exchange that integrates education with research has led a workshop entitled “System Modelling for Urban Health and Well-Being” held at BAU, Faculty of Architecture - Design and Built Environment. The paper proposes that Vester Sensitivity Model can be considered as a supportive decision-making tool responsible for finding the most effective variables related to Traffic Noise Reduction. The main aim of this paper is to identify the key variables affecting traffic noise reduction system through detecting the variables’ reciprocal impacts using Vester Sensitivity Model. It also depicted that the most influencing variables are those related to social, institutional, infrastructure, and resource flows of the city rather than its fixed physical infrastructure.

Keywords

Traffic Noise, Vester Sensitivity Model, Urban Health, Resilience, Urban Development, BAU Urban Lab

Authors

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This article is available in BAU Journal - Creative Sustainable Development: https://digitalcommons.bau.edu.lb/csdjournal/vol3/iss2/9

1. INTRODUCTION

Urbanization is a phenomenon that transforms the social and environmental landscape of every continent on a global scale. Besides natural urban demographic development, urbanization is a result of population migration from rural areas. For the first time in history, the world's population living in cities and towns exceeded 50 percent in 2007 and this proportion is increasing ("WHO | Urbanization and health", 2020). Moreover, the quality of global and local ecosystems, especially in the urban environment due to the uncontrolled urban spread, will have a tremendous impact on public health, with issues ranging from solid waste disposal, provision of clean water and sanitation, air pollution, urban poverty, in addition to traffic noise ("WHO | Urbanization and Health ", 2020).

Traffic is one of the main causes of noise pollution in urban areas. Traffic noise is an environmental problem caused by urbanization, industrialization and motorization that threatens human health, their well-being and which negatively affects the quality of life. Yet, it has a negative impact on the mental and physical health of a person. According to the World Health Organization, it leads to discomfort, sleep disturbance and hearing loss, etc... However, traffic noise pollution is mainly caused by vehicles and their engines and the tire-road surface interaction. This urban threat was significantly observed in Tarik Al Jadidah which is considered one of the most populated neighborhoods in the city of Beirut, Lebanon. It is an area that does not only suffer from heavy traffic, but also from high pedestrian density, which both caused an increasing noise level exceeded the World Health Organization (WHO) standards.

BAU Urban Lab strengthens the role of BAU in society through creating mechanism for the co-production of knowledge to develop innovative solutions for urban challenge and bringing societal urban agenda to the academic community. Nevertheless, the area of study "Tarik Al Jadidah", the problem "Traffic Noise", and the software "Vester Sensitivity Model" are enclaved in the framework in BAU Urban Lab. Tarik Al Jadidah was selected since it is on the priority list of Beirut Municipality. Specifically, Sulayman Al Boustany Street in Tarik Al Jadidah neighborhood hosts the main headquarter of Beirut Arab University and its campuses, and it has been the focus of different studies done previously by the Faculty of Architecture - Design and Built Environment.

The paper proposes that Vester Sensitivity Model is a supportive decision-making tool responsible for finding the suitable improving variables related to Traffic Noise Reduction that can help in identifying the most appropriate urban interventions to reduce traffic noise for a better quality of life, health and well-being in the framework of BAU urban lab. The paper aims to identify the key variables affecting traffic noise reduction system through detecting the variables' reciprocal impacts using Vester Sensitivity Model.

2. LITERATURE REVIEW

Traffic Noise is any unwanted sound that disrupt the quality of life of people caused by traffic. Noise levels are measured in decibels. As stated by the World Health Organization (WHO) noise must be recognized as a major threat to human wellbeing affecting both physical and mental health. traffic noise can cause heart diseases, hypertension, and carotid intima-media thickness, fatigue, migraine, cardiovascular problems, respiratory, and metabolic complications. The link between traffic noise and blood pressure may lead to myocardial infarction (Sorensa M. et al., 2012), non-adrenalin concentrations in urine, and pregnancy issues like pre-term birth as well (Nieuwenhuijsen, M. et al. 2017). Concerning the mental effects, it leads to annoyance, difficulties in communication, learning capabilities, concentration, teaching, and cognitive functions especially for children, sleep interference, stress, and tension (Evans, G.et al. 2001).

Moreover, traffic noise affects negatively the quality of life, and the housing prices. A study done in 2001 by a Scottish executive, has showed that housing prices were increased between 0.3% and 1.6% for every decibel (dB) increase in road traffic noise (The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study, January 2001). Roads are classified into three main types; a. urban or rural areas, b. local or collector and c. arterial road according to road functional class, or two-lane road, or a multi-lane road according to the number of lanes. Moreover, the noise standard level within city residential areas is 44-55db(A) in day time and 40-50db(A) according to the environmental noise guidelines (WHO, 2018)

2.1 Reducing Traffic Noise

The first is vehicle design: Engines, tires, latches can be designed to be quitter. The second category is related to traffic operations which consists of: 1) Routing/location: Avoid traffic in noise sensitive areas. 2) Speed: must be limited since noise increases with speed. 3) Traffic Density: each traffic division density reduces 3 decibels noise. 4) Traffic Flow: To be smooth encouraged (limited speed). 5) Reckless operation: Prohibit high-speed turns and spinning of tires.

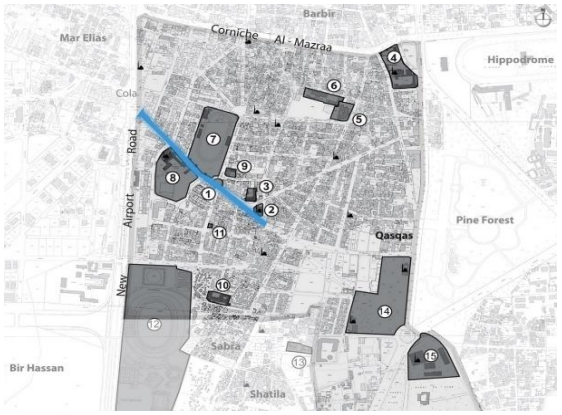
As for the third category, it is related to Road design: 1) make it gradient: each upgrade increase noise by 3 decibels. 2) Elevation: Place Road grade above or below listener level. 3) Tunnels decrease outside noise level. 4) Noise Barriers: walls and berms reduces 22 decibels of noise. 5) Paving: Smooth aggregates decrease noise level by 7 decibels. And at last, the fourth category is Planning of Land Use: 1) Roadway distance: Reflective areas and doubling distance between source and the listener reduce noise. 2) Width of the street: Noise increases in narrow streets. 3) Buildings layout and orientation: Noise is reduced by orienting most open sides away from noise source. 4) Insulating building: Windows are the weakest link in sound proofing.

2.2 Pilot Study Case: Tarik-Al-Jadidah Neighborhood

Tarik al Jadidah is one of the most densely populated neighborhoods located within the governorate of Beirut city (Fig. 2). It is a mixed-use area including public and private entities. It is important because of its prominent urban aspects which includes the municipal stadium, the sports city, and Beirut Arab University Campus. It is also a strategic region with commercial markets that serves many people from different regions as Figure 1 illustrates.

Fig.1:Maps showing the location of Beirut, Lebanon and then Tarik Al Jadidah in Beirut.
Source: Google Earth & Google Maps

It is one of the main educational and commercial street in Tarik Al Jadidah. The street receives thousands of visitors every day, either addressing the educational institute Beirut Arab University and various other secondary schools- or heading towards the shopping and commercial area along the middle to the end of the street (Fig 2). Yet, the street needs to be redesigned and redeveloped so that its fabric meets the needs of its inhabitants and visitors-in term of helping the region cop up the ever-increasing traffic and human needs.



1. Hassan Khaled Square
2. Ali Ben Abi Taleb Mosque
3. Omar Ibn al-Khattab School – Maqassed
4. Maqassed institutions: college, nursing home, secondary school, health clinic
5. Maqassed Hospital
6. The Social Welfare Institutions
7. Municipal Stadium and al-Ansar grounds
8. Beirut Arab Arab University
9. Al-Ansar Club
10. Islamic Hospital
11. Garage Darwish
12. Sports City
13. Hariri Schools II and III
14. Martyrs' Cemetery
15. Imam Mohamed Shamseddine Mosque & Complex

Fig.2: Map showing the land use map of Tarik Al Jadidah including Sulayman al Boustany Street (marked in blue)

2.3 Factors Affecting Traffic Noise in Tarik Al Jadidah

As for the case study, Sulayman Al Boustany Street in Tarik Al Jadidah is a two-lane, local road in an urban area. The materials used were PCC or Portland Cement Concrete; usually a mix of aggregates, water and Portland cement. The transmission loss of a sound for a 100 mm thick concrete barrier is 40 dBA. In addition to that, there were brick and masonry; another type of barrier materials. Blocks of dimensions 70x95x200mm are usually used. For a thickness of 150mm, the transmission loss is around 40 dB(A). Transparent panels are made of glass, for thickness of 50 mm, hence 45 dB(A) is reduced. Knowing that Tarik Al Jadidah is a residential area within the city, it could be concluded that the approximate existing noise level in Sulayman Al Boustany Street in Tarik Al Jadidah ranges between 76 dBA and 86 dBA during the day and 55 dBA and 73 dBA during night and early evening which exceeds the limit and standards of noise level in urban residential areas which should be between 45-55 day time and 40-50 Evening time.

After identifying the traffic noise problem in the selected zone, the factors that affect traffic noise were extracted and then related and implemented them in the application. Traffic, Context, Weather, Dwelling and Road Characteristics are the main five factors that affect traffic noise. Regarding traffic, it includes: Speed, flow and density of the traffic, traffic composition, behavior of the driver, and traffic fluidity (one way or two-way streets, traffic lights, signs, signals). As for context, it consists of: Height and inclined distance from the road to the recipient of the traffic noise, reflection of traffic noise, presence of screens (artificial or natural), and noise absorption. For the weather factor, it affects through Snow conditions or dry conditions or rain condition, and wind speed and direction. Living areas orientation, Windows size, and Noise attenuation through windows are conditions related to dwelling. And at last, road characteristics specify Road width, Type of road surface, Road gradient and road's curvature degree, and Road design (tunnels, bridges, embankment).

3. METHODOLOGY

To accomplish this aim, the research achieves several objectives. First, to create basic knowledge and data acquisition based on existing literature and sources about Vester sensitivity model. Second, to establish traffic noise reduction partial system analysis by defining variables that constitute the urban system according to specific criteria of analysis related to social, technological, and ecological dimensions of a city. Then, determining the interconnections of all variables to each of the others, based on a qualitative experts' knowledge of multidisciplinary researchers. Third, to understand the systemic role, which the variables have, and carrying out simulations; how the system behaves over time. Fourth, to find out the suitable improving variables related to social institutional infrastructure and resource flows of the city rather than fixed physical infrastructure of the city.

This paper follows a qualitative and quantitative research method. The workshop done and an inductive method provided a set of observations and data collection in addition to literature reviews. Then, the process of applying Vester Sensitivity Model on Tarik Al Jadidah helped in building a Partial System Analysis for Traffic Noise reduction that encompasses a Systematic Analysis.

The systematic analysis is composed of seven chronological steps to be discussed in the below section. In addition to that and after specifying the most influencing variables and in order to validate the practicality of the software applied on the traffic noise system, an analysis was conducted on two already suggested interventions in Tarik Al Jadidah neighborhood by the Faculty of Architecture Design and Built Environment.

3.1 Vester Sensitivity Model

Vester Sensitivity Model is a software invented by Frederic Vešter, The software is an approach to policy analysis and design. A trans-disciplinary modeling one used since 1980s where its computerized 'System Tools' are developed as a practical planning tool. Vester sensitivity model emphasizes on the basis of its interdisciplinary research on cells, on brains, on ecosystems, on economies and human-created systems of all kind, how these functioning systems are able to work with such great efficiency; analysis of causal

structures of interrelatedness real-world issues.The system is a recursive structure of the nine tools of the software, a replica of how evolutionary management works in nature. One of the main previous experiences of using vester sensitivy model is when it was used in Dhaka Bangladesh, as System Dynamics for Marginality Analysis, by BRAC Center, RED, Dhaka Bangladesh.

The System Applied in Tarik Al Jadidah was a process composed of seven main steps explained below through using Vester Sensitivity Model.

3.1.1 System description (the system problem)

Traffic Noise is the chosen system problem since it addresses health issues, urban issues, and enable collaborative intelligence building and collective learning. The system problem was defined based on a participatory method: Combining interrelated experts backgrounds and discussing how to reduce Traffic Noise which is a considered as a major urban problem in Tarik Al Jadidah.

3.1.2 Set of variables: variables selection & definition

Selecting and defining variables (Table 1) was based on previous studies, descriptive documents, secondary data, in addition to group discussions among multidisciplinary researchers including sociologists, urban designers, planners, architects and civil engineers about subjective heuristic knowledge regarding Traffic Noise, Vester tool, and Tarik al Jadidah as a case study.

Variables; system components, should be from "spheres of life": people, economy, space, human ecology, exchange with environment, resource flows, energy and waste, ways of communication & mobility (infrastructure), laws and culture…etc. The variables were selected in relation to:

- Location (Tarik Al Jadidah): Aspects, characteristics and specification, such as population, mobility, etc...
- Topic (Traffic Noise): Factors affecting traffic noise + reducing it like road width, paving, road design, etc..., and
- Expert's knowledge (Planners, engineers, Specialists): Factors affecting traffic noise + reducing it, similar to building heights, satisfaction of living, etc...

Table 1: The selected variables and their definitions

Var. #	Variables	Definitions
1	Number of Cars	The total number of cars parked and passing through a segment or a region (vehicle)
2	Population Density	The number of people living in each unit of area (inhabitant/km2)
3	Mobility	The total number of trips done daily by a single person (trips/person/day)
4	Green Space	Spaces including green areas and vegetation
5	Road Width	The width of travelled way and its component in a certain region (m)
6	Height of Buildings	The height of buildings in a certain region measured from the ground floor (m)
7	Wind Flow	Urban Corridor
8	Building Envelop	Outer envelope of the buildings
9	Transportation Type	Mode or means of transportation
10	Pavement Type	Type of pavement (concrete, asphalt)
11	Private/Public Area	Space available for private property Space available of general public (m2)
12	Traffic Noise	Unwanted sound derived from vehicles operating on roadways (dB)
13	Public Parking Space	Area or Space to park for general public (m2)
14	Intersections	Meeting points of two roads
15	Road Direction	Direction of traffic flow
16	Traffic Noise Regulation	Regulation or guidelines related to traffic noise
17	Traffic Calming Measures	Measures or design to reduce traffic noise

Var. #	Variables	Definitions
18	Flow of traffic (LOS)	Ratio of the Volume of traffic flow to the Capacity of the road; Degree of congestion.
19	Incomes Level	Flow of cash received or capital or land in a certain region
20	Speed of Cars	Distance traveled per unit time (km/h)
21	Land Use at GF	Function/activity occurring at the ground floor
22	Air Pollution	Presence of pollutant that is harmful in the ambient air
23	Noise Stress	Stress triggered by sound pollution
24	Fuel Prices	Pricing of gasoline or diesel
25	Demographic Distribution	Populations statistical study, distribution in response to birth, migration, aging & death
26	Road Maintenance	Remedying defects of roads, deterioration and distresses
27	Housing Prices	Index that measures the price of residential housing inn a certain region
28	Satisfaction of Living	Index that assesses feelings and attitudes about person's life at a certain time
29	Gender	Refers to the norms, roles and socially constructed characteristics of women and men
30	Traffic Behavior	Relationship between psychological processes and the behavior of road users
31	Traffic Law Enforcement	List of laws or amendments to prohibit the violation of rules and laws related to traffic

3.1.3 Defining inter-relationships/ draft interdependencies

This stage illustrates how the system components (the variables) will relate to each other as shown in Fig. 3. Based on the Group Discussions and expert's knowledge, the interrelationship between variables was proposed as a first step for conducting the impact matrix (Influence matrix).

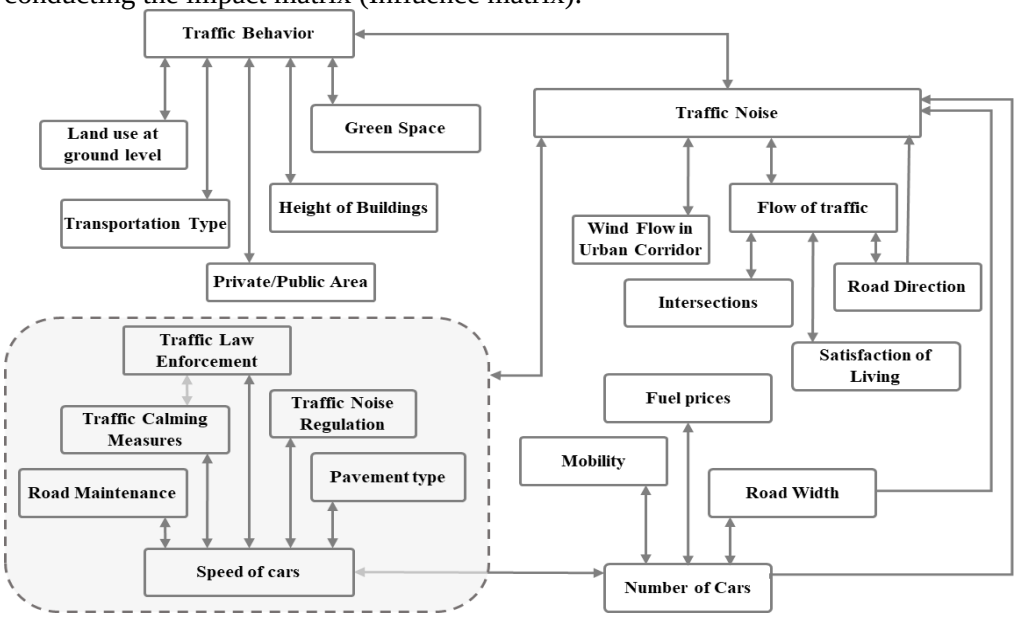


Fig.3:The draft interdependencies diagram is conducted based on interdisciplinary knowledge of the researchers

3.1.4 Formation of impact matrix (Influence Matrix)

After the Group Discussion, the impact matrix was conducted based on the following impact scales (Fig.4):

a. Making the Impact value scale

The Sensitivity Model uses impact values, which measure the strength of the impact of one variable on another. Those values mainly qualitative and they are qualified as having either no impact, an equally proportional impact, an under- or over proportional impact on another variable.

The quality of the impact is: **0** = no impact

1 = change of var1 has a weak impact on var2; under proportional impact (weak). A one unit change of var1 results in a "less than one" unit change of var2

2 = change of var1 has a medium impact on var2; proportional impact (medium)

3 = change of var1 has a strong impact on var2; over proportional impact (strong). A one unit change of var1 results in a "more than 1" unit change of var2.

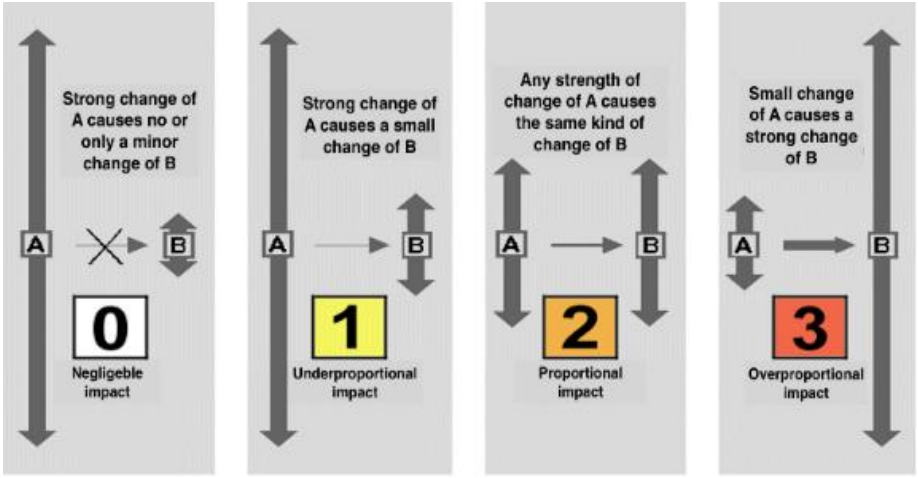


Fig.4: showing the Impact Value Scale to be applied in the impact matrix in Vester Sensitivity Model Software

It should be noted here that the values are specified base on experts' analysis and knowledge, on site Observations, and Statistics

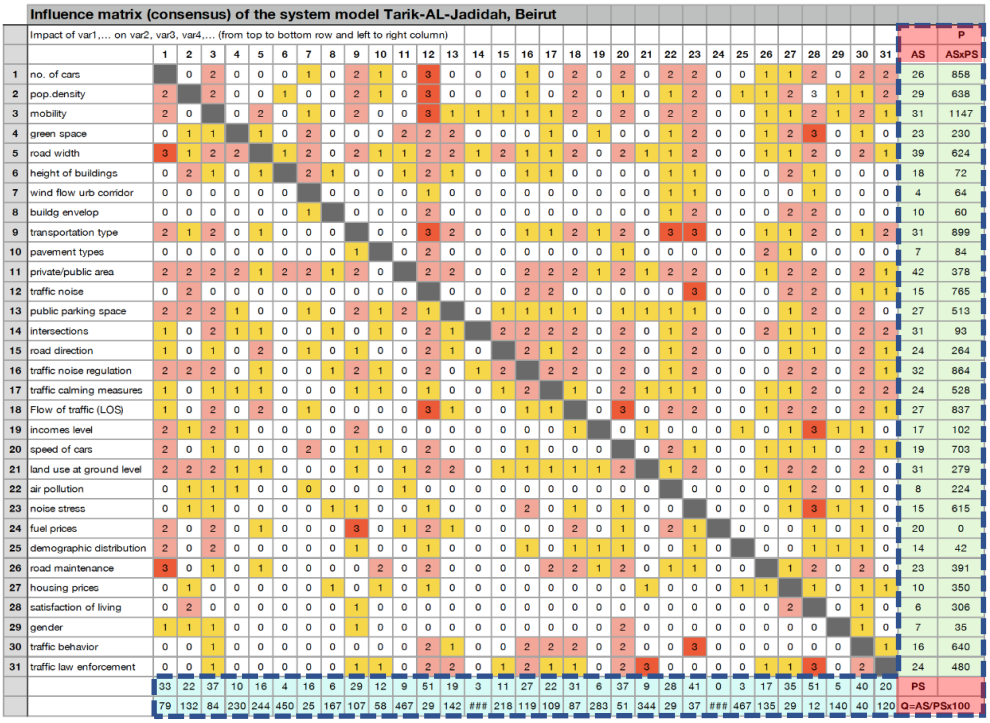
b. Defining the types of values in Vester Sensitivity Model and conducting the impact matrix (based on the discussion between the interdisciplinary researchers' which resulted the identification of the number and strength of impact of system variables on all others by using the impact value scale).The impact matrix is conducted from Vester software, it calculates 4 types of values, in order to define the systemic role of each variable: 1) the active sum, 2) the passive sum, 3) the Q- values and 4) the P-values. (Fig.5).

AS & PS Value: Variables with High AS value means that they impact on many other variables or their impact values are strong, or both. Variables with High PS value means that these variables are being impacted on by many others or few but with a strong impact value. If PS=0 means that it is not being influenced by changing any of the system variables.

P value: Variables with High P value means that it is Buffering variable with low interwovenness, important variable for stabilizing the system and making the system resilient.

Variable with Low P Value means that it is Critical variable with high interwovenness. This means variable is connected to many other variables in the system where this variable plays an important role in the system; changing them has a strong impact on all variables and can change the entire system.

Q value: If Q value > 1 → Active: Indicates that the variable is highly active. This means that they impact stronger on other variables of the system but are not as much impacted by other variables of the system. If Q value < 1 (and high PS value), Reactive: Means that a variable is more impacted on by other variables than it impacts on other variables. It still has a strong impact on a specific variable; however, its average systemic role is more passive than active.



Influence matrix (consensus) of the system model Tarik-AL-Jadidah, Beirut

Impact of var1,... on var2, var3, var4,... (from top to bottom row and left to right column)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	AS	P ASxPS
1	no. of cars		0	2	0	0	0	1	0	2	1	0	3	0	0	0	1	0	2	0	2	0	2	2	0	0	1	1	2	0	2	2	26	858
2	pop.density	2		2	0	0	1	0	0	2	1	0	3	0	0	0	1	0	2	0	1	0	1	2	0	1	1	2	3	1	1	2	29	638
3	mobility	2	0		0	2	0	1	0	2	0	0	3	1	1	1	1	1	2	0	2	0	2	2	0	0	1	1	2	1	2	1	31	1147
4	green space	0	1	1		1	0	2	0	0	0	2	2	2	0	0	0	1	0	1	0	0	1	2	0	0	1	2	3	0	1	0	23	230
5	road width	3	1	2	2		1	2	0	2	1	1	2	2	1	2	1	1	2	0	2	1	1	2	0	0	1	1	2	0	2	1	39	624
6	height of buildings	0	2	1	0	1		2	1	0	0	1	2	1	0	0	1	1	0	0	0	0	1	1	0	0	0	2	1	0	0	0	18	72
7	wind flow urb corridor	0	0	0	0	0	0		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	4	64
8	buildg envelop	0	0	0	0	0	0	1		0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	2	2	0	0	0	10	60
9	transportation type	2	1	2	0	1	0	0	0		0	0	3	2	0	0	1	1	2	1	2	0	3	3	0	0	1	1	2	0	1	2	31	899
10	pavement types	0	0	0	0	0	0	0	0	1		0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	2	1	0	0	0	0	7	84
11	private/public area	2	2	2	2	1	2	2	1	2	0		2	2	0	0	2	2	2	1	2	1	2	2	0	0	1	2	2	0	2	1	42	378
12	traffic noise	0	2	0	0	0	0	0	0	0	0	0		0	0	0	2	2	0	0	0	0	0	3	0	0	0	2	2	0	1	1	15	765
13	public parking space	2	2	2	1	0	0	1	0	2	1	2	1		0	1	1	1	1	0	1	1	1	1	0	0	0	1	2	0	2	0	27	513
14	intersections	1	0	2	1	1	0	0	1	0	1	0	2	1		2	2	2	2	0	2	0	1	2	0	0	2	1	1	0	2	2	31	93
15	road direction	1	0	1	0	2	0	1	0	1	0	0	2	1	0		2	1	2	0	2	0	1	2	0	0	0	1	1	0	2	1	24	264
16	traffic noise regulation	2	2	2	0	1	0	0	1	2	1	0	2	0	1	2		2	2	0	2	0	1	2	0	0	0	2	2	0	2	1	32	864
17	traffic calming measures	1	0	1	1	1	0	0	0	1	1	0	1	0	0	1	2		1	0	2	1	1	1	0	0	1	1	2	0	2	2	24	528
18	Flow of traffic (LOS)	1	0	2	0	2	0	1	0	0	0	0	3	1	0	0	1	1		0	3	0	2	2	0	0	1	2	2	0	2	1	27	837
19	incomes level	2	1	2	1	0	0	0	0	2	0	0	0	0	0	0	0	0	1		0	1	0	0	0	1	0	1	3	1	1	0	17	102
20	speed of cars	2	0	1	0	0	0	2	0	1	1	0	2	0	0	0	1	0	0	0		0	2	1	0	0	1	1	1	0	2	1	19	703
21	land use at ground level	2	2	2	1	1	0	0	1	0	1	2	2	0	1	1	1	1	1	1	2		1	2	0	0	1	2	2	0	2	0	31	279
22	air pollution	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		0	0	0	0	1	2	0	1	0	8	224
23	noise stress	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	2	0	1	0	1	0	0		0	0	0	1	3	1	1	0	15	615
24	fuel prices	2	0	2	0	1	0	0	0	3	0	1	2	1	0	0	0	0	2	0	1	0	2	1		0	0	0	1	0	1	0	20	0
25	demographic distribution	2	0	2	0	0	0	0	0	1	0	0	1	0	0	0	1	0	1	1	1	0	0	1	0		0	0	1	1	1	0	14	42
26	road maintenance	3	0	1	0	1	0	0	0	0	2	0	2	0	0	0	0	2	2	1	2	0	1	1	0	0		1	2	0	2	0	23	391
27	housing prices	0	1	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1		0	1	1	10	350
28	satisfaction of living	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2		0	1	0	6	306
29	gender	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0		1	0	7	35
30	traffic behavior	0	0	1	0	0	0	0	0	0	0	0	2	1	0	0	2	2	2	0	2	0	0	3	0	0	0	0	0	0	0		1	16	640
31	traffic law enforcement	0	0	1	0	0	0	0	0	1	1	0	2	2	0	1	2	1	1	0	2	3	0	0	0	0	1	1	3	0	2		24	480
		33	22	37	10	16	4	16	6	29	12	9	51	19	3	11	27	22	31	6	37	9	28	41	0	3	17	35	51	5	40	20	PS	
		79	132	84	230	244	450	25	167	107	58	467	29	142	###	218	119	109	87	283	51	344	29	37	###	467	135	29	12	140	40	120	Q=AS/PSx100	

Fig.5: A Screenshot from vester sensititvty software showing the impact matrix of system model Tarik al Jadidah

c. Active and Passive Variables; Strength of Impact Types

The Illustration from Vester software (Fig. 6) showing the Active variables that indicate how much the variables affects other variables and the Passive variables show how much the variable is being affected by other variables.

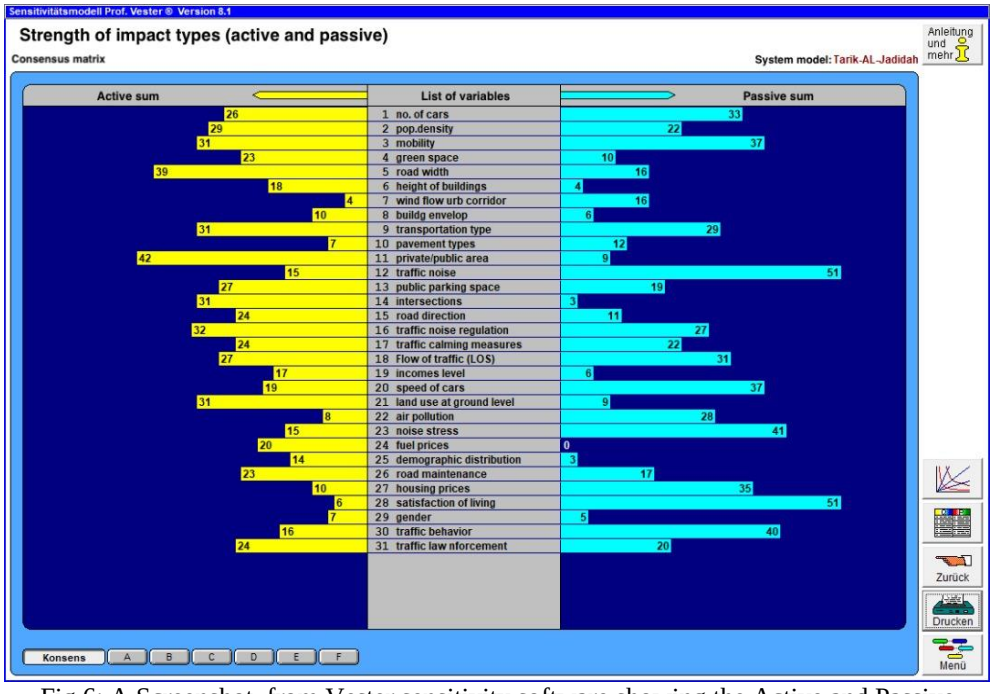


Fig.6: A Screenshot from Vester sensitivity software showing the Active and Passive Variables affecting traffic noise,

3.1.5 Formation of table showing PS, AS, Q and P values of all variables

By using Vester Sensitivity Model Software, the impact values: PS, AS, P and Q values of all variables are summarized in a table illustrated by the Authors in order to identify the most influencing variables and lever variables impacting the target variable (var12: traffic noise) (Table 2).

3.1.6 Systemic role and effect system

Using Vester sensitivity model, a systemic role diagram (Fig.7) was extracted and it shows to what extent the whole system is connected. It shows the variables if they are in the critical or buffering zone or whether they are in the active or reactive zone depending on the Q and P values.

The effect system diagram (Fig.7) is conducted as well and it shows actual interrelation between the variables. This network is to be built up on basis of the impact matrix with this, another way of visualizing the system's interrelation starts and thus the recognition of main focuses, structures, patterns.

Note: Variables in the 'critical' systemic role area have high P-values. Changing them (using them as a lever or for intervening) has a strong impact on all other variables and thereby changes the entire system strongly. Variables in the 'buffering' systemic role area have low P-values. They are less interconnected to all other variables. Changing them does not affect the entire system as strongly as changing more active variables. They are important for stabilizing the system and making the system more robust or resilient. In the case of Tarik Al Jadidah, the systemic role diagram reflects that the system proposed is Resilient, changing a variable does not collapse the system, and thus Effective variables are easily managed.

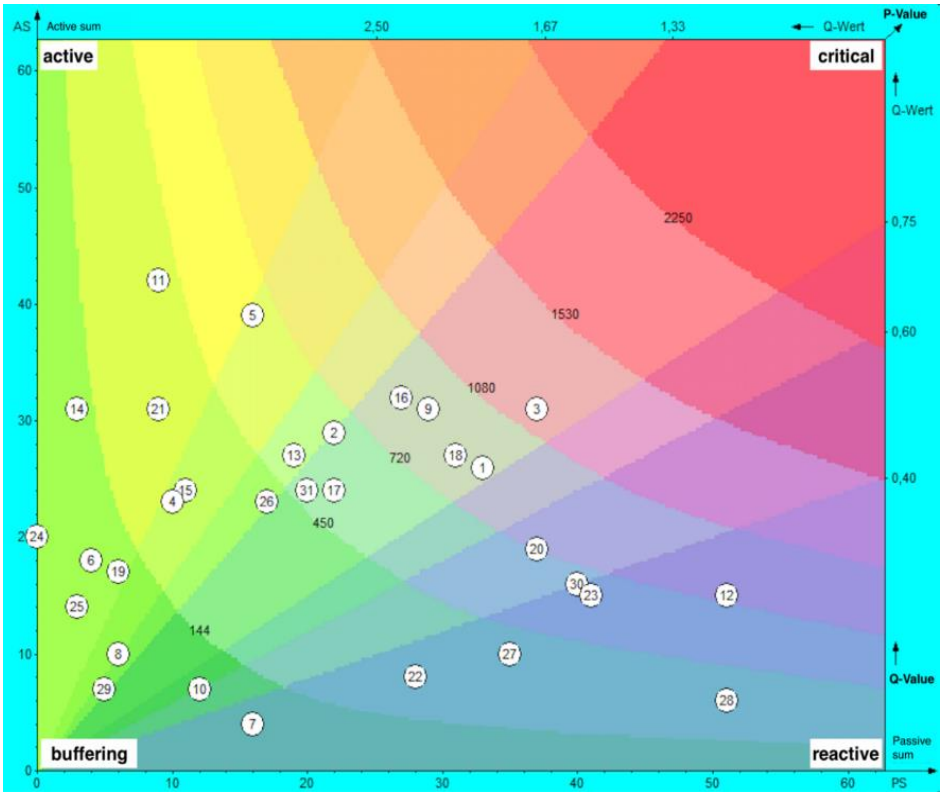


Fig.7: A screenshot of the Systemic Role Diagram of the system model Tarik Al Jadidah Beirut Lebanon from Vester Sensitivity Model

Table 2: Variables with Q value, P value, AS values, and PS value, and its impact on Var. 12 (Traffic Noise) using Vester Sensitivity Model

Variable #.	Variables	Q-value	P-value	AS	PS	Impact value on Var12
1	No of cars	0.79	858	26	33	3
2	Pop. density	1.32	638	29	22	3
3	Mobility	0.84	1147	31	37	3
4	Green space	2.30	230	23	10	2
5	Road width	2.44	624	39	16	2
6	Height of buildings	4.50	72	18	4	2
7	Wind flow: urban corridor	0.25	64	4	16	1
8	Building envelope	1.67	60	10	6	2
9	Transportation type	1.07	899	31	29	3
10	Pavement types	0.58	84	7	12	2
11	Private/public area	4.67	378	42	9	2
12	Traffic noise	0.29	765	15	51	
13	Public parking space	1.42	513	27	19	1
14	Intersections	10.33	93	31	3	2
15	Road direction	2.18	264	24	11	2
16	Traffic noise regulations	1.19	864	32	27	2
17	Traffic calming measures	1.09	528	24	22	1
18	Flow of traffic (LOS)	0.87	837	27	31	3
19	Income levels	2.83	102	17	6	0
20	Speed of cars	0.51	703	19	37	2
21	Land use at ground level	3.44	279	31	9	2
22	Air pollution	0.29	224	8	28	0
23	Noise stress	0.37	615	15	41	1
24	Fuel prices		0	20	0	2
25	Demographic distribution	4.67	42	14	3	1
26	Road maintenance	1.35	391	23	17	2
27	Housing prices	0.29	350	10	35	1
28	Satisfaction of living	0.12	306	6	51	0
29	Gender	1.40	35	7	5	0
30	Traffic behavior	0.40	640	16	40	2
31	Traffic law enforcement	1.20	480	24	20	2
Average				21	21	2

Legend:

- Variables that have proportional impact on traffic noise; var12, they cannot be easily changed, which is shown by their low PS-value yet they are not impacted strongly by others, and unsuitable as lever variable.
- Most Influencing Variables, those which impact more on others than others impact on them, i.e. Q-values > 1. To reduce the likelihood of unintended changes when changing the lever variable.
- Target Variable TV: Traffic Noise

Specification of most influencing variables

The conducted impact matrix and systemic role diagram configured the most influencing Variables in the system model impacting on target variable (variable 12: traffic noise) and configuring the lever variables.

The most influencing variables for changing certain aspects or behaviors of the system and having the highest impact on traffic noise comes from those variables listed in the table below (Table 3); yet they are those:

- which are part of the system (PS>0)
- have a direct impact on the target variable (impact values > 0, in column of the impact matrix for the target variable)
- are not too much interconnected to all other variables in the system (average or below average P-value); or higher P-value for only those variables closer connected to the target variable (traffic noise)

- are not impacted on by the target variable more than they impact on the target variable that means Q-values>1
- have a positive (desired) impact value on the variable to be changed
- have a positive impact on other variables they are connected to (creating co-benefits).

Table 3: The most influencing variables deducted based on analysis in Vester Sensitivity Model

Var. #	Description	Impact value on var-12 (Traffic Noise)	PS values	Q-values > 1	Recommended lever variables
1	No. of cars	3	33	0.79	
2	Pop. density	3	22	1.32	X
3	Mobility	3	37	0.84	
9	Transportation type	3	29	1.07	X
10	Pavement type	2	12	0.58	
15	Road direction	2	11	2.18	X
16	Traffic noise regulation	2	27	1.19	X
18	Flow of traffic	3	31	0.87	
20	Speed of cars	2	37	0.51	
26	Road maintenance	2	17	1.35	X
30	Traffic behavior	2	40	0.40	
31	Traffic law enforcement	2	20	1.20	X

Analysing the Q and P values

The qualifications 'active', 'reactive', 'critical' and 'buffering' are derived from the ratio and product of the impact values which inform about how much a variable impacts on others and is being impacted on by others. Those values are calculated from the number and strength of their impact.

Table 4 : Q & P values Result Table conducted from Vester Sensitivity Model

Var.		Q-value		Var.		Q-value
Highly active				**Highly critical**		
24	Fuel prices	-			-	
14	Intersections	10.33		**Critical**		
25	Demographic Distribution	4.67			-	
11	private/public area	4.67		**Slightly Critical**		
6	height of buildings	4.50		3	Mobility	1147
21	Land use at ground level	3.44		**Neutral**		
19	Income level	2.83		9	Transportation type	899
Active				16	Traffic noise regulation	864
5	Road width	2.44		1	No. of cars	858
4	Green space	2.30		18	Flow of traffic (LOS)	837
15	Road direction	2.18		12	Traffic noise	765
8	Building envelope	1.67		**Weakly Buffering**		
5	Road width	2.44		20	Speed of cars	703
Slightly Active				30	Traffic behavior	640
13	Public parking space	1.42		2	Population density	638
29	Gender	1.40		5	Road width	624
26	Road maintenance	1.35		23	Noise stress	615
Neutral				17	Traffic calming measures	528
2	Population density	1.32		13	Public parking space	513
31	Traffic law enforcement	1.20		31	Traffic law enforcement	480
16	Traffic noise regulation	1.19		**Buffering**		

Var.		Q-value		Var.		Q-value
17	Traffic calming measures	1.09		26	Road maintenance	391
9	Transportation type	1.07		11	private/public area	378
18	Flow of traffic (LOS)	0.87		27	Housing prices	350
3	Mobility	0.84		28	Satisfaction of living	306
1	No. of cars	0.79		21	Land use at ground level	279
Slightly Reactive				15	Road direction	264
	-			4	Green space	230
Reactive				22	Air pollution	224
10	Pavement type	0.58		**Strongly Buffering**		
20	Speed of cars	0.51		19	Income level	102
30	Traffic behavior	0.40		14	Intersections	93
Strongly Reactive				10	Pavement type	84
23	Noise stress	0.37		6	height of buildings	72
12	Traffic noise	0.29		7	Wind flow urban. corridor	64
22	Air pollution	0.29		8	Building envelope	60
27	Housing prices	0.29		25	Demographic distribution	42
7	Wind flow urban. corridor	0.25		29	Gender	35
28	Satisfaction of living	0.12		24	Fuel prices	0

After analyzing the above table (Table 4), it was concluded that there is no high or critical variables, but few reactive variables and 17/31 variables are buffering

3.2 Vester Applicability on Proposed BAU Urban Solutions in Tarik Al Jadidah, Beirut Lebanon

In order to validate the system model of traffic noise, an analysis was conducted on two already suggested proposals of interventions in Tarik El Jadidah (Sulayman al Boustany street) based on the most influencing variables related to traffic noise in Vester sensitivity model. The proposals are done by the Faculty of Architecture, Design and Built Environment. The aim of this analysis is to prove the effectiveness of the Vester tool in the decision-making, and in guiding the best plan for traffic noise reduction in Tarik Al Jadidah. Both proposals aimed to improve the social, economic and urban aspects of the street through different approaches, in order to enhance the health and the wellbeing of the residents of the neighborhood and its visitors. The proposals have tackled different urban issues in the street, including traffic noise. Due to the interconnection present between traffic noise with the other urban problems, we are going to fully assess each proposal. The analysis is based on the recommended levers for improving traffic noise in Tarik-Al-Jadidah concluded from the partial analysis of the system.

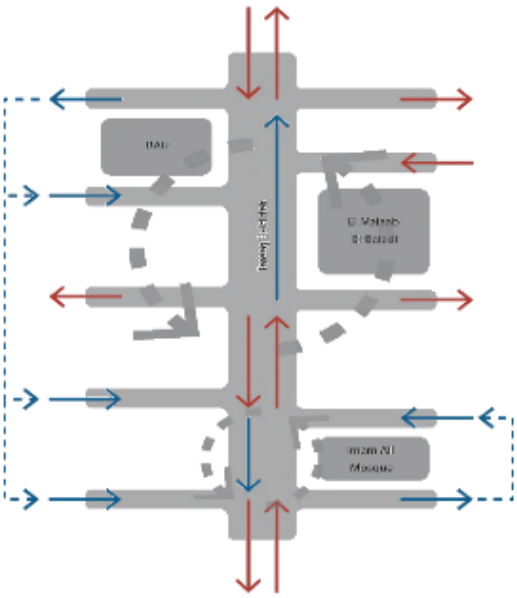


Fig.7: Traffic flow diagram for proposal one
Source: BAU Urban Lab, 2018

Proposal 1 interventions:

1) Turn the street into a partial roundabout system road through the tertiary streets to distribute the traffic flowing along one street
2) It increases street furniture: street scape fixture, benches'
3) It provides more organized parking spaces around the transitional zone between the gateway and the detour zones
4) It tries to improve pavements: quality and design
5) It offers new green spaces
6) Expand the transitional Zone between the university and its surrounding through adding commercial Kiosks and adding parametric urban furniture produced by the university.

A diagram for the proposed traffic flow is illustrated in Fig. 8.

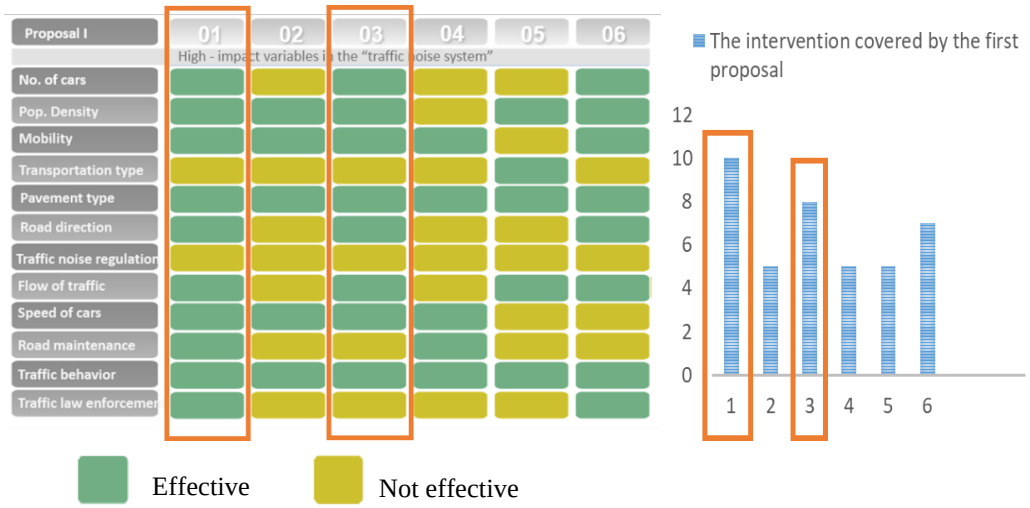


Fig.8: Assessment Table and chart showing the effective variables impact

The assessment table (Fig 9) showed that, "Turning it into partial roundabout system road through the tertiary streets to distribute the traffic flowing along one street" (1) and creating "More organized parking spaces around the transitional zone between the gateway and the detour zones "(3) are the most effective interventions for traffic noise reduction

Proposal 2 interventions:

1) Turn the street into one way road.
2) It creates new bus stops
3) It creates organized parking lots above and underground the road
4) It creates taxi point stops
5) It provides new green spaces
6) Design a pedestrian corridor equipped with new urban furniture

Figure 10 represents a sketch for the interventions that proposal 2.

The assessment table (Fig 11) showed that, "Turn it into one way road" (1) and "Design a pedestrian corridor equipped with new urban furniture (lighting, trees, outdoor benches, park meters, signs, bollards, bins, flower boxes, telephone cabins, new landmark statues and bike parking"(6) are the most

Fig.9: A sketch for proposal two
Source: BAU Urban Lab, 2018

effective interventions for traffic noise reduction.

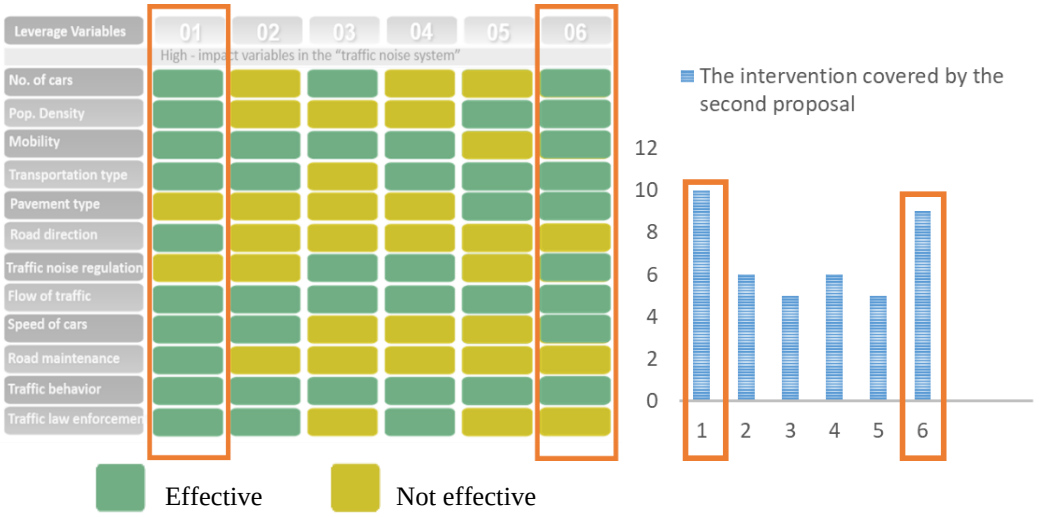


Fig.10: Assessment Table and chart showing the effective variables impact

As a result of both assessments, it could be seen that the two proposals are effective in the reduction of "Traffic noise", but mainly there is a couple of interventions that will majorly play a role in reducing "Traffic noise".

Therefore, it can be concluded that Vester sensitivity model, helped in identifying the most appropriate interventions, in order to achieve our goal effectively for a better quality of life, health and well-being. Hence, it proves how important it is as a decision-making tool in in the hand of the authorities responsible for finding solutions and implementing improvements.

4. RESULTS AND CONCLUSIONS

The results of this research were directed mainly towards the software, from the partial systems analysis, the variables which have a strong direct impact on the target variable; traffic noise, could be identified. The suitable levers for improving traffic noise in Tarik-Al-Jadidah are those which do not belong to the fixed physical infrastructure of a city, but rather belong to the social-institutional infrastructure and the resource flows of a city such as the number and flow of people and cars, as well as rules and regulations, behaviors, maintenance of roads and law enforcement.

Out of all, a set of conclusions that deals with traffic noise, its affecting variables, and the role of Vester Sensibility as a software to assist urban problems can be set. It was found that traffic noise is an urban problem that has direct negative influence on both mental and physical health of human beings. After discussing this urban problem, it was concluded that it is a system of different factors. The factor that affects traffic noise are not only related directly to traffic and roads but also to other urban considerations like the land use at ground level and public private areas.

As for the selected software, Vester sensitivity model can be considered a complimentary tool, which leads to a comprehensive investigation regarding any problematic and it is able to find a wider set of solutions. It is an interactive system not only built from the viewpoint of experts, but it engages the individuals involved in these systems. It is a mechanism to replace doubt with certainty. And thus, it can be considered as a supportive decision and assessment tool to help decision-makers, as well as it provides the audience with necessary arguments in the process of transparency and accountability.

5. RECOMMENDATIONS

Since the research deals with Traffic Noise as an urban problem facing urban residential zones, thus it targets different parties. Each one of these parties has a major role to play in order to minimize the negative impact of traffic noise and consequently aim after a better level of urban health and wellbeing as follows:

- Local Authorities: Governmental and Nongovernmental
  - Consider more development plans about Tarik Al Jadidah; the case study since any modification in its existing condition may affect Traffic noise.
  - Consider the variables that directly matches with the responsibilities of the local authorizes in charge such as the municipality and law enforcement forces. These variables are related to the Transportation type, Private/public area, Public parking space, Traffic noise regulations, Traffic calming measures, Speed of cars, Fuel prices, Road maintenance, Satisfaction of living, Traffic law enforcement
- Professionals and academics: Urban designers and planners, and researchers
  - This analysis is based on a partial systems analysis with data including the number and strength of impacts of system variables on another. It is recommended to build a complete system model to deepen the analysis in order to better understand the impacts' changes of the variables on the system as a whole.
  - Conduct further research about Tarik Al Jadidah; the case study, mainly from an academic point of view since the topic is interrelated with many different domains and so reducing its impact might be considered as a sub aim for different conducted researches.
  - Vester sensitivity model is an effective software recommended to be implemented in BAU Urban Lab.
  - Shed more light on the variables related to urban design and planning, those include:
  - Green Space, Road Width, Height of Buildings, Building Envelop, Transportation Type, Pavement Type, Land Use at GF
- The public: Inhabitants
  - Inhabitants as well have a great role to play in order to reduce traffic noise since they can in a way or another interact with these variables: Number of Cars, Mobility, Traffic Noise Regulation (Applying the rules), Traffic Noise Regulation (Applying the rules), Traffic Behavior

It is clear that there are a set of actions that even if considered personal initiatives yet still have a notable influence on the degree on traffic noise produced.

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