

ROAD SAFETY ASSESSMENTS AND ROAD SAFETY AUDITS ON THE EXISTING ABU DHABI INTERNAL ROAD NETWORK

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ABSTRACT

Road safety auditing is a process to pro-actively review the potential for road safety improvements on any road or transportation project, whether in a design phase or as an existing road facility. The process is based on the critical assessment of the project features as they would be experienced by any road user. ARRB Group Ltd (ARRB, the Australian Road Research Board) in co-operation with Parsons International Ltd (PIL) conducted road safety audits on a selection of the internal road network of the Municipality of Abu Dhabi City, UAE.

The project was conducted in 2011 and consisted of various tasks:

- Conducting a network level road safety assessment of 2 600 carriageway-km of roads and streets to identify high risk areas;
- Conducting road safety audits on a sub-set of roads and streets of about 300 carriageway-km forming part of the high risk areas;
- Recommending remedial measures;
- Developing program level cost estimates for remedial treatments
- Prioritising remedial treatments based on their cost effectiveness

The network level road safety assessment had been conducted using the Hawkeye video survey system and the risk levels of different sections of the network determined by utilizing the proprietary NetRisk software. Available crash information was superimposed on maps showing the network risk levels. In this manner a clear impression could be formed of those areas where safety concerns existed, based on the pro-active review of road features in the road safety assessment process in coordination with the reactive process of crash analysis.

Road safety audits were then conducted on the areas with the highest risk levels. The audits were undertaken by combining traditional on-site reviews with a comprehensive geo-referenced inventory of road safety problems extracted from the video surveys.

A first order estimate of the cost of the works to remedy the safety concerns on the 300 carriageway-km of audited roads and streets indicated a programme value in excess of USD 93,5Million¹ (at 2011 prices).

¹ AED 433Million

This paper focuses on the audit stage, road safety findings and proposed remedial works that had been identified on sections of the highways and interchanges on Abu Dhabi Island, as well as the major arterial roads on the Island. It shows that the process that had been used in the assessment and audit of the relevant roads forms an efficient way to assess and audit existing urban roads and streets, especially those with high traffic volume.

1. INTRODUCTION

Abu Dhabi Municipality (ADM) commissioned ARRB Group (ARRB) to undertake a road safety study of parts of the ADM road network meeting the following objectives:

- Carry out road safety assessments/existing facilities road safety audits and produce road safety audit reports, risk assessments and analysis of available crash statistics;
- Analyse the road network to determine measures that will have the highest accident reduction potential in relation to the cost;
- Propose road user safety improvements in the studied areas.

A total length of 2 612 carriageway-km (cw-km) of municipal roads and streets was video-logged and reviewed to identify areas of higher risk. The areas reviewed in this manner were spread over a large part of the city covering the following sections:

- Abu Dhabi Island: Highways, Interchanges and Arterial roads and streets;
- Shahama Internal Roads;
- Baniyas Internal Roads;
- Musaffah Arterial and Collector Roads;
- Khalifa City A & B Internal Roads;
- Mohammed Bin Zayed City Internal Roads

The Highways, Interchanges and Arterial roads and streets that had been surveyed on Abu Dhabi Island totaled 1 054 cw-km. A sub-set of 111cw-km had been road safety audited and this subset was divided in two groups that are discussed in this paper: highways plus interchanges and arterial roads.

2. PROJECT METHODOLOGY

Data collection on the extended network had been done by means of videologging using the ARRB's Hawkeye road network survey system to record visual images of the condition of the road environment in both the forward and rear direction. The survey constantly records GPS coordinates for the images as well as the longitudinal progression in meters from the starting point.

These video recordings were then reviewed by knowledgeable enumerators assessing the safety of the road environment based on a limited set of criteria using the NetRisk software. These criteria provide a Risk Score for each 100m section of roadway. These Risk Scores were then combined with a crash value for each section of roadway and the resulting network risk scores displayed on a GIS map of the area. By colour coding of the network risk scores an indication could be given of the relative changes in the safety of various sections of the road network. These GIS maps provided a strategic level road safety risk assessment of the network and were then used to identify priority locations across the Abu Dhabi road network where traditional existing facility road safety audits were required.

Manual road safety audits were conducted on the priority sections of the network to identify typical road safety concerns. These concerns were grouped in specific areas of concern for which particular remedial measures were identified and standardized. The locations of the specific road safety problems were geo-referenced using the video recordings of the relevant sections of roadway and an inventory of road safety problems prepared for each section of the project.

Typical drawings were prepared for the different remedial measures and used to prepare a first order cost estimate for such treatment.

By utilising the ARRB's proprietary Road Safety Risk Manager (RSRM) software the output from the safety audit process and the cost estimates for specific treatments were combined to assess the extent to which the risk at a particular location may be reduced at a commensurate cost. This provided for the establishment of a Risk reduction: Cost ratio (broadly similar to a benefit:cost type of ratio where the benefit is the amount of risk reduction that is achieved by the nominated road safety treatment, rather than a financial benefit.) This can be used to determine the level of the budget allocation required to implement an annual works program.

3. ROAD SAFETY AUDIT FINDINGS AND RECOMMENDATIONS

3.1 Highways and Interchanges

The project audited the Musaffah and Maqta Bridge free flow interchanges as well as the roundabout Interchange (IP145) on Airport Road (Road 2) and comprised about 29 carriageway-km. . The layouts of the Maqta Bridge and Musaffah Bridge Interchanges are on the left shown in Figure 1. The risk levels of the NetRisk Scores that had been developed from the video assessment and used to determine the road sections to be subjected to road safety auditing for this portion are shown on the right in Figure 1. (After reviewing the NetRisk Scores and the variation thereof on the interchanges, it was decided that it would be appropriate to conduct an audit on the entire interchange rather than only selectively.)

3.1.1 *General Findings*

During the road safety audit various general findings were made and possible remedial measures recommended. These included the following:

- **General Problem 1:** The extent of information transfer to the travelling public does not support early decision making by the driver and proper lane selection to exit. This leads to abrupt manoeuvres close to hazardous locations on the road.
Recommendation 1: Information transfer to the travelling public should be improved by upgrading and correcting directional signs and warning signs in particular, the review and re-consideration of closely spaced signs and the improvement of forward visibility to signs.



Figure 1: Layout of Maqta Bridge and Musaffah Bridge Interchanges with NetRisk risk levels

- **General Problem 2:** Shaped concrete safety barriers in the audited sections are inconsistent and may be considered more hazardous in their own right, than protecting other hazards of higher levels of risk. The terminal sections of concrete safety barriers are ramped on their ends and aligned directly towards approaching vehicles. Certain installations are too short to fully protect the physical hazard as intended.
Recommendation 2: The ramped end terminal sections of concrete safety barriers should be revised by physical reconstruction and/or the installation of crash cushions.
- **General Problem 3:** The lack of visibility of pavement markings does not support early decision making by drivers and does not provide continuous guidance to drivers.
Recommendation 3: The display of pavement markings should be upgraded and standardized and the level of maintenance of pavement markings improved.
- **General Problem 4:** Physical objects have been installed in close proximity of moving traffic on the adjacent roadway, often immediately behind ordinary kerbs and with no further protection.
Recommendation 4: These physical objects should be removed or relocated. In site specific locations where this may prove to be not feasible, protection in the form of safety shaped barriers or re-directive barrier kerbs should be installed.
- **General Problem 5:** Pedestrians find it particularly difficult to use roundabouts. The traffic using the large roundabout formed by IP145 exits the roundabout at a high speed, making the crossing of the exit lanes particularly difficult for pedestrians.
Recommendation 5: Pedestrian facilities on the exit from large roundabouts should be relocated farther from the roundabout itself, pedestrian warning signals provided and zigzag pedestrian crossing warning pavement markings introduced.

3.1.2 Specific Findings

The specific list of road safety problems were recorded as an inventory in a spreadsheet format. The information included the GPS coordinates for each specific location, the classification of the safety concern, detail of the problem and a standardized remedial measure that could be applied to remove or reduce the safety problem. GIS maps of the road safety problem locations were prepared displaying a unique serial number for each problem and acting as cross reference to the inventory.

The audit team made 162 specific findings and recommendations for the greater Maqta Bridge/Musaffah Bridge Interchange area. The most common problems identified by the audit team as requiring attention on included signage and road markings (62%), roadside hazards and physical objects (13%), and geometric issues (13%).

The audit team also made 70 findings on the IP145 Roundabout Interchange. In the latter the most common problems had been signage and road markings (33%), roadside hazards and physical objects (26%), and pedestrian issues (21%).

Figure 2 is an extract from the GIS map for the Musaffah Bridge interchange showing specific problem locations and the associated level of risk for these problems.



Figure 2: Problem locations on Musaffah Bridge Interchange

A first order estimate had been made to identify the potential cost to remedy the specific problem issues on this section of the project. The estimate for improving the safety based on the 192 identified problems amounted to AED 7,096,000. (USD 1.93Million)

3.2 Arterial roads on Abu Dhabi Island

The arterial roads on Abu Dhabi are generally older than the highways and interchanges and it could be expected that these roads would display more problems, especially because of their location but also because of the extent of pedestrian and general traffic conditions.

Based on the NetRisk scores and overview of available information on crashes as shown in Figure 3 the following roads were selected for manual auditing, totalling a length of 82 carriageway-km:

- | | |
|-----------------------|-------------------------|
| Road 1: Corniche Road | Road 6: Baniyas Street |
| Road 2: Airport Road | Road 7: Zayed Street |
| Road 4: East Road | Road 9: Al Falah Street |
| Road 5: Hamdan Street | |

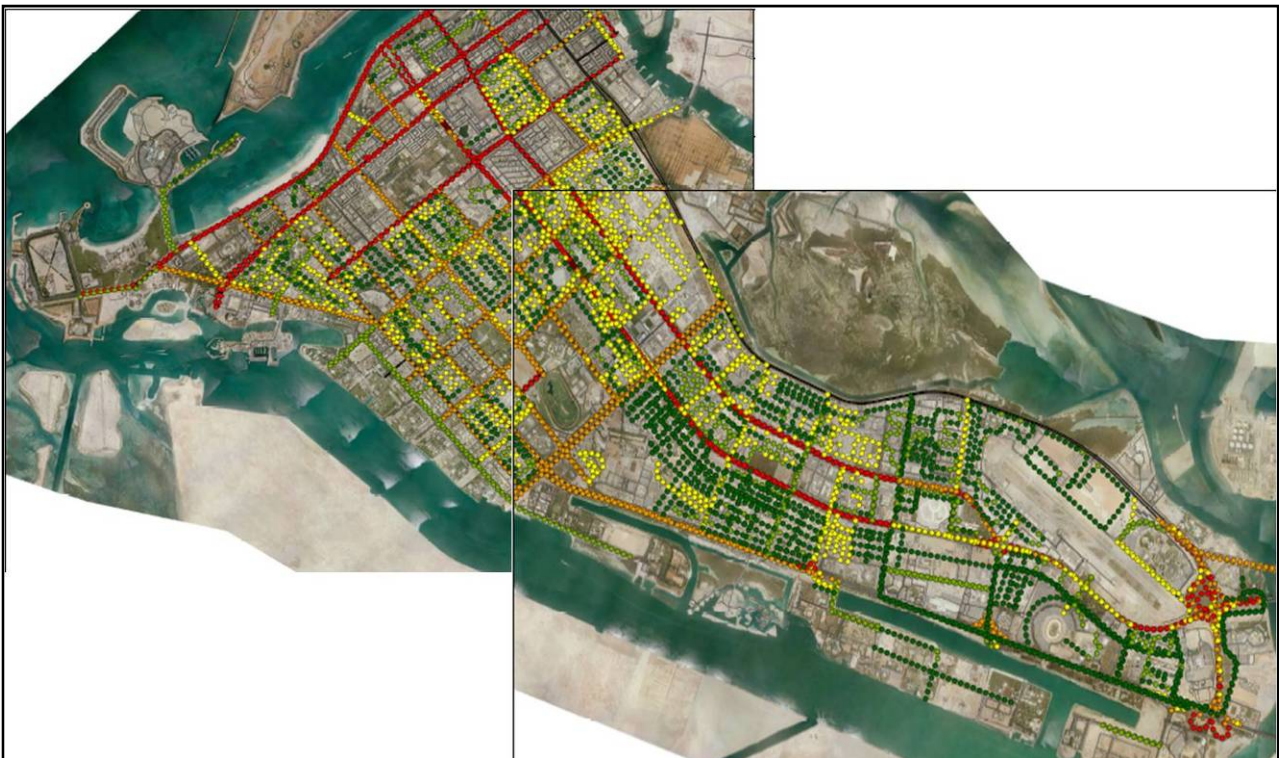


Figure 3: Arterials on Abu Dhabi Island showing priority rating

3.2.1 *General Findings*

The general problems identified on the arterial roads were closely related to the extent to which pedestrians were using the roads as well as the insufficient appreciation of the complexities of the vehicular traffic movements on these roads.

- **General Problem 1:** Information required for early warning of a potential hazard or allowing the driver to position him appropriately for lane changes or exits is either not given or given too late. This is particularly prevalent on multi lane junctions between major roads where dedicated turning lanes exist. In periods of higher flow the tails back formed by waiting vehicles extends far back on the approaches to the junction requiring that the directional information should be provided well in advance of the junction.

Furthermore, the location of ground mounted direction signs and the letter sizing used on such sign faces does not enable the early recognition of destination information. All of these issues contribute to late decision making by the driver and abrupt manoeuvres close to hazardous locations on the road.

Recommendation 1: Information transfer to the travelling public should be improved.

- **General Problem 2:** Facilities for pedestrians in the immediate vicinity of the major roads are inadequate. Although a number of pedestrian underpasses have been provided to cross dual carriageway roads the existence of damaged pedestrian fences on the median combined with well worn informal footpaths confirmed the extent to which jaywalking occurs and the need for more midblock pedestrian crossing facilities. Where midblock pedestrian crossings exist they are typically uncontrolled and at the same level as the roadway. The adjacent sections of median are generally at least 300mm high resulting in steep ramps leading to the crossing. These conditions place the users of the crosswalks in a precarious situation.

Recommendation 2: The facilities for pedestrians should be upgraded. Locations where crossing of multilane major roads is required should receive specific attention in the short term to improve the safe use by pedestrians of the crosswalks in a hostile vehicle environment. The signage to advise of the existence of pedestrian facilities, should also be standardized.

- **General Problem 3:** Physical objects have been installed in close proximity of moving traffic on the roadway, often immediately behind ordinary kerbs and with no further protection.

Recommendation 3: Physical objects in close proximity of the roadway should be removed, relocated or redesigned to reduce their negative influence on road safety.

- **General Problem 4:** The intersection of major roads with wide medians and turning lanes invariably leads to very large areas of asphalt. The use of such areas for multiple turning lanes and the lack of clear guidance for turning vehicles increase uncertainty and exposure of traffic to crashes. The large intersections also result in traffic signal heads being located far from the stop lines and not in the same plane, all increasing the potential confusion that such large intersections can cause.

Recommendation 4: The drivers should be assisted in their use of such large intersections through greater use of guidance line markings and the standardization of display of traffic signals and pedestrian signals.

- **General Problem 5:** Numerous safety issues had been identified as being the result of the deterioration of roadway facilities. The limited extent to which maintenance actions succeed in retaining the functionality of pavement markings (for example) contribute to the increased exposure of traffic to hazardous conditions.

Recommendation 5: Increased attention should be given to the establishment, development and execution of maintenance procedures and management to allow the early detection of conditions that could develop into hazardous situations.

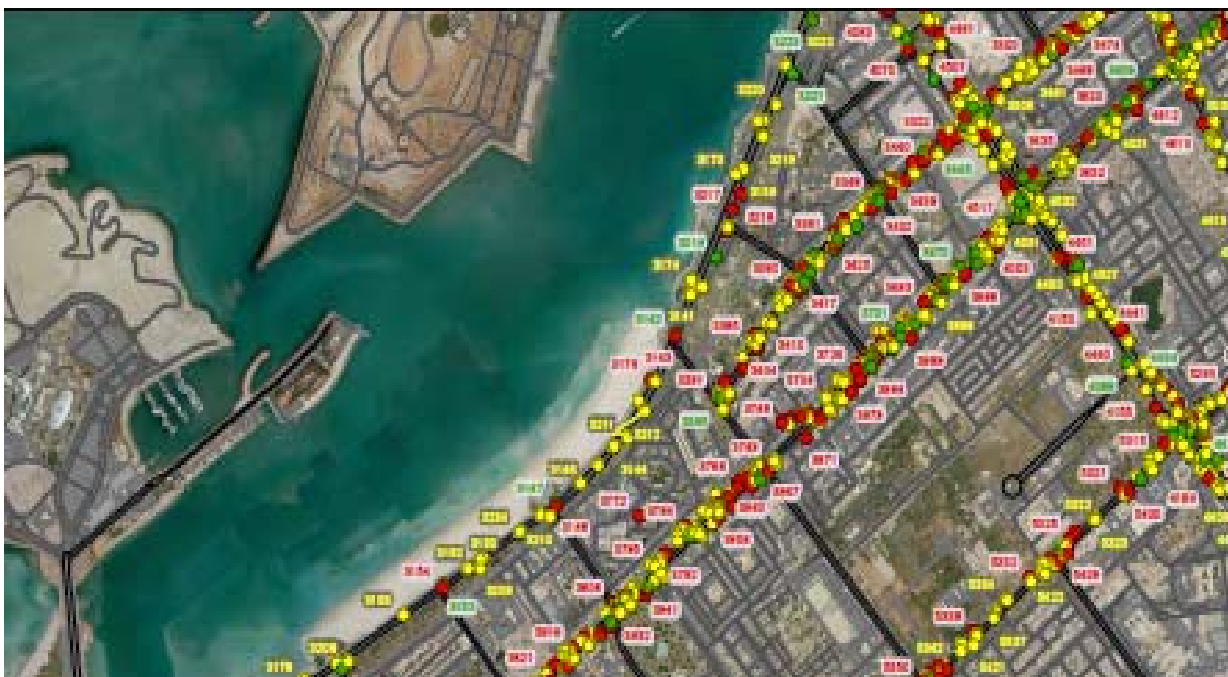
The specific road safety concerns on the arterial roads were extensive. The audit team recorded a total of 2,338 site specific findings. The major areas of concern for the different arterial roads are shown in Table 1.

Table 1: Site specific safety issues identified on Arterial Roads

SAFETY ISSUE	Road 1 Corniche Rd	Road 2 Airport Rd	Road 4 East Rd	Road 5 Hamdan St	Road 6 Baniyas St	Road 7 Zayed St	Road 9 Al Falah St
Signs, markings and signals	44%	40%	44%	39%	43%	42%	41%
Pedestrians	39%	38%	30%	46%	34%	41%	31%
Geometry and design	9%	3%	8%	6%	9%	10%	5%
Roadside obstructions	3%	16%	16%	2%	9%	2%	20%
Total number of findings	124	512	493	306	188	515	200

The first order estimate to remove or revise the road safety issues on the audited sections of the Arterial Roads amounted to AED 106,514,000. (USD 28.9 Million). This gives an average of AAED 45,500 per site.

Figure 4: Typical problem locations on Arterial Roads showing level of risk



4. CONCLUSIONS

This project proved that it is technically feasible to conduct large scale road safety projects under complex traffic conditions utilizing a two stage process, whereby an initial data collection process can be utilized to determine the safety characteristics of the broad road network, which can then be screened to identify areas of higher priority to be subjected to traditional existing facility road safety audits. The road safety audit results can also benefit from data like GPS coordinates collected in the initial process.

By standardizing on the identification of safety concerns, typical remedial actions and cost, the safety audit process can also contribute towards establishing budget estimates for the remedial works.

5. REFERENCES

Australian Road Research Board, NetRisk-Road Network Safety Assessment, Brochure, www.arrb.com.au

McInerney, Rob & N Doyle, 2006, Queensland Alliance Road Safety Risk Management: The complete solution, *22nd ARRB Conference – Research into Practice, Canberra Australia*,