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Investigation of Factors Affecting Recovery Priority of Roads Damaged by Natural Disasters/Armed Conflicts

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ABSTRACT

Natural disasters/armed conflicts can cause major damage to road networks of the affected area. This can lead to significant impact not only on the road networks. The major challenge in the aftermath of such events is to ensure a speedy recovery/rehabilitation of roads and transportation networks so that regeneration can commence in an effective manner. Prioritizing regeneration of the road network may need context of a range of requirements including health, education, security, and economic amongst many that will also require addressing. This study has been conducted to give a better understanding of major factors that govern road recovery prioritization across the affected region in Iraq. These factors need to be used in an effective and efficient manner that can help in determining the road recovery priority.

Interviews and a questionnaire survey are conducted with experts in road reconstruction and maintenance organisations to investigate the impact of the important proposed affecting factors that can be critical for determining the recovery priority of damaged roads. Five estimated groups of factors have been included in this study, which are: socio-economic, road network, traffic, damage and financial factors. Each group also consists of a number of estimated sub-group factors. As a result, twenty nine factors have been chosen in this study.

It has been found from the results of the interviews and questionnaire that the proposed factors and factor groups are with a level of importance of high and very high. This indicates that the groups and factors included in this study are important for the successful building and implementation of the process and procedures of the road recovery priority in the road rehabilitation projects.

Each estimated factor within each proposed group used in this study contributes a different weight value to the overall road recovery priority. According to the questionnaire's results, the most important factors are: number of critical socio-economic facilities, type of road, delay time, severity of damage and effect on the economic. Moreover, a different weight has been contributed by each estimated group. Based on the questionnaire results, it was found that the major contribution is from the financial factor group.

Keywords: Disasters/armed conflicts, Road recovery factors, Road recovery Prioritization.

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بحث العوامل المؤثرة على أولوية اعمار الطرق المتضررة بسبب الكوارث الطبيعية/الصراعات المسلحة

الخلاصة

الكوارث الطبيعية/الصراعات المسلحة ممكن أن تسبب أضرار كبيرة لشبكات الطرق في المنطقة المتضررة. وهذا يمكن أن يؤدي إلى تأثير كبير ليس فقط على شبكات الطرق. التحدي الرئيسي في أعقاب هذه الأحداث هو ضمان الاعمار/اعادة التأهيل العاجل للطرق وشبكات النقل بحيث يمكن للتجديد أن يبدأ بطريقة فعالة. أولوية التجديد لشبكة الطرق تحتاج لمجموعة من المتطلبات بما في ذلك الصحة, التعليم, الأمن والاقتصاد التي بدورها تتطلب التحديد. تم اجراء هذا البحث لإعطاء فهم أفضل للعوامل الرئيسية التي تحكم تحديد أولوية اعمار الطرق في جميع أنحاء المنطقة المتضررة في العراق. هذه العوامل تحتاج إلى استخدامها بطريقة فعالة وكفوءة بحيث يمكن أن تساعد في تحديد أولوية اعمار الطريق.

تم اجراء المقابلات والاستبيان مع خبراء في مؤسسات اعادة انشاء واعمار الطرق لبحث ودراسة تأثير العوامل المقترحة والتي تكون ضرورية لتحديد أولوية اعمار الطرق المتضررة. تم شمول ومعالجة خمس مجاميع من العوامل في هذه الدراسة وهي:العوامل الاجتماعية-الاقتصادية, عوامل شبكة الطرق, العوامل المرورية, عوامل الضرر والعوامل المالية. تتكون كل مجموعة أيضا من عدد من العوامل المقترحة. نتيجة لذلك, تم اختيار تسعة وعشرين من العوامل لتتم دراستها في هذا البحث.

وجد من نتائج المقابلات والاستبيان أن العوامل ومجاميع العوامل المقترحة ذات مستوى أهمية عالي وعالي جدا. هذا يدل على أن العوامل ومجاميع العوامل المدرجة في هذه الدراسة مهمة لبناء ونجاح تنفيذ الخطوات اللازمة لتحديد أولوية اعمار الطرق لمشاريع اعادة تأهيل الطرق.

كل عامل مقترح ضمن كل مجموعة عوامل مقترحة في هذه الدراسة يساهم بقيمة وزن مختلفة لدرجة الأهمية نسبة الى درجة الأهمية الكلية لأولوية اعمار الطرق. حسب النتائج المستحصلة من الاستبيان, فان العوامل الأكثر أهمية كانت: عدد المؤسسات الاجتماعية-الاقتصادية, نوع الطريق, وقت التأخير, درجة الضرر والتأثير على الاقتصاد. علاوة على ذلك, ساهمت كل مجموعة مقترحة من العوامل بنسب وزنية مختلفة من درجة الأهمية. بالاعتماد على نتائج الاستبيان, تبين أن اهم هذه المجاميع من حيث درجة الأهمية لتحديد أولوية اعمار الطرق هي مجموعة العوامل المالية.

INTRODUCTION

Natural disasters/armed conflicts not only cause fatalities and injuries but also result in infrastructure damage, substantial social and economic impacts (Sinha, 2008).

Road is a major component of lifelines and a vital tool for the transportation of goods and services between different regions. A significant natural disaster tends to severely violate the functionality of roads in disaster area (Qin *et al.*, 2011). The roadway transportation system is the key channel for transportation and civil activities. Its destruction after a disaster can have a great impact on road connections, inhibiting the progress of rescue missions (Yan and Shih, 2008). Similarly to natural disasters, armed conflicts can also damage road networks.

Post-war (or the more euphemistic 'post-conflict') reconstruction has only recently been articulated as an important concept in international discourse, even though wars and the reconstruction after wars have been a constant of human history. The last decade, saw concepts of post-war recovery, rehabilitation and reconstruction becoming increasingly the focus of international organizations and governments, as well as becoming an important area for research and academic study. This new focus is not only at the level of political discourse but is rapidly being institutionalized as new administrative structures have sprung up in the international and governmental institutions of the world charged with addressing the particular problems perceived to be characteristic of the aftermath of conflict. Committing specific resources to the management of post-war recovery and development in this way suggests that it is part of a wider strategic agenda, beyond the familiar territories of humanitarianism and development. In fact, the reconstruction of nations post-conflict is now recognized as a key element in achieving global stability, security and eradication of poverty in the 21st century (Barakat, 2005).

Therefore, transportation network protection against natural and human-caused hazards has become a topical research theme in engineering and social sciences (Liu *et al*., 2008).

Mitigation of the adverse impacts of natural disasters/armed conflicts has been investigated in a number of research studies. Existing research in this important area focused on: (1) measuring the performance of damaged transportation networks in post-disaster environments (Chang and Nojima, 1998; Chang and Nojima, 2001; Chen and Eguchi, 2003; Nojima and Sugito, 2000); (2) analyzing recovery planning strategies and developing post event recovery planning models (Farris and Wilkerson, 2001; Kozin and Zhou, 1990; Lambert *et al*, 1999; Opricovic and Tzeng' 2002); (3) evaluating pre-disaster mitigation policies and developing pre-event mitigation planning models (Gunes and Kovel, 2000; Masri and Moore, 1995); (4) investigating the role of public agencies in post-disaster environments (Kovel and Kangari, 1995; Lambert and Patterson, 2002; Wallied, *et al*., 2009); (5) analyzing post-disaster procurement methods for reconstruction (Le Masurier, *et al.*, 2006); (6) developing loss estimation tools for disaster response (Huyck *et al.*, 2006); (7) allocating available funds to transportation network recovery projects (Kaarlaftis, *et al.*, 2007) and (8) analyze the link between structural damage and economic impact (Chang and Nojima, 1998; Wallied *et al.*, 2009). Despite of the significant contributions of the above research studies, there is no reported research that focused on the impact weighting of the affecting factors which is the level of importance for each affecting factor (i.e., how much the percentage of effect for each factor on the road recovery priority.

This paper presents an investigation of fundamental factors to address the issues of road recovery priority after natural disasters/armed conflicts and discussing the impact percentage of each factor in order to determine the road recovery prioritization. The structure of this paper is as follows. After the introduction, section 2 presents a fundamental literature review. In section 3, a survey is described and the estimated factors are discussed. Results and discussion are presented in section 4. Finally, section 5 gives conclusions and recommendations.

FUNDAMENTAL LITERATURE REVIEW

Sugiyanto ***et al.***, (2011) stated that Congestions will generate many problems due to inefficiency. With congested roads, vehicle speed will be simultaneously up and down, and the average speed will be lower and hence the cost will increase. Therefore, road users will suffer from increasing vehicle operating cost and losing more time and environment will be in worse conditions due to pollutions. In other words, transportation costs will be increased due to congestions.

The time loss of road vehicles because of traffic congestion, in general, is determined on the basis of roughly estimated queue lengths, time periods of congestion and mean queue speed. The time loss of road users due to traffic congestion is determined, in general, by comparing the average trip time on congested links with the trip time under free-flow conditions corresponding to the design speed of the road. The easiest manner of registration of congested traffic is used frequently by observing the queue length (Hansen, 2001).

In the first days after the event, the travel pattern in the city is quite different from normal situation as indicated by Shriat ***et al.***, (2004). Travels for job, entertainment, school, and shopping are not the same as before and are usually omitted. So, the paths which provide access to and from hospitals to population centres can be considered as the basic network. The reliable provision of accesses between population centres and hospitals is considered as the first criterion for the functionality assessment of the city transportation network. Another criterion is the importance of the relief centre or the hospital.

The researchers stated a concept, which they called it Accessibility Index, for the decision making on prioritization of the transportation system components retrofit. They used the total number of population centres in the city, the number of available hospitals and the capacity of the hospitals as factors in their method. Also they used five types of damage classification of the bridges: no damage, slight, moderate, extensive and collapse (Shriat ***et al.***, 2004).

User service time measure was defined for quality of service. In the case of roadways, for example, a project may improve the quality of service if it decreases the traffic delays experienced by motorists (Miley (Lee) ***et al.***, 1997).

Sinha, (2008) stated that multi-objective decision analysis should be done in order to prioritize recovery activities based on available data pertaining to average daily traffic (ADT), population density and total estimated cost. Accordingly, the activities located in highly populated areas with heavy traffic flows have received high priority.

The physical damage to road infrastructure and the related hazards provide the beginning of an economic damage assessment. The direct losses such as the repair or replacement costs for the damaged structures, roads, etc. are easy to notice and observe, since they are directly caused by the incident. However, they are only part of the total losses that are caused by the disasters. From an economic perspective there are indirect costs too, associated with the damage caused by natural disasters like temporary unemployment, business interruption, etc. (Sinha, 2008).

Goodwin, (2005) treats time as a sort of money – spends, save, lose or waste it – with a value that depends on a whole range of factors. The traditional way of calculating the total economic cost of congestion compares the actual travel conditions, with the conditions that would apply if everyone is travelling at 'free flow' speed – i.e. unencumbered by any other vehicles, and driving as fast as they choose (subject, of course, to the legal speed limit).

Orabi *et al*., (2009) stated that the performance loss is measured in terms of the additional travel time spent by travellers on the damaged transportation network compared to the pre-disasters conditions. This total daily travel time is compared to the pre-disaster total daily travel time to estimate the additional daily travel time.

The travel time is often considered to be the most important factor affecting travellers on damaged transportation networks, especially when they need to travel longer detours or their original routes but with significantly reduced speeds. Travellers are often reported to choose routes that they perceive to have the least travel time. Accordingly, travel routes that are perceived to be faster attract larger traffic volumes. These routes can then experience traffic volumes that exceed their capacities, creating traffic congestions and increased travel times that in turn cause travellers to consider other faster alternatives. As the recovery efforts progress, the functional status of different road segments can dynamically alternate between open, partially closed and closed.

The data is needed in the network performance loss model to represent the traffic data and the topology of the transportation network. The traffic data include: (1) the traffic demand on the network which can be described by the origin-destination (OD) pair flows; (2) the capacity of the road segments; (3) the free flow speed for each road on the network; and (4) the functions used to estimate the travel time on the different routes of the network. The network topology include data on: (1) the nodes which represent the traffic loading/ unloading points to/from the network such as cities, intersections and exits; (2) the links which represent the road segments connecting different nodes; and (3) the incidence information which identifies the relationship between nodes and links and the direction of traffic flow on each link.

The model designed by the researchers to focus on the construction-related costs of the recovery efforts, including direct cost (DC) and indirect cost (IC) while non-construction related costs (e.g. road user and business disruption) are not included. The DC includes the cost of reconstruction resources. The IC includes time-dependent costs such as site overhead (Orabi *et al*., 2009).

Available metrics for measuring the functional performance of transportation networks include: travel time, distance, direct cost, reliability and comfort as indicated by Bell and Iida, (1997).

Longer road lengths are likely to score higher with more facilities, services and population along its length. Another important basic indicator is the population served by the road (Jo Leyland, 2010).

Sakakibara *et al*., (2004) proposed a research where a topological index was used to quantify road network depressiveness/concentration in a disaster situation and prevent isolating city districts for evacuation. The most robust network was defined as the network that minimized the isolation of districts in a catastrophic disaster. The topological index was calculated based on the various links and nodes representing a given road network structure.

A model found by Sandy, (2009) allows specific routes to be chosen for reconstruction based on a set of criteria determined by the user. The criteria for his research include giving priority to local industry in order to speed the economic recovery of a disaster stricken area. Typically, entities such as hospitals, schools, residential areas or business parks are those where the restoration of transportation accessibility is critical.

Impacts from a natural disaster have a widespread effect on the economy of that area. Experience has shown that the effects of disasters on highway components not only disrupt traffic flows, but the economic recovery is also impacted (Werner *et al*., 2000).

Kovel, (2000) has suggested that an effective recovery model should consider, at a minimum, which roadways should be evaluated, the resources available for repairs and the extent of likely damage to these roadways and the transportation components contained within them. A list of factors considered in the development of this model is given below:

1. Functional classification of roadways considered for reconstruction, such as interstates, arterials and collectors
2. Administrative classification of roadways was also considered, such as US highways and state routes
3. Types of transportation components in the study area
   - Examples include bridges, overpasses and tunnels
   - Other transportation components such as intersections and uninterrupted segments of roadway were not considered for this research
4. Size of the transportation components. Examples include the number of spans or length on a bridge or length of a tunnel
5. Cost of repair or replacement of the transportation components
6. Location of the transportation components
7. Possible damage levels to the facilities with varying types of disasters. Damage levels are classified as slight damage, moderate damage, extensive damage or complete damage
8. Location of major roadways used by priority entities as decided by state and local officials. Examples of priority entities could include hospitals, schools, residential areas or businesses
9. Location of major businesses
10. Shortest paths from businesses to the perimeter of damage of a disaster Kovel, (2000).

Traffic congestion, queues on roads, does cost money as stated by Koopmans, (2003). The fact that motorists cannot reach their destination within the time that corresponds with freely flowing traffic conditions leads to a loss of time, and therefore a loss of productivity.

Natural disasters often cause significant damages to existing transportation networks leading to substantial socioeconomic disruption for the public (Housner and Thiel, 1995).

As a result of the 1991 Northbridge earthquake, the level of service of critical highways was severely disrupted at four locations in the north-western Los Angeles metropolitan area (Chang and Nojima, 2001).

Zamichow and Ellis, (1994) stated that the 1991 Northbridge earthquake resulted in major disruptions in the movement of people and goods. In addition, the closure of parts of Interstate 10 (Santa Monica Freeway) alone caused financial losses to Los Angeles and its neighbouring communities which were estimated at $ 1 million per day in lost wages and depressed economy.

Extreme weather conditions or other natural phenomena can make large parts of the road network impassable as indicated by Berdica, (2002). The resulting congestion effects and delays cause serious losses in terms of travel time as well as other costs e.g. in case of ‘just in time ‘deliveries.

Travel time is identified as a common thread, in that it exists not only as a direct measure but also as an element of other indicators. In the Highway Capacity Manual, speed is chosen as a simple indicator for the level of service. Speed is directly influenced by traffic flow in that low volumes permit high, steady speed while high volumes cause low, varying speed. In other words, traffic volume should be kept at a lower level than the capacity of the street in order to retain high transport quality. These indicators can measure transport system performance (Berdica, 2002).

Noland *et al.,* (1998) found that the extra travel costs resulting from increased travel times were in fact not as great as those connected to an increasing probability of arriving at the ‘wrong’ time, so called scheduling capacity.

An inspection was carried out by Tanaka *et al.,* (2000) to grasp the overview of the expressway network damage and to construct the repair strategies and estimating the restoration time for all structures. The inspection was focused on structural damage and road surface condition. The structural damage is classified into 5 categories; they are collapse, major damage, moderate damage, minor damage and no damage. The road surface condition is classified into 3 categories; they are impossible to driving, possible to driving with some problems and possible to driving without any problems.

In road network system, according to necessary of network reliability analysis and studied of earthquake damage materials, the researchers divided damage degree into 3 grades as stated by Chunguang and Huiying, (2000):

1. Basic good. Road is basically good or slight crack, bridge is basically good, but some non-structures have slight damage. It can meet normal transportation capacity, and can be used.
2. Slight destruction. Road has many cracks, but can be still gone through. Some parts of bridge have damages. It can be used by appropriately repairing and strengthening.
3. Heavy destruction. The surfaces of road have many cracks. It is inevitable to repair in a period time; the important parts of bridge have damages. The load capacity will decrease (Chunguang and Huiying, 2000).

The functional performance measures of highway system after earthquakes reflect (a) physical performance of links, (b) network properties such as capacity and redundancy, (c) decrease in O-D trips due to overload, (d) increase in trip length due to detouring actions, and (e) increase in travel time due to detouring and congestion (Nojima and Sugito, 2000).

The required inventory data, which were needed for the earthquake risk assessment model for Taiwan, can take two forms. The first is the inventory data such as the square footage of buildings of a specified type, the length of roadways or the population in the study region. They are used to estimate the amount of exposure or potential damage in the region. The second data type include characteristics of the local economy, which are important in estimating losses, e.g., rental rates, construction costs, regional economic output, or regional unemployment rates (Loh *et al.*, 2000).

Hosseini and Vayeghan, (2008) proposed a somehow new concept for roads, the 'road service area', which is based on a major origin-destination pair and their surrounding industrial, cultural centres, or the centres of any type of economic activity. By using this concept, each country cab be divided into some "road service areas" and then these areas can be prioritized based on various parameters, including hazard, vulnerability, and the transportation service presented in each area.

The parameters which are used in the risk calculation are of two kinds. One kind is related to seismic hazard and vulnerability, and the other is related to transportation service. The relative length of the road is one of the parameters included in the seismic hazard and vulnerability in each "service area". The relative population is one of the parameters with regard to transportation service in each "service area" (Hosseini and Vayeghan, 2008).

When applied to a specific damage condition of road network, maximum flow is an essential ingredient in determining serviceability of the system (Fenves and Law, 1979).

Nojima, (1998) stated that maximum flow is introduced as a performance measure of road networks subject to failure. When detailed and precise information is available, one can estimate network performance in terms of flow-dependent measures such as traffic volume at arbitrary routes or cross sections, and travel time required for arbitrary O/D (origin/destination) pairs.

Functional degradation can be evaluated on the basis of pre-quake capacity of individual links and post-earthquake structural damage pattern (Nojima, 1998).

Basoz and Kiremidjian, (1996) consider the time delay and use the information primarily for retrofit prioritization strategies.

Kiremidjian *et al.,* (2007) illustrated that the risk from earthquakes to a transportation system is evaluated in terms of direct loss from damage to bridges and travel delays in the transportation network. The time delays can result from closure of particular routes because of excessive damage to key components such as bridges, or due to reduced flow capacity (either from imposed lower speed limit or closure of number of available traffic lanes) due to minor or moderate damage.

The fragility functions are used to estimate the damage to the bridges for the scenario event resulting from ground shaking. The fragility functions define the probability of being or exceeding one of five damage states for a given ground motion level. The five damage states are: (1) no damage; (2) minor; (3) moderate; (4) major; and (5) complete (Basoz and Mander, 1999).

I agree with the factors aforementioned by the previous researchers, which is my belief that they are important when dealing with the issue of recovery priority for roads damaged by natural disasters/armed conflicts. I also believe that, to a large extent, other factors are also essential for a successful strategy for road recovery such as the restoration time for all roads. It is also necessary to estimate how much traffic congestion, queues, travel delay, loss of time, and loss of productivity costs in terms of money. So, here in this work, efforts has been made to join the above-mentioned factors which can more comprehensively estimate the performance of the stochastic road network and provide a more reasonable calculation method in order to determine the first priority roads for recovery after natural/man-made disasters.

In the field survey of this study, interviews have been conducted to provide useful information, obtained by suggestions, recommendations, opinions and experiences of the respondents, which can help in investigating the important factors that may be affect on the road recovery priority after natural disasters/armed conflicts. This information, in turn, has been used to identify factors that may be included in priority of roads recovery. Then, a questionnaire has been used to estimate the level of importance for each factor in term of the impact weight.

SURVEY

Interviews

Many people, including practitioners and academics from the highway sector known for having experience and/or published work, were chosen and asked to participate in interviews for the purpose of this study. Also, some face-to-face discussions were arranged to encourage discussion and solve problems.

The aim of the interviews is to provide useful detailed opinions and ideas, and to identify and discuss important topics, which enabled this study to identify factors that can be important and influenced on the road recovery priority after natural disasters/armed conflicts. The respondents were asked to provide their opinion about the most influencing factors that affect prioritization of road recovery.

Respondents

In 2003, road networks were damaged seriously in Iraq War. Practitioners and academicians who had been asked about their opinions were chosen from the following government institutions in different regions, experiences and cultures in Iraq:

1. Ministry of Transportation
   - Department of Planning and Following Office.
   - Department of Researches and Studies
2. Ministry of Construction and Housing
   - The State Corporation for Roads and Bridges
   - National Centre for Engineering Consultations
   - General Office for Works and Maintenance
   - Construction Engineering Office

3. Mayoralty of Baghdad
   - Projects Division
4. Ministry of Planning and Development Cooperation
   - The Central Bureau of Statistics and Information Technology
5. Ministry of Higher Education and Scientific Research
   - Consultant Offices in University of Technology, Baghdad University and Al-Mustanseria University
6. Roads companies.

Estimated Factors

Suggestions, recommendations, opinions and experiences of the respondents provide useful information to this study to identify and estimate the important factors that may be included in road recovery priority after natural disasters/armed conflicts.

According to the factors which had been handled by previous researchers and the opinions of the reviewers, five estimated groups of factors have been included in this study to be influenced on the road priority for recovery. Each group also consists of a number of estimated sub-group factors. As a result, twenty nine factors have been chosen in this study. The classification of these groups and the factors which are included in each group are shown in Table (1).

It is essential for an efficient transport measures to take the cost consideration into account. Total cost caused by natural disasters/armed conflicts include direct losses such as re-construction/repair construction for the damaged roads, and indirect losses caused by transport networks disruption which include time-dependent costs. Most of the estimated factors above-mentioned cause time-dependent cost. For example, increasing the area of socio-economic buildings served by the damaged road means increasing the number of people working in it and leads to traffic congestion, low traffic flow, long trip length, more delay time, and may be more traffic accidents. This in turn leads to less working hours and productivity, and therefore less income. Another example when increasing percent of damaged road cause low traffic flow, more delay time, more traffic disruption, and more traffic congestion. This in turn causes increasing time loss in addition to increasing the recovery cost.

Table (1) Classification of the estimated groups and factors.

Group (G)		Factor (f)	
No.	**Name**	**No.**	**Name**
1	Socio-Economic Factors	1,1	No. of critical socio-economic facilities
		1,2	Area of socio-economic buildings (m^2)
		1,3	Capacity of socio-economic buildings (person/m^2)
		1,4	Population served by a road (habitant)
		1,5	Area served by a road (km^2)
		1,6	Type of area
2	Road Network Factors	2,1	Type of road
		2,2	No. of nodes

Group (G)		**Factor (f)**	
No.	**Name**	**No.**	**Name**
		2,3	No. of links
		2,4	Length of road (km)
		2,5	No. of lanes in both directions
		2,6	Pavement structure
3	Traffic Factors	3,1	Traffic classification
		3,2	Traffic flow (vpd) (vehicle per day)
		3,3	Delay time (min.)
		3,4	Additional trip length (km)
		3,5	Queue length (m)
		3,6	Level of service (LOS)
		3,7	Reduction in average speed (km/hr)
		3,8	Traffic control pattern
4	Damage Factors	4,1	% Damaged road
		4,2	Severity of damage
		4,3	No. of damaged lanes in both directions
		4,4	No. of damaged layers
		4,5	PSI (Present Serviceability Index)
5	Financial Factors	5,1	Direct cost (reconstruction or repair)
		5,2	Time cost
		5,3	Extra fuel consumption
		5,4	Effect on economic (temporary unemployment cost and business interruption cost)

Questionnaire

Questionnaire survey has been conducted and aims to estimate the weight value (level of importance) $W_{g,f}$ of each factor in each factor group (which can be defined as the contribution weight of the f^{th} factor in the g^{th} factor group) and the weight value (level of importance) W_g of each group (which can be defined as the contribution weight of the g^{th} factor group) which are influential on the road recovery priority.

The questionnaire was designed to include two main sections; section 1 asks respondents, according to their experiences and opinions, to give the level of importance of the estimated influencing factors within each of the five suggested groups. Section 2 asks respondents to evaluate the impact level of the five groups of factors.

The responses evaluate the impact level of the listed suggested factors and groups according to the respondents‟ experiences, opinions and perceptions. This evaluation uses a five-point scale where 1 means very low impact, 2 means low impact, 3 is medium impact, 4 is high level of impact and, finally, 5 means very high impact level.

The description of each criterion is given in Table (2) below. The respondents were asked to leave boxes blank if they did not know or were unsure of the response.

Table (2) Criteria's description of the five-point scale for the impact rate.

Impact Rate (IR)	Criteria	Description
1	very low impact	The effect percentage is 0 – 20 %
2	low impact	The effect percentage is 20 – 40 %
3	medium impact	The effect percentage is 40 – 60 %
4	high impact	The effect percentage is 60 – 80 %
5	very high impact	The effect percentage is 80 – 100 %

Respondents

Respondents who had been asked about their opinions were chosen as the following:

1. Academicians in Highways and Transportation Department in the universities of Baghdad city.
2. Highways and Transportation Department PhD students in the UK.
3. Practitioners in companies and government institutions regarding highway works in Baghdad city.

Experience Years

In order to obtain reasonable results; the experience years of the respondents are included in the questionnaire. Different weight values have been given for different years of experience for people as shown in Table 3. People with (0-5) years of experience have been given a weight of (0.2), others with (5-10) years of experience have been given a weight of (0.3) and a weight of (0.5) has been given to people with (over 10) years of experience. For example, for a participant with 7 years of experience, its estimated impact rate value for each factor and each group, which is obtained from the questionnaire, will be multiplied by an experience weight value of 0.3.

Table (3) Experience weight values.

Experience (E) (Years)	Weight Value (W) (%)
E_1= 0 – 5	W_1= 0.2
E_2= 5 – 10	W_2= 0.3
E_3= over 10 years	W_3= 0.5

Response Characteristics

From 120 people contacted, a total of 86 questionnaires were received, representing 71.7% response rate.

CALCULATIONS, RESULTS AND DISCUSSION

In order to determine the weight value for each factor within each group $W_{g,f}$, the weighted average method has been applied and is given in Equation (1) (James and John, 1980):

$$AIR_{g,f} = \frac{\sum_{E=1}^{3}\sum_{IR=1}^{5} IR \times N_{IR,E} \times W_E}{\sum_{E=1}^{3}\sum_{IR=1}^{5} N_{IR,E}} \quad \dots\dots(1)$$

where $AIR_{g,f}$ is the average impact rate for the f^{th} factor in the g^{th} factor group, E is the experience years range for the participant which is a three-point scale according to Table (3), W_E is the experience weight value which can be obtained using Table (3), IR is the impact rate for each participant in the questionnaire which is a five-point scale according to Table (2), and $N_{IR,E}$ is the number of participant for each of the five-point scale impact rate for each of the three-point scale experience years.

Equation (1) should be used for each factor within each group. For example, for socio-economic group which includes six factors; Equation (1) should be repeated six times order to obtain the average impact rate $AIR_{1,f}$ for each factor within this group.

Then by dividing each single $AIR_{g,f}$ for each factor by the sum of the $AIR_{g,f}$ values for all factors within a group; the weight value $W_{g,f}$ of the f^{th} factor in g^{th} group can be calculated as shown in Equation (2) (James and John, 1980):

$$W_{g,f} = \frac{AIR_{g,f}}{\sum_{f=1}^{F} AIR_{g,f}} \quad \dots\dots(2)$$

Similarly, Esquation (3) and (4) can be used to determine the average impact rate for g^{th} factor group AIR_g and the weight value for each group W_g respectively as:

$$AIR_g = \frac{\sum_{E=1}^{3}\sum_{IR=1}^{5} IR \times N_{IR,E} \times W_E}{\sum_{E=1}^{3}\sum_{IR=1}^{5} N_{IR,E}} \quad \dots\dots(3)$$

$$W_g = \frac{AIR_g}{\sum_{f=1}^{F} AIR_g} \quad \dots\dots(4)$$

Where AIR_g stands for the average impact rate for the g^{th} factor group and W_g stands for weighted value of the g^{th} group Excel spreadsheets are here used to list the input data regarding respondents impact weight and to use Equations (1) to (4) in order to obtain the required output results of the final impact contribution weight for each factor, $W_{g,f}$, and for each group of factors, W_g.

The questionnaire results, which are obtained by applying Esquation (1), (2), (3) and (4), are given in Table (4).

The first part of the questionnaire was to determine the weighted values for each factor within each group. The weight values $W_{1,f}$ for factor group 1 (socio-economic group) are represented in Figure (1). It can be noticed from this Figure that the number of critical socio-economic facilities and the population served by a road have the greatest level of importance on the road recovery priority within this group and have a close weight value ($W_{1,1}$ = 0.216 and $W_{1,4}$ = 0.214). Conversely, the area of socio-economic buildings has the smallest effect ($W_{1,2}$ = 0.102).

Table (4) Questionnaire result values of factor's weight $W_{g,f}$ and group's weight W_g.

Group (g)	Factor (f)	$W_{g,f}$		W_g	
		No.	Value	No.	Value
1	1	$W_{1,1}$	0.216	W_1	0.204
	2	$W_{1,2}$	0.102		
	3	$W_{1,3}$	0.130		
	4	$W_{1,4}$	0.214		
	5	$W_{1,5}$	0.150		
	6	$W_{1,6}$	0.188		
2	1	$W_{2,1}$	0.204	W_2	0.180
	2	$W_{2,2}$	0.168		
	3	$W_{2,3}$	0.165		
	4	$W_{2,4}$	0.175		
	5	$W_{2,5}$	0.171		
	6	$W_{2,6}$	0.117		
3	1	$W_{3,1}$	0.119	W_3	0.202
	2	$W_{3,2}$	0.135		
	3	$W_{3,3}$	0.138		
	4	$W_{3,4}$	0.124		

	5	$W_{3,5}$	0.126		
	6	$W_{3,6}$	0.128		
	7	$W_{3,7}$	0.126		
	8	$W_{3,8}$	0.104		
4	1	$W_{4,1}$	0.230	W_4	0.206
	2	$W_{4,2}$	0.236		
	3	$W_{4,3}$	0.197		
	4	$W_{4,4}$	0.151		
	5	$W_{4,5}$	0.186		
5	1	$W_{5,1}$	0.303	W5	0.208
	2	$W_{5,2}$	0.215		
	3	$W_{5,3}$	0.165		
	4	$W_{5,4}$	0.317		

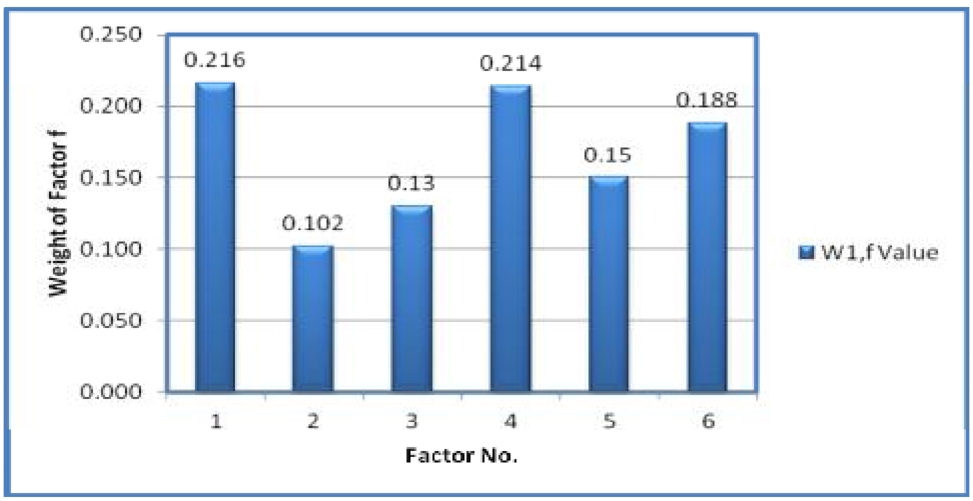

Figure (1) Weight values $W_{1,f}$ of factor *f* within socio-economic group.

The questionnaire results shown in Figure (2) for road network group demonstrate that the type of road (whether it is interstate, bridge, highway, primary or secondary) has a significant impact ($W_{2,1}$ = 0.204) compared with other factors in this group. The second level of impact goes to the length of road and number of lanes in both directions in which their weight values are nearly identical ($W_{2,4}$ = 0.175 and $W_{2,5}$ = 0.171). The smallest level of importance is for the pavement structure factor ($W_{2,6}$ = 0.117).

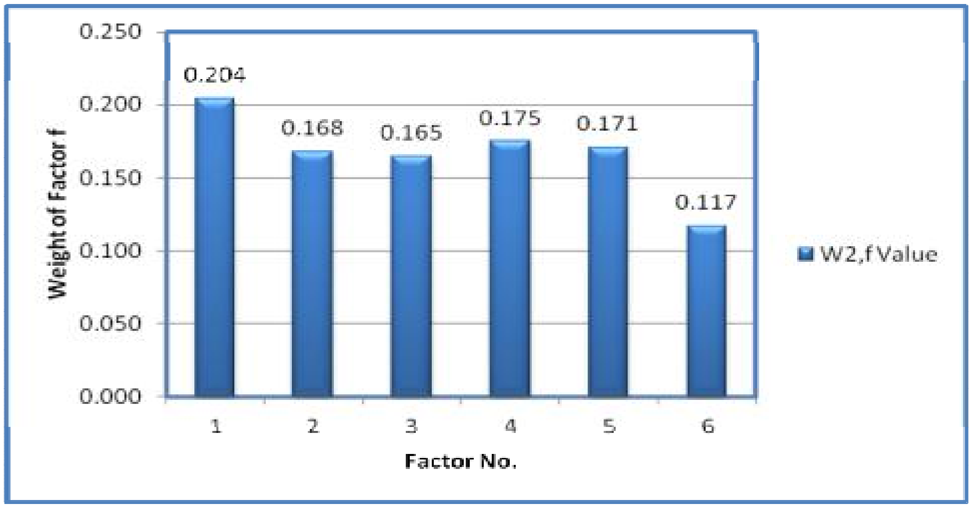

Figure (2) Weight values $W_{2,f}$ of factor *f* within road network group.

Regarding the traffic factor group, the results founded from the questionnaire indicate that there is a slight difference in the weight values for the factors as illustrated in Figure (3). The delay time factor ($W_{3,3}$ = 0.138) and the traffic flow factor ($W_{3,2}$ = 0.135) have the greatest level of importance on the road recovery priority. On the other hand, the traffic control pattern factor has the smallest weight value ($W_{3,8}$ = 0.104) compared with the other factors.

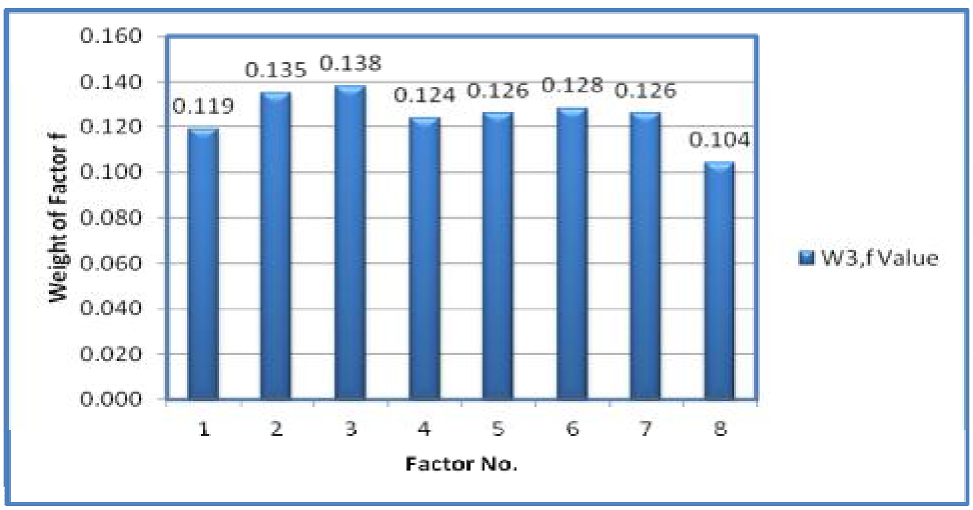

Figure (3) Weight values $W_{3,f}$ of factor *f* within traffic group.

It can be noticed from Figure (4) for factor group 4 (damage factors group) that there are considerable differences between the weight values of the factors. There is a marked impact of the severity of damage factor (whether it is severe, major or minor)

($W_{4,2}$ = 0.236) and the percentage of damage road factor ($W_{4,1}$ = 0.230). The number of open lanes in both directions factor takes the third place ($W_{4,3}$ = 0.197), while there is a slight impact of the number of damaged layers factor ($W_{4,4}$ = 0.151).

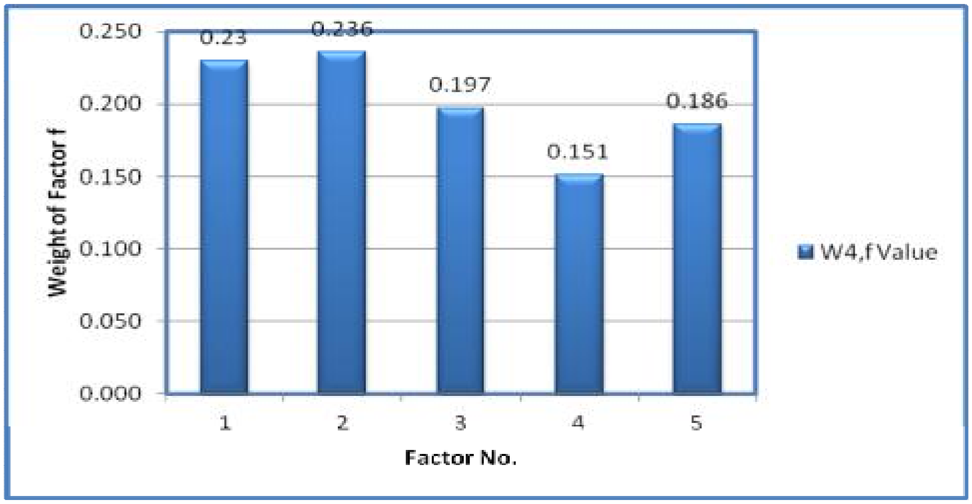

Figure (4) Weight values $W_{4,f}$ of factor *f* within damage group.

Figure (5) shows the questionnaire results for the financial group. It can be noticed that the effect on the economic factor has a significance level of importance on the road recovery priority ($W_{5,4}$ = 0.317). The second percent of impact is for the direct cost factor ($W_{5,1}$ = 0.303), while the extra fuel consumption factor has the smallest weight value ($W_{5,3}$ = 0.165).

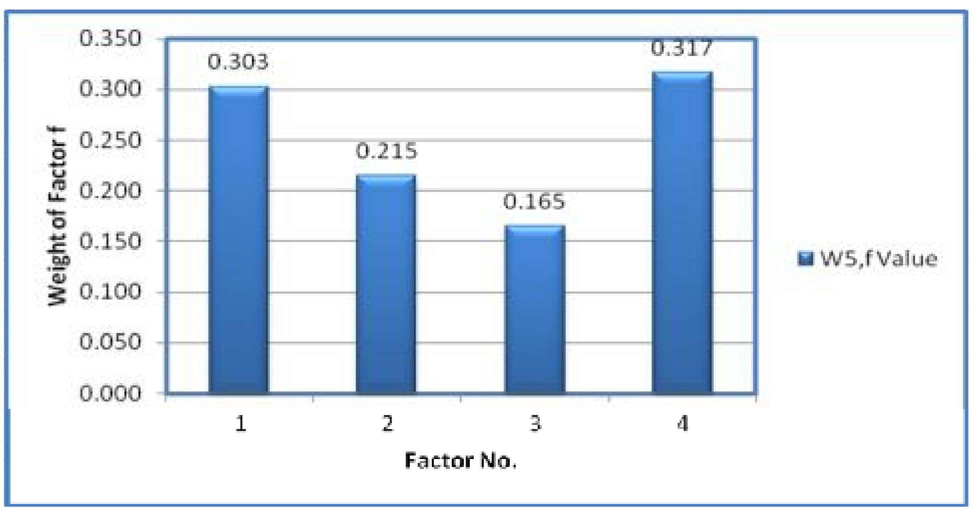

Figure (5) Weight values $W_{5,f}$ of factor *f* within financial group.

Determining the weight values for each factor group W_g was obtained in the second part of the questionnaire. The questionnaire result values of group's weight W_g are listed in Table 4 and illustrated in Figure 6. It is obvious from Figure 6 that the resulted level of importance for four groups are quite close, which are the financial group (W_5 = 0.208), damage group (W_4 = 0.206), socio-economic group (W_1 = 0.204) and traffic group (W_3 = 0.202). The financial group is considered to be the highest impact group on road recovery priority, while the road network group has a slight impact (W_2 = 0.180) compared with other groups.

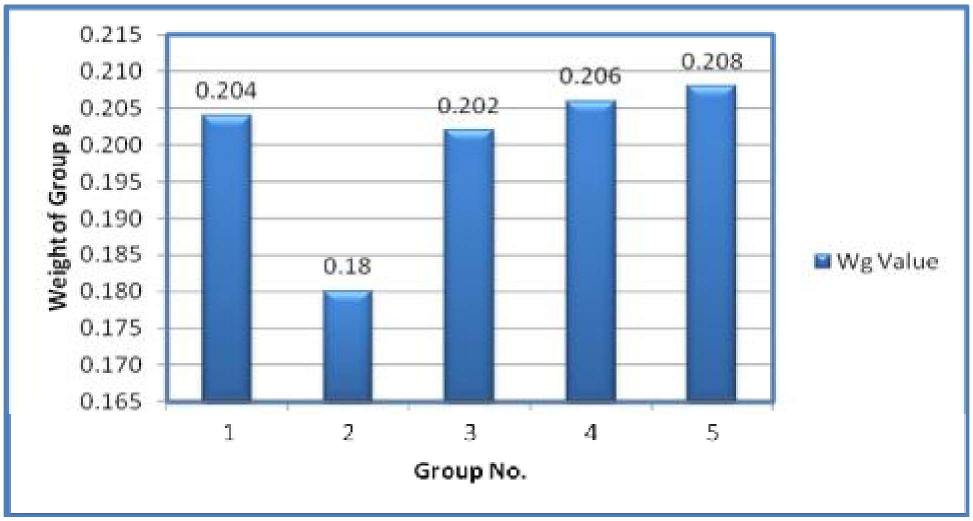

Figure (6) Weight values W_g of each factor group *g*.

As a summary, the obtained percentage impact of each single factor within the overall percentage (100%) of all of the estimated twenty nine factors is given in Table (5) and illustrated in Figure (7).

It is obvious from the obtained data of this study that the effect on economic factor has the highest impact on road recovery priority ($W_{5,4}$ = 6.594 %). The second percentage of impact is for the direct cost factor ($W_{5,1}$ = 6.302 %). Then, severity of damage factor and % of damaged road factor ($W_{4,2}$ = 4.862 % and $W_{4,1}$ = 4.738 % respectively). On the other hand, traffic control pattern has the lowest impact on road recovery priority ($W_{3,8}$ = 2.101 %).

As a summary of the obtained weight values for all estimated factors, it can be concluded that the impact of these factors on road recovery priority has been classified into five types depending on the weight value which are: very high, high, moderate, low and very low. The values with highest weight value are considered as very high impact such as effect on economic factor and direct cost factor. Then, the moderate impact such as severity of damage factor and % of damaged road. While factors with lowest weight values such as traffic control pattern and area of socio-economic buildings factor are considered as very low impact. Table (6) shows the final resulted impact hierarchy of factors where as factors have been ranked from highest to lowest weight values depending on the obtained results of the questionnaire.

Table (5) the percentage of impact of each factor within the overall percentage.

Factor No.	Name	Weight Value $W_{g,f}$
1,1	No. of critical socio-economic facilities	4.406
1,2	Area of socio-economic buildings (m^2)	2.081
1,3	Capacity of socio-economic buildings (person/m^2)	2.652
1,4	Population served by a road (habitant)	4.366
1,5	Area served by a road (km^2)	3.060
1,6	Type of area	3.835
2,1	Type of road	3.672
2,2	No. of nodes	3.024
2,3	No. of links	2.970
2,4	Length of road (km)	3.150
2,5	No. of lanes in both directions	3.078
2,6	Pavement structure	2.106
3,1	Traffic classification	2.404
3,2	Traffic flow (vpd)	2.727
3,3	Delay time (min.)	2.788
3,4	Additional trip length (km)	2.505
3,5	Queue length (m)	2.545
3,6	Level of service (LOS)	2.586
3,7	Reduction in average speed (km/hr)	2.545
3,8	Traffic control pattern	2.101
4,1	% Damaged road	4.738
4,2	Severity of damage	4.862
4,3	No. of damaged lanes in both directions	4.058
4,4	No. of damaged layers	3.111
4,5	PSI	3.832
5,1	Direct cost (reconstruction or repair)	6.302
5,2	Time cost	4.472
5,3	Extra fuel consumption	3.432
5,4	Effect on economic	6.594

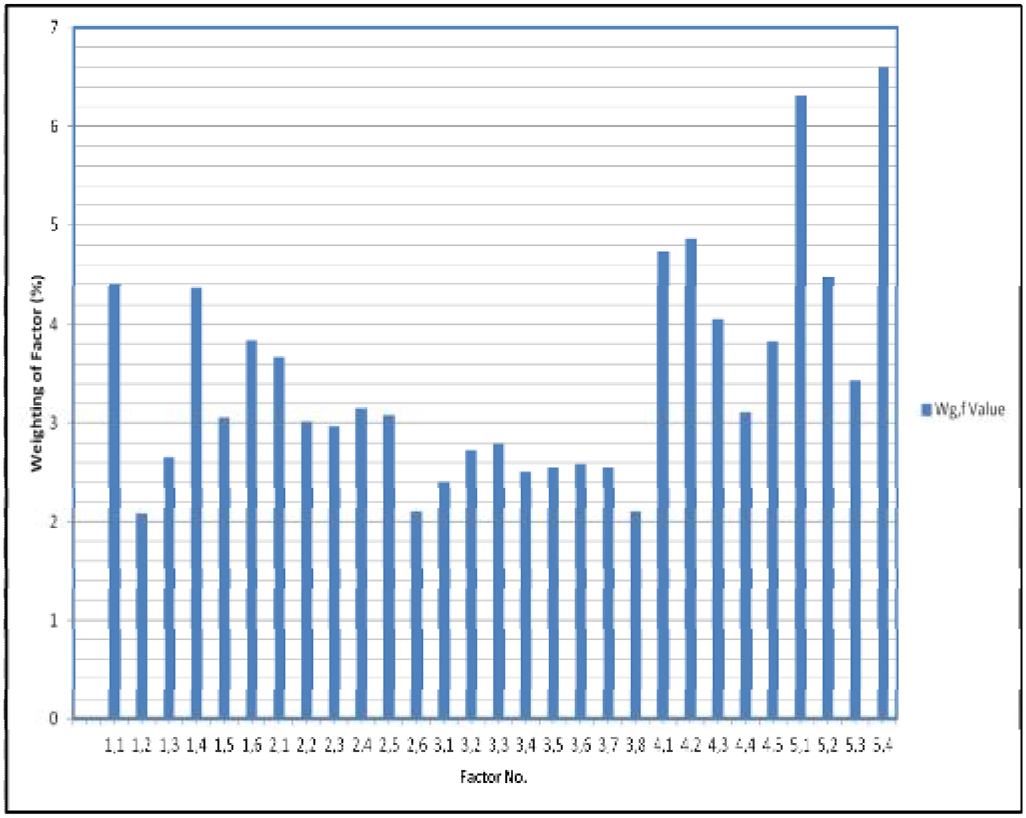

Figure (7) The overall weight values of $W_{g,f}$.

Table (6) The resulted impact hierarchy of factors.

Type of Impact	Factor	Weight Value (%)	Impact Hierarchy
Very high	Effect on economic	6.594	1
	Direct cost (reconstruction or repair)	6.302	2
Moderate	Severity of damage	4.862	3
	% Damaged road	4.738	4
	Time cost	4.472	5
	No. of critical socio-economic facilities	4.406	6
	Population served by a road	4.366	7
	No. of damaged lanes	4.058	8
Low	Type of area	3.835	9
	PSI	3.832	10
	Type of road	3.672	11
	Extra fuel consumption	3.432	12
	Length of road	3.150	13
	No. of damaged layers	3.111	14
	No. of lanes in both directions	3.078	15

Type of Impact	Factor	Weight Value (%)	Impact Hierarchy
	Area served by a road	3.060	16
	No. of nodes	3.024	17
Very Low	No. of links	2.970	18
	Delay time	2.788	19
	Traffic flow	2.727	20
	Capacity of socio-economic buildings	2.652	21
	Level of service (LOS)	2.586	22
	Reduction in average speed	2.545	23
	Queue length	2.545	24
	Additional trip length	2.505	25
	Traffic classification	2.404	26
	Pavement structure	2.106	27
	Traffic control pattern	2.101	28
	Area of socio-economic buildings	2.081	29

CONCLUCIONS AND REMARKABLE

Many factors have been identified in this study to be included in the road recovery priority after natural disasters/armed conflicts. The author here believes that these factors are major factors when dealing with road recovery priority because some of them have been handled by other researchers regardless of the fact that they have been included in other transportation issues. However, there is a lack of studies dealing with road recovery priority issue and it’s affecting factors. In addition, suggestions, recommendations, opinions and experiences of the respondents which are obtained

from the interviews and the questionnaire have been contributed in providing a good help to identify and estimate the important factors that may be included in the issue of the road recovery priority after natural disasters/armed conflicts.

As a result, the identified factors have been grouped into five groups which are: socio-economic group, road network group, traffic group, damage group and financial group. Each of these groups consists of number of estimated factors. For example, there are six estimated factors in the socio-economic group. As a result, twenty nine identified factors have been used in this study.

As an average result for all groups, 57.4 per cent of questionnaire’s respondents indicate that the proposed factors are with level of importance of high and very high. While 18.6 per cent of responses indicate that these factors are of low and very low level of importance. The percentages of the questionnaire’s respondents that indicate that the presented groups of factors with level of importance (rate of impact) of high and very high is 78.8 per cent, while 4.2 per cent of the responses indicate that the presented groups is of low and very low level of importance. This indicates that, in general, the groups and factors included in the questionnaire are important for the Successful building and implementation of the process and procedures of the road recovery priority in the road rehabilitation projects.

Each estimated factor within each proposed group used in this study contributes a different weight value to the overall road recovery priority. According to the questionnaire's results, the most important factor within the proposed socio-economic group is the number of critical socio-economic facilities with an impact weight of 21.6 per cent. The type of road (whether it is interstate, bridge, highway, primary or secondary) has the most impact rate of 20.4 per cent compared with other factors in the road network group. For the traffic group, the questionnaire results indicated that the delay time factor has the greatest level of importance on the road recovery priority with an impact weight of 13.8 per cent. Regarding the damage factor group, the results found from the questionnaire indicated that the severity of damage factor (whether it is severe, major or minor) with an importance rate of 23.6 per cent is the highest impact factor. Finally, the greatest level of importance on the road recovery priority factor within the financial factor group obtained from the questionnaire is for the effect on the economic factor with an impact weight of 31.7 per cent.

A different weight has been contributed by each estimated group used in this study. Based on the questionnaire results, it was found that the major contribution is from the financial factor group which contributes 20.8 per cent. The damage factor group has the second place of impact which is 20.6 per cent. While road network factor group has the lowest impact on road recovery priority which is 18.0 per cent.

It has been found from the results of the interviews and questionnaires that it is highly important to include sufficient details and descriptions about the estimated groups and factors that may affect the road recovery priority efforts in the road reconstruction and rehabilitation organisations.

The result of this study has demonstrated that the estimated factors and groups and the obtained weight values can provide engineers, managers and decision makers with useful information that can be used in performing recovery process for roads damaged by natural disasters or armed conflicts.

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