

Analysis of Safety Performance of Signalized Intersections in Abu Dhabi

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Abstract

This research study's objective was to define the standards that road safety auditors rely on when auditing signalized intersection. Further, the research study aimed to determine the safety indicators used by specialists in evaluating existing hubs and prioritizing countermeasures. Additionally, the study explored gaps in the decision-making process, which often ignored safety concerns. The research study was divided into two phases. Notably, phase one was based on qualitative analysis in which statistical analysis of traffic crashes at the signalized section was conducted. The Poisson Regression Model was utilized in this case. The second phase of the research was based on the qualitative analysis in which interviews were conducted based on the statistical analysis results obtained in phase one. Here, interviews were conducted by the corresponding author on ten certified road safety auditors in Abu Dhabi. In the interviews, the study subjects were queried on several aspects such as the general information regarding their careers as auditors and the decision-making process typically effected at a signalized intersection in Abu Dhabi. The study participants also explored the significance of some of the variables identified in phase one of the research. The objective here was to validate the outcomes obtained in phase one of the research work and highlight the experience required to enhance road safety by auditors. The variables identified in phase one of the qualitative analysis are highlighted in Table 1, Table 2, and Table 3 in the qualitative research

Keywords

Road Safety Auditing, Signalized Intersections, Thematic Analysis

1. Introduction

Road safety performance is an essential proponent to the overall road safety matrix. According to (Essa, Sayed, & Reyad, 2019) safety models are regression models used to underline the expected number of collisions based on qualitative data, including geometric characteristics of the road and traffic exposure.

Therefore, factors affecting traffic crashes and severity need to be more understood and more investigation to this end. A number of theoretical models at signalized intersections have been discussed; crash-based models, conflict models, and non-crash non-conflict models. Crash based models draw inspiration from crash data (Imprialou, & Quddus, (2019). Traffic Conflict is an observed situation in which two or more road users approach each other such that there is a risk of collision if the said road users do not alter their movement (Amundsen, & Hyden, 1977). Non-

crash non-conflict model integrates observable characteristics as possible variables in determining potential safety problems and mainly relies on the experience of road safety engineers or auditors (Wang, Xu, & Dai, 2019).

Due to the limitation of the crash-based models in real applications, especially with the newly constructed infrastructure and the difficulties in capturing conflicts at the signalized intersections, the non-crash non-conflict model was developed. These models do not depend on crash or conflict data, but rather on site characteristics (Lu, Pan, & Xiang, 2008). A past analysis is often useful in fashioning non-crash non-conflict models and is the basis of the model (Candappa, Logan, Van Nes, & Corben, 2015, Woolley, Stokes, Turner, & Jurewicz, 2018, Simionescu, & Preda, 2016). Ranking of parameters also assists in identifying the most serious safety issues in regards to the severity of traffic crashes (Cheng, Diehl, Hinz, Hamza, Nührenberg, Rickert, & Truong-Le, 2018). Non-crash non-conflict model is easy to fashion since they only depend on data obtained from the surveying the field and not historical data collected from crash and conflict incidents in the past (Lu, et al., 2008). Implementation of real applications methods is relatively easy, and they provide safety evaluation procedures for roads in a short time (Yuan, Lu, Zhang, & Xiang, 2008). This has the overall effect of ensuring road safety procedures are implemented by field safety engineers rapidly.

The research is divided into two parts, the qualitative part which has been accomplished in (Alghafli et al., 2020) by analyzing 593 severe accidents from the year 2013 to the year 2017 and showed that the number of crashes per intersection ranges from 1 to 35 crashes. Those crashes resulted in about 1,246 casualties: 93% are minor injuries, 6% severe injuries and 1.0% fatalities. About 65% of the investigated crashes are caused due to red-light running, and 64% are right-angle collision. However, the investigated effect of road geometric features and operational conditions on the occurrence and severity of traffic accidents at signalized intersections in Abu Dhabi city, UAE. Speed, number of lanes, lane configuration, traffic signal sequence (lead/lag or split phasing), average hourly traffic volume per lane were used as independent variables. The accident occurrence was tested using the use of a multinomial logit modelling approach using Poisson's regression modeling and the accident severity. The Poisson model showed that at 4-leg intersections, one of the major causes of the accident is passing a street (either minor or major street). It was also found that at a 3-leg intersection, the accident's main cause is minor street passing through the intersection. The research also found that the higher the traffic volume the higher the chance of occurrence of traffic accidents. The multinomial logit model showed that five significant variables affect the severity of traffic accidents occurs at signalized intersections. The significant variables are the main road speed, traffic signal sequences, number of through lanes of minor road number of left lanes of main and minor roads. The second part of the research is validating the outcomes obtained from part 1 of the research with the perspective of the different specialists (Road Safety Auditors) in Abu Dhabi.

Since the part of the research is related the perspective of road safety specialist, qualitative type of a research should be performed. However, since the number of the targeted personals who perform the road safety auditing in Abu Dhabi are limited, interviews will be used to collect data from road safety auditors.

2. Methodology

2.1. Interviews

The interview questions were constructed based on the outcomes of the phase 1 of the research. The aim was to answer the questions that could not be answered based on the crash data such as the decision-making process. The correspondence author presented the interview questions to three experienced personals holding PhD in Civil and Environmental Engineering degree with a research background not less than 10 years, and two civil engineers with experience in road safety not less than 15 years to evaluate the questions and give a feedback to enhance the quality of the questions.

After that, 10 road safety auditors in Abu Dhabi were interviewed by the correspondence author. The interviewees were from different departments and organizations, including the Internal Roads and Infrastructure, Road Safety Unit and Integrated Traffic Center in Department of Transport and Municipalities in Abu Dhabi, Traffic Engineering and Road Safety Department in Abu Dhabi Police, Tatweer Middle East and Africa L.L.C, Parsons International. The above held different job titles, including road safety specialists, traffic safety experts, and so forth. They were also vastly experienced, with the most experienced having 27 years of experience while the least experienced seven years. Since UAE government had gathering restrictions at the time of the data collection due to Covid 19 situation, the interviews were mostly conducted virtually on Zoom or Microsoft Teams Application between June and July in 2020.

The interview was divided into five parts. In the first part of the interview, the interviewees were probed on their general information. When they obtained their auditing licenses and the number of road safety audits, they had performed in over the years. The results obtained revealed that the most experienced interviewee performed over 400

audits a year. In the second part of the interviews, the interviewees were queried on the road safety standards they typically relied on when auditing roads. Here, questions such as their thoughts on the Abu Dhabi road safety manual standards and how they could be improved were asked. The third part of the interview was based on safety parameters utilized in evaluating existing intersections. Here, the interviewees were probed regarding the entities that participate in the design audit, at the opening stage of a signalized intersection, among other questions. In the fifth stage, the study participants were asked about gaps in the decision-making process. The fifth and final part of the interview probed into the safety performance monitoring. The interviewees were quizzed on aspects such as frequency of audits at a signalized intersection, their opinion on police red light enforcement system, among other questions. Generally, the phase 2 interview sort to determine the perspective of the different specialists concerning some of the variables obtained in phase 1.

2.2. Qualitative Research Analysis

A thematic research methodology was used for analyzing the interviews. This approach was chosen mainly due to its flexible nature, ease of use, and the ability to fetch valuable insights into highly complex datasets (Castleberry, & Nolen, 2018). While there is software used to conduct the thematic analysis such as Quivo, the thematic approach utilized for this research was reviewed manually. Thematic analysis is a qualitative analysis approach used to identify, analyze, and report patterns - themes - inherent in a given data set. Typically, it cleanly organizes data set in a detailed and rich manner (Vaismoradi, Turunen, & Bondas, 2013). Further, thematic analysis can be used to interpret research topics. The range of thematic analysis is vast and often based on the number of inferences the researcher wishes to obtain from a particular data corpus. While thematic analysis is a widely used approach of qualitative research analysis, there is generally no apparent concurrence in regards to how to go about it (Castleberry et al., 2018).

There are many methods through which qualitative researches are analyzed. The thematic research analysis approach is one of the foundational techniques through which qualitative research can be analyzed and forms the basis of this analysis. The process is one of the first qualitative analysis methods that researchers learn as it generally provides many core skills that prove useful in conducting other forms of qualitative research analysis (Rosenthal, 2016).

Thematic analysis was chosen because of its flexibility and ease of use. Because thematic analysis is grounded on theoretical freedom, it provides the researcher with a broad, flexible, and useful method through which detailed and rich inferences can be obtained from a fairly complex data set (Braun & Clarke, 2006). Given that thematic analysis can be relatively flexible and often will rely on the researcher conducting the study, we limited this flexibility, which though advantageous, can lead to an analysis method where everything goes. As such, we set concise and clear guidelines around the thematic analysis conducted in this study. In short, the work strived to allow some level of flexibility in the thematic analysis used- as this is a core advantage of the approach - while at the same time demarcating clear and concise rules for which the thematic analysis was conducted.

2.3. How the Thematic Analysis Was Conducted

The steps followed in the thematic analysis conducted were based on steps outlined in (Kiger, & Varpio, 2020). Once the interviews with the ten interviewees were conducted, they were transcribed verbatim. While this process is quite tedious, it helps the researcher become familiar with the data (Kuckartz, & Rädiker, 2019). The voice interviews were transferred to a written form, and this greatly improved the ability to review the data. The second step of the analysis involved going through all the transcribed data to get a clear view of what it entailed. All the transcribed interviews were read several times. The objective here was to familiarize oneself with the data as this would be an essential part of the next step, where themes inherent in the data set were sought. Note-taking and jotting down the views was a critical method used in familiarizing with the data. This step was somewhat time-consuming and demanding.

In the next step, the work sought to identify ideas/ generate codes within the data. Microsoft Excel and the ideas from (Bree, & Gallagher, 2016) were of great help in this endeavor. Essentially, the research sought patterns and meaning from the information which the study subjects had offered during the interviews. The data sets in the interviews were reviewed several times to identify codes inherent in the data. One of the most important proponents of this phase was penning down what each of the interviewees had said in regards to the different queries that had been fronted. The work jotted down ideas and coding schemes from each of the data items. Codes and ideas are a fairly significant proponent of thematic analysis as they aid the research organizes their work in a more meaningful way. The coding, in this case, was approached with specific questions in mind. These comprised question ns that had been fronted during the interview phase and were mostly based on phase 1 of the research work.

Next, the coding schemes and ideas that were prevalent were researched. Essentially, these themes were compared with researches. The variables which had been identified in phase 1 of the research work were quite valuable in this endeavor. Further, reviewing reports and research studies that appeared to corroborate the ideas that were prevalent in the interviews and those that were in contrast with the codes identified in the research was quite revealing. One of the most significant advantages of this endeavor was that it sensitized the analysis of subtle features within the data.

The fifth step involved searching for themes from the codes that had been generated in the previous step. Theme uncovering is the basis of thematic analysis (Greenwood, Kendrick, Davies, & Gill, 2017). The previous step had enabled coding and collating disparate data sets, and the study now had a long list of codes identified in the prior step. Essentially this step focused on a broader level rather than codes. Typically, different codes were sorted into various themes. Here the work analyzed other codes and then considered how these codes could combine to form one core overarching theme. Some codes became themes and subthemes, while many combined to form a single overarching theme (Greenwood et al., 2017, Clarke, Braun, & Hayfield, 2015). Some codes appeared to be independent of other codes and did not fit into any theme or subtheme. These were designated as miscellaneous codes. The fifth step concluded by identifying several main themes, subthemes, and miscellaneous codes.

The sixth step entailed reviewing the themes, subthemes, and miscellaneous codes that had been identified in the previous step. Each of the above themes, subthemes, and miscellaneous coded were refined and researched, where some were combined, and others subdivided into distinct themes. The data within each theme were tallied.

Essentially, this step was composed of two stages, including reviewing and refining the themes, subthemes, and miscellaneous codes. The first level involved reviewing coded extract; here, the study examined the extracted codes inherent in each theme, subtheme, and miscellaneous codes and how these formed a coherent pattern. The second step was contingent on the first step creating identifiable themes. The second level was similar to the first level in that it involved a lot of reviewing of the coherent patterns that had observed in the first level. Here, the work considered the validity of the data inherent within each of the individual themes identified within the themes and subthemes. The goal here was to review whether the data within the themes accurately reflected the themes in which they had been placed. In short, in this level the study reviewed whether themes and subthemes accurately reflect the data sets; any additional data sets that had been missed or placed in inappropriate themes and subthemes were coded appropriately. Upon completion of the above steps, the work now had a fairly clear thematic map.

The thematic analysis's seventh step involved defining and refining the themes and subthemes that had been identified in the thematic map draw in the sixth step. This step was essentially involved in identifying each theme's essence and what aspect of the data was captured in each theme. In each theme, a detailed analysis was written and the story of each theme highlighted. How this story fits in the overall story of the analysis were also underlined. Effectively, each theme was considered in and of itself and then considered in relation to the other themes. Subthemes- themes within theme- were also reviewed in relation to the story of the overall theme.

The final step was compiling the results obtained from the thematic analysis. Essentially, a detailed account of the different themes and the story the data tells was the basis of the final step. Vivid extracts from the data were used to corroborate the findings of the data story/ the findings. The goal here was to collate the themes clearly and concisely, thereby underlining inferences from the data sets. Figure 1 show the research methodology

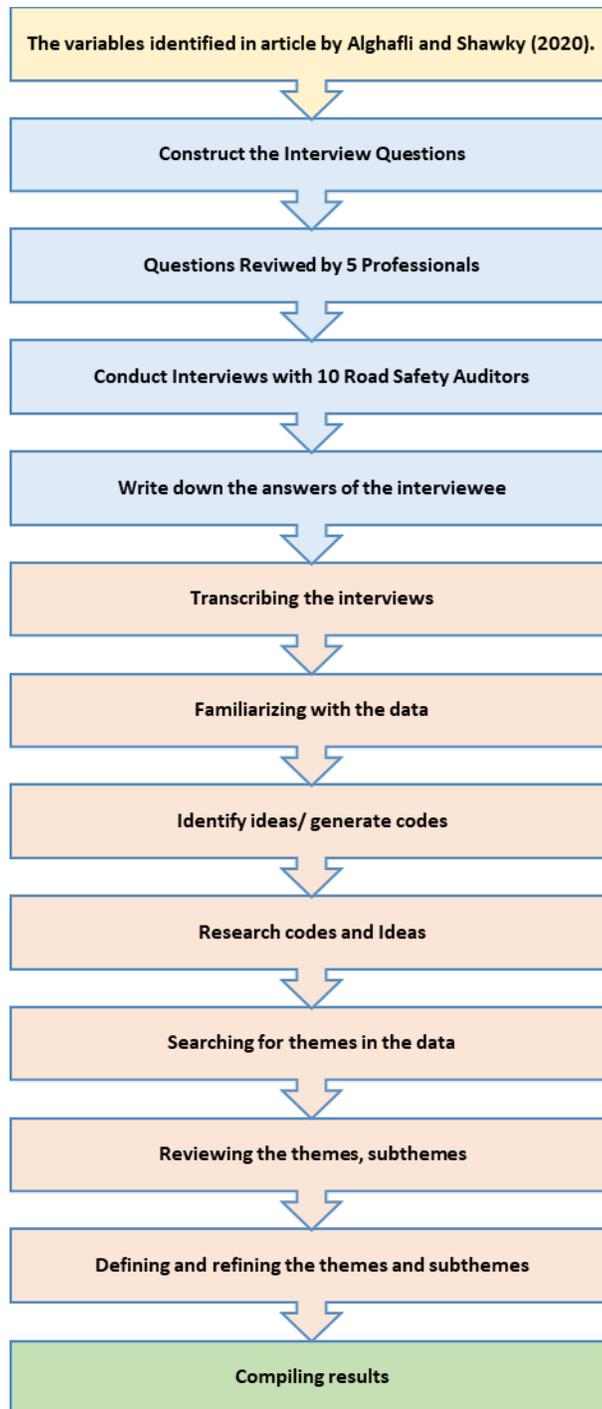


Figure 1: Research Methodology

2.4. Limitation of research methodology

The research methods employed in this study have limitations. For instance, Data that were used in the statistical analysis were obtained of a number of archives. This means that the accuracy of the findings depended on the accuracy of these data. If data has hidden errors, these errors are included in the analysis, affecting the accuracy of the findings. The research also involved collection of views and perceptions of various experts such as experienced civil engineers. However, the qualitative collected accuracy depends on the willingness of the those interviewed to give accurate information.

2.5. Validity and reliability of the interview data

2.5.1. Validity

The validity of data collected from the interviews is difficult to determine using statistical analysis. This is mainly because the collected data is not quantitative in nature and is not suitable for validity tests using statistical tests such as correlation matrix. The method commonly used to ensure that the collected data is valid, is by performing one-on-one interviews which can be done through face to face contact, via telephones or virtually through digital platforms such as Zoom and Microsoft Teams Application. As such, in this study, one-on-one interview was conducted virtually using Zoom and Microsoft Teams Application between June and July in 2020 depending on the application the interviewee preferred. One-on-one interviews ensured that the interviewee provided only relevant information. If any point regarding an interview question was not understood, the interviewer (the researcher) or the interviewer clarified the issue on spot.

2.5.2. Reliability

As already mentioned, this part of the study involved collection of qualitative data through interviews. To ensure that tool used to collect the data (the set of questions to be answered during the interviews) is reliable, the interview questions were standardized. This means that the interviewees were asked exact same questions in the exact same order. Also, the duration of the interview is been set (45-60 mins). This technique was adopted to ensure repeatability of the qualitative research.

3. Results and Discussion

Research Objective 1 (Issues associated with Abu Dhabi's road safety auditing standard manual (the standard manual that road Abu Dhabi road auditors use to audit the city's road safety) and proposed solutions). As highlighted prior the qualitative aspect of this study was based on three objectives. The first objective was to examine standards that road safety auditors use on in auditing. The standard manual the Abu Dhabi uses to audit road safety is known as Abu Dhabi Road Safety Manual. This objective's intension was to identify issues associated with this standard and find solutions to the issues identified. The analysis of the interview data identified three themes (these are shown in Table 1. Based on the themes a number of issues (codes) associated with standards have been identified and summarized as shown in table 1. Solutions to these issues as proposed by those interviewed are also shown in 1. Table 1 summarizes the themes, issues and datasets (proposed solutions) associated with the first objective of the qualitative aspect of the study.

Table 1: Themes, codes and sample data sets associated with the first objective

Theme	Codes	Data Set
The Abu Dhabi Road Safety Manual needs Improvement	Check-list The Manual lacks parameters The manual is a good beginning	“In my opinion, the Road Safety Manual of Abu Dhabi needs to be reviewed and updated at least once every 5 years...” “Updated periodically every 2 years”
The Road Safety Manual is fine though poorly implemented	Poor implementation	“The manual is fine. The problem as with most things is in the implementation of the system...”
International manuals can improve the Abu Dhabi Road Safety Manual	UK GG-119 LSS Program Ireland model Sweden model Netherland model USA model	“UK GG-119 (previously known as HD19) which our standard is based on.” “Firstly, select the best standards that have been tested in other countries...”

	Several books and Road Safety Manual	
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The data map drawn by the above themes shows that the Abu Dhabi Road Safety Manual is currently the standard manual used in auditing. Notwithstanding, the manual should be improved. Data obtained show that the manual needs to be improved because it lacks the prerequisite parameters that make a good road safety manual in its current state. According to the data, the Abu Dhabi Road Safety Manual requires further refinement and continued improvement at least every two years. Additionally, the interviews data show that skipping some parts of the manual is considered poor implementation and thus does not do a good job. Further, schooling auditors so that they become better at determining what is critical in the auditing of road will greatly improve the overall road audit. A number of international manuals were identified as some of the best and could play a major role in improving the Abu Dhabi Road Safety Manual. These manuals include the UK GG-119, LSS Program, Ireland model, and the USA model.

Research Objective 2 (The safety indicators to be used in evaluating the existing intersections and prioritize countermeasures). The second objective of the qualitative aspect of this research, as highlighted in the prior sections of this work, was to determine the safety indicators used in evaluating the existing intersections and prioritising countermeasures. This was based on the findings of the qualitative study. The qualitative research found that signalized intersections are the worst affected by the traffic crashes especially the 4-leg intersections when compared to 3-leg intersections. Even though both the 4-leg and 3-leg signalized intersections are associated with more crashes than other intersections, 4-leg intersections are the worst affected. Based on the above findings (qualitative research findings) a number of themes were identified and investigated through interviews. These themes are shown in table 2. The factors (codes) that should be evaluated have also been provided in the table 2. The interviews have identified a number of safety indicators to be used in evaluating the existing intersections and prioritize countermeasures. These are shown in table 2 and more discussion are given in the next paragraph. Table 2 shows the themes, codes and datasets associated with the identified safety indicators used in evaluating the existing intersections and prioritizing countermeasures. Table 2 show the codes and sample data sets associated with the second objective

Table 2: Themes, codes and sample data sets associated with the second objective

Theme	Codes	Data Set
Parameters to consider are numerous	Who can be hurt? and how?	“Every single aspect is important and there would be too many to list...” “You cannot physically list every possible issue...” “Everything that impacts the safety or severity of a collision should be considered.”
Some of the Parameters to consider	Illumination, Signs Road Marking Delineation Pavement markings, roadside barriers, Channelization Intersection Geometry etc.	“Providing physical separation for left turning vehicles in case of using lead lag operation traffic signal.” “Adequate road/street lighting.” “Check radius of curves with speed limit of road and the visibility.”
Signal phasing	Cause of crash Geometry improvement An important parameter Coordinated Corridor	“In fact, a number of fatal crashes in Al Ain are suspected to be due to phasing problems...” Stage-2 needs to look at Traffic Signals phasing and timing...”

<p>Other important Parameters</p>	<p>Traffic Flow, movements, Capacity, Horizontal and Vertical Alignment, Cycling Facilities, Traffic Calming, The expected traffic volume Geometry design of intersection</p>	<p>One of the most important is pedestrian volumes and demand corridors to ensure median waiting areas are big enough to accommodate pedestrians, cyclists and pushchairs as may be required in both length and width, that is minimum width 2.1m and minimum...”</p>
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The data map drawn from the above theme shows that there are countless parameters that determine the safety indicators used in evaluating the existing intersections. Accordingly, the question who can get hurt and how appears to underline which safety indicators should be used to evaluate the existing intersections. Some of the critical importance parameters included Illumination, Signs, Road Marking, Delineation, the expected traffic volume, geometric design of intersection among others. Poor signal phasing was a core cause of road crash. Notwithstanding, effective signaling can be a great benefit to road safety and road efficiency. In this regard, the Abu Dhabi Transportation Department can benchmark using countries such as Japan, the UK, United States and other nations where the safety of signalized intersections is prioritized.

Research Objective 3 (The gaps in the decision-making process which may ignore the safety concerns). The third objective of the research was to determine the gaps in the decision-making process which may ignore the safety concerns. During analysis of the data collected from the interviews, a series of themes and codes became apparent. The decision-making gaps are also identified and shown in under the data set column in table 3. Specifically, 3 themes plus several codes were found in our analysis. Table 3 shows the themes, codes and datasets associated with the gaps in the decision-making process which may ignore the safety concerns.

Table 3: Themes, codes and sample data sets associated with the third objective

Theme	Codes	Data Set
<p>Not carrying out RSA early enough</p>	<p>RSA fine People not following it</p>	<p>“RSA is not being carried out early enough in the planning process. Too often the development or building is already under construction before RSA is undertaken on the infrastructure..”</p>
<p>Not respecting recommendation</p>	<p>Designer skip audits Lack of experience</p>	<p>“Not all of the comments in the report are taken seriously.” “RSA not even forming part of the decision-making process. RSA not being undertaken at all.”</p>
<p>Underestimating RSA</p>	<p>No liability for ignoring RSA Stakeholders not cognizant with RSA</p>	<p>“Consultants and Contractors are under severe Time and Cost pressure to reduce the RSA process to a tick box exercise and in some cases avoided it all together.”</p>

The data map shows that the RSA were largely ignored and these were largely the main reason for the gaps in the decision-making process and ignorance of the auditing process's safety concerns. According to the data, RSA was insignificant and often not performed early enough and was generally not taken seriously. Further, RSA was not enforceable under the law. These led to a lot of gaps in the decision-making process and subsequent safety concerns.

Research Objective 4 (Review of the safety performance monitoring). The interviews also sought to review safety performance monitoring. Table 4 below highlights themes and codes that relate to safety performance monitoring. The analysis identified three themes associated with safety performance monitoring, they are: Monitoring of intersection done after 36 months; Analysis of crash data is the best method for monitoring safety of signalized intersection; and Police red light enforcement is helpful in improving road safety. The codes and data set (opinion of the interviewees) regarding the safety performance monitoring are shown in table 4.

Table 4: Themes, codes and sample data sets associated with the fourth objective

Theme	Codes	Data Set
Monitoring of intersection done after 36 months	TR 540 of the RSA manual LSS program monitoring	“They don’t. TR-540 the RSA manual for the Emirate states it should be audited for the last time at 36 months following completion.”
Analysis of crash data is the best method for monitoring safety of signalized intersection	Crash frequency, Crash Severity, Road users complain, Number of Red-Light Crossing Violations Time delays and LOS Data Crash	“Analysis of crash history and red-light violation.”
Police red light enforcement is helpful in improving road safety	Effective control of driver behavior Police red light enforcement Important Reduces crashes	It appears to have helped. Tawam signals, Khabisi Signals and Al Ain Mall signals all have seen drops...” “It is considered as one of the most efficient enforcement solutions that playing an important role in decreasing the number of Red-Light Crossing Violations and crashes...”

The data map shows that monitoring of intersection is done 36 months pursuant to TR 540 of the RSA manual. Further, the datasets underline that data analysis is one of the most important safety and monitoring activity. Additionally, police red light enforcement, the data show helps improve road safety and has led to reduced crashes.

4. Conclusions

All in all, the thematic research methodology can be used to analyze fairly complex data in a rather robust and effective fashion. In this work, the interviews were analyzed using the thematic analysis approach. Several inferences were drawn from the finding:

- i. Abu Dhabi Road Safety Manual lacks the prerequisite parameters extracted from the traffic crash studies which it makes a good road safety manual. As a result, the Abu Dhabi Road Safety Manual needs periodic improvements based on traffic crashes in the city.
- ii. Skipping early stages of RSA causes poor implementation of the Abu Dhabi Road Safety Manual while auditing traffic safety issues by assigned auditors.
- iii. Poor signal plans is major cause of crashes at the signalized intersections in Abu Dhabi according to those interviewed and providing physical separation for left turning vehicles in case of using lead lag operation traffic signal should be considered.
- iv. The safety indicators include: Identifying who can be hurt and how they can get hurt in case of a traffic crash at the intersections; geometric design of the intersections; visibility of the intersections and road; and the effectiveness of the signal phasing used in the intersection.
- v. It was found that some RSA comments are not being considered seriously. Thus, there are gaps in the decision-making process and ignorance of the safety concerns from the auditing process.

- vi. Monitoring of intersection is done 36 months pursuant to TR 540 of the RSA manual. And meanwhile, the traffic engineering department should keep monitor the red-light crossing violations and the crashes occurred.

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Biography

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